

# PRINCIPLES OF MODERN COMMUNICATIONS

## PHYSICAL LAYER PROPAGATION

based on 2011 lecture series by Dr. S. Waharte.  
Department of Computer Science and Technology,  
University of Bedfordshire.



12<sup>th</sup> January 2013



# Outline

Modern  
Communications

David Goodwin  
University of  
Bedfordshire

Signals & Propagation

4-Pair UTP

LAN Optical fibre

Carrier Transmission

① Signals & Propagation

② 4-Pair UTP

③ LAN Optical fibre

④ Carrier Transmission





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# SIGNALS & PROPAGATION





# Physical Layer Propagation

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- The Physical Layer
  - – The only layer that does not deal with messages.
    - Individual bits are converted directly into signals.
  - – It alone deals with signals, transmission media, and connectors.
  - – It alone deals with propagation effects—changes in signals as they propagate.







# Signal and Propagation

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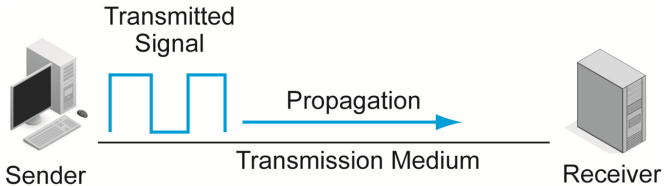
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The sender transmits a signal  
(disturbance in the medium)  
The signal propagates down the medium.





# Signal and Propagation

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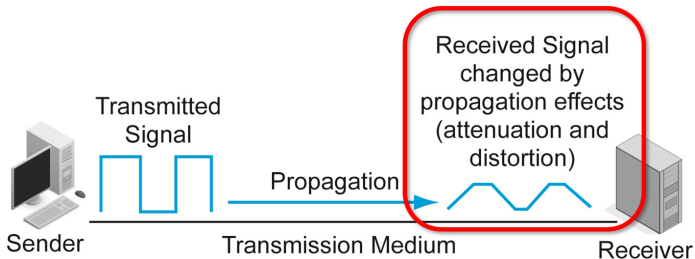
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If propagation effects are too large, the receiver cannot read the signal.





# Physical Layer Propagation

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- Signaling

- – In analog signaling, the signal rises and falls smoothly in intensity.
  - Small propagation errors are not fixed.
- In binary signals, there are two states per clock cycle.
  - Small propagation effects do not create errors in reading the signal.





# Physical Layer Propagation

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- Signaling

- – In digital signals, there are a few states per clock cycle.
  - 2, 4, 8, 16, 32, and so on
  - Can transmit multiple bits per clock cycle
  - Less error immunity to propagation errors than in binary transmission
- – Today, most transmission is binary.





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# 4-PAIR UTP

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# 4-Pair Unshielded Twisted Pair (UTP)

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- 4-Pair UTP Cable
  - – Ethernet is the dominant LAN standards family.
  - – Ethernet LANs typically use 4-pair unshielded twisted pair wiring to connect hosts to the nearest switch.
  - – They may also use UTP to connect switches to other switches.
  - – UTP cabling uses copper wires.



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# 4-Pair UTP Cord

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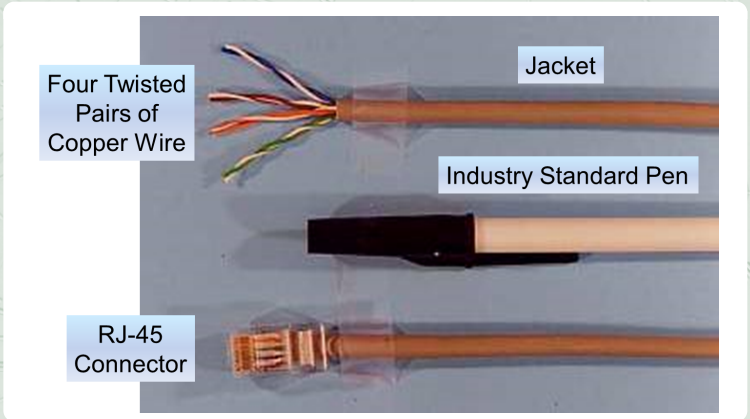
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# 4-Pair UTP

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- Cord Organization
  - – A length of UTP wiring is a cord.
  - – Each cord has eight copper wires.
  - – Each wire is covered with dielectric (nonconducting) insulation.



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# 4-Pair UTP

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- Cord Organization

- – The wires are organized as four pairs.
  - Each pair's two wires are twisted around each other several times per inch.
- – There is an outer plastic jacket that encloses the four pairs.

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# 4-Pair UTP

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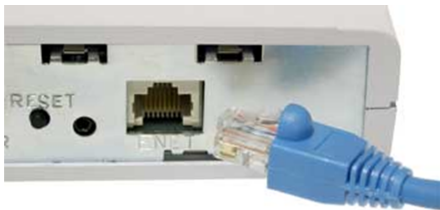
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- Connector
  - – RJ-45 connector is the standard connector.
  - – It plugs into an RJ-45 jack in a host, switch, or wall jack.



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# 4-Pair UTP

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- Characteristics

- – Inexpensive and easy to purchase and install
- – Rugged: can be run over with chairs, and so on
- – Dominates media for access links between a host and the nearest switch



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# Attenuation and Noise in UTP

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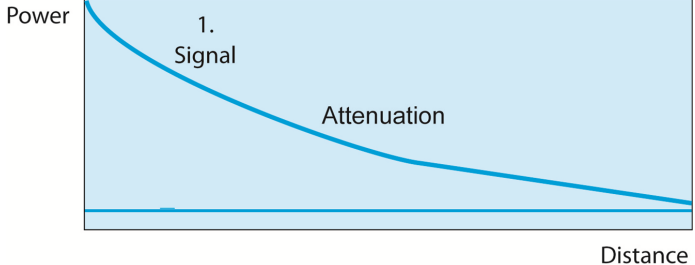
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As a signal propagates, its energy attenuates.  
If the attenuation is too much,  
the signal will be unreadable.



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# Attenuation and Noise in UTP

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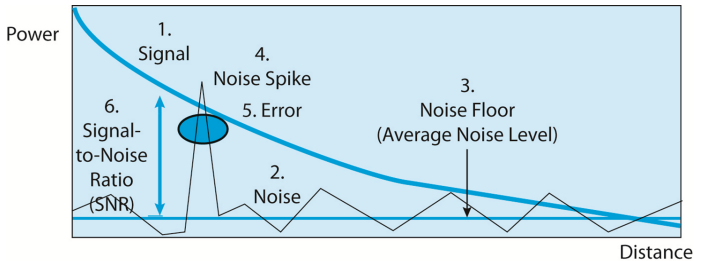
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Noise is energy caused by moving electrons in the wire.  
Noise energy adds to or subtracts from the signal.



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- Solution:
  - – Limit cord length to 100 meters.
    - This makes attenuation propagation effects negligible.
    - This also makes noise propagation effects negligible.



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# EMI and Twisting in UTP

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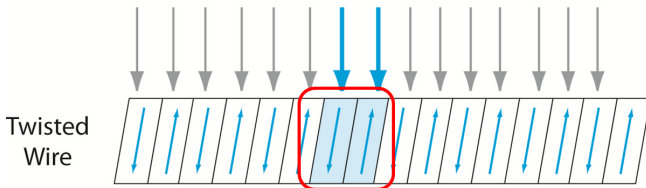
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## Electromagnetic Interference (EMI)



EMI cancels out over the two halves of a twist  
(Adds on one half and subtracts on the  
second half for a net impact of zero)



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# Crosstalk and Terminal Crosstalk EMI

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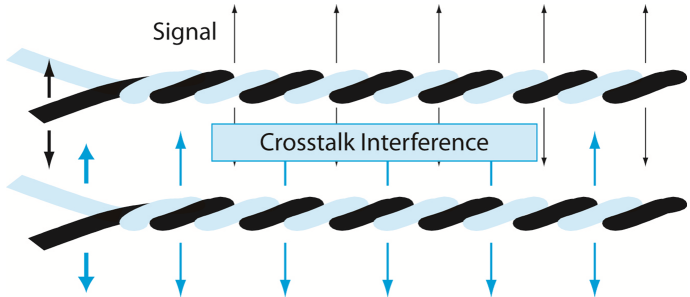
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Cross-talk interference is EMI between wire pairs in the same bundle. Because the pairs are so close, it is strong. But twisting limits it to an acceptable level.



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# Crosstalk and Terminal Crosstalk EMI

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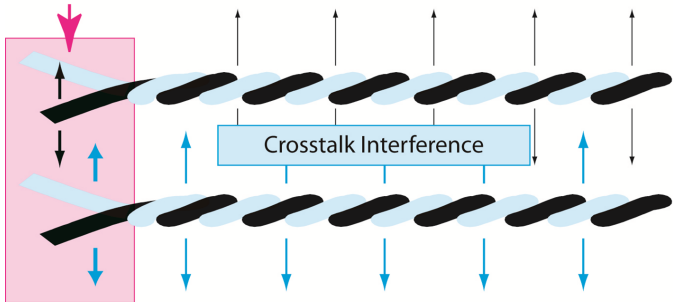
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## Terminal Crosstalk Interference



Terminal cross-talk interference takes place at the untwisted ends, where twisting provides not protection.



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# Crosstalk and Terminal Crosstalk EMI

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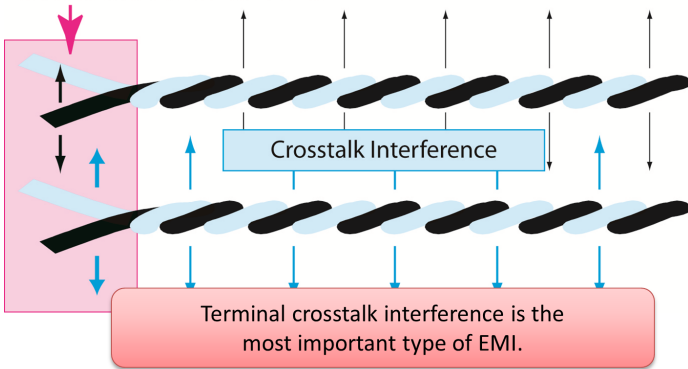
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## Terminal Crosstalk Interference



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# Types of Interference

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Type of Interference	Propagation Effect Reduced to Insignificance	Mitigation
Interference	All interference from outside a UTP wire pair	Twisting wire pairs
Cross-Talk Interference	Interference between wire pairs in a cord	Twisting wire pairs
Terminal Cross-Talk Interference	Interference between untwisted ends of wire pairs in a cord	Not untwisting wire pairs more than 1.25 cm (0.5 inches) when inserting them into an RJ-45 connector



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# Types of Interference

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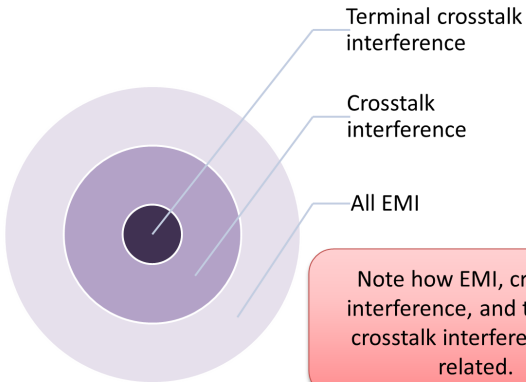
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# Controlling UTP Propagation Effects

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## Precaution

## Propagation Effect Reduced to Insignificance

Limiting UTP distance to 100  
meters

Attenuation  
AND  
Noise

Limiting the untwisting of  
wires to less than  $\frac{1}{2}$  inch at  
the connector

Terminal crosstalk  
interference



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# Serial versus Parallel Transmission

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One Clock Cycle



Serial  
Transmission  
(1 bit per clock cycle)

In serial transmission, the signal is sent on a single pair of wires.

One bit is sent per clock cycle.



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# Serial versus Parallel Transmission

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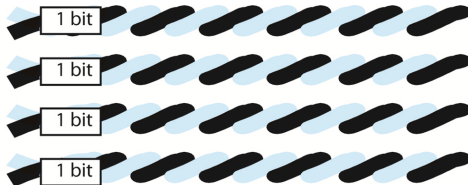
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Parallel  
Transmission  
(1 bit per clock cycle  
per wire pair)  
4 bits per clock cycle  
on 4 pairs



Note: Parallel means that transmission occurs on multiple pairs, not just four pairs.

In parallel transmission, the signal is sent on several pairs.  
Multiple bits are sent per clock cycle.  
The benefit of parallel transmission is higher speed.  
Faster Ethernet uses parallel transmission.



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# Serial versus Parallel Question

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## Example

- How many wire pairs are used in parallel transmission?

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# Wire Quality Standards

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Category	Technology	Maximum Speed	Maximum Ethernet Distance at this Speed
5e	4-Pair UTP	1 Gbps	100 meters
6	4-Pair UTP	1 Gbps	100 meters
6	4-Pair UTP	10 Gbps	55 meters
6A	4-Pair UTP	10 Gbps	100 meters

“Category” is a measure of UTP cord quality.



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# LAN OPTICAL FIBRE

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# Optical fibre

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- Sends light waves through glass
- On/Off signaling
  - – On during a clock cycle = 1
  - – Off during a clock cycle = 0
  - – Binary

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# Frequency and Wavelength

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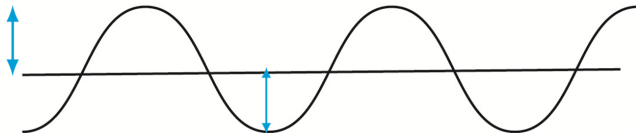
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Amplitude



Amplitude

Amplitude:  
The power or intensity of the wave



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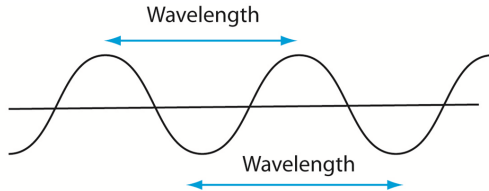
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**Wavelength:**

The physical distance between comparable points on adjacent cycles.  
Optical fiber transmission is described in terms of wavelength.



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# Frequency and Wavelength

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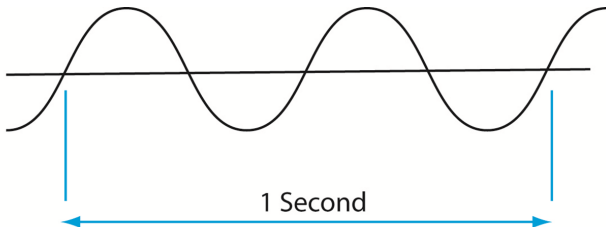
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Carrier Transmission

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Frequency : The number of cycles per second.  
In this case, there are two cycles in 1 second,  
so the frequency is two hertz (2 Hz).  
Radio transmission is measured in terms of frequency.

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# Frequency and Wavelength

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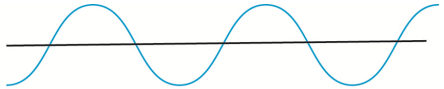
LAN Optical fibre

Carrier Transmission

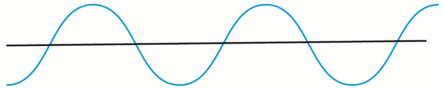
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Phase

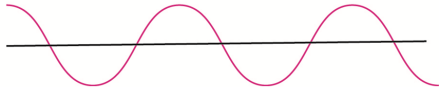
Carrier



In phase



180 degrees  
out of phase



Waves with different phases can interfere  
with one another.



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# Optical fibre Wavelength

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- Windows for very good glass propagation
  - – 850 nanometers (nm)  $\pm$  50 nm
  - – 1,310 nanometers (nm)  $\pm$  50 nm
  - – 1,550 nanometers (nm)  $\pm$  50 nm
- Longer wavelengths travel farther.
- Longer wavelengths are more expensive to generate.
- For LAN distances, 850 nm dominates because it gives sufficient distance.



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# Optical fibre Transmission

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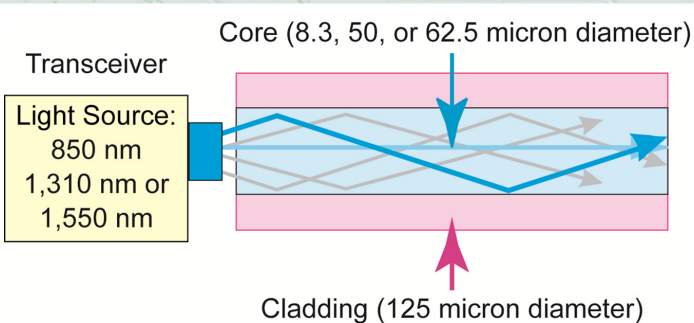
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Light travels through the core.  
The core is surrounded by the cladding.



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# Optical fibre Transmission

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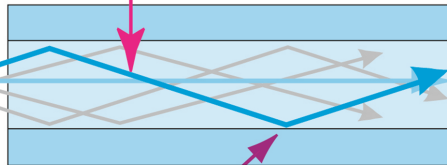
Carrier Transmission

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Transceiver

Light Source:  
850 nm  
1,310 nm or  
1,550 nm

Light Ray



Perfect internal reflection at core/cladding boundary;  
no signal energy escapes the core



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# UTP versus fibre

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- fibre is good for going farther, not going faster.
  - – Both can be used for speeds up to 10 Gbps
  - – Optical fibre can span longer distances
- Less than 100 meters, use less expensive 4-pair UTP.
- Beyond 100 meters, use fibre.



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# Roles of UTP and fibre in LANs

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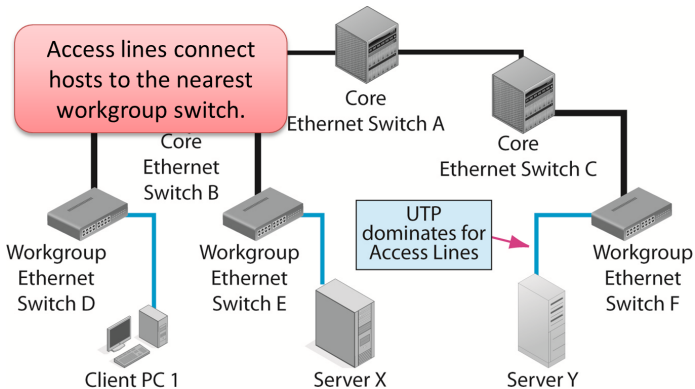
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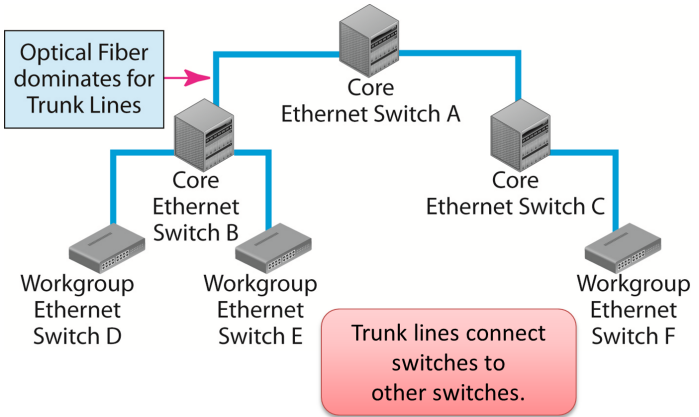
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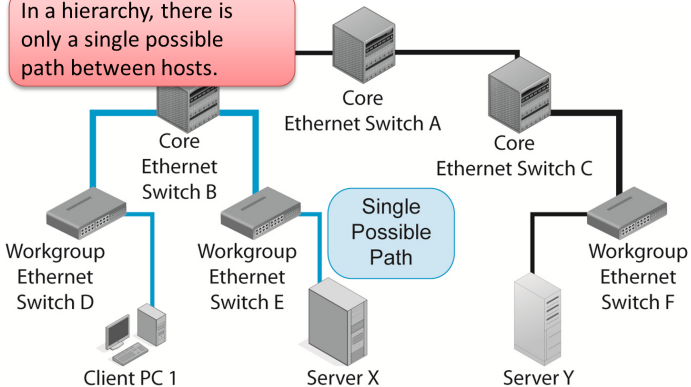
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In a hierarchy, there is only a single possible path between hosts.



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# Full Duplex fibre with Connectors

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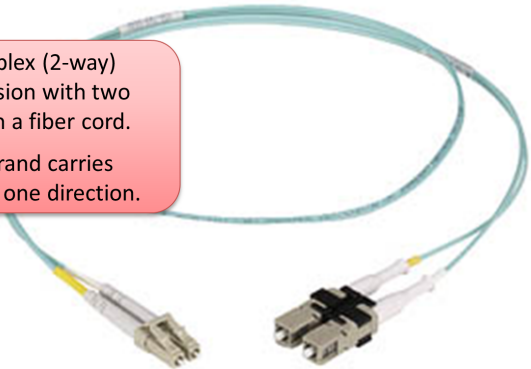
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Full-Duplex (2-way)  
transmission with two  
strands in a fiber cord.  
  
Each strand carries  
a signal in one direction.



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# Full Duplex fibre with Connectors

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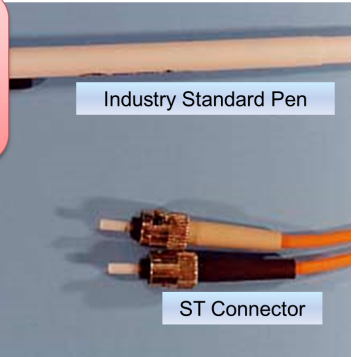
4-Pair UTP

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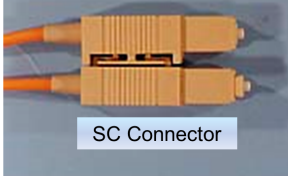
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UTP only has RJ-45  
connectors.  
Fiber has several  
types of connectors.



Industry Standard Pen



SC Connector



ST Connector



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# Multimode and Single-Mode fibre

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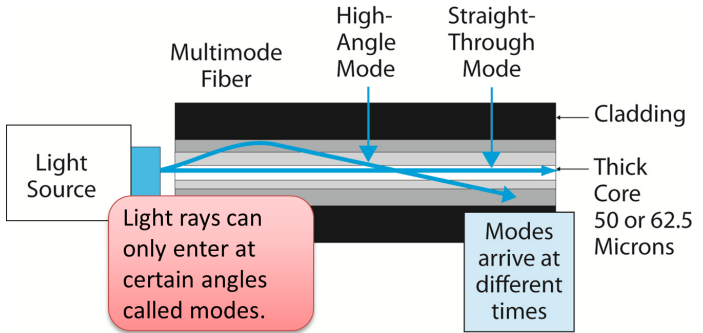
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Distance for Multimode Fiber Is Limited by Modal Dispersion



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# Multimode and Single-Mode fibre

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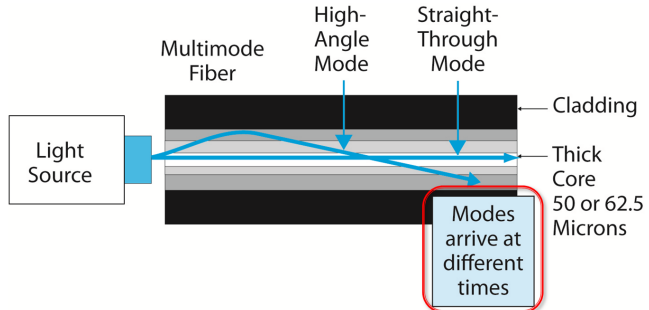
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If travel distance is long, modes from different pulses will overlap.  
This will make the signal unreadable.



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# Multimode and Single-Mode fibre

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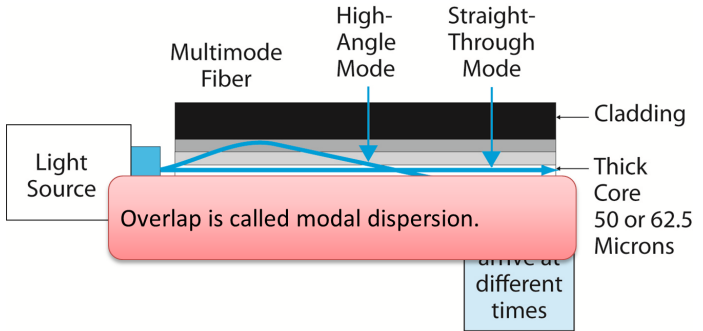
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Distance for Multimode Fiber Is Limited by Modal Dispersion

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# Multimode and Single-Mode fibre

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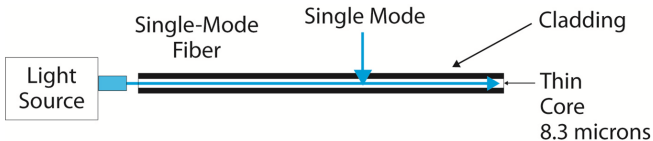
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Single-mode fiber has a tiny core.  
Only the straight-through mode can propagate.  
With only one mode, there is no modal dispersion.  
Single-mode fiber is limited by absorptive attenuation.



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# Ethernet 1000BASE-SX

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Wavelength	Core Diameter	Modal Bandwidth	Maximum Propagation Distance
850 nm	62.5 microns	160 MHz.km	220 m
850 nm	62.5 microns	200 MHz.km	275 m
850 nm	50 microns	500 MHz.km	550 m

To span longer distances with 850 nm light, use higher-quality multimode fiber or a 50 micron core.



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# LAN versus Carrier WAN fibre

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Characteristic	LAN Fiber	Carrier WAN Fiber
Distance Span	200 m to 300 m	1 to 40 kilometers
Transceiver Wavelength	850 nm	1310 nm (and sometimes 1550 nm)
Type of Fiber	Multimode (thick core)	Single mode (thin core)
Core Diameter	50 microns or 62.5 microns	8.3 microns
Primary Distance Limitation	Modal dispersion	Absorptive attenuation
Quality Metric	Modal bandwidth (MHz.km)	NA



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# CARRIER TRANSMISSION

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# Public Switched Telephone Network

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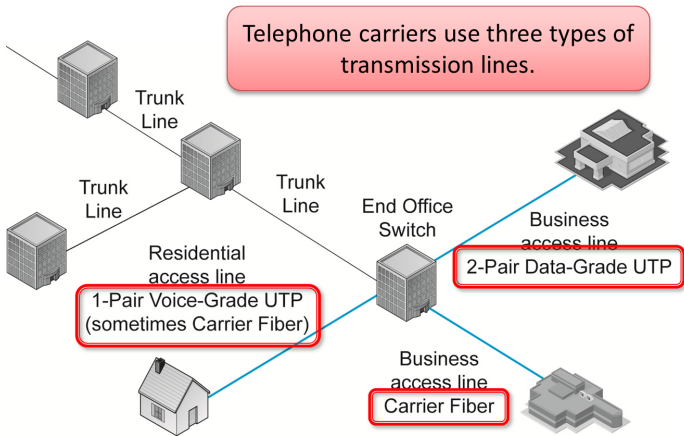
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# Local Loop Technologies

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4-Pair UTP

LAN Optical fibre

Carrier Transmission

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Local Loop Technology	Business or Residential	Considerations
2-Pair Data-Grade UTP	Business	For leased lines up to 2 Mbps Must be pulled to the customer premises, so expensive Not limited to 100 meters
Optical Fiber	Business	For leased lines faster than 2 Mbps Must be pulled to the customer premises, so expensive



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# Local Loop Technologies

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4-Pair UTP

LAN Optical fibre

Carrier Transmission

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Local Loop Technology	Business or Residential	Considerations
1-Pair Voice-Grade UTP	Residential	Designed only for voice transmission Not limited to 100 meters If a 1-pair VG UTP line carries data, the service is called digital subscriber line (DSL) service Already installed, so avoids the expense of pulling a new line to residences
Optical Fiber	Residential	Fiber to the Home (FTTH) New Installing FTTH in whole neighborhoods to reduce installation costs



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Carrier Transmission

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- Note that 4-pair UTP is NOT used for carrier transmission.
- Note also that carrier fibre is NOT limited to 100 metres.



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# Asymmetric Digital Subscriber Line (ADSL)

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4-Pair UTP

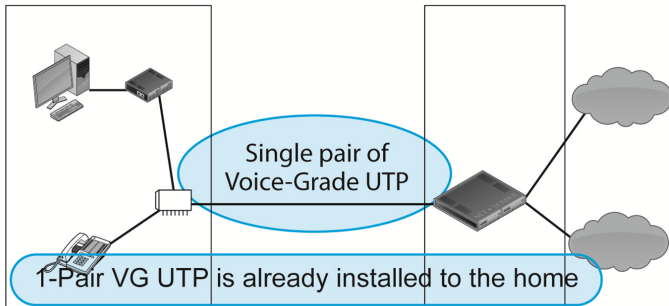
LAN Optical fibre

Carrier Transmission

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Customer Premises

Telephone Company  
End Office Switch



Installed media minimizes provisioning cost, making ADSL inexpensive.

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# Asymmetric Digital Subscriber Line (ADSL)

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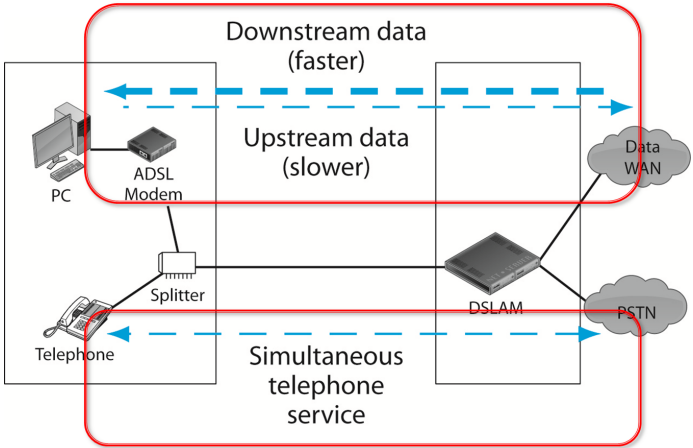
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4-Pair UTP

LAN Optical fibre

Carrier Transmission

57



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# Asymmetric Digital Subscriber Line (ADSL)

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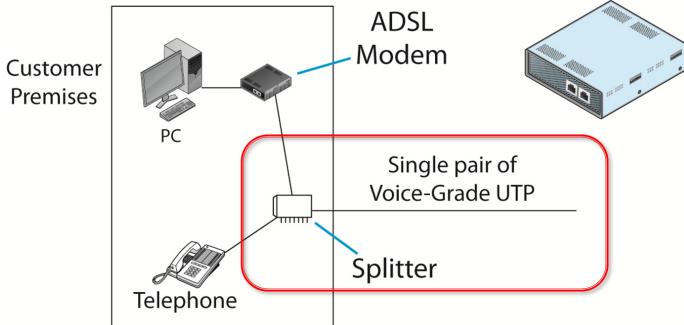
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LAN Optical fibre

Carrier Transmission

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A splitter must be plugged into each wall jack.  
It separates voice from data signals.



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# Asymmetric Digital Subscriber Line (ADSL)

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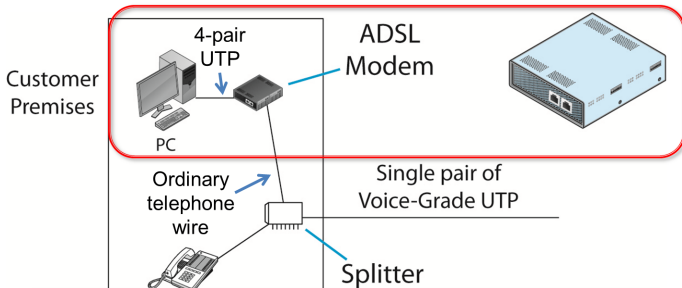
Signals & Propagation

4-Pair UTP

LAN Optical fibre

Carrier Transmission

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The ADSL modem is needed for the PC.  
It plugs into the PC via 4-pair UTP.  
It plugs into the splitter via a telephone line



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# Asymmetric Digital Subscriber Line (ADSL)

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4-Pair UTP

LAN Optical fibre

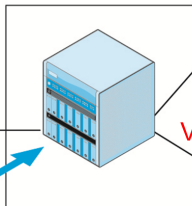
Carrier Transmission

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Telephone Company  
End Office Switch

Mixed Voice and Data

DSL Access  
Multiplexer



Data

Voice



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# Cable Modem Service

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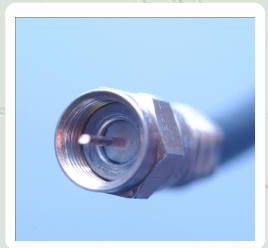
4-Pair UTP

LAN Optical fibre

Carrier Transmission

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- Provided by cable television companies
- The drop line to homes from the main cable uses coaxial cable.
- In “coax,” one wire is in the center and the other conductor is a ring around it, on the same axis.



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# Cable Modem Service

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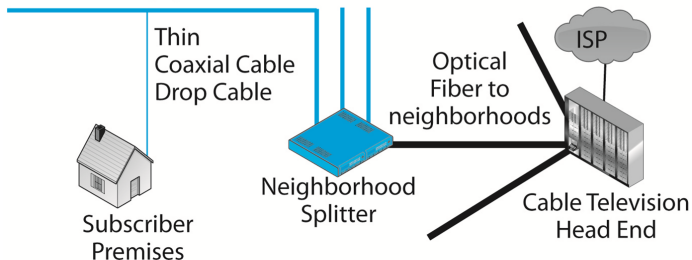
4-Pair UTP

LAN Optical fibre

Carrier Transmission

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Thick Coaxial Cable  
in neighborhood  
(shared throughput)



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# Cable Modem Service

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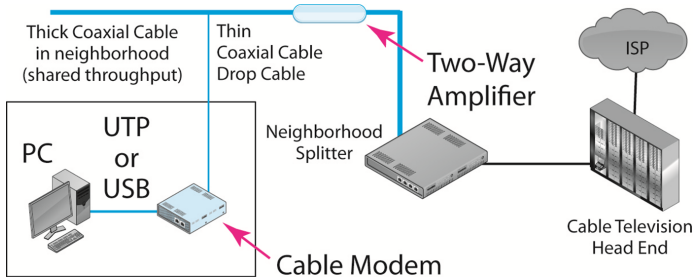
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4-Pair UTP

LAN Optical fibre

Carrier Transmission

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Data transmission requires  
two-way amplifiers and a cable modem.



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# ADSL versus Cable Modem Service

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Signals & Propagation

4-Pair UTP

LAN Optical fibre

Carrier Transmission

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- Myth:

- – There is sharing in cable modem service but not in ADSL service.
- – Truth: Cable trunk line speed is shared, as are backhaul lines to the ISP.
- – Truth: ADSL access lines are not shared, but DSLAMs are, and so are backhaul lines to the ISP.



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# ADSL versus Cable Modem Service

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- In General:
  - – Cable modem service tends to be somewhat faster.
  - – ADSL service tends to be somewhat less expensive.



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# fibre to the Home (FTTH)

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4-Pair UTP

LAN Optical fibre

Carrier Transmission

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- fibre is run throughout a neighborhood
- Installed all at once to reduce cost
- Only drop lines have to be added to individual homes
- Can produce breakthroughs in downstream and upstream speeds to homes
- Multiple simultaneous HDTV signals to a home
- In practice, the improvement may not be dramatic



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# Next Lecture

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Signals & Propagation

4-Pair UTP

LAN Optical fibre

Carrier Transmission

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- Lecture 4: Digital Communication



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