Networks

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And the models are also weaker on security than they ought to be

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Compounding the issue of lack of support for security in the Internet protocols, early TCP/IP implementations were woefully poor: many exploitable bugs

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And the implementations were very fragile and easily hacked

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More on security later

Long term plan

We shall now work our way up the layers, looking in detail at what TCP/IP does for each

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This is going to be a long journey!

Networks

Hardware

First, hardware

Networks

Hardware

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There are several popular hardware implementations. Some you should have come across are

- Ethernet: a wired network
- ADSL and VDSL: telephone networks
- Wi-Fi: a short range wireless network
- Cellular: mobile phones

Networks

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- Ethernet: a wired network
- ADSL and VDSL: telephone networks
- Wi-Fi: a short range wireless network
- Cellular: mobile phones

We shall look at some of these

Exercise How many different radio/wireless systems does your mobile phone support?

Networks

Ethernet

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In comparison, current consumer Ethernet runs at 1Gb/s, while typical top-end Ethernet runs at 100Gb/s, with 400Gb/s starting to be used in datacentres and plans for 800Gb/s and 1.6Tb/s

Networks

Ethernet

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The signalling rate is the rate of delivery of bits across the physical network

Due to layering encapsulation and other physical overheads, this is overwhelmingly *not* the rate of delivery of bits to the application you are running

For example, there is always a gap between packets where data is not being transmitted!

However, the signalling rate is the number marketers like to use

Networks

Ethernet

However, the signalling rate is the number marketers like to use

The rate actually realised can be much lower; e.g., a 54Mb/s Wi-Fi 3 (802.11g) network might only deliver half that figure to an application

The Ethernet standard covers both the PHY and the MAC layers, so we shall look at them together

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And we begin with the frame format

Networks

Ethernet

Ethernet frame

Numbers are byte counts: so, e.g., the destination address is 6 bytes long

Networks

Ethernet

Destination address	Source address	type	Data	CRC
6	6	2	46-1500	4

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- 2 byte type indicates what kind of network layer data follows, e.g., (hex) 0800 for an IP packet
- The data, maximum 1500 bytes
- **Minimum 46 bytes.** The data must be padded with extra bytes if fewer than 46 bytes are supplied

Networks

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Ethernet frame

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Ethernet frame

- A higher layer must detect and remove this padding when necessary
- 4 byte checksum, also called *cyclic redundancy check* (CRC)
- Use to check for corruption errors in the frame

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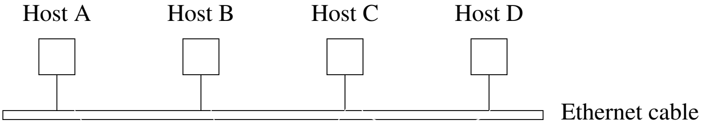
Ethernet just drops corrupted frames; no more action is taken

(Original) Ethernet is *shared*, so every host sees every frame on the local network



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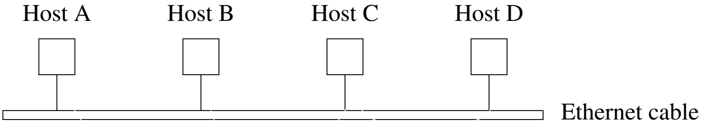

Original Ethernet

So how is a frame matched up to the intended destination host?

Networks

Ethernet

Every Ethernet card has a unique address built into it

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(Not the full story, but true enough for now)

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So the destination address on the frame allows an Ethernet card in a host to recognise that a frame is for it and so can read and process it

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There is a security issue here…

The source address on the frame allows a host to determine who sent the frame and so it can reply if needed

Networks

Ethernet

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`000010000000000000100000100110100011010011011101` is an example Ethernet address, a 48-bit value

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For convenience we write this as `08:00:20:9a:34:dd`, six hexadecimal numbers

Networks

Ethernet

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Ethernet is purely a local area network technology

What of the signalling on the wire?

Networks

Ethernet

What of the signalling on the wire?

Ethernet uses *carrier sense, multiple access with collision detection* (CSMA/CD)

Networks

Ethernet CSMA/CD

Ethernet is a *multiple access* (shared) medium, meaning that several hosts use the same piece of wire to send data to one another

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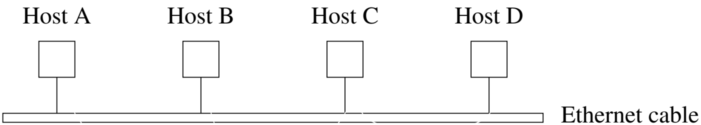

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Suppose A wishes to send to B

Networks

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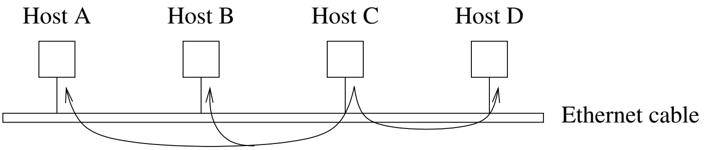

Original Ethernet

Suppose A wishes to send to B

If C is already sending to D, the whole network is occupied with its signal, so A must wait

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Ethernet CSMA/CD

If two hosts try to send simultaneously, there will be a *collision*

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If not, it sends the data

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So before they send data, a host *listens* to the Ethernet to see if anyone else is using it at the moment: *carrier sense*

If not, it sends the data

Otherwise it must wait, listening until the carrier is free

This still isn’t quite enough

Networks

Ethernet CSMA/CD

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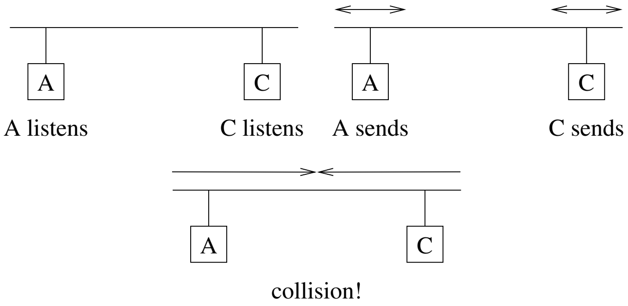

Frame collision

Networks

Ethernet CSMA/CD

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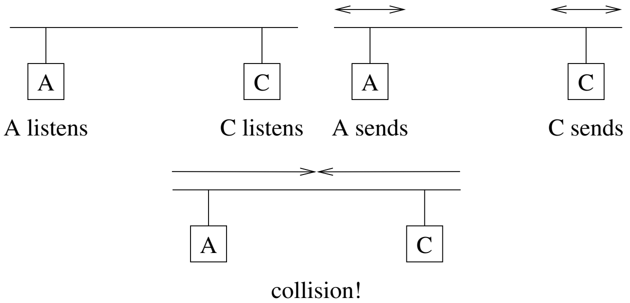

Frame collision

So each host **continues to listen while transmitting** to make sure there are no collisions: *collision detection*

Networks

Ethernet CSMA/CD

If a collision is detected, each host stops transmitting, waits a (small) **random** period of time and retries with the carrier sense

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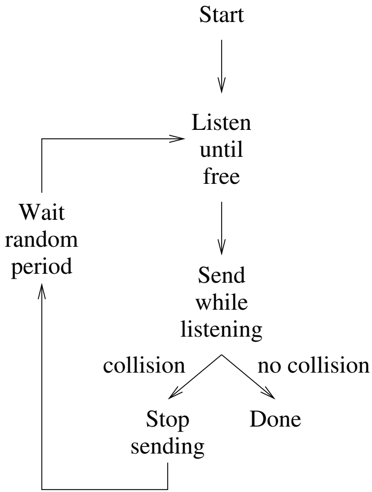
Detecting collisions on an Ethernet is simple: if the signal you are seeing on the network is not the same as the signal you are putting on the network, that means someone else is transmitting, too

Networks

Ethernet CSMA/CD



CSMA/CD flowchart

Exercise Explain why we need to go back to carrier sense after the random pause

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Exercise Read further about jamming signals and what to do if the transmission repeatedly fails

Collision detection is why there is a minimum frame size

Networks

Ethernet CSMA/CD

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The frames must be on the wire long enough that the hardware can detect a collision

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(The speed of a signal in a cable is approx 2/3 c; 100m is 520 cpu cycles of a 1GHz cpu)

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Exercise Find out how CSMA/CD differs from Aloha

Networks

Physical Ethernet

There have been many Ethernet physical layers

Standard	cable	max len	rate
10Base5	Thick coax	500m	10Mb/s
10Base2	Thin coax	200m	10Mb/s
10BaseT	Twisted pair	100m	10Mb/s
10BaseF	Fibre optic	2000m	10Mb/s

Base means *baseband*, namely using a single chunk of frequencies from 0 (the base) up to a single cut-off point

Networks

Physical Ethernet

And these evolved (just a selection here):

Standard	cable	max len	rate
100BaseT4	Twisted pair	100m	100Mb/s
100BaseT	Twisted pair	100m	100Mb/s
100BaseF	Fibre optic	2000m	100Mb/s
1000BaseT	Twisted pair	100m	1Gb/s
2.5GBaseT	Twisted pair	100m	2.5Gb/s
5GBaseT	Twisted pair	100m	5Gb/s
10GBaseT	Twisted pair	100m	10Gb/s

Networks

Physical Ethernet

The cables used in these PHYs change over time. Unshielded Twisted Pair (UTP) comes in various qualities:

- Category 1: No performance criteria
- Category 2: Rated to 1 MHz (used for telephone wiring)
- Category 3: Rated to 16 MHz (used for Ethernet 10BaseT)
- Category 4: Rated to 20 MHz (used for Token-Ring, 10BaseT)
- Category 5/5e: Rated to 100 MHz (used for 1000BaseT, 100BaseT, 10BaseT)

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Category 5 has been replaced by Category 5e which has slightly better construction specifications

Networks

Physical Ethernet

All the twisted pair cables are bundles of 4 pairs of wires with an RJ45 plug on the end

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Physical Ethernet

All the twisted pair cables are bundles of 4 pairs of wires with an RJ45 plug on the end

Then we have shielded cables, where each pair has a metal foil wrapper:

- Category 6: Rated to 250 MHz
- Category 6a: Rated to 500 MHz
- Category 8.1: Rated to 2000 MHz
- Category 8.2: Rated to 2000 MHz, special end plugs

Plus extra rules on how the plugs on the end are joined on

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Currently (2023) the best cable to buy is Cat6a as it supports any speed your home network is likely to have and is fairly cheap

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Currently very few home users will have anything faster than 1 Gb interfaces and switches