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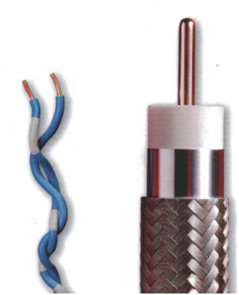
However, the copper wires used is good(ish) quality coaxial cable that is well screened against interference and crosstalk, and so the data rates it supports are much higher

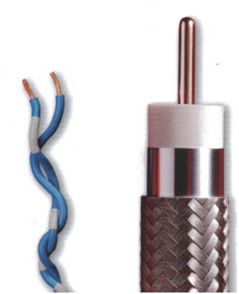
Cable TV



Telephone wire and coaxial cable

Picture from Virgin Media

Cable TV



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Exercise *Read up on Data Over Cable Service Interface Specification* (DOCSIS)

Wireless

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So some wireless systems are only allowed with very low power, e.g., Wi-Fi

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Such bodies manage the radio spectrum, allocating various frequencies to various purposes, ensuring minimal interference between the competing concerns for parts of the spectrum

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So signals from *multiple* networks can interfere; not just the hosts *within* one network

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Conversely, wireless networks generate interference themselves which must be controlled so not to be to annoying to other people

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But a limited range can cause complications

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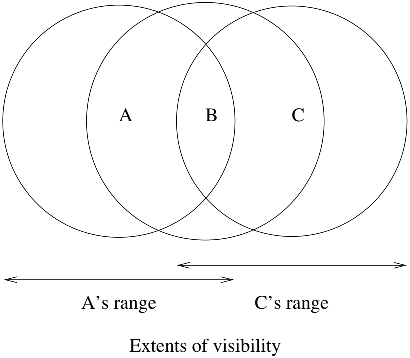
When we have wireless, we get the *hidden host* problem:



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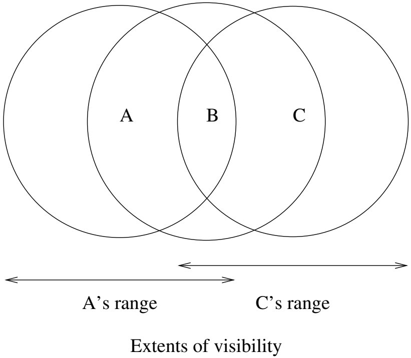

Hidden host

Hosts A can B can “see” each other; B and C can see each other, but A cannot see C, so A cannot tell if its packets to B are colliding with C’s to B

Wireless Problems

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CSMA/CD relies on everyone's signals being visible to everybody

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Only use a Wi-Fi network if you have permission to do so

Wireless 802.11

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Wi-Fi 1	802.11b
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And the recently announced (2020) Wi-Fi 6E (using the recently freed 6GHz band)

Wireless 802.11

Other parts of 802.11, like 11c, 11d, 11e, 11f, 11h, 11i deal with things like power management, quality of service, security and authentication and so on

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802.11b extended this to rates of 5.5Mb/s and 11Mb/s

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And the frequency fell within the capabilities of low-power chips that were buildable at the time

Wireless 802.11

		channel bandwidth	rate
WiFi 1	11b	20MHz	11Mb/s
WiFi 2	11a	20MHz	54Mb/s
WiFi 3	11g	20MHz	54Mb/s
WiFi 4	11n	40MHz	top 150Mb/s, typical 72Mb/s
WiFi 5	11ac	80MHz	160MHz optional, top 6.9Gb/s, typical 433Mb/s
WiFi 6*	11ax	160MHz	top 9.6Gb/s, typical 600Mb/s
WiFi 7	11be	320MHz	ratified 2024?

*WiFi 6E uses the newly released 6GHz waveband (lots of new spectrum)

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Improvements are achieved through more sophisticated encodings and using more wireless channels simultaneously

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Exercise Look these up. Particularly the use of multiple aerials for *beamforming* and *spacial multiplexing*

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Administered by the Wi-Fi Alliance, a consortium of interested companies

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The number of channels available depends on the country

- Most of Europe: 13
- North America: 11
- Japan: 14

Wireless 802.11

Channel	GHz
1	2.412
2	2.417
3	2.422
4	2.427
5	2.432
6	2.437
7	2.442
8	2.447
9	2.452
10	2.457
11	2.462
12	2.467
13	2.472
14	2.484

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There are recommendations on using channels

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- This means we can have three non-interfering co-located networks on channels 1, 6 and 11

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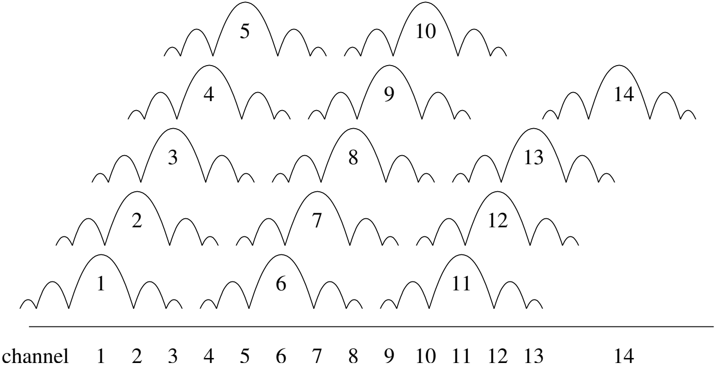

Overlapping WiFi channels at 2.4GHz

Wireless 802.11

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Exercise Mobile phones have wireless apps that display the wireless environment. Walk around and see what it is like

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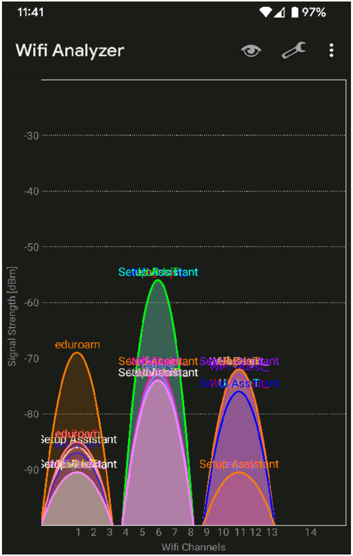

WiFi Analyzer app

CSMA/CA

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- Go back to carrier sense

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But collision avoidance does not *guarantee* no collisions, particularly with hidden hosts, so we need more

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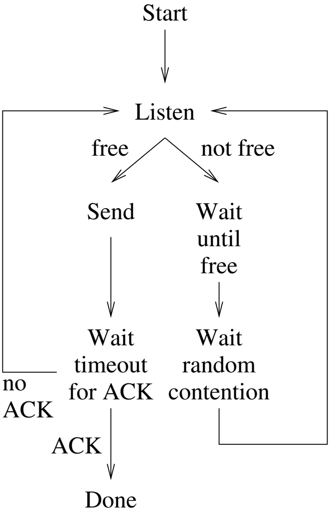
Note the ACK is also visible to everyone in range of the destination, giving extra indication to others when a transmission has finished

CSMA/CA



CSMA/CA flowchart

CSMA/CA

Exercise Compare and contrast the CSMA/CA flowchart with the CSMA/CD flowchart