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With Ethernet, detecting another host's signal on a wire is easy as the power of its signal is roughly the same as yours

CSMA/CA

In contrast, detecting another host's radio signal can be very difficult as it can be a tiny fraction of the power of yours, and your signal will drown out the colliding signal and make it undetectable

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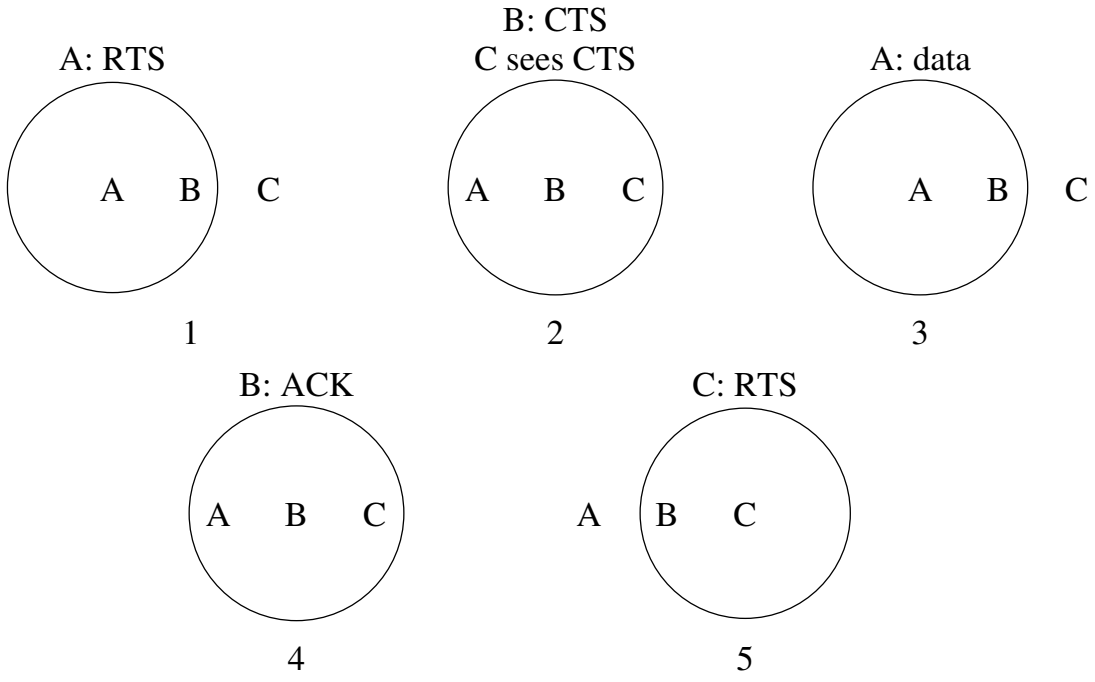
Recall the wide range of power that Wi-Fi signals encompass: another destination might be transmitting quite powerfully, but its signal can be very small by the time it reaches you

Wi-Fi

To help further with the visibility problem, there is optional *RTS/CTS handshaking*, which can improve performance in certain circumstances

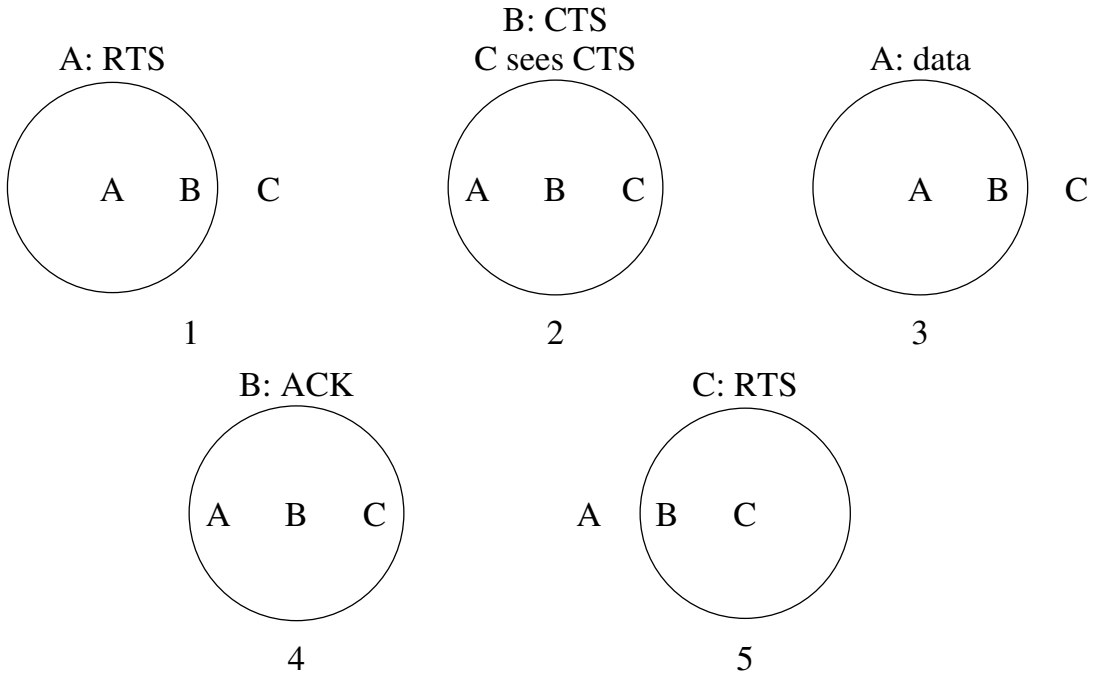
RTS/CTS



RTS/CTS handshaking

1. Before sending a data packet the source A can send a *request to send* (RTS) packet to B;

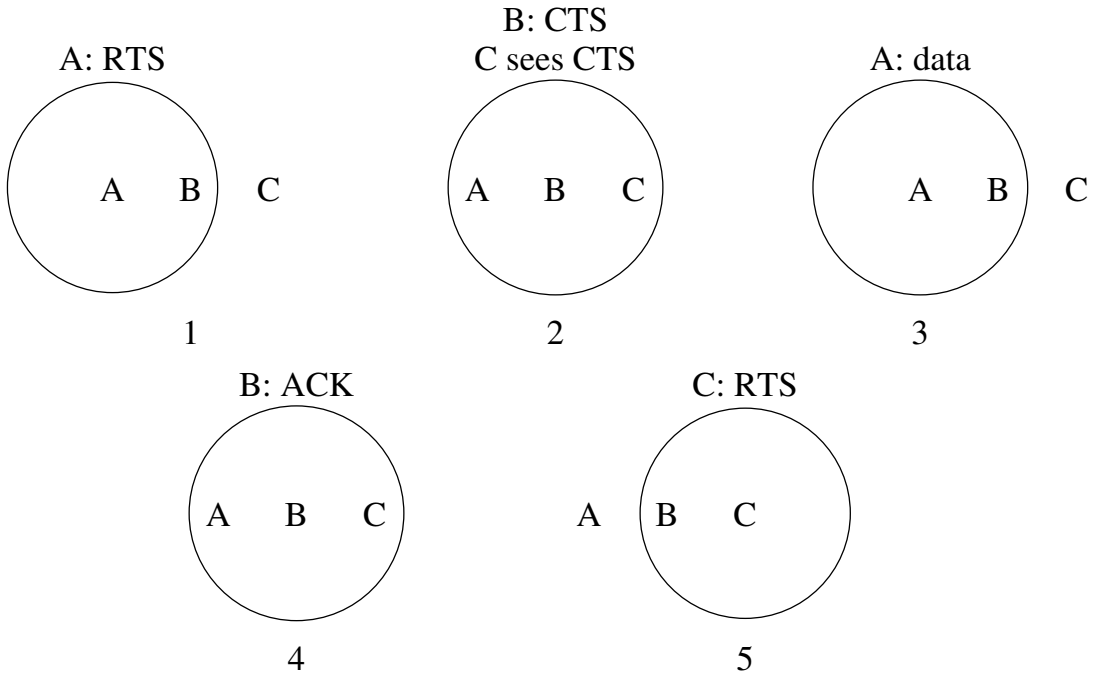
RTS/CTS



RTS/CTS handshaking

2. If the destination B is happy (it is not already receiving from another host that A cannot see) it responds with a *clear to send* (CTS) packet;

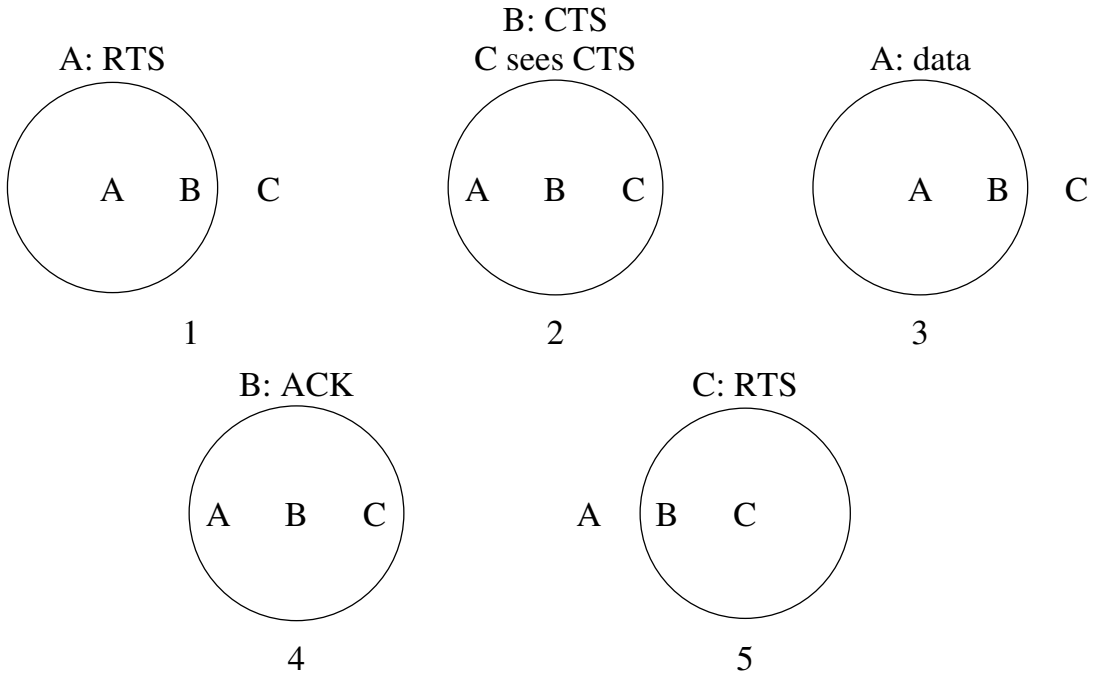
RTS/CTS



RTS/CTS handshaking

2. Every other host within the range of the destination will see the CTS and so know not to send themselves;

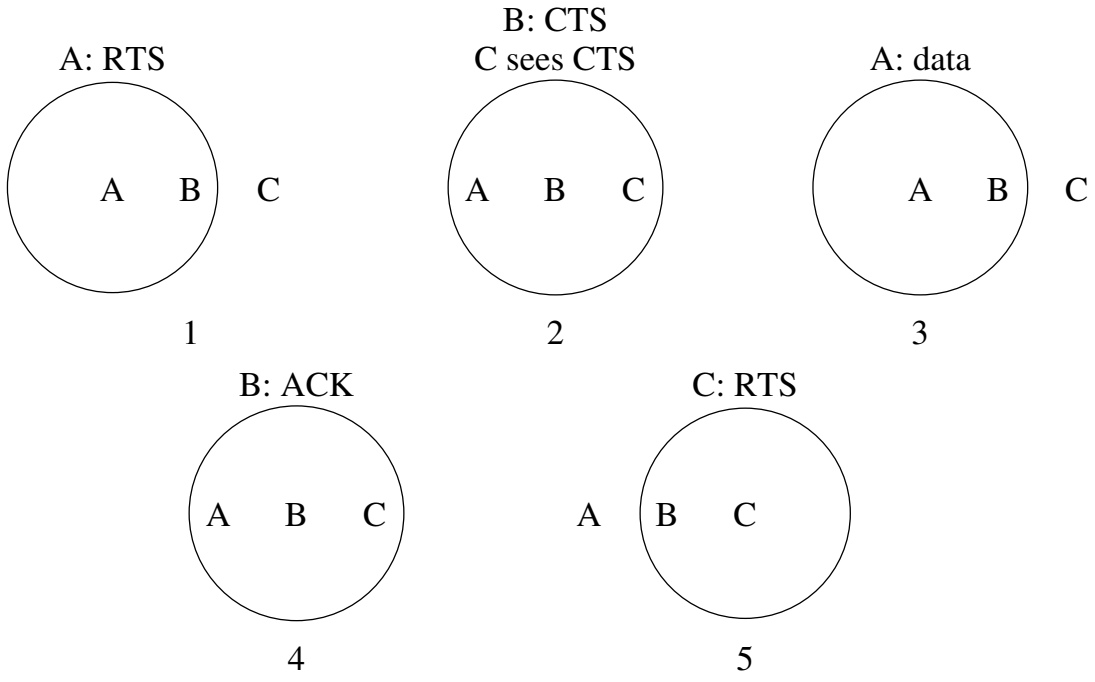
RTS/CTS



RTS/CTS handshaking

3. The RTS and CTS contain the length of the desired transmission so other hosts know how long they will have to wait;

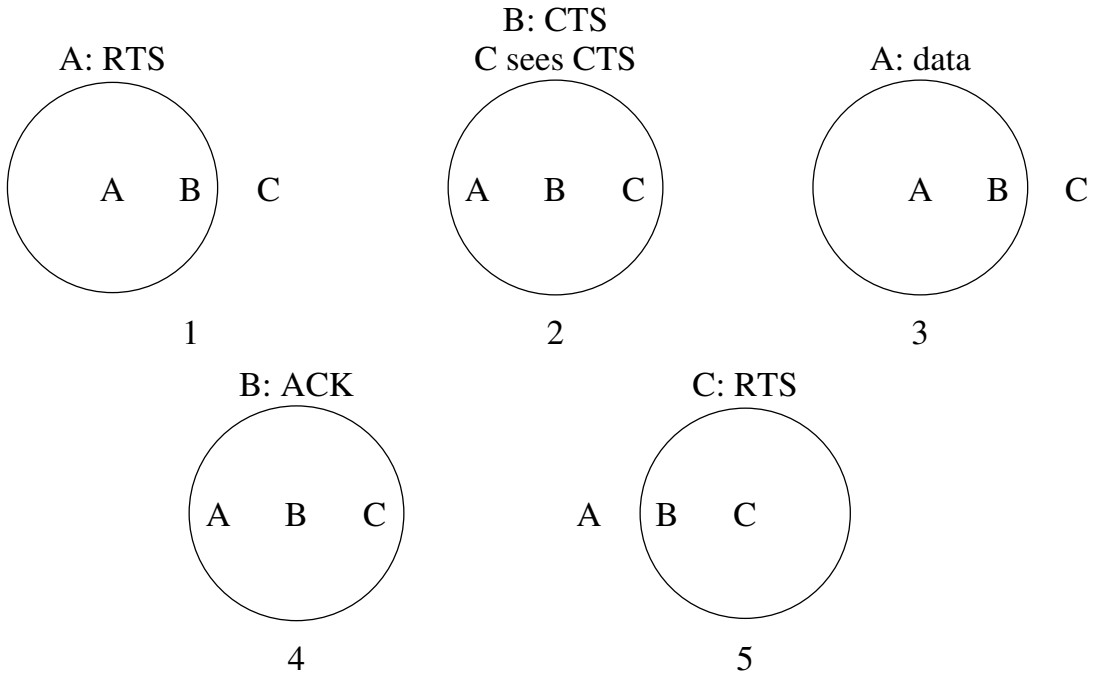
RTS/CTS



RTS/CTS handshaking

4. Similarly, the final ACK is visible to everyone;

RTS/CTS



RTS/CTS handshaking

5. Then C can start with its own RTS

RTS/CTS

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RTS/CTS for large packets only: a compromise that reduces the relatively large overhead for small packets

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Some of the later 802.11 standard improve speeds by reducing overheads (as well as using better encodings)

802.11

Exercise 802.11ac (branded “Wi-Fi 5”) is common and 11ax (“Wi-Fi 6”) hardware becoming more common. Read up on what they promise and what they deliver

Wireless Networks

While the use of access points is common, this is not the only way to set up a wireless network

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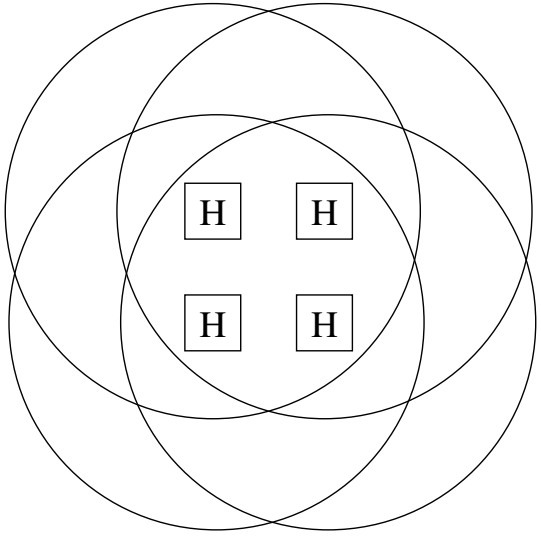
802.11 can be arranged in point-to-point networks called *Ad-Hoc* or *Independent Basic Service Set* (IBSS)

Wireless Networks



Point−to−point connections

IBSS

Ad-Hoc network

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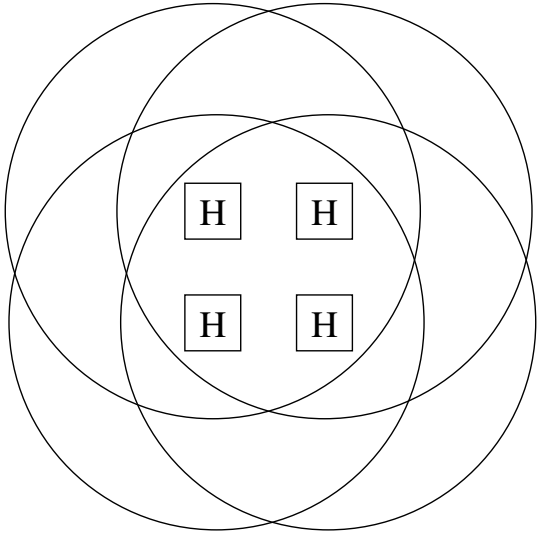


Point–to–point connections

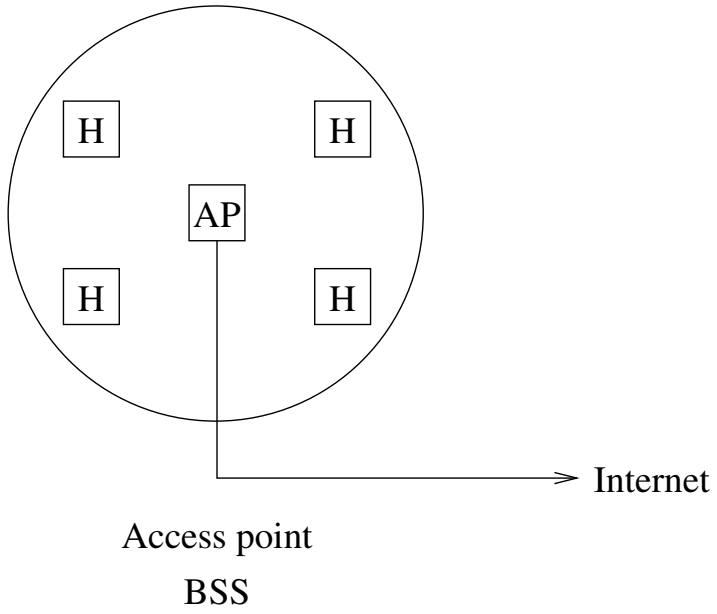
IBSS

Ad-Hoc network

Each host communicates directly with each other without an access point

Wireless Networks

But the usual Wi-Fi network is a *Infrastructure* or *Basic Service Set* (BSS), where a central hub (*access point*) relays traffic between hosts



Usual access point setup

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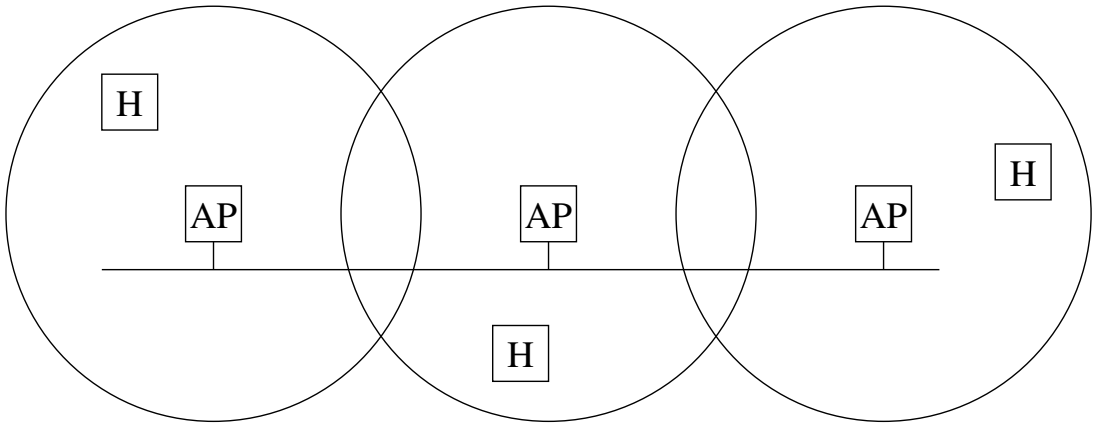
Also the AP can connect into a wired network and so the rest of the Internet

Wireless Networks

Extended Service Set (ESS) connects several APs by a wired network



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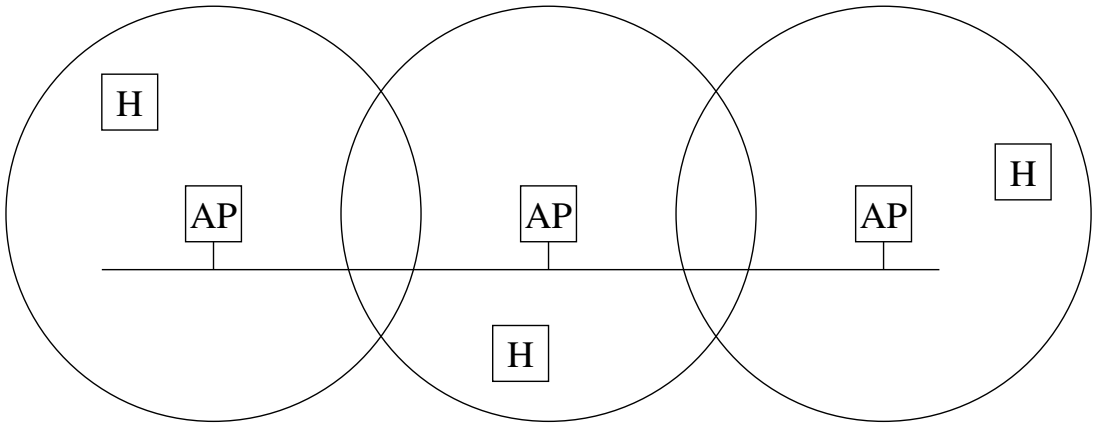

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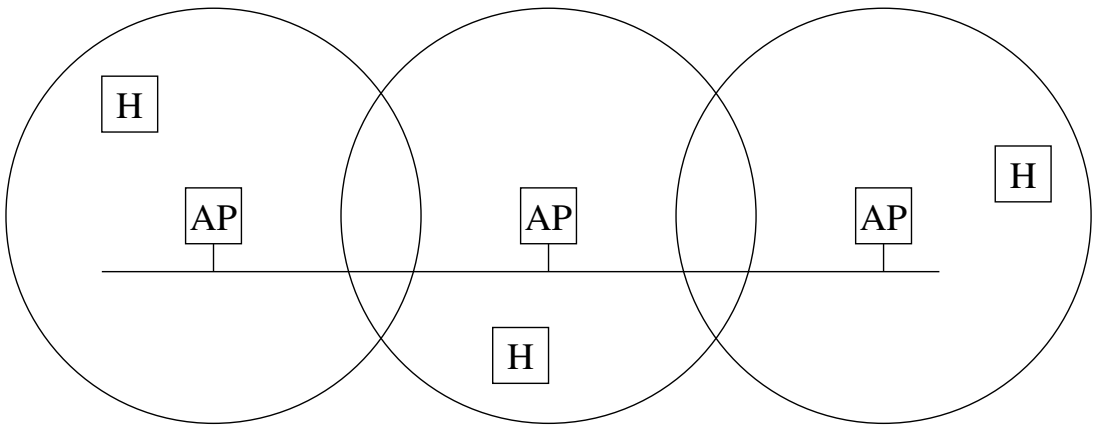

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An ESS can cover an area as large as you like

Wireless Networks

Exercise Read about *Wi-Fi Direct*, another peer-to-peer wireless connection between hosts, often used as a device setup mechanism. Compare with Ad-Hoc mode

Exercise Read about Mesh networks

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But only private from people not on the network!

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As can its successor, *Wi-Fi Protected Access* (WPA)

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Exercise Read about the new WPA3

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We usually find BSS using WPA-PSK and ESS using WPA-Enterprise, but either can use either

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WPA-Enterprise is more complex

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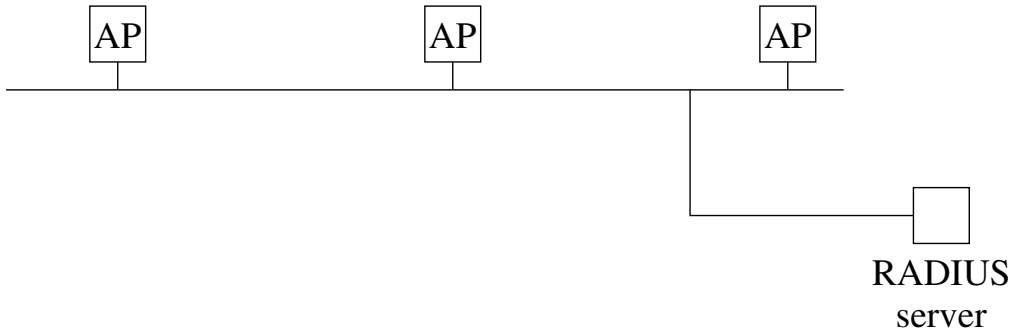
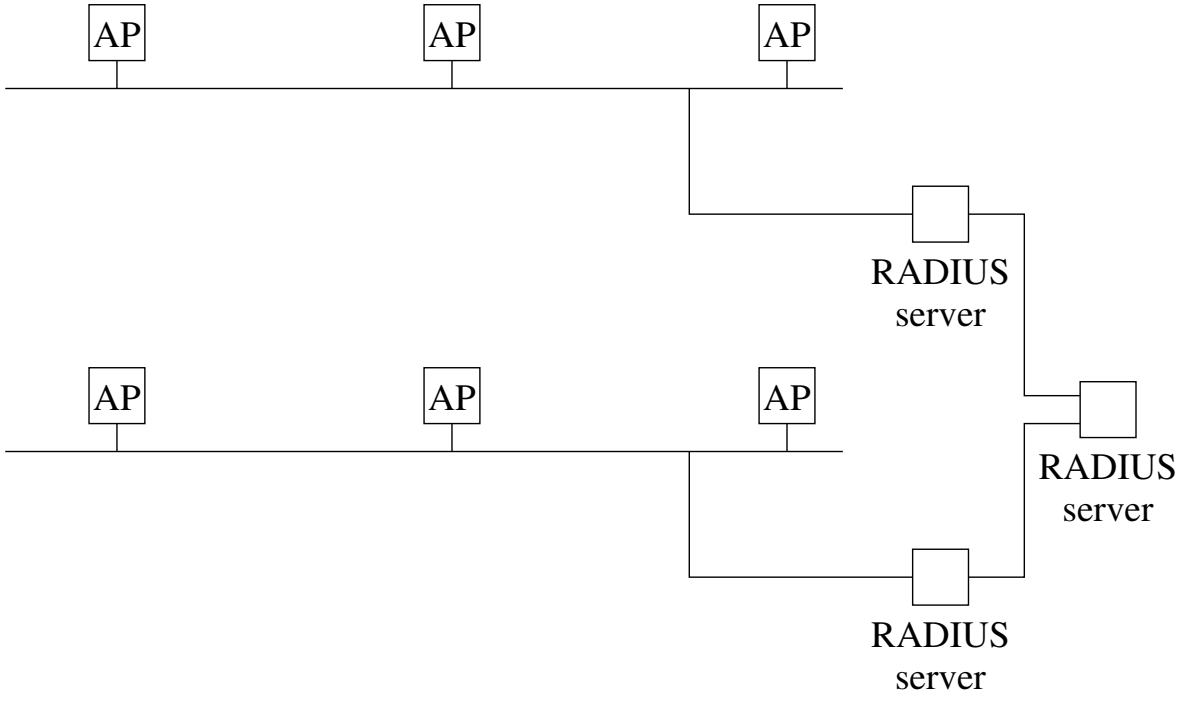


RADIUS authentication

Wireless Security



Multi-institution

Wireless Security

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Authentication is done in the RADIUS server on both the username and the password

Wireless Security

Exercise Read about how Eduroam uses WPA-Enterprise

Exercise Read about RADIUS: *Remote Authentication Dial In User Service*

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Exercise A common system we see on public Wi-Fi is a redirect to a login web page: sometimes called a *captive portal*. What kind of security (privacy and authentication) does this provide? Note this is *not* WPA-Enterprise

Wireless 802.11

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Exercise What implication does this have for Ethernet collision domains?

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Exercise For hardware hackers: read about the IEEE layers:

- *Physical Medium Attachment* (PMA) for things like frames
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But it does mean we don't have to discuss Wi-Fi any further!

Other Wireless

Many other wireless networks exist, from local to wide-area

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Bluetooth gives short range, point-to-point communication

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Bluetooth Low Energy (BLE), is a non-backwards-compatible evolution designed to reduce power consumption

Other Wireless

Exercise Read about *Adaptive Network Topology* (ANT and ANT+) for short range low power wireless, similar to BLE, but for use with fitness (and other) sensors (by Garmin)

Exercise Read about *Zigbee* for short range low data rate, low power wireless, for use in home automation and control

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The ITU (who say what “4G” is supposed to mean) actually gave in to commerce and retroactively changed the definition of 4G to allow for LTE

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Some phones and systems support *voice over LTE* (VoLTE) using a suitable digital encoding of sound over the data channel

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A device will be able to connect even if it is moving at 500km/h (e.g., in a plane); latencies will be 1ms, compared to the current 20ms on LTE

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- or upgrading old ones and re-purposing existing frequencies used by 3G

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(The base-stations will need really good onward connectivity!)

Other Wireless

2G and 3G signals are due to be phased out by 2033 so their frequencies can be reused by 4G and 5G

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Exercise Read about how this affects 4G not natively supporting voice and limited VoLTE support

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Exercise How many radios are there in your mobile phone?

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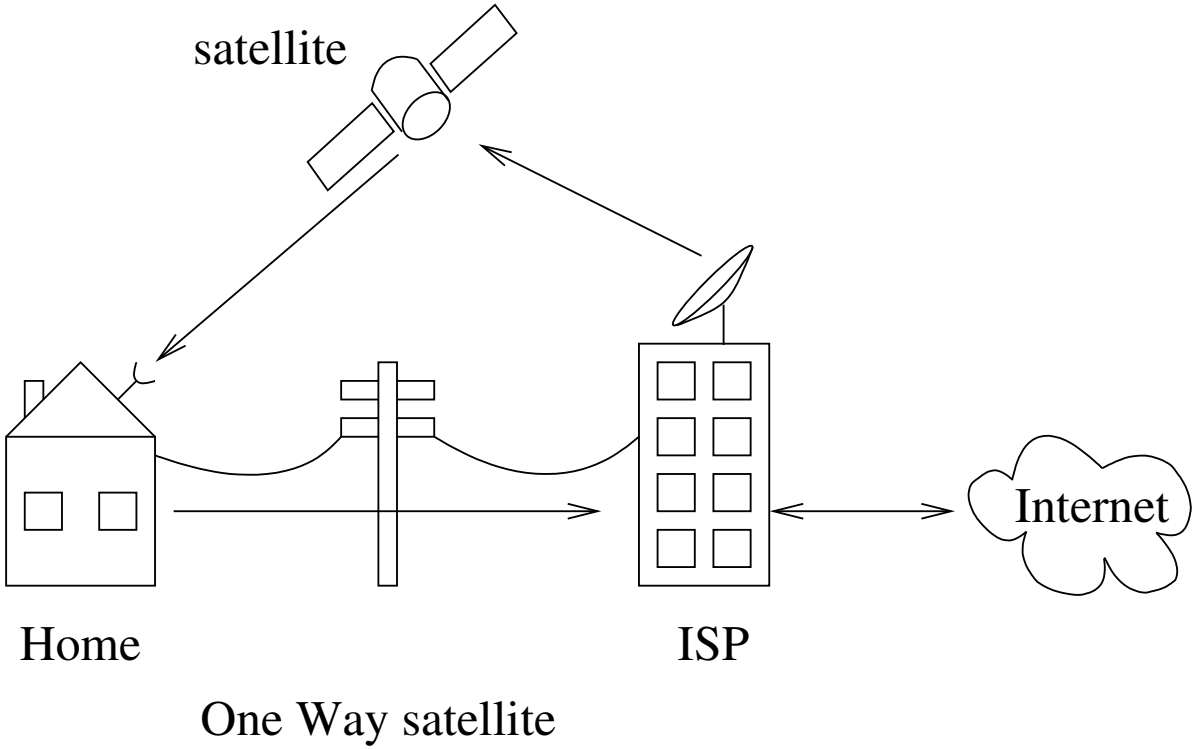
There are two main variants

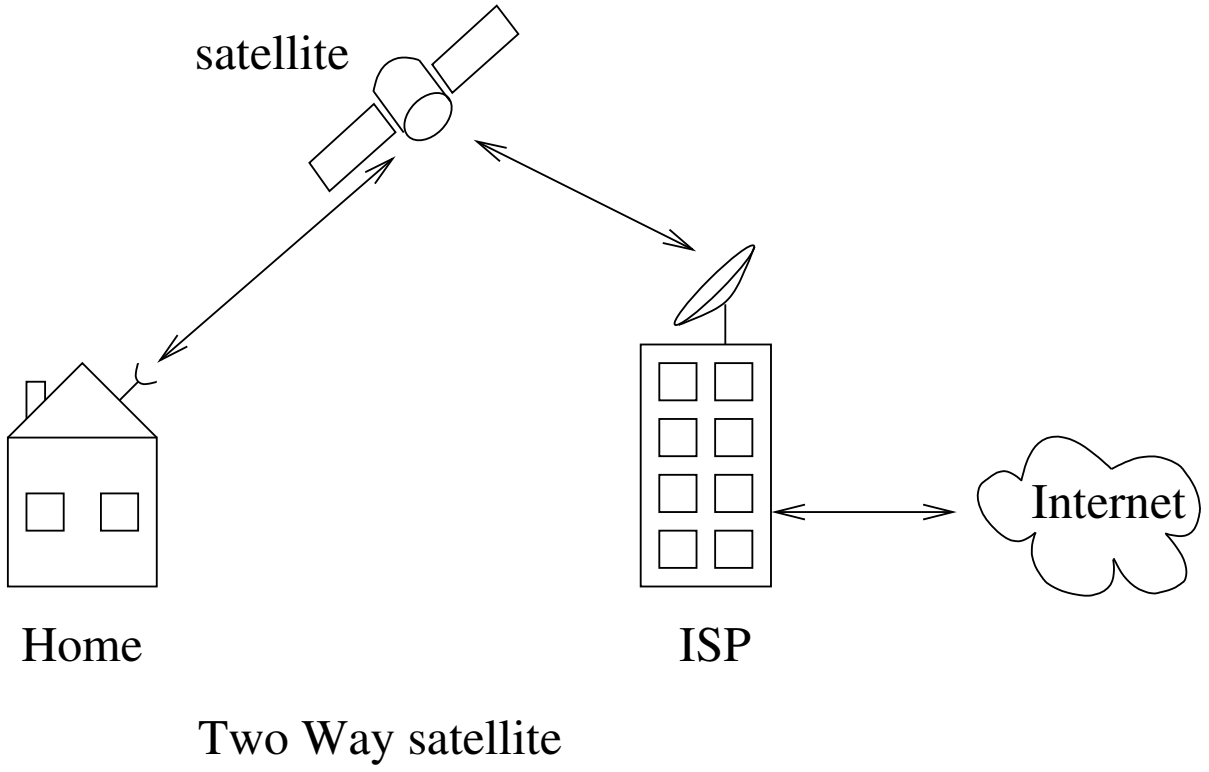
Other Wireless



One way satellite

One way satellite: this employs the usual asymmetry. Data away from the home travels by telephone wire; data towards the home travels through a satellite connection

Other Wireless



Two way satellite

Two way satellite: satellite connections both ways. More expensive in equipment in the home, but not reliant on a telephone network

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Lower latency $\Longrightarrow$ lower orbit $\Longrightarrow$ faster moving satellites $\Longrightarrow$ more satellites needed to maintain coverage

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Due to the cost, this may turn out to be a “top up” service for the hard to get at places; not a general connection for all

The Physical Layer

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Fortunately, as we go up the layers, the amount of variety decreases!