Chapter 5
The Physical and Link Layers 3: Wireless and Beyond

Wireless and Beyond

- The problem with wired networks is the wires
- They cost a lot to install
- They are difficult to manage (large bundles are very unwieldy and get in the way)
- They tie a machine to a specific location
- Can't have mobile access with a wired system

Wireless and Beyond

- Wireless networks have been around for a long time: for example cellular telephone systems
- Everything wireless is overseen by national and international bodies: can't have a free-for-all in a shared resource
- One wireless system can affect another hundreds or thousands of miles away: there must be some sort of cooperation

Wireless and Beyond

- Europe have the *European Telecommunication Standards Institute* (ETSI)
- USA has the *Federal Communication Commission* (FCC)
- Such bodies manage the airwaves, allocating various frequencies to various purposes, ensuring minimal interference between the competing concerns for parts of the spectrum

Wireless and Beyond

Wireless Ethernet

- 802.11 groups of standards deal with wireless Ethernet
- In principle, like CSMA/CD over wireless, but with some extra problems unique to wireless

Wireless and Beyond

Wireless Ethernet

- Wireless networks generally have fairly high error rates due to interference from electrically noisy environments, signal reflections, etc.
- So the bandwidth achievable is dependent on the circumstances of the environment
- Wireless networks generate interference themselves

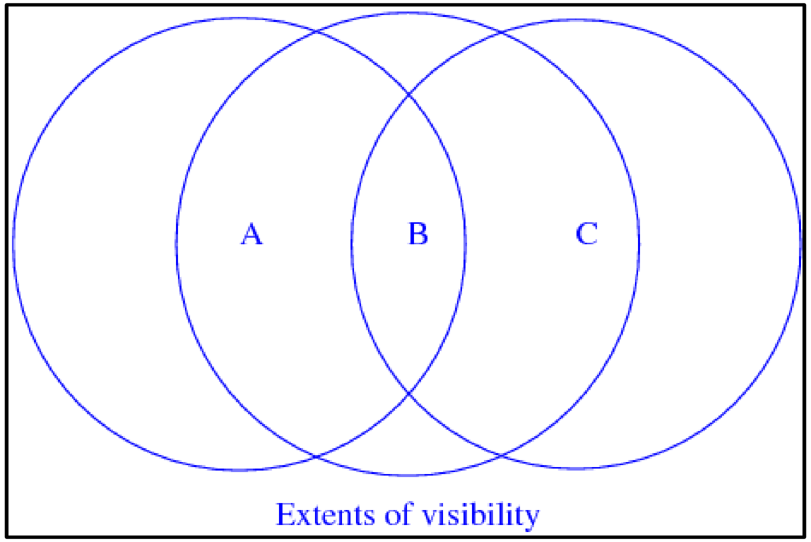
Wireless and Beyond

Wireless Ethernet

- The allowed power of transmission is generally kept quite low by the standards bodies to minimise interference
- Thus the range achievable is often quite limited

Wireless and Beyond

Wireless Ethernet



- Host A can “see” B and B can see C, but A cannot see C, so it cannot tell if its packets to B are colliding with C's to B

Wireless and Beyond

Wireless Ethernet

- As packets are broadcast, wireless networks are intrinsically insecure, so extra effort must be taken over security and authentication
- “War Driving” is driving your laptop around the neighbourhood until you find an unsecured wireless signal: then you have free access to the Internet!

This is illegal in the UK and elsewhere

Wireless and Beyond

Wireless Ethernet

- There are several parts to the 802.11 standard, in particular 802.11a, 802.11b, 802.11g
- Others parts, like 11c, 11d, 11e, 11f, 11h, 11i deal with things like power management, quality of service, security and so on

Wireless and Beyond

Wireless Ethernet 802.11

- The original standard specified rates of (up to) 1Mb/s and 2Mb/s
- Up to 100m (300 feet) indoors and 300m (1000 feet) outdoors
- An Infra-Red mode as well as a radio mode, but this has not been widely implemented
- 802.11b extended this to rates of 5.5Mb/s and 11Mb/s

Wireless and Beyond

Wireless Ethernet 802.11b

- They use the unlicensed 2.4GHz waveband
- That means you do not need to get a licence to use that frequency at low power
- This was a frequency that was otherwise unusable and is subject to interference from microwave ovens

Wireless and Beyond

Wireless Ethernet 802.11b

- 802.11 hardware is branded *Wi-Fi,* which is actually a certificate of interopability given to manufacturers whose equipment demonstrably works with other manufacturers'
- Administered by the *Wi-Fi Alliance*, a consortium of interested companies

Wireless and Beyond

Spread Spectrum

- The bits in 802.11 are not simply transmitted over the air like a radio station: there is a lot of environmental interference to overcome
- Instead the signal is spread over many frequencies using variety of techniques called *spread spectrum*

Wireless and Beyond

Spread Spectrum

- *Frequency Hopping Spread Spectrum* (FHSS) hops amongst the available frequencies in a pseudo-random fashion, spending a little time transmitting at each frequency before moving on to the next
- 802.11 generally uses 79 1MHz channels
- It hops every 400ms (2.5 hops/sec)
- Each hop is 6MHz or more

Wireless and Beyond

Spread Spectrum

- A hopping pattern covers all available frequencies before repeating
- There are 78 hop patterns to choose from
- All this (times, patterns, etc.) is specified in 802.11

Wireless and Beyond

Spread Spectrum

- Each host on the network gets about the full 1 or 2Mb/s as each is on a different hopping pattern any they rarely clash
- A 1 bit is encoded as a signal at slightly higher than the current frequency; a 0 is slightly lower
- This gives a 1Mb/s rate

Wireless and Beyond

Spread Spectrum

- For the 2Mb/s rate, there are four signal levels that encode for the bit pairs 00, 01, 10 and 11
- FHSS is rarely used, overwhelmingly more common is DSSS

Wireless and Beyond

Spread Spectrum

- *Direct Sequence Spread Spectrum* (DSSS) spreads the bits in a different way
- This uses a *chipping code* where a single bit is spread into a sequence of 10 to 20 *chips*
- A chip is a 0 or 1, so a 1 bit might become 01001000111 and a 0 become 10110111000 (a *Barker sequence*)

Wireless and Beyond

Spread Spectrum

- The number of chips used is called the *processing gain*
- This is much more resilient to interference: a few chips can be lost and the bit can still be recognised
- The signal looks pretty much like random noise even when, say, a long stream of 1 bits are transmitted: this spreads the power of transmission rather than having a big spike in the power spectrum

Wireless and Beyond

Spread Spectrum

- The bandwidth is regained by using fixed 22MHz channels vs. hopping 1MHz channels for FHSS
- The chips are encoded in a variety of ways

Wireless and Beyond

Spread Spectrum

- 1Mb/s: *Differential Binary Phase Shift Keying* (DBPSK) processing gain 11, 11 million chips/sec, using phase shifts to represent chips
- 2Mb/s: *Differential Quadrature Phase Shift Keying* (DQPSK) as DBPSK but with four phase shifts to represent chip pairs

Wireless and Beyond

Spread Spectrum

- 5.5Mb/s in 802.11b: *Complementary Code Keying* (CCK) based on DQPSK, but with varying spreading codes to encode more chips per symbol. Two bits as phase shifts and two bits by the choice of one of four spreading codes
- 11Mb/s: using CCK with two chips as phase shifts and six chips as the choice of one of 64 possible spreading codes

Wireless and Beyond

Spread Spectrum

- The allocated frequency band is split into 14 overlapping 22MHz channels each centred on specified frequencies
- The number of channels available depends on the country
  - Most of Europe: 13
  - North America: 11
  - Japan: 14

Wireless and Beyond

Spread Spectrum

Channel	Freq (Ghz)	USA/Can	Fra	Spa	Eu	Jap
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					•

Wireless and Beyond

Spread Spectrum

- Neighbouring channels overlap, so you need to take care which channels you use to avoid interference

Wireless and Beyond

Spread Spectrum

- Rough recommendations:
  - Separate channels by at least 2 (e.g., 1 and 4) to reduce interference
  - Separate by 4 (e.g., 1 and 6) to have no interference at all
  - This means we can have on three co-located networks on channels 1, 6 and 11

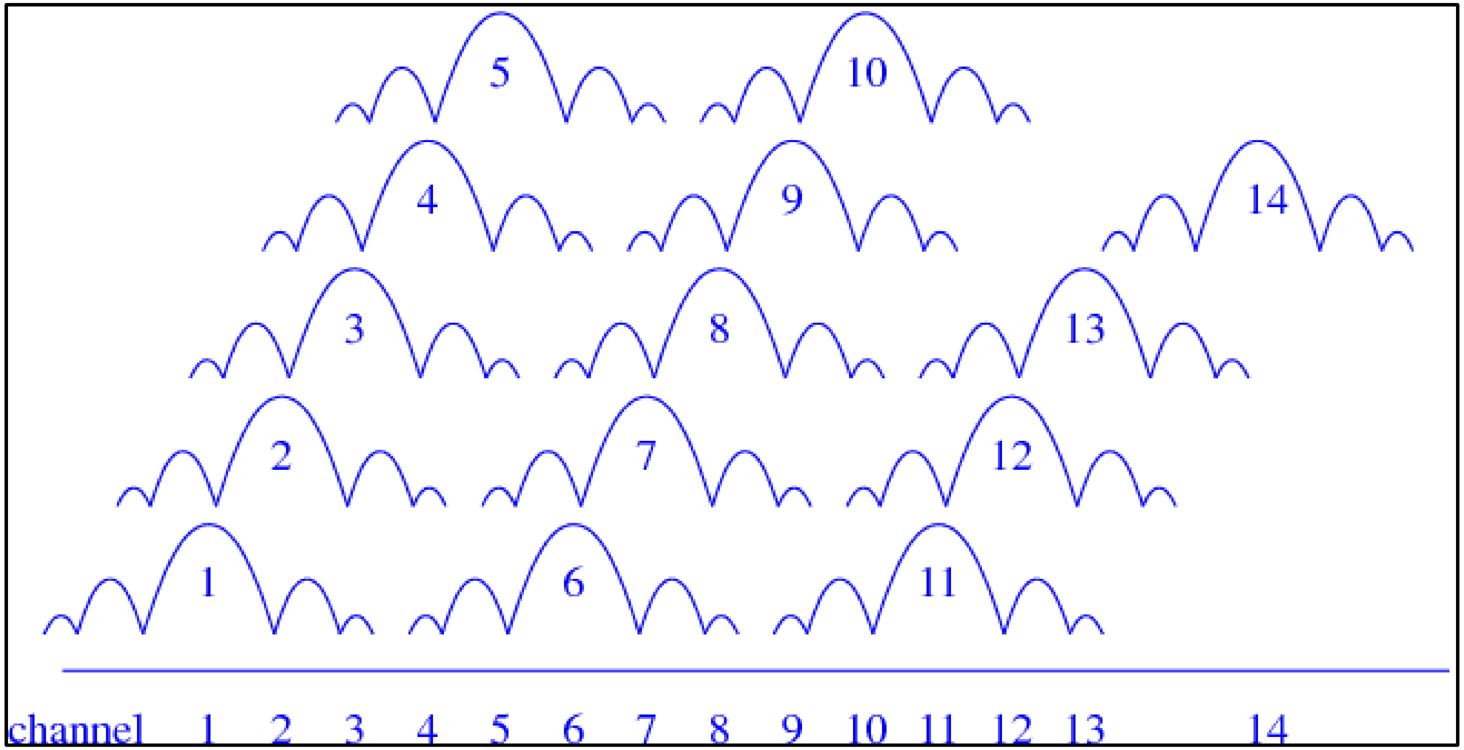
Wireless and Beyond

Spread Spectrum

- Separating networks physically gives more leeway:
  - Separate by 1 (e.g., 1 and 3) if the networks are more than 40m apart
  - Adjacent channels (e.g., 1 and 2) are OK over 100m
  - Channels can be reused when the networks are well separated

Wireless and Beyond

Spread Spectrum



Wireless and Beyond

DSSS vs. FHSS

- DSSS has better immunity to noise
- DSSS has less latency as there are no pauses while the frequency hops
- DSSS provides more per-channel bandwidth of 11Mb/s, while FHSS only gives 2Mb/s
- FHSS allows 26 networks to coexist, while DSSS only can really do three

Wireless and Beyond

DSSS vs. FHSS

- FHSS has an aggregate bandwidth of 26 networks x 2Mb/s = 52Mb/s
- DSSS has an aggregate bandwidth of 3 networks x 11Mb/s = 33Mb/s
- FHSS uses less power and so is better for portable devices
- FHSS is cheaper to build
- FHSS degrades more gracefully under heavy load

Wireless and Beyond

DSSS vs. FHSS

- DSSS has overwhelmingly taken the market and FHSS is impossible to find

Wireless and Beyond

CSMA/CA

- 802.11 uses *carrier sense, multiple access, collision avoidance,* similar to CSMA/CD in Ethernet
  - Carrier sense: listen for a signal
  - If free, send a packet
  - If busy, wait until the end of the transmission and enter a *contention period* (wait a random period)
  - Listen again at end of contention period

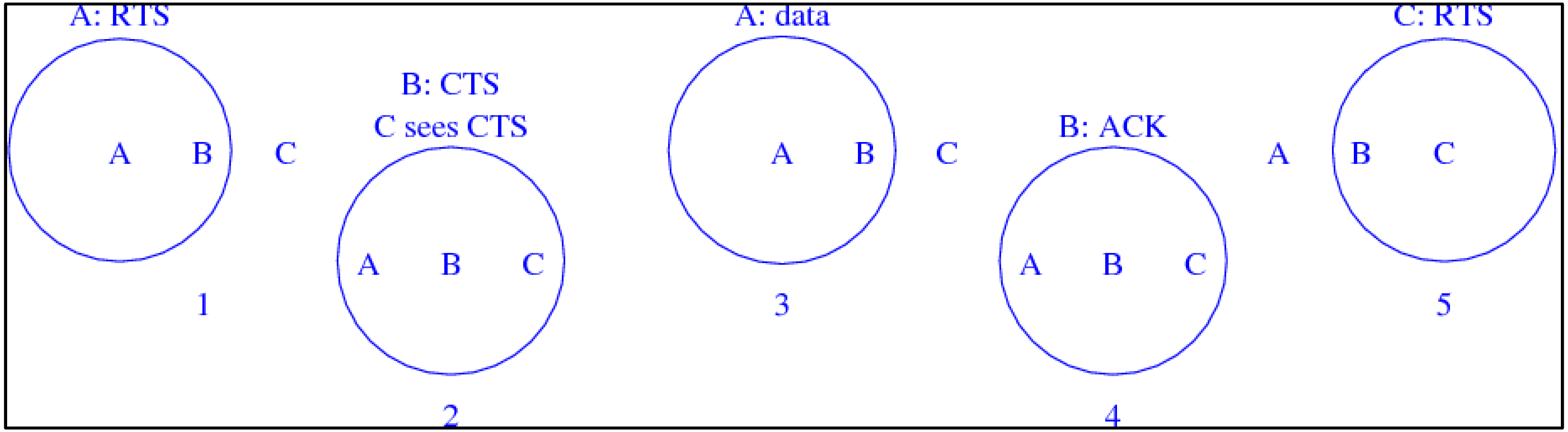
Wireless and Beyond

CSMA/CA

- Additional features are:
  - If the packet is safely received the destination sends an acknowledgement (ACK) packet back to the source
  - If the source doesn't get the ACK, it resends
  - For the visibility problem, there is optional *RTS/CTS handshaking*

Wireless and Beyond

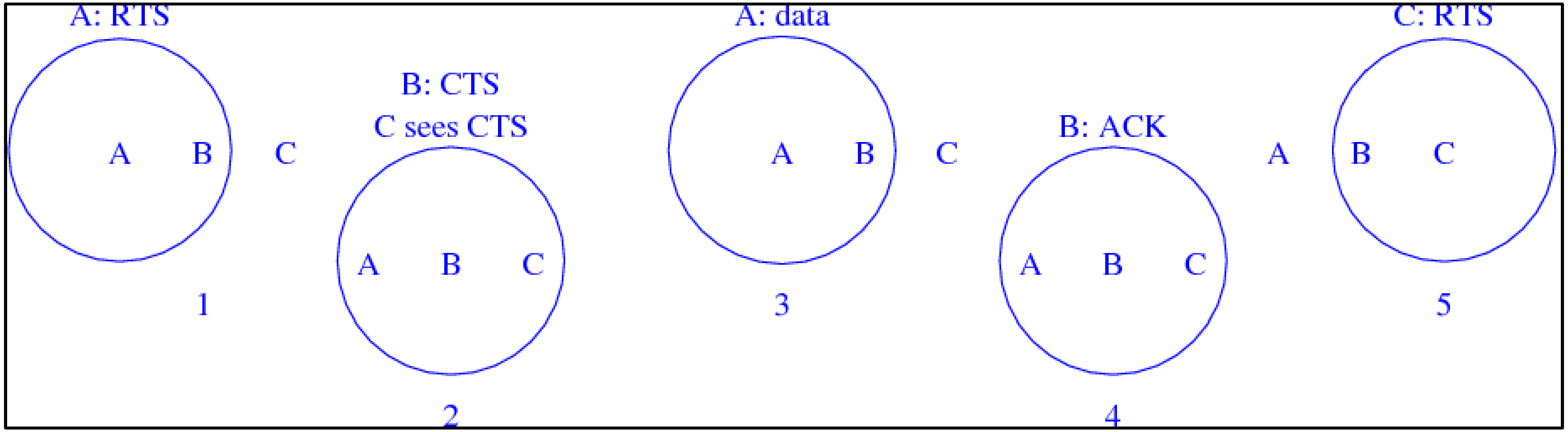
CSMA/CA: RTS/CTS



- Before sending a data packet the source sends a *request to send* (RTS) packet

Wireless and Beyond

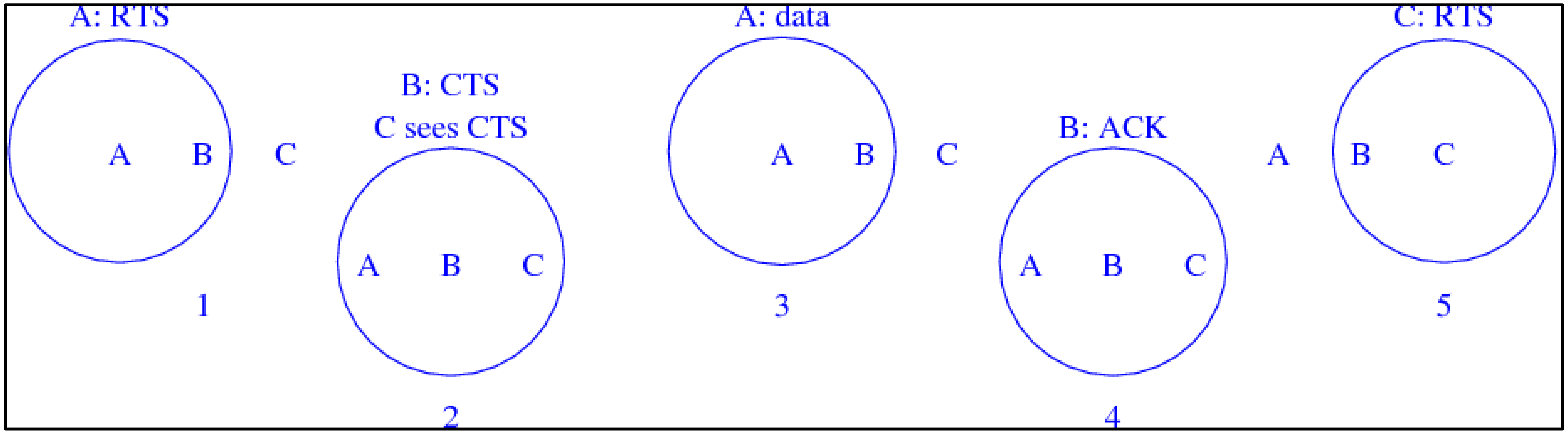
CSMA/CA: RTS/CTS



- If the destination is happy (it is not already receiving from another host that the first cannot see) it responds with a *clear to send* (CTS) packet

Wireless and Beyond

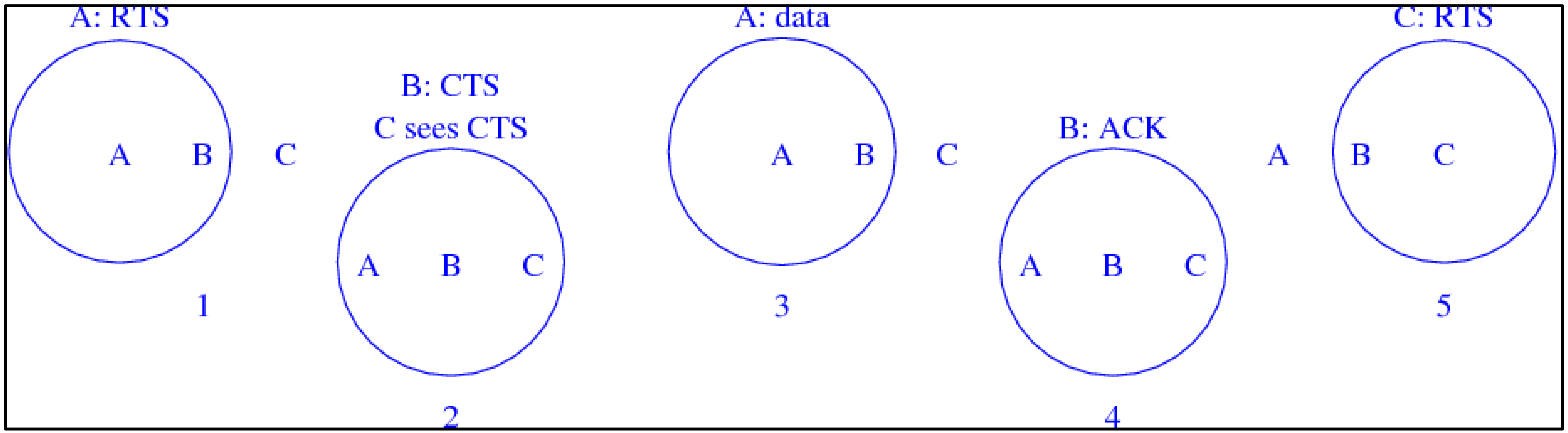
CSMA/CA: RTS/CTS



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

Wireless and Beyond

CSMA/CA: RTS/CTS



- The RTS and CTS contain the length of the desired transmission so other hosts know how long to wait

Wireless and Beyond

CSMA/CA: RTS/CTS

- This means there is a lot of latency compared to Ethernet, so RTS/CTS can be switched off
  - RTS/CTS always on: good for large or busy networks
  - RTS/CTS never on: good for small or lightly loaded networks where every host can see all other hosts
  - RTS/CTS for large packets only: a compromise that reduces the relatively large overhead for small packets

Wireless and Beyond

Marketing Alert

- Although 802.11b is nominally 11Mb/s and 802.11g is nominally 54Mb/s these are the *signalling rates,* not the data rates
- The signalling rate is the raw bit rate over the airwaves: a lot of that is consumed in overheads
- Realistically, 802.11b gives about 3 to 4Mb/s and 802.11g about 20Mb/s

Wireless and Beyond

802.11a

- Designed for higher bandwidth applications
- Uses 5GHz band: less contended than 2.4GHz band
- Uses *orthogonal frequency division multiplexing* (OFDM), similar to a chipping code
- Rates from 6Mb/s to 54Mb/s (nominal)
- Shorter physical range than 802.11b/g

Wireless and Beyond

802.11a

- For a given distance and power it has a higher rate than 802.11b/g
- Get an actual rate of about 22 to 26Mb/s over a short distance

Wireless and Beyond

802.11g

- Backwardly compatible with 802.11b/g (uses 2.4GHz and will interoperate with 802.11b/g at rates of 11Mb/s and slower)
- A nominal rate of 54Mb/s
- Distances comparable to 802.11b/g

Wireless and Beyond

802.11a vs. 802.11g

- They have same bandwidth and both use OFDM
- 11a is more lossy and will barely pass through walls; 11g travels further
- 11a requires more power as it uses a higher frequency
- The 5GHz band is much less crowded than the 2.4GHz, so there is less potential interference

Wireless and Beyond

802.11a vs. 802.11g

- Only can get three 11g networks co-located, but 11a allows 12 or more
- 11g is backwards compatible with 11b
- 11g is widely available, while 11a is much harder to find
- 11a may become more popular in the future when the airwaves become more clogged
- Probably both will be overtaken by newer technology: 802.11n