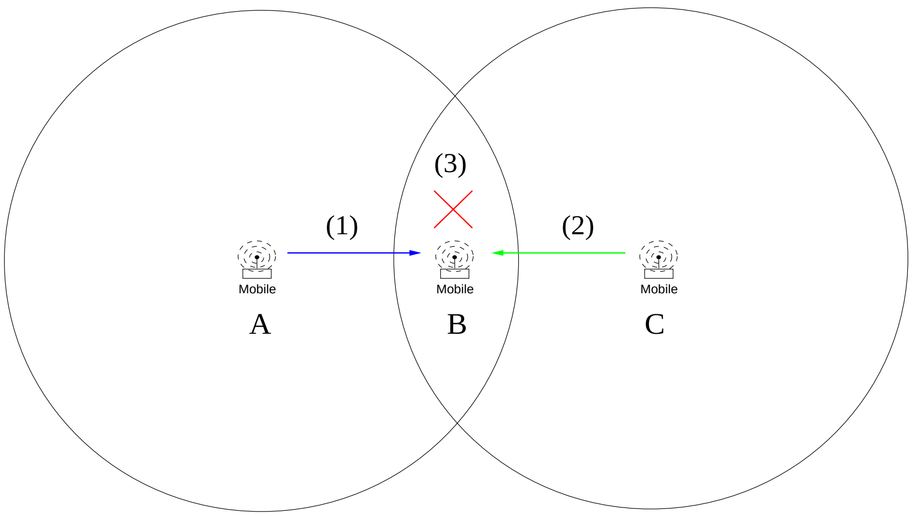
Additional issues with CSMA in wireless media:

Hidden station problem:



Hidden Station Problem

(1) A transmits to B

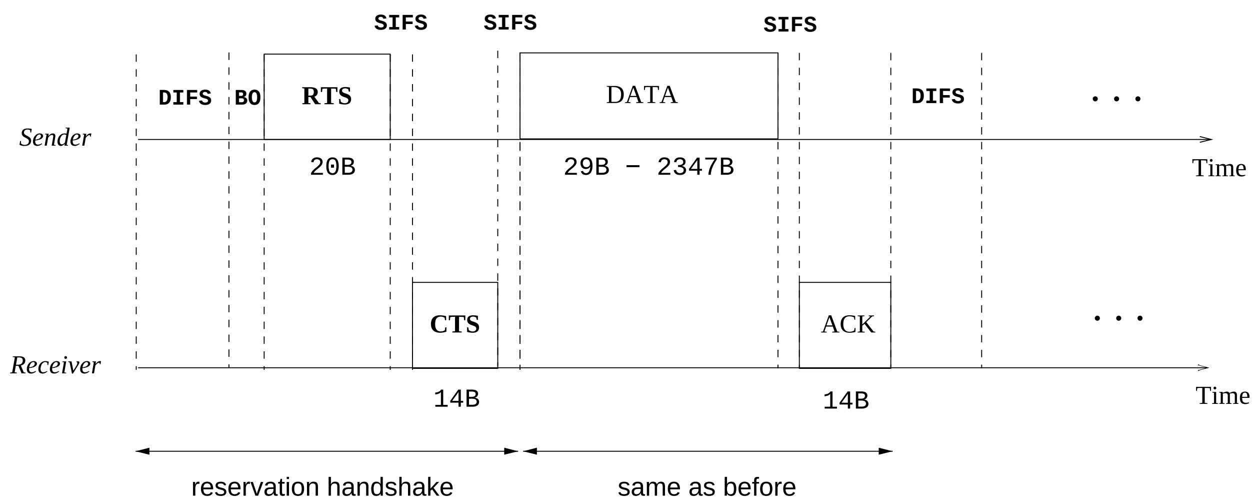
(2) C does not sense A; transmits to B

(3) interference occurs at B: i.e., collision

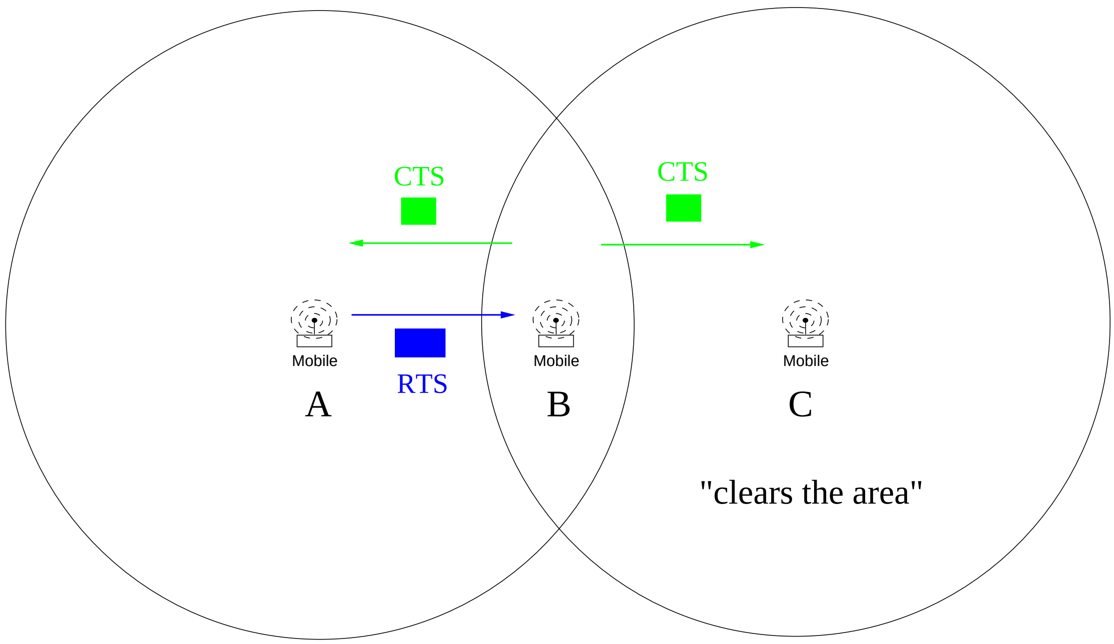
Hidden station problem: CA (congestion avoidance)

$\longrightarrow$ RTS/CTS reservation handshake

- Before data transmit, perform RTS/CTS handshake
- RTS: request to send
- CTS: clear to send



Hidden station problem: RTS/CTS handshake "clears" hidden area



RTS/CTS Handshake

RTS/CTS perform only if data > RTS threshold

$\longrightarrow$ why not for small data?

. . . feature available but not used

But: collision does not always mean junk

$\rightarrow$ capture effect

If A's frame has stronger signal strength than C's frame, B may still be able to successfully decode A's frame

$\rightarrow$ relative signal strength has to exceed capture threshold

$\rightarrow$ good for throughput but also source of unfairness

$\rightarrow$ why?

$\rightarrow$ recall spatial diversity results

Another problem: starvation

→ related to hidden station problem

→ A cannot hear C, C cannot hear A

→ B can hear both A and C

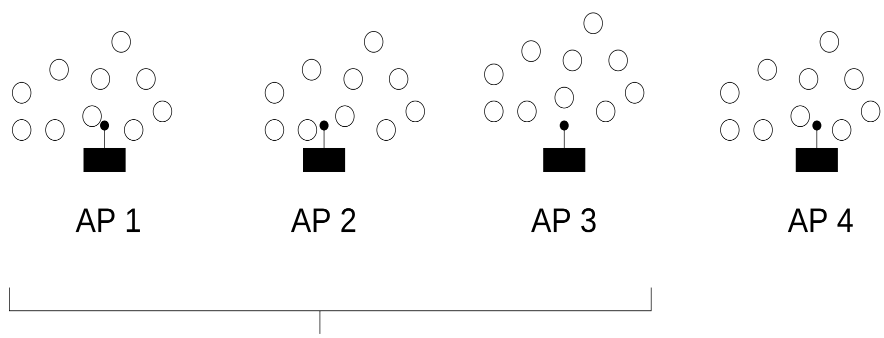
→ by CS: B gets less chance to speak

→ "sandwiched" between A and C

→ may even lead to near-starvation

Example: four 802.11 hot spots, each with 10 clients

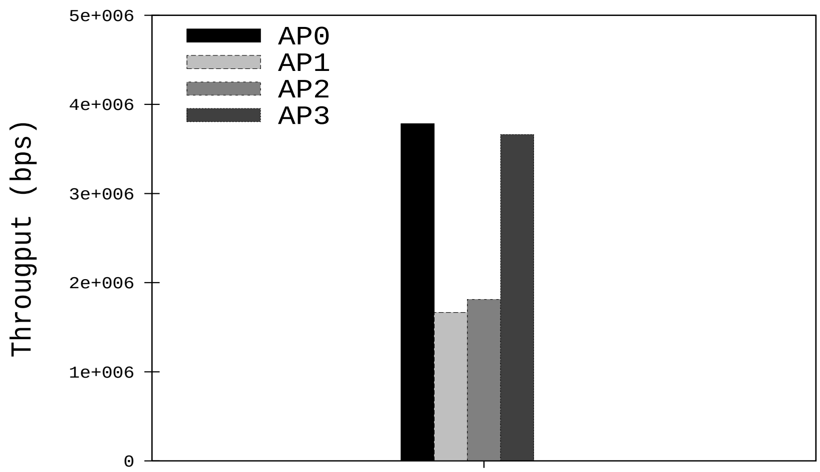
→ e.g., 4 neighboring coffee shops on a street



→ 3 neighboring hot spots (BSS's) are within hearing range of each other

→ AP1 and AP4 are outside CS range

Throughput at four hot spots:



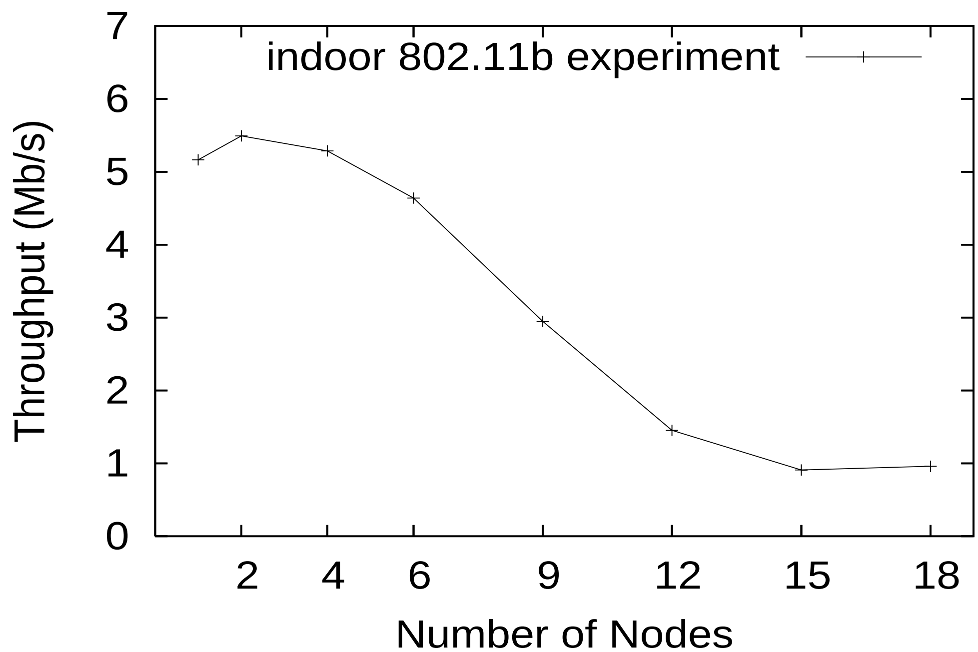
→ middle two get half the throughput

→ depending on configuration, can be even less

WLAN throughput collapse

→ IEEE 802.11b hot spot experiment

→ similar for 802.11g/n



→ throughput collapse to 1 Mbps

→ only moderate contention

IEEE 802.11b defines four data rates

→ 1, 2, 5.5, 11 Mbps

→ 802.11g defines 8 rates: 6, 9, 12, 18, 24, 36, 48, 54 Mbps

→ difference: amount of FEC protection

Note: the higher the data rate, the smaller the frame size

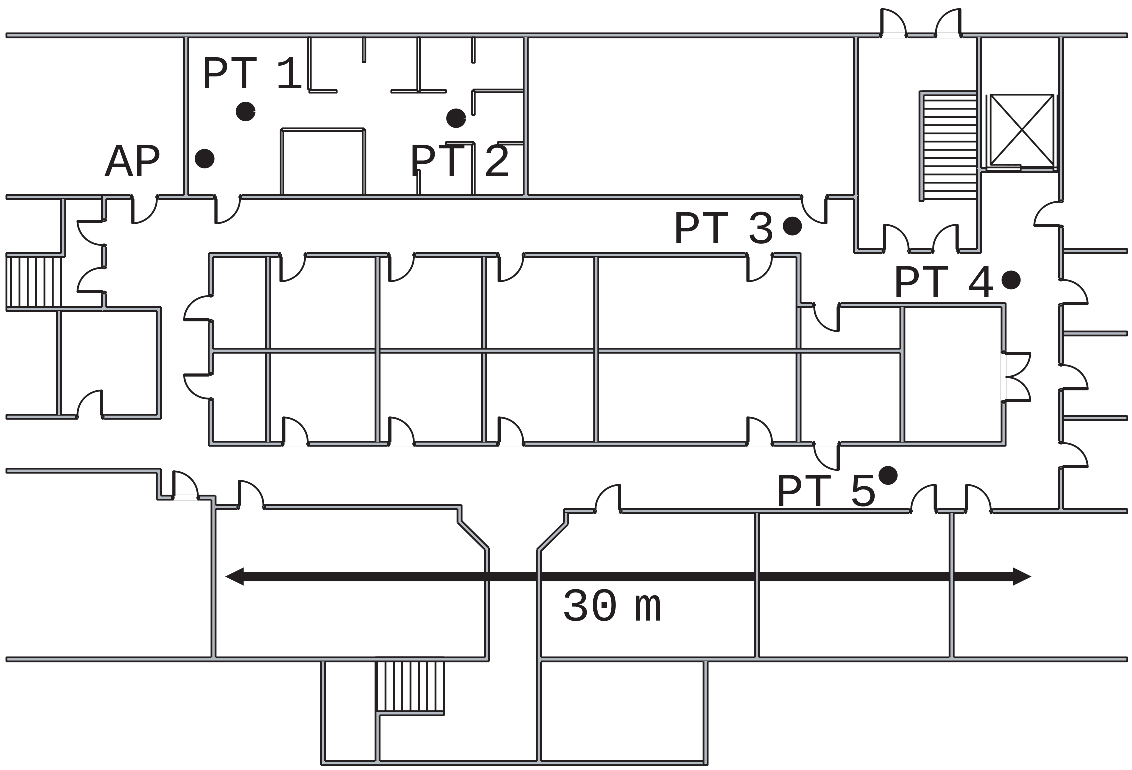
→ why?

→ multiple data rates needed due to noise

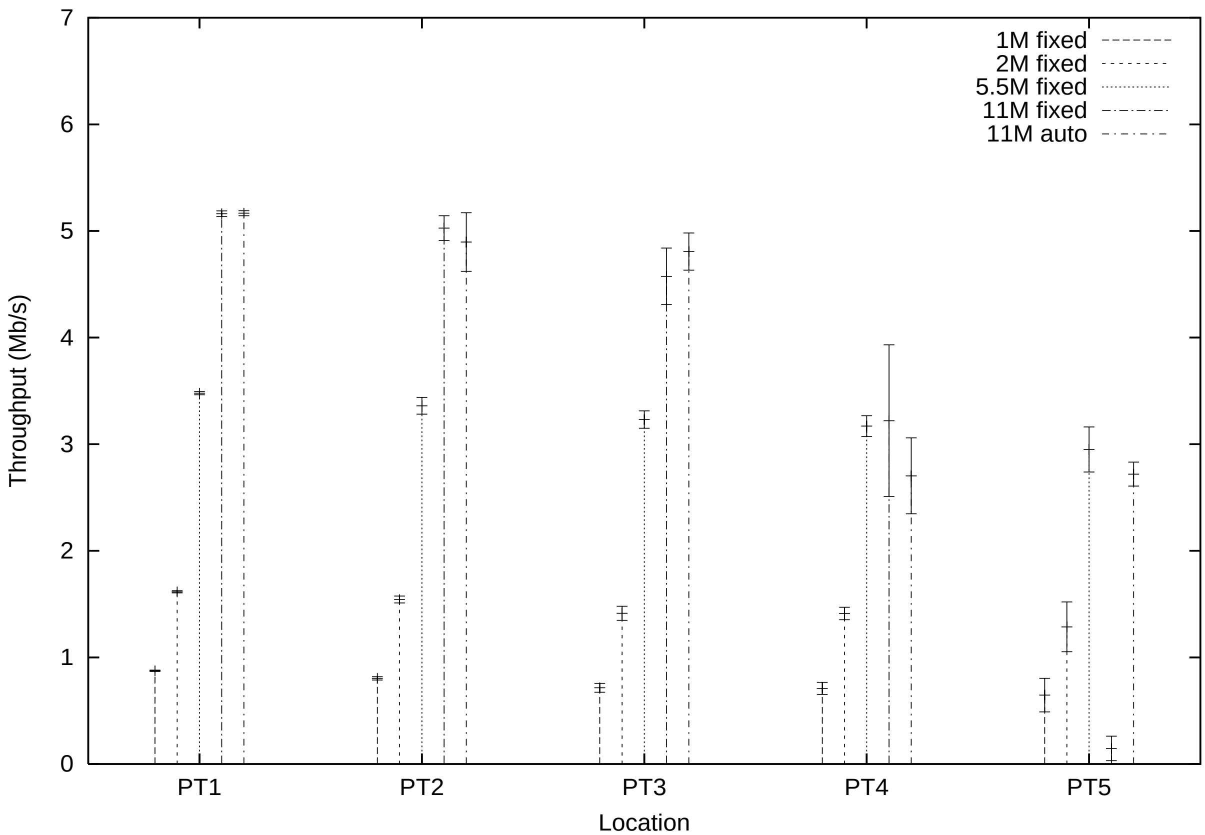
→ same in cellular networks

Ex.: HAAS basement corridor experiment

→ single wireless client



Throughput at different locations:



→ through driver can instruct NIC to fix data rate

→ auto: adaptive method implemented in WLAN cards

→ default mode

→ note inversion: 5.5 vs. 11 Mbps code rates at PT5

How does auto mode work?

→ called automatic rate fallback (ARF)

→ not part of IEEE 802.11 standard

→ vendor could implement different method (most implement ARF)

ARF protocol:

- if 2 successive 802.11 ACK frames are not received, downshift
- if 10 successive 802.11 ACKs are received, upshift

→ origin: Bell Labs WaveLAN (late '90s)

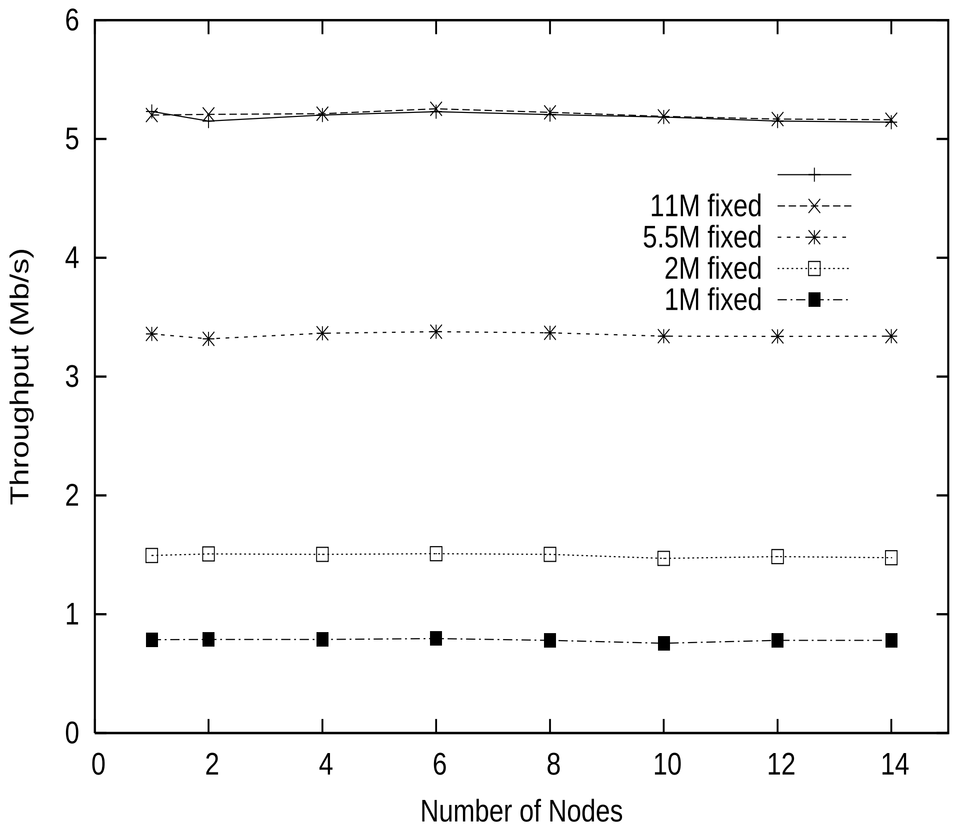
→ note: up/down thresholds are asymmetric

ARF: causes the WLAN throughput collapse

$\rightarrow$ how?

WLAN performance without ARF

→ fix data rates



→ no more throughput collapse

→ if throughput is bad, try fixing data rate

Huge problem but no good solutions yet

→ implementation: firmware fix

→ good problem for start-up company ...

Cellular networks

→ use multiple data rates for FEC as in WLAN

→ throughput collapse doesn't arise

→ why?

802.16 (WiMax)

→ also part of 4G

802.15

→ OFDM based wideband communication

→ may be mixed: e.g., TDMA over OFDM

MIMO (multiple input multiple output)

→ space division multiple access (SDMA)

→ send parallel bit streams over multiple antennas using single carrier frequency

→ spatial diversity principle

→ 2x2: up to 2-fold potential throughput increase

RFID (radio frequency identification)

$\rightarrow$ tag, reader

$\rightarrow$ passive (no battery), active

$\rightarrow$ passive: EM principle

$\rightarrow$ protocol: variant of ALOHA