Softspeak:
Making VoIP Play Well in Existing 802.11 Deployments

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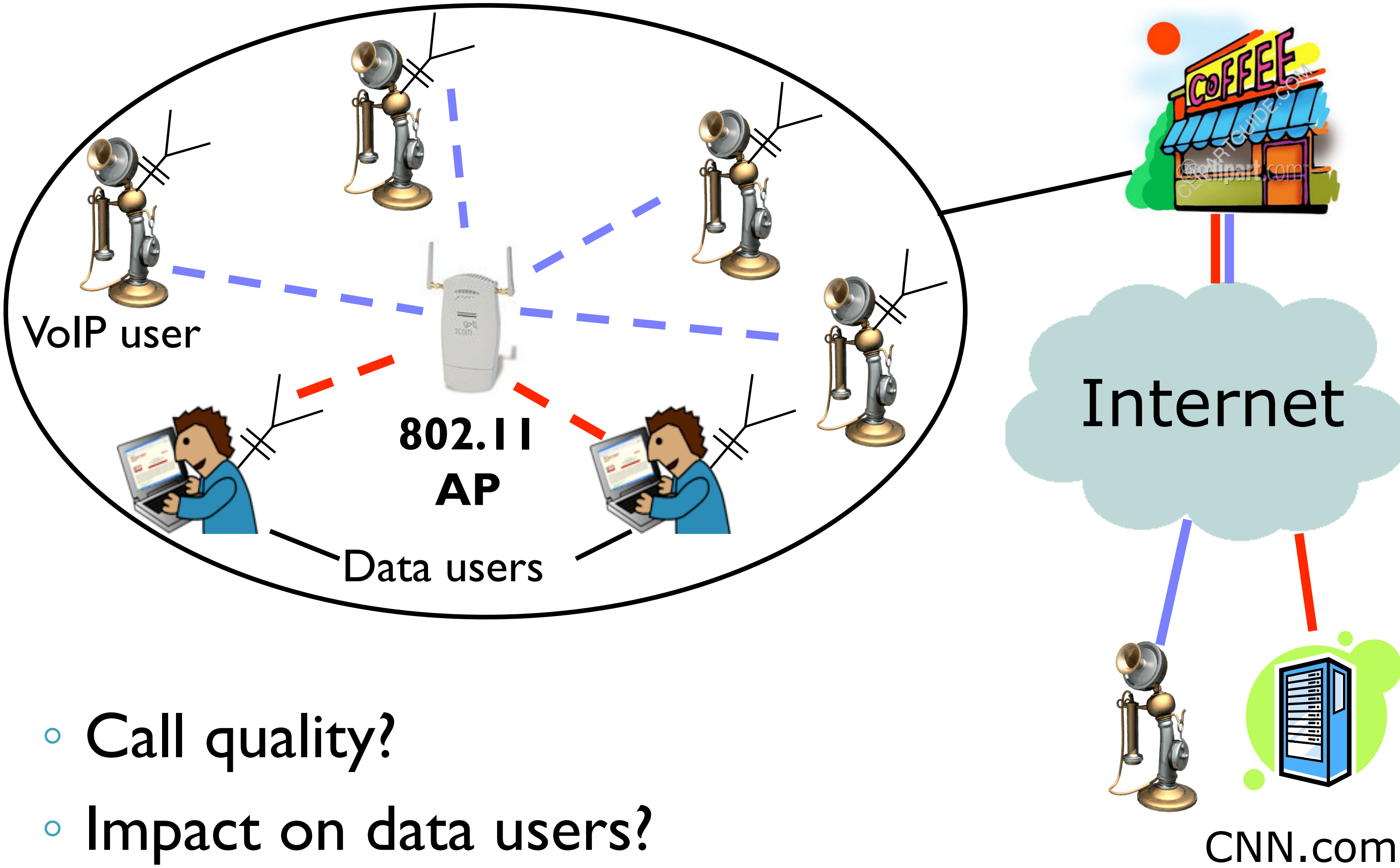
Mobile VoIP usage

- Voice over IP (VoIP) and WiFi increasingl popular

- Cell phones with WiFi + VoIP:
  - iPhone (+ Skype, Fring, iCall, ..)
  - T-mobile UMA and @home

>1M downloads of Skype for iPhone in just two days

Impact of VoIP on WLANs



- Call quality?
- Impact on data users?

VoIP vs. WiFi (802.11)

- 802.11 designed for data traffic
- Substantial per-packet overheads
  - Framing (headers, ACK)
  - Contention (backoff, collisions)
- VoIP:
  - Small packets
  - High packet rate (20-100 pps)

VoIP makes inefficient use of WiFi

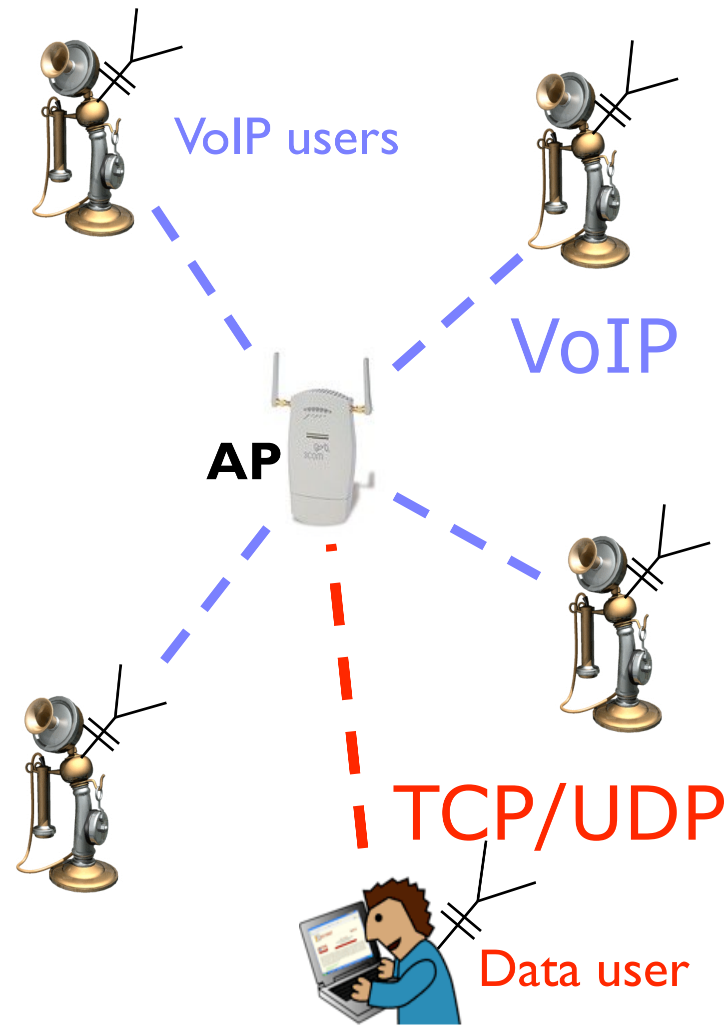
Measuring the impact of VoIP

- Residual capacity
  - TCP / UDP throughput

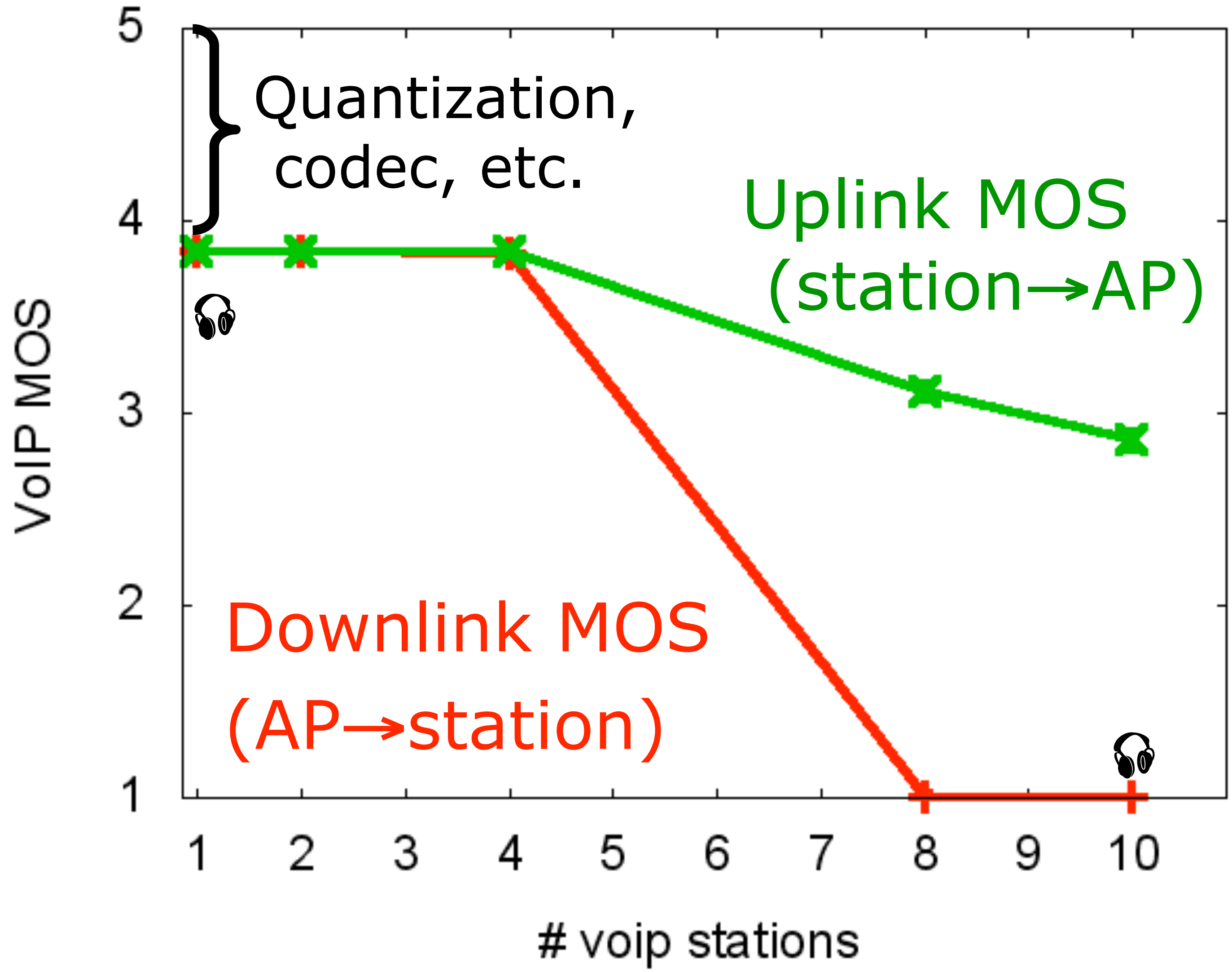
- Mean opinion score (MOS)
  - How audio appears to a real person
  - Score: 1 (bad) – 5 (very good)
  - Can be calculated based on: [Cole et al., 2001]
    - Voice codec
    - Network packet loss, delay, jitter

Measuring the impact of VoIP

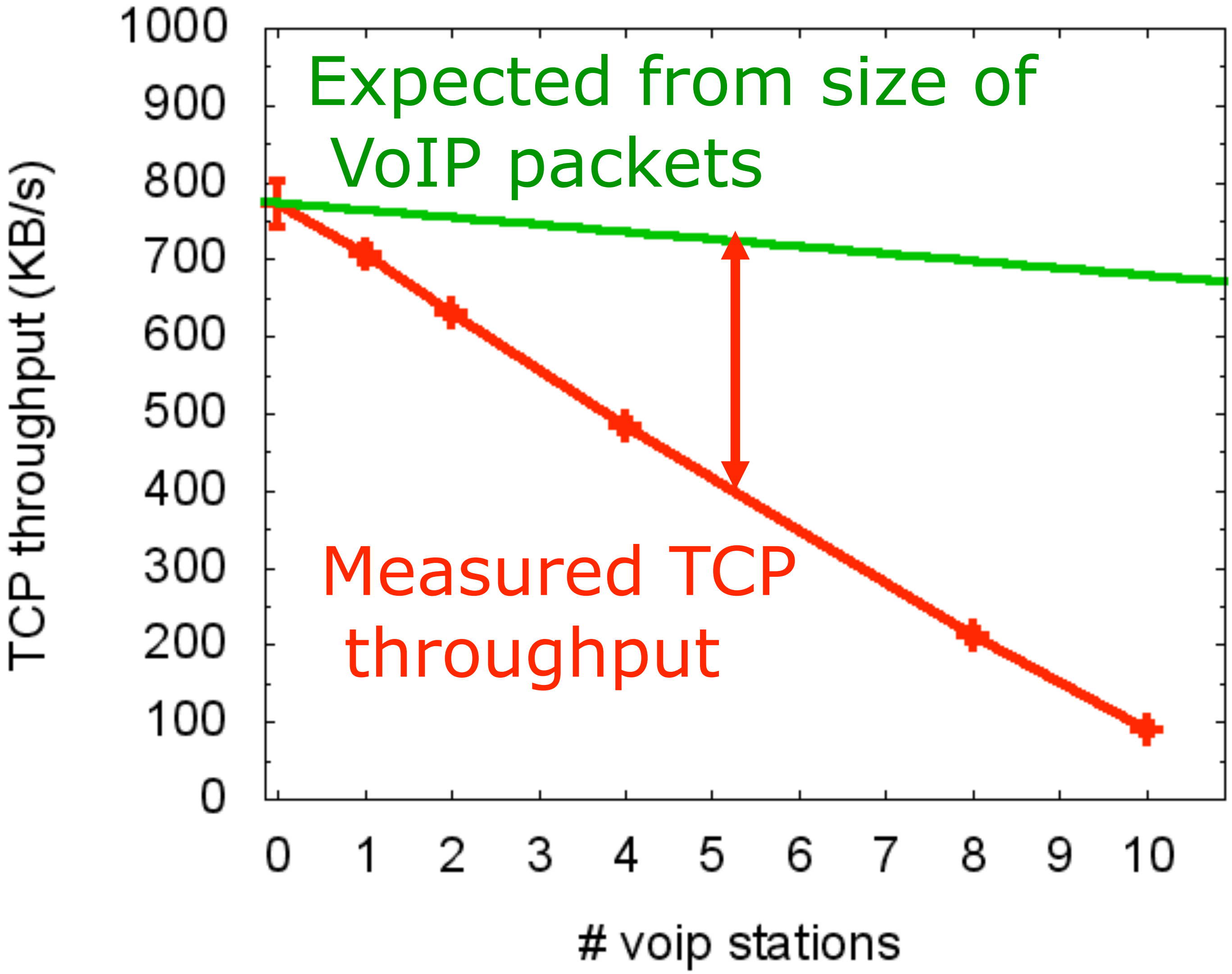
- 802.11 b/g testbed:
  - 10 VoIP stations
  - One data station
- Gradually activate more VoIP stations



Degradation of call quality

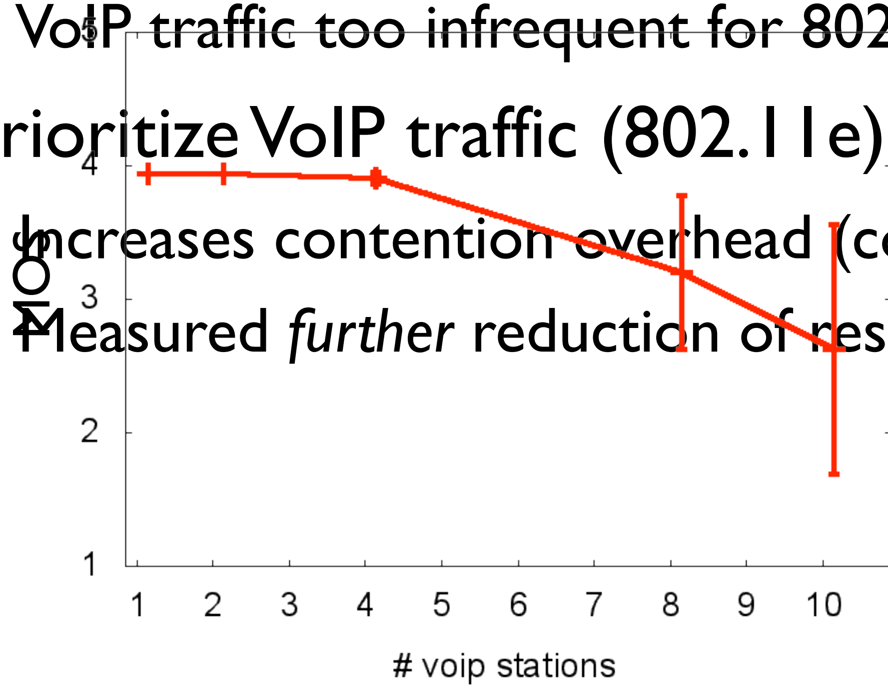


Degradation of TCP



Solutions deployable today

- Decrease VoIP packet rate
- Use higher speeds (802.11g, 802.11n)
  - 'Protection' in the presence of older versions of 802.11
  - VoIP traffic too infrequent for 802.11n aggregation
- Prioritize VoIP traffic (802.11e)
  - Increases contention overhead (collisions)
  - Measured *further* reduction of residual capacity

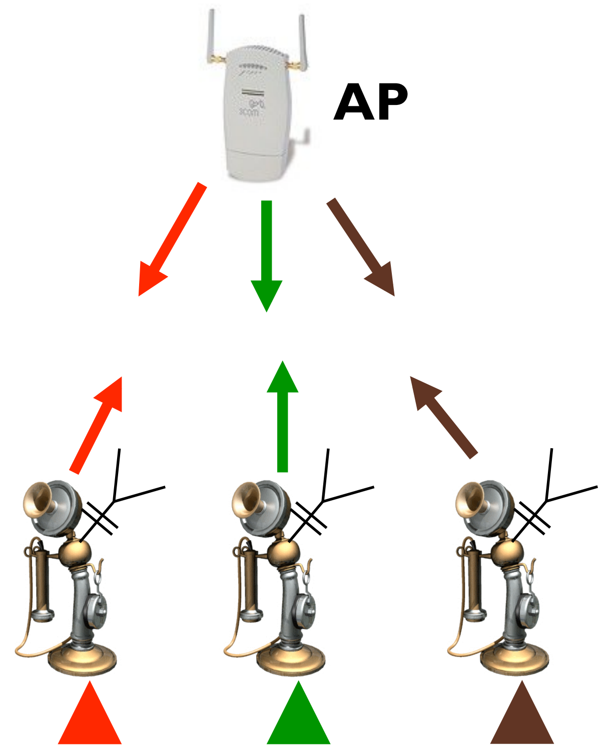


802.11g +
lower VoIP packet rate

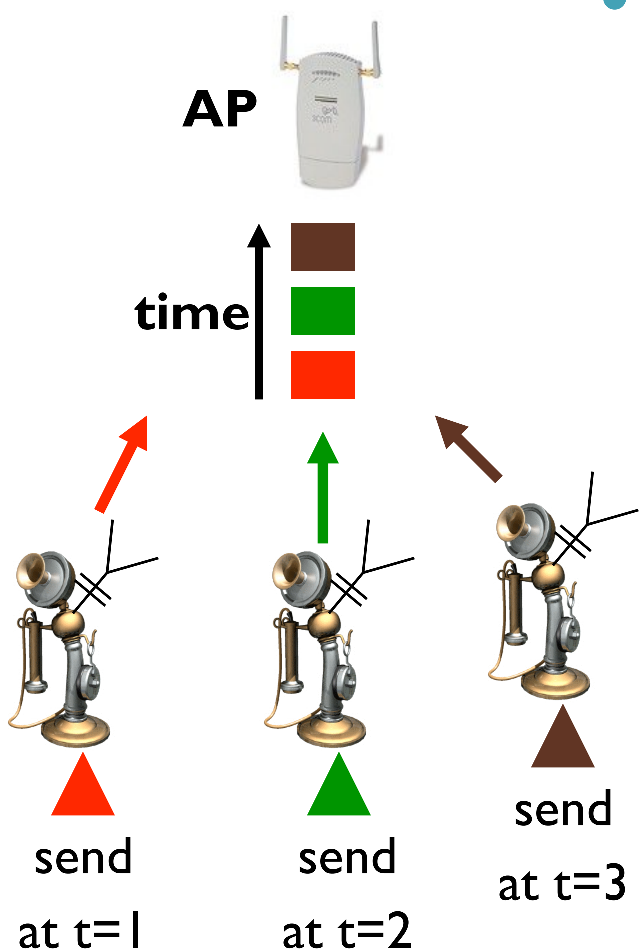
Softspeak overview

- Downlink direction:
  - Aggregation across *multiple* receivers
  - Addresses framing and contention overhead

- Uplink direction:
  - Prioritized TDMA (Time Division Multiple Access)
  - Addresses contention overhead



Uplink: prioritized TDMA

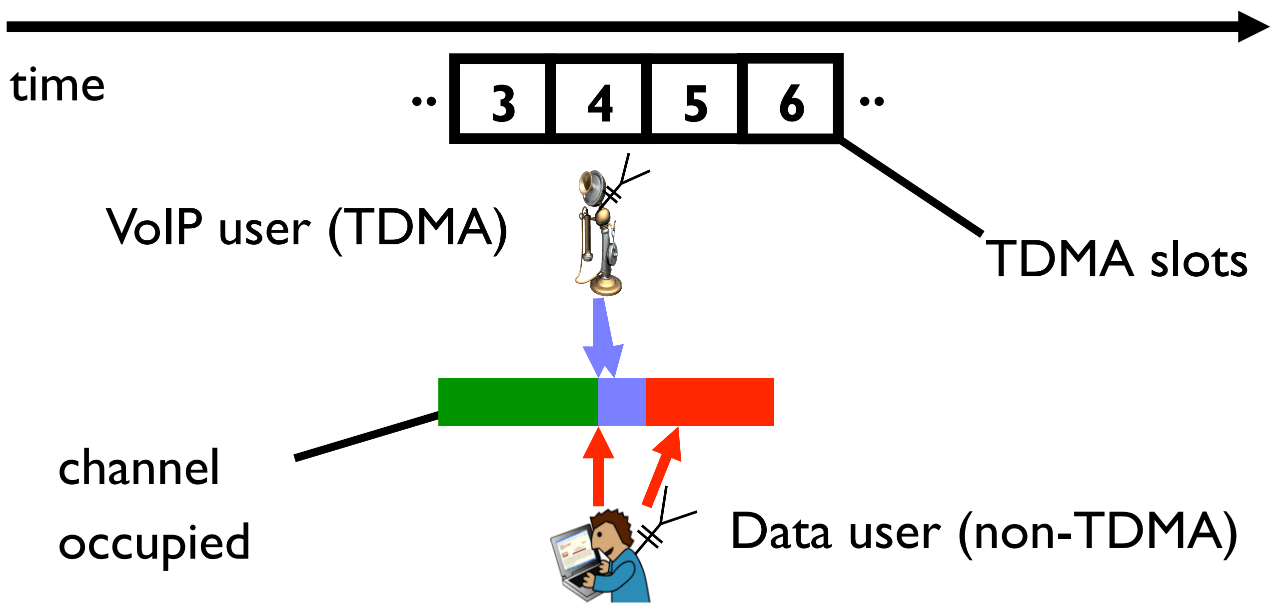


- TDMA by VoIP stations:
  - Avoids collisions by serializing channel access
  - Cycle of 10 TDMA slots, each 1 ms

- VoIP stations must:
  - Establish TDMA schedule
  - Synchronize clocks
  - Compete with non-TDMA traffic

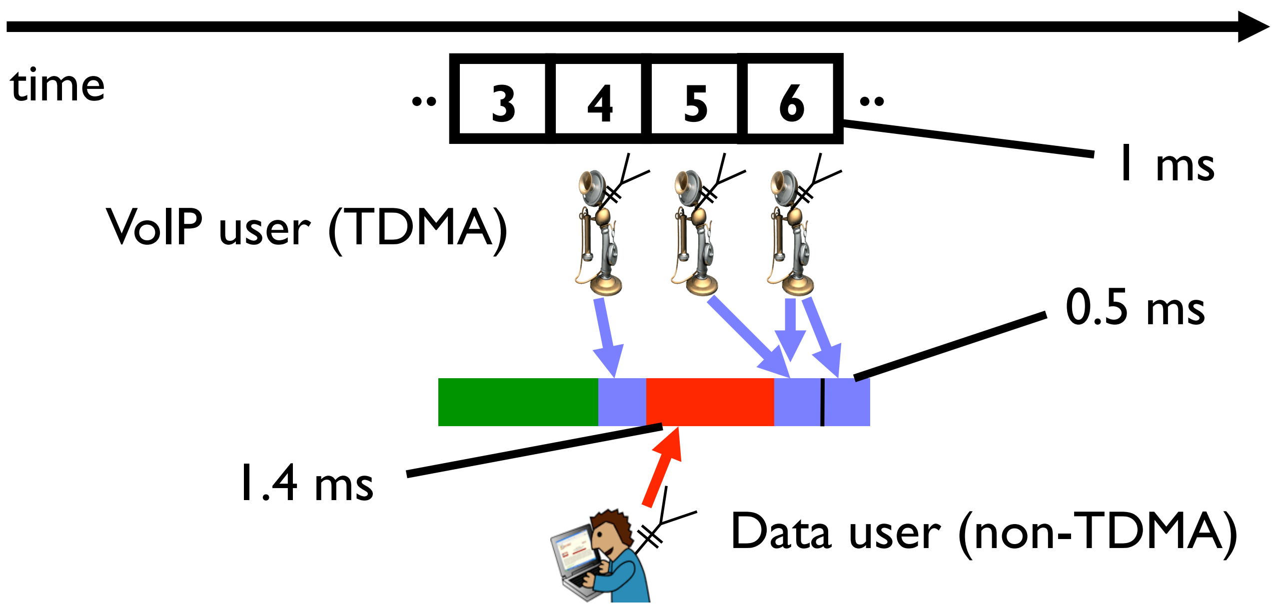
TDMA vs non-TDMA traffic

- Problem:
  - Non-VoIP stations unaware of TDMA
  - May prevent VoIP stations from sending on time
- Let VoIP stations *prioritize* their traffic
  - ..by changing 802.11 contention parameters

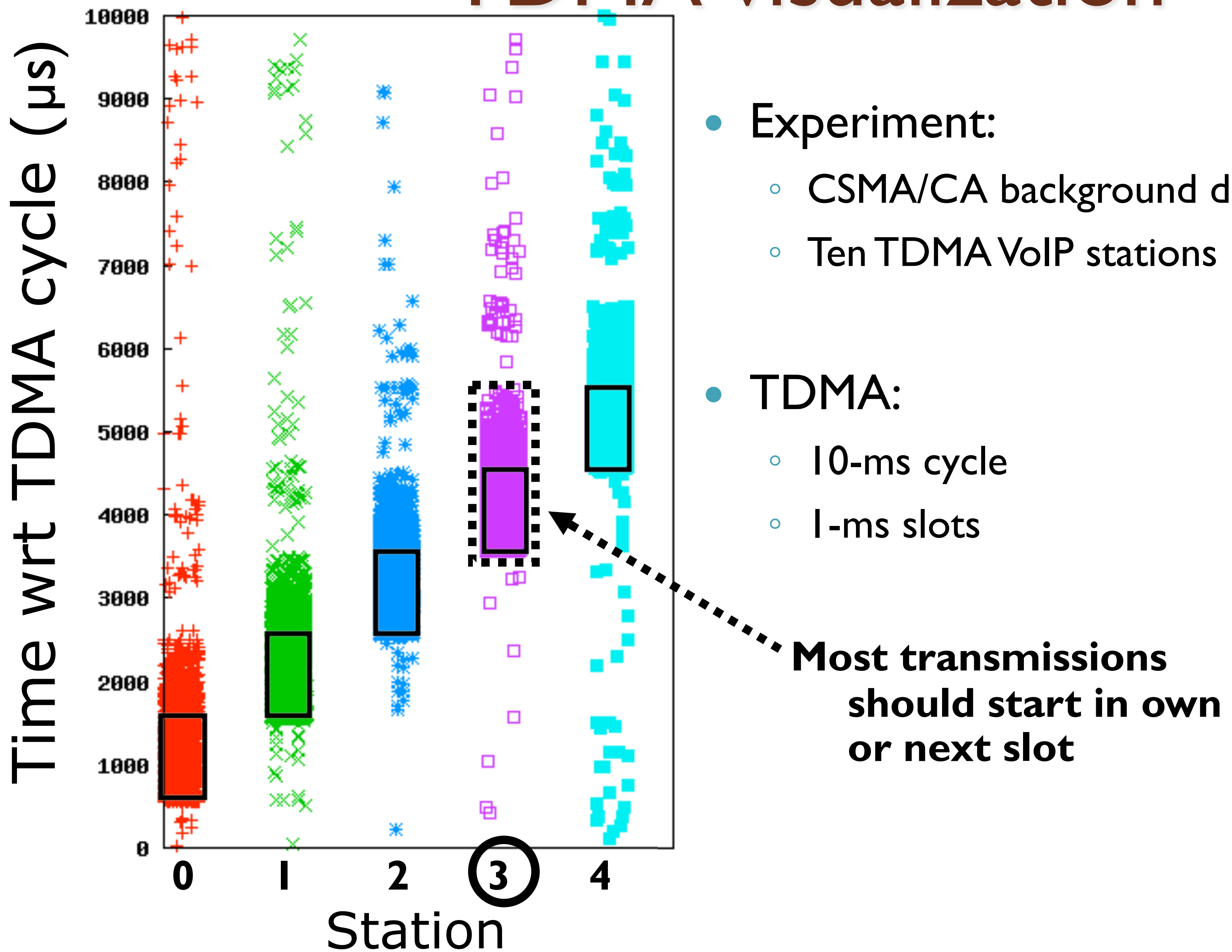


TDMA vs TDMA traffic

- Data packet overruns TDMA slot 5!
  - VoIP station 5 must wait..
  - .. therefore stations 5 and 6 collide in slot 6
- Solution: prioritize *among* VoIP stations 5 and 6



TDMA visualization



- Experiment:
  - CSMA/CA background data traffic
  - Ten TDMA VoIP stations
- TDMA:
  - 10-ms cycle
  - 1-ms slots

Softspeak overview

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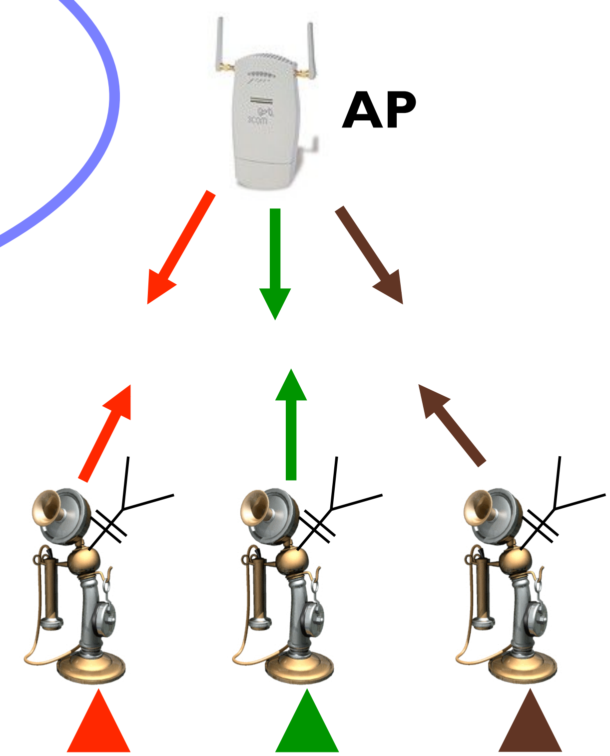
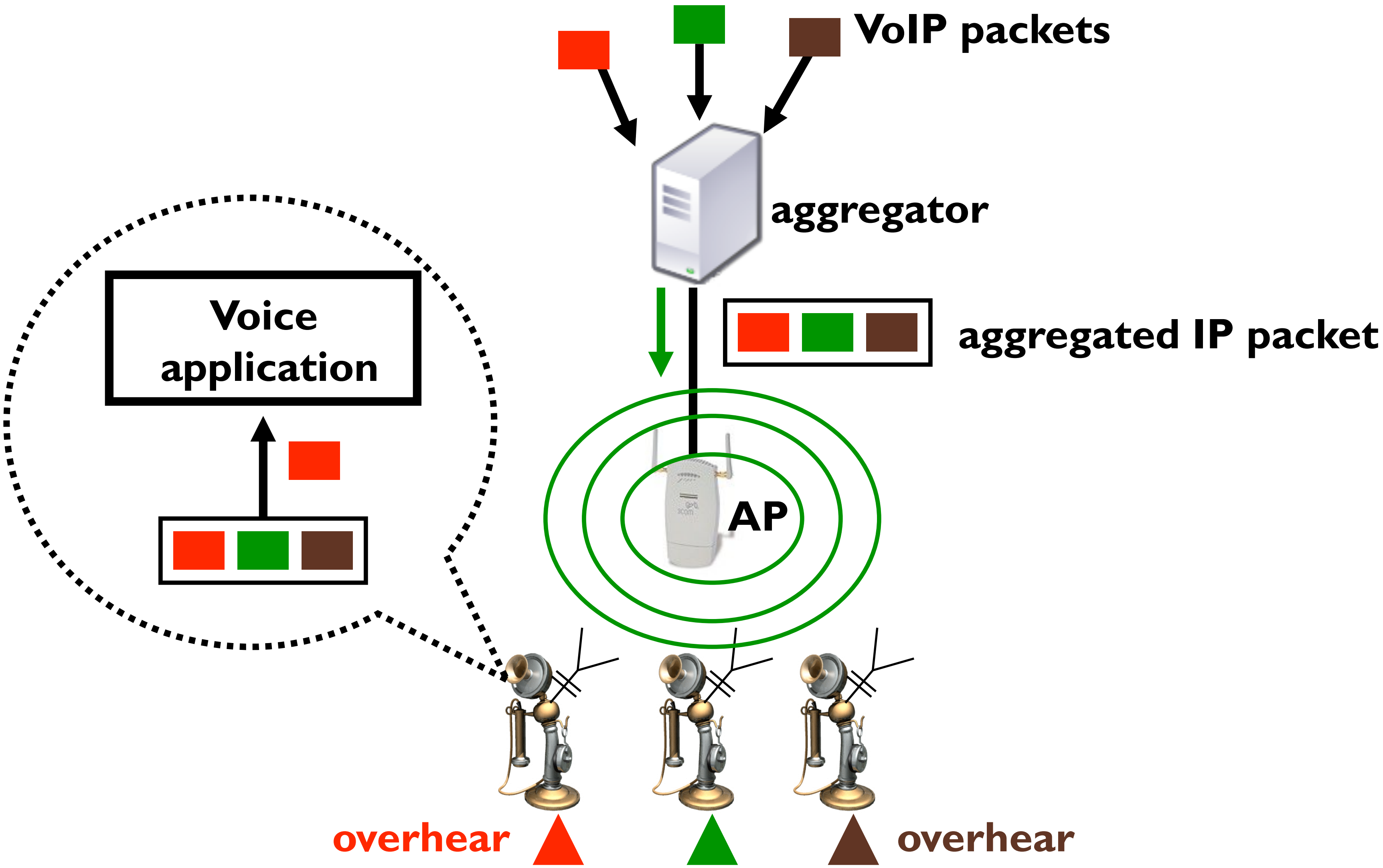
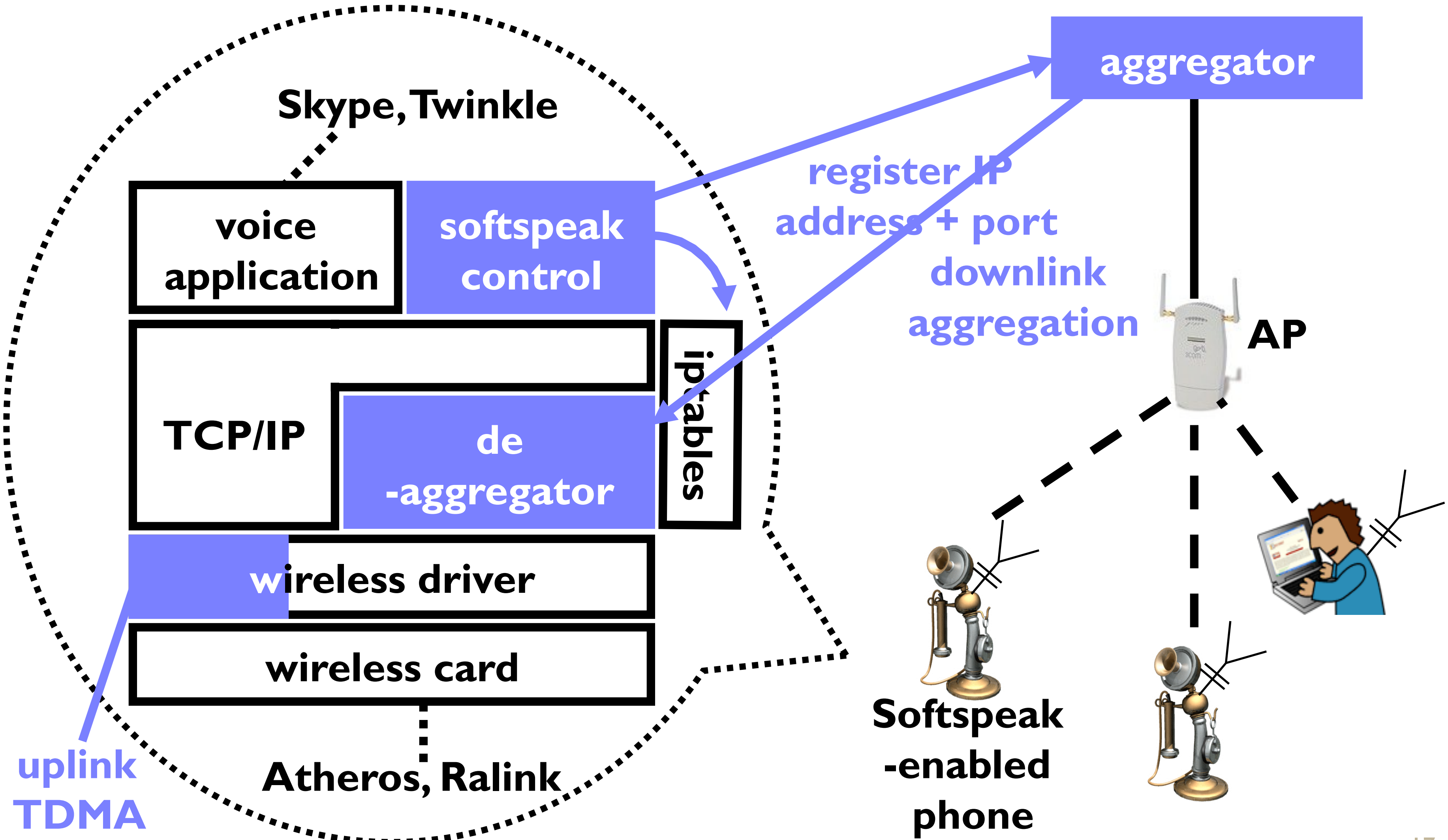


- Uplink direction:
  - Prioritized TDMA (Time Division Multiple Access)
  - Addresses contention overhead

Downlink aggregation



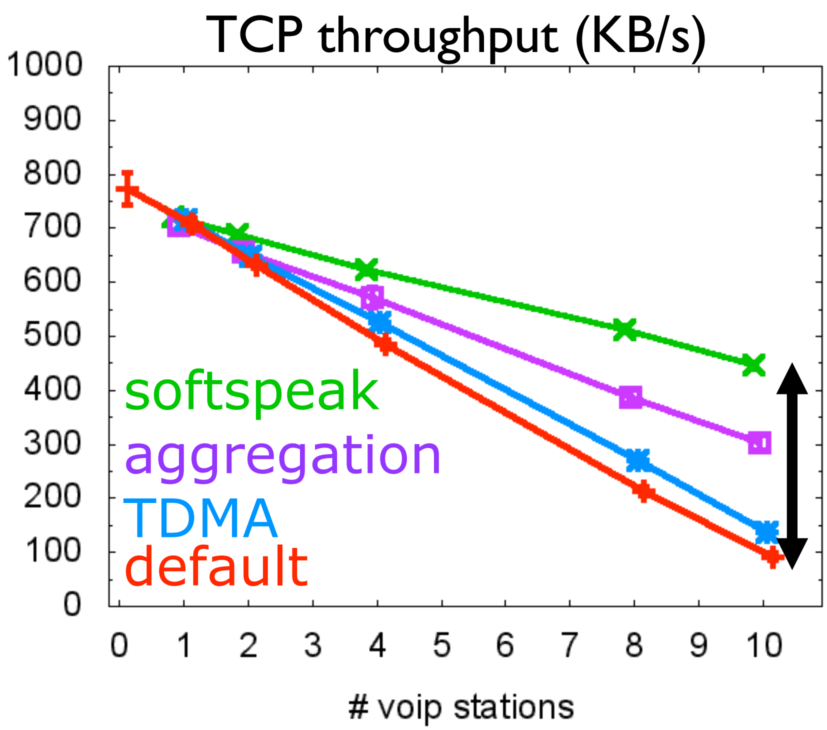
Implementation

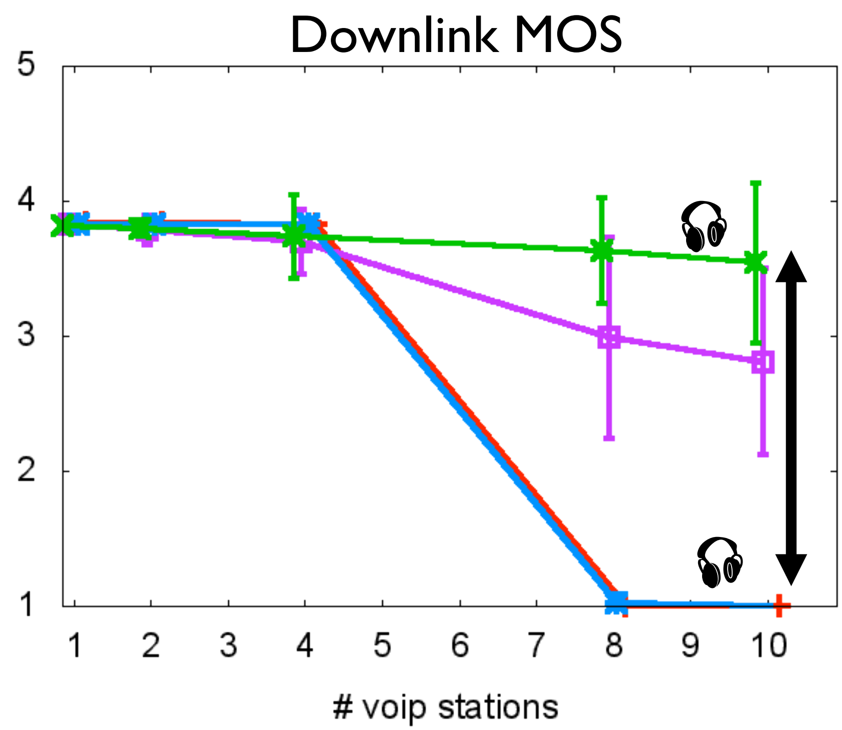


Evaluation

- Impact of Softspeak on:
  - Call quality
  - Residual throughput
- TCP data traffic, 10-ms voice codec
- See paper for:
  - UDP data traffic
  - 20-ms codec
  - Simulation results

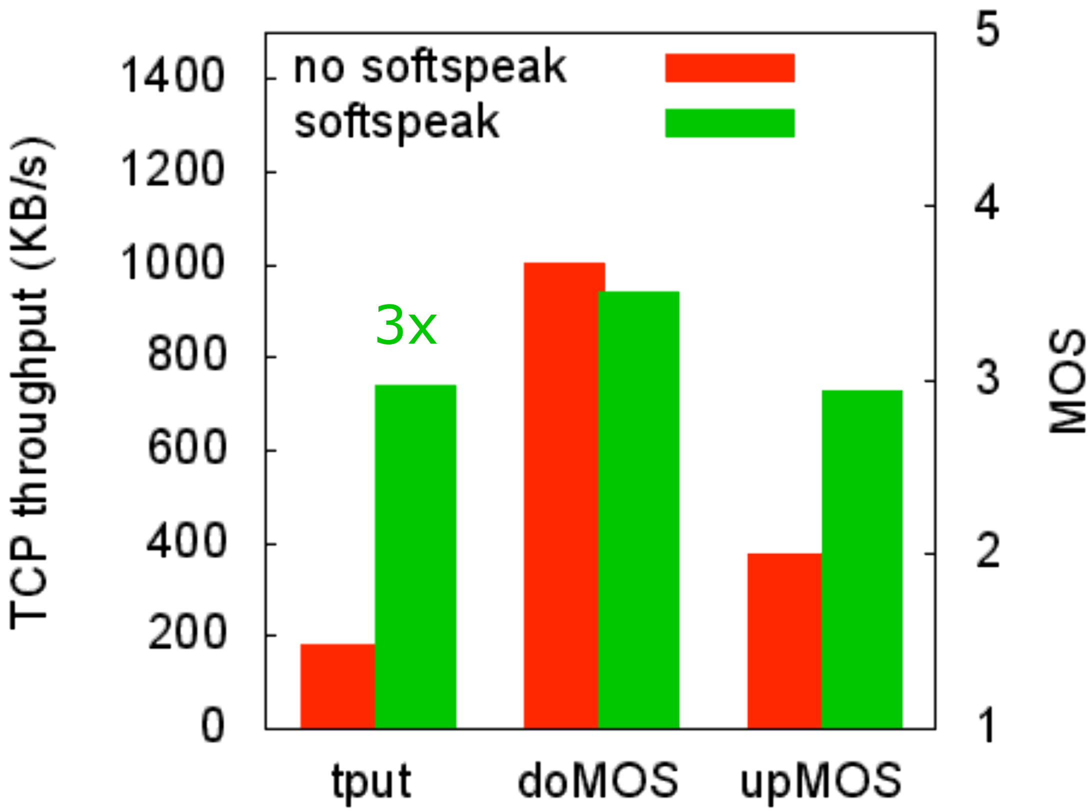
Results for 802.11b





	Throughput	Downlink MOS	Uplink MOS
When TCP downloads	5x	3.5→3.3	3.7→3.6
When TCP uploads	+50%	1 →3.5	2.9→3.8

Results for 802.11g in practice



Performance while sipping a latte

- Testbed with voice + Web + bulk TCP
- When enabling Web traffic:
  - Bulk TCP *upload* improvement disappears
  - However *combined* TCP capacity improvement is preserved
- Exactly as is the case without VoIP traffic

Conclusion

- Softspeak:
  - Protects call quality and data throughput
  - Using TDMA and aggregation
  - Implementable in software based on commodity hardware
- Source code and audio samples at:
  - http://sysnet.ucsd.edu/wireless/softspeak/

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Related work

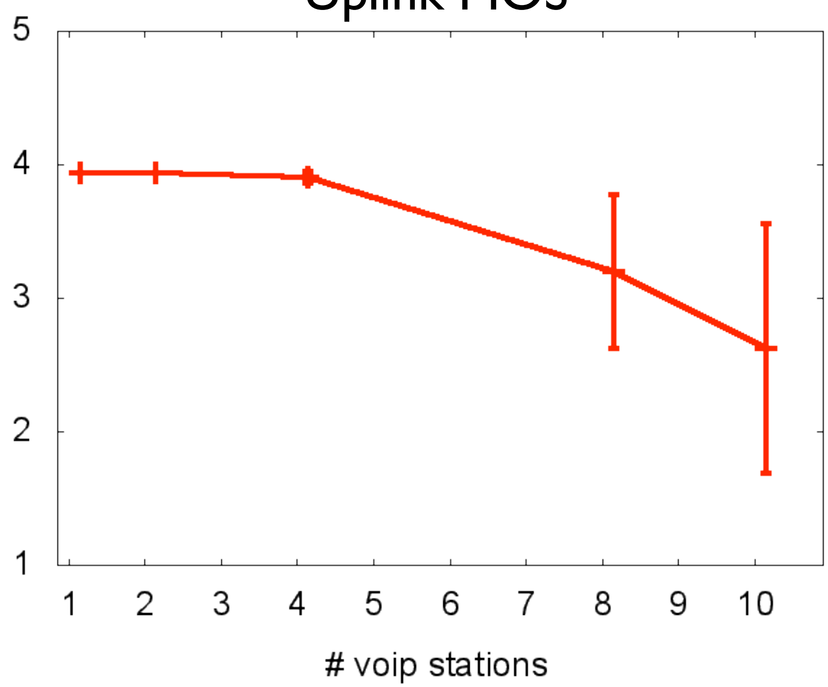
- Abundance of prior work:
  - Prioritizing voice, TDMA, aggregation, AP polls stations (PCF), …
- Share one or more limitations:
  - Targets framing *or* contention overhead
  - Replaces CSMA/CA contention mechanism
  - Requires changes to AP or WiFi hardware

802.11 extensions

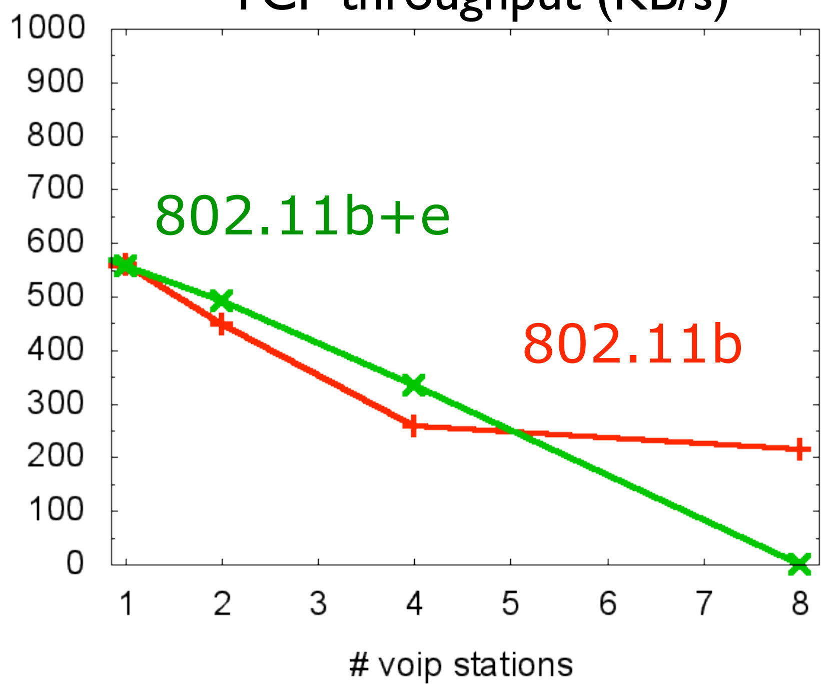
- 802.11g
- Higher speed

- 802.11e
- QoS extension
- Prioritizes VoIP

Uplink MOS

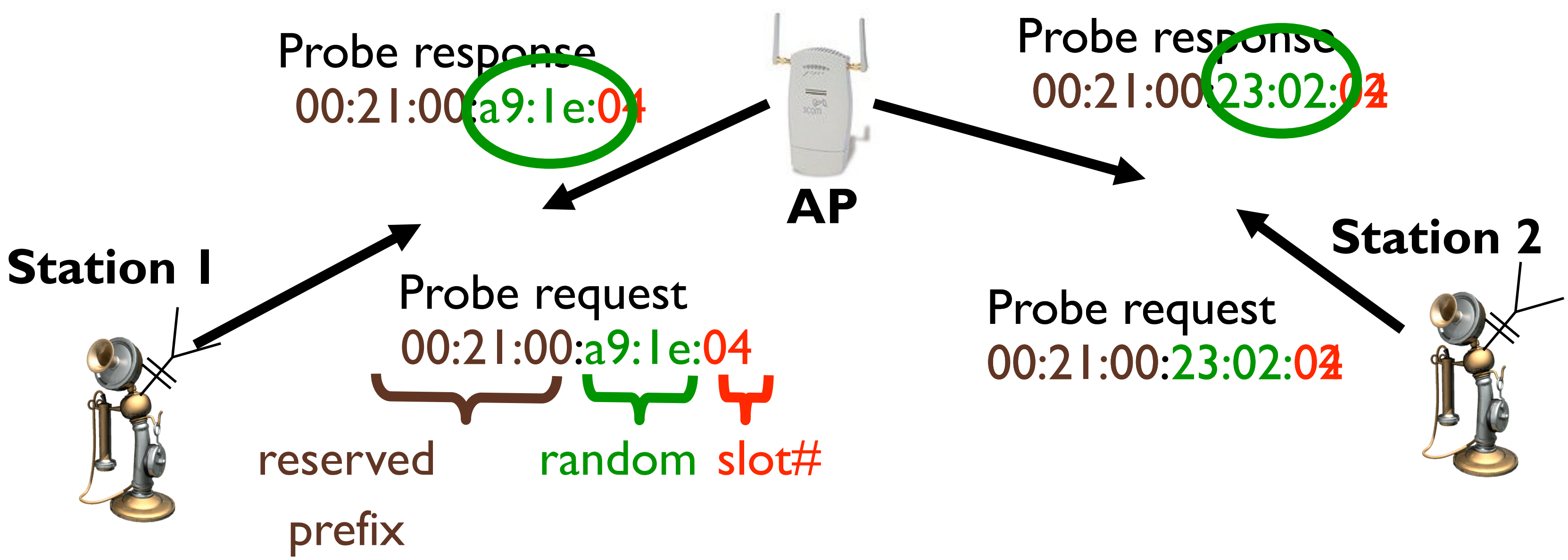


TCP throughput (KB/s)

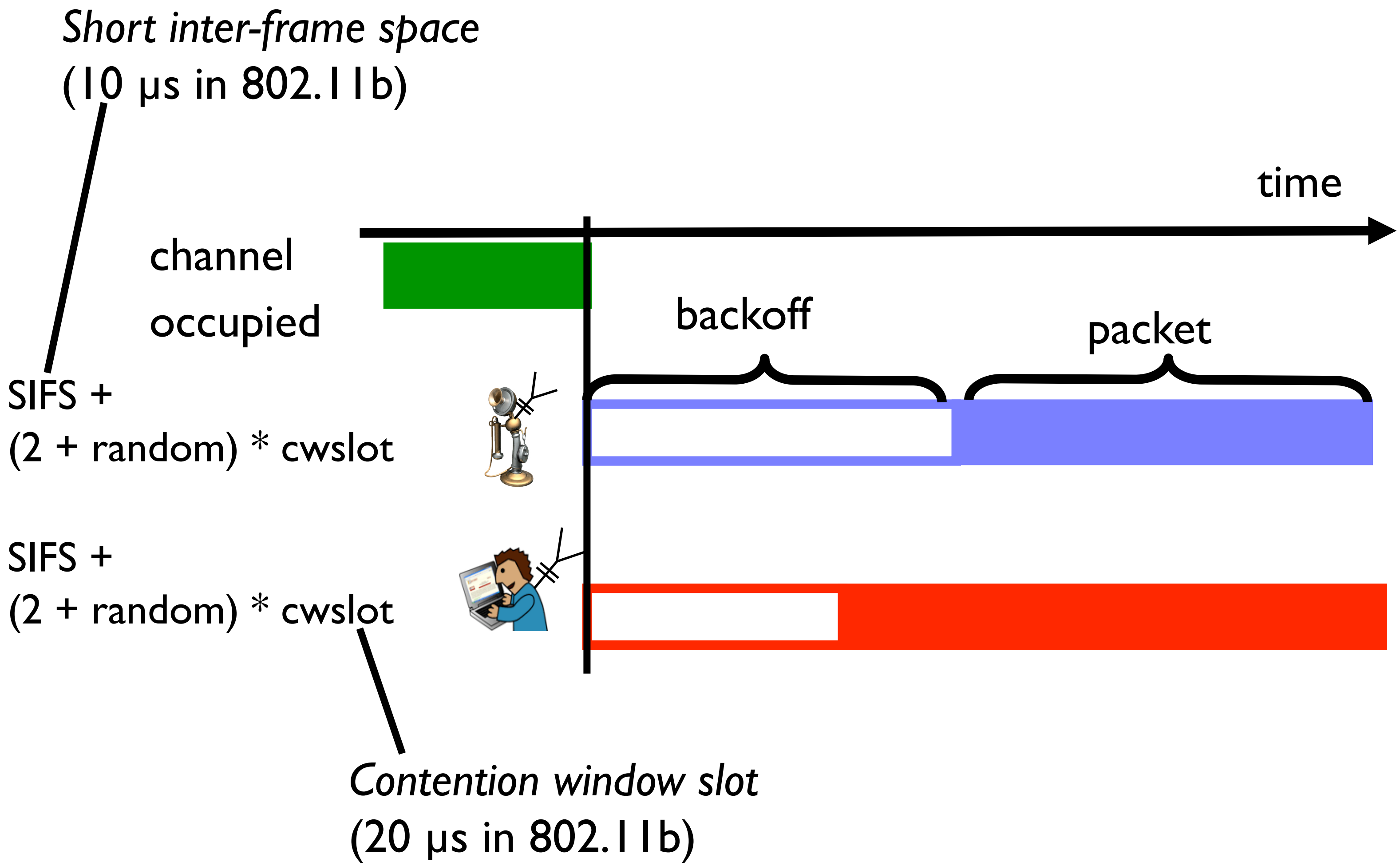


Establishing TDMA schedule

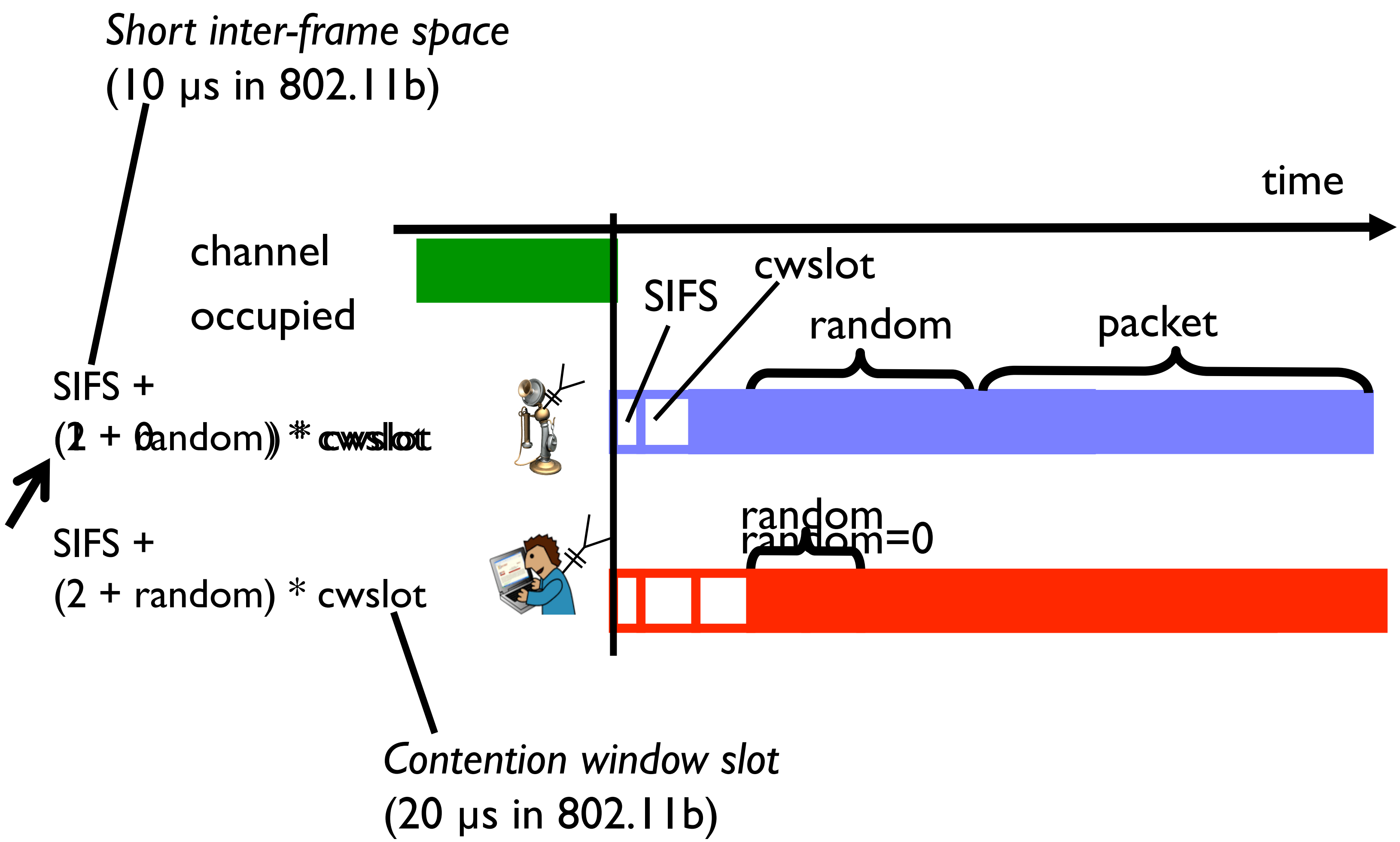
- Goal: agree on TDMA schedule
  - Cycle of 10 TDMA slots, each 1 ms
- However:
  - Stations might not hear each other
  - Unmodified access point



Prioritizing TDMA traffic

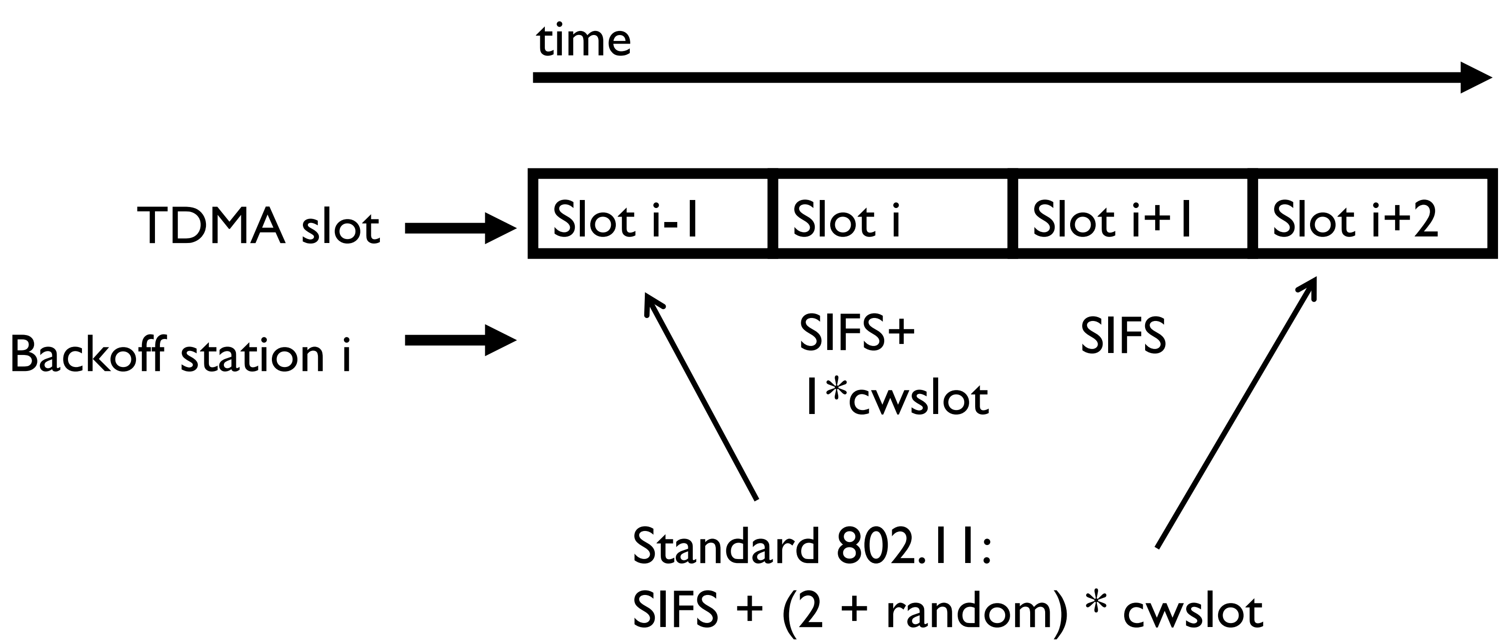


Prioritizing TDMA traffic



Prioritizing among TDMA traffic

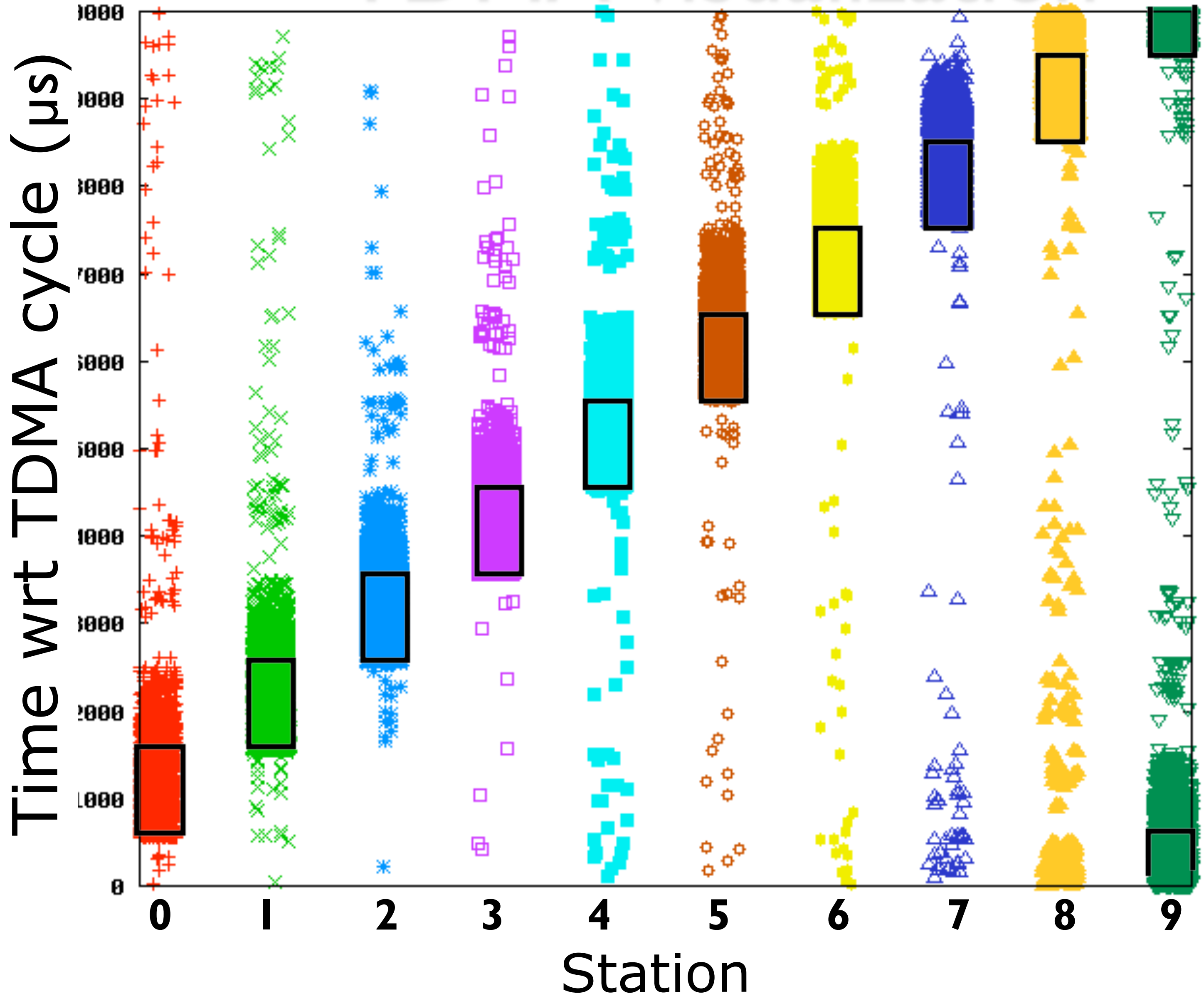
- Station i periodically modifies its contention parameters



Synchronizing TDMA slots

- Stations need a shared time reference
- Access points send beacons
  - E.g. every ~100ms
  - Heard by all stations
- To synchronize:
  - Reset TDMA clock after each beacon
  - Note: also counters clock drift

TDMA visualization



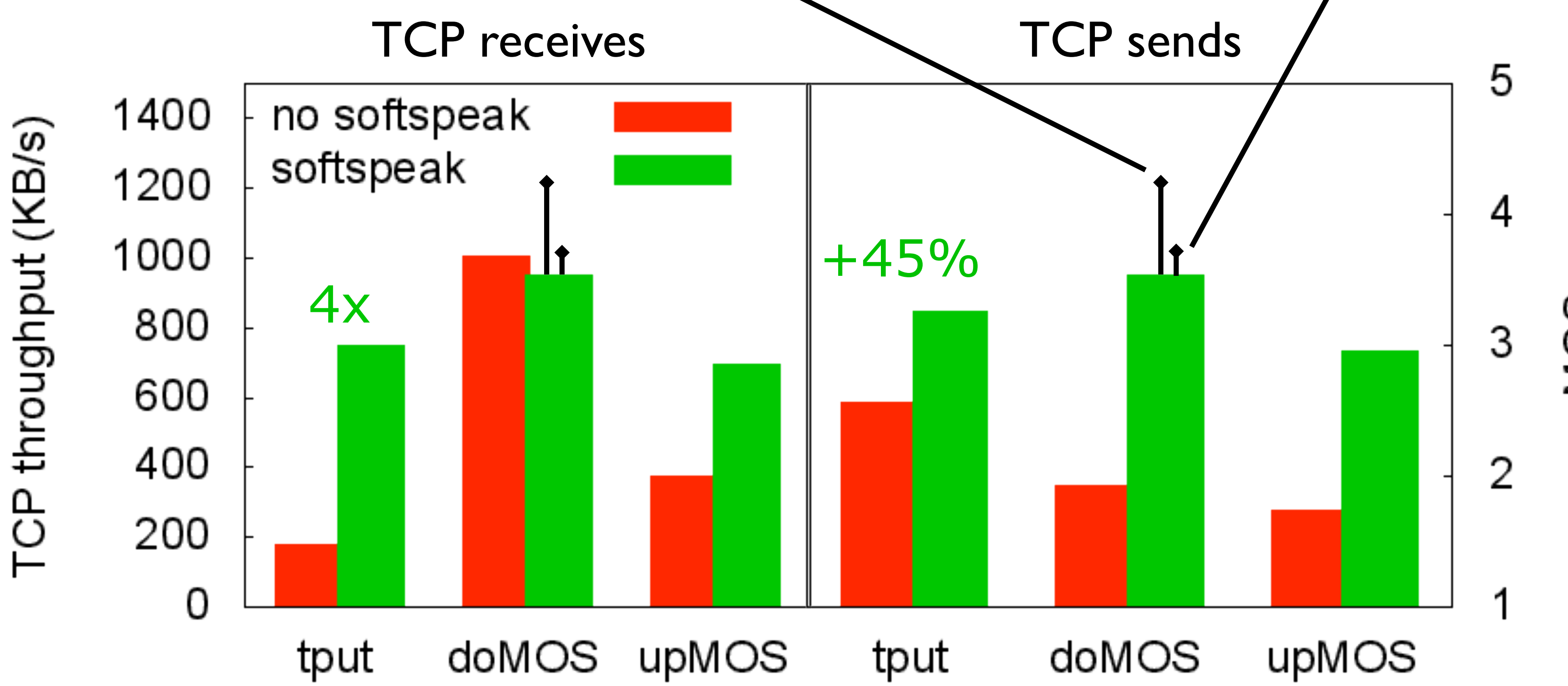
Addressing imperfect overhearing

- No retransmission for poor overhearer
- Exacerbated at higher 802.11g rates
- Mitigating steps:
  - Pick specific destination as receiver:
    - Have it associate at lower MAC rate
    - Helps if it's a poor receiver
    - Note: can be dedicated device
  - Poor receivers can simply opt out

Results for 802.11g

No overhearing improvements: 20%

Overhearing improvements: 7%



802.11g, 20ms codec