An Approach for Solving the Unfairness Problem in WLANs

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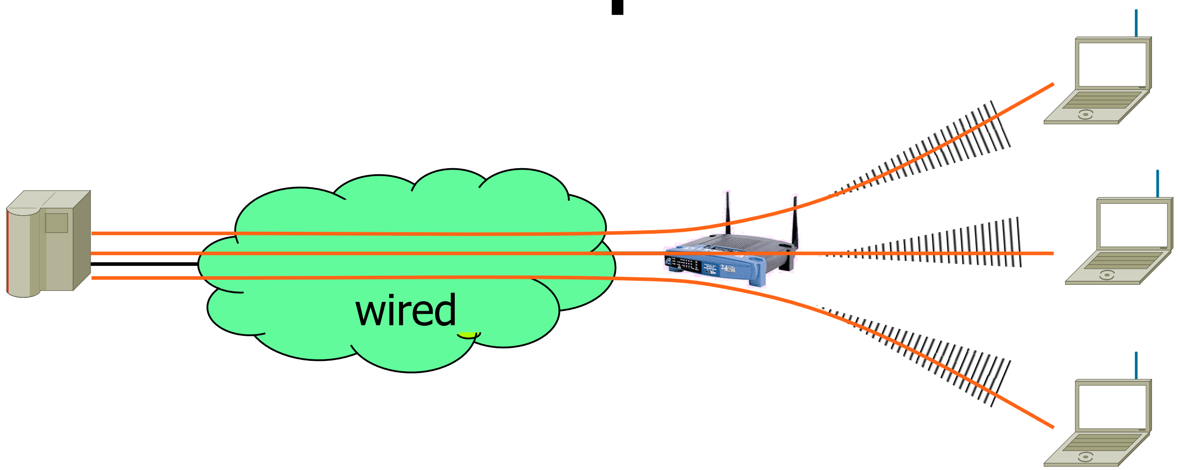
Outline

- WLAN unfairness problem
- Idea of Asymmetric Access Point
- Implementing AAP
- Performance of Asymmetric Access Point
- Conclusions

Unfairness problem

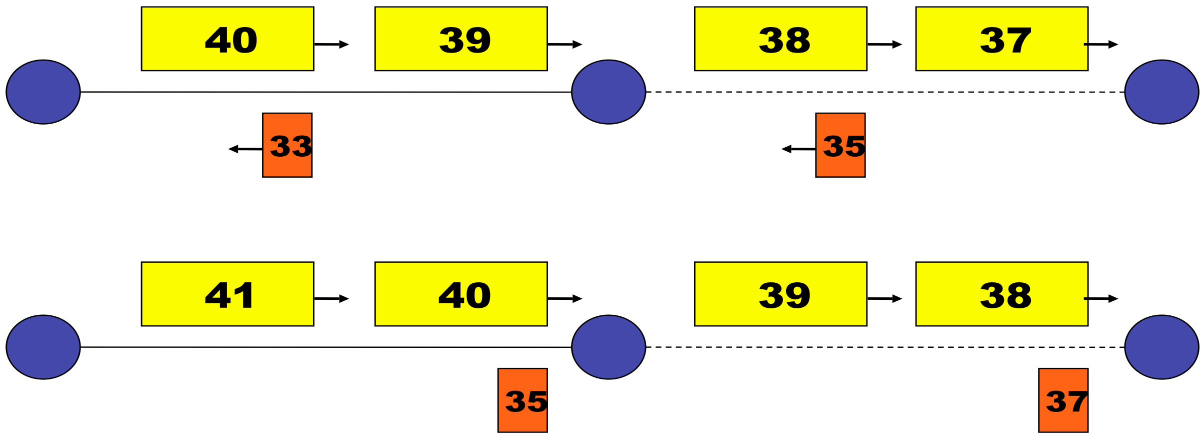


- TCP connections to mobile stations
  - downloads, uploads
- Sporadic UDP traffic with real-time requirements (VoIP)
- We assume that wireless LAN is the bottleneck

DCF characteristics

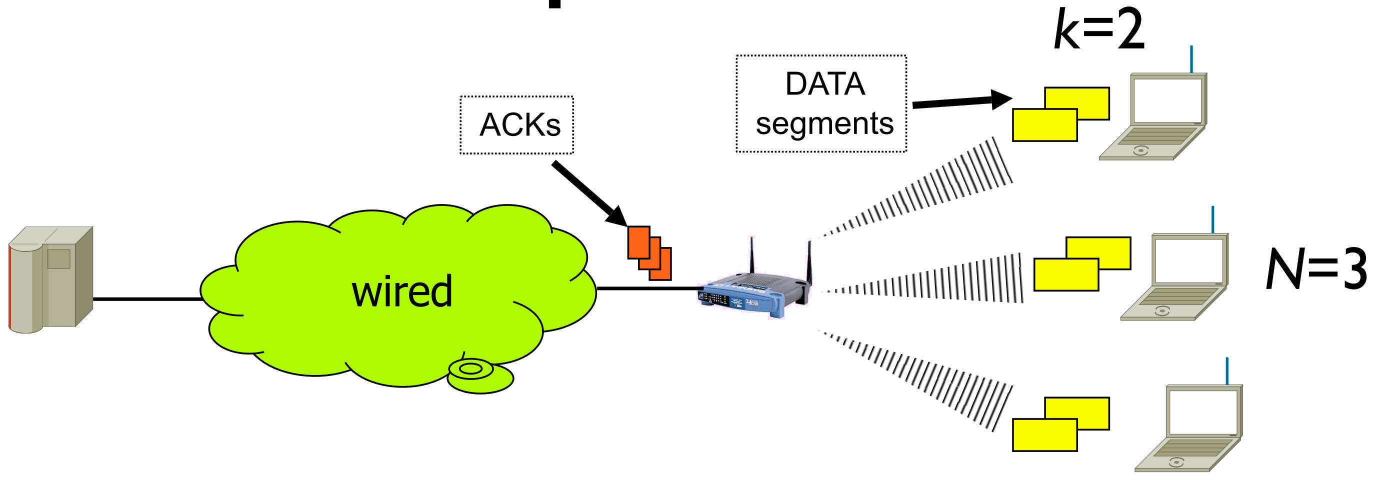
- Half-duplex operation
  - One frame at a time
- Equal channel access opportunities for all contending entities
  - AP and any of *N* stations
    - statistical share of $1/(N+1)$
  - Independent of frame length/transmission speed
- Exponential backoff
  - Short term unfairness for larger *N*
  - Increased unfairness if bad channel conditions

TCP Delayed Acknowledgements



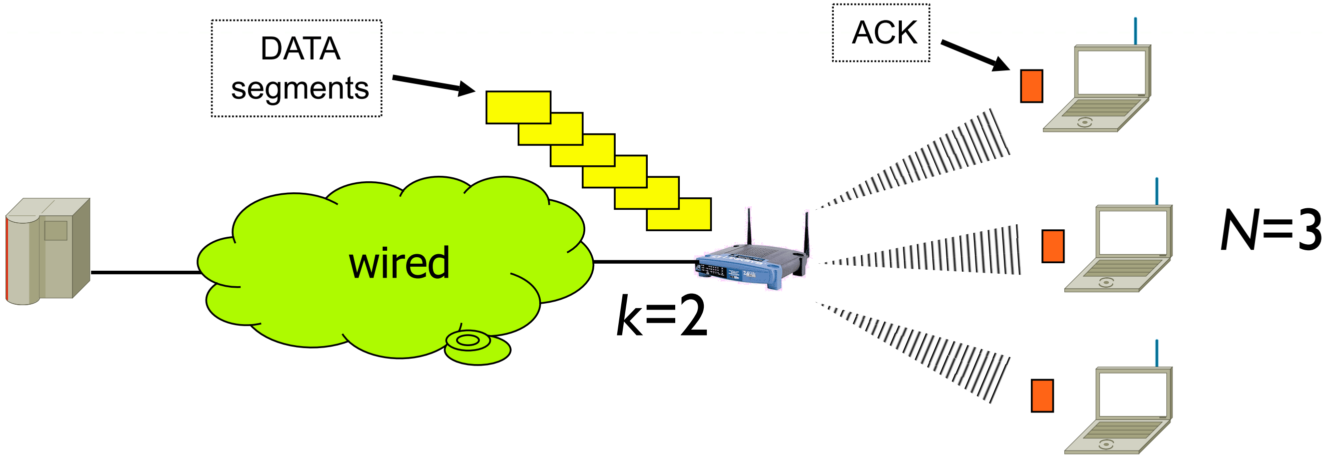
- An ACK is delayed until (timeout or)
  - *k* segments are received (*k*=2 typical)
  - *k*: number of data segments per ACK

N uploads



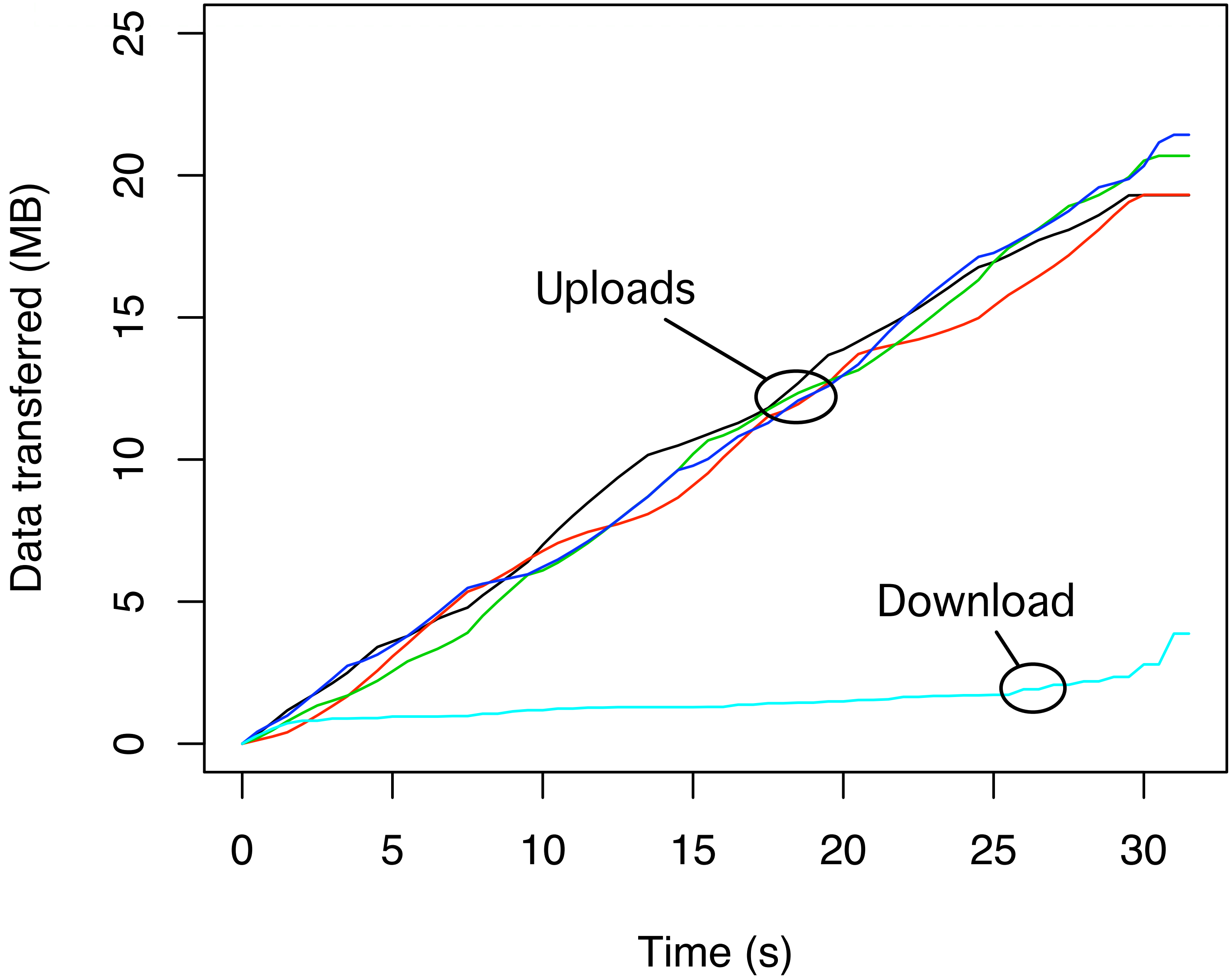
- *kN* data segments at stations, *N* ACKs at AP
- AP share needs to be *N/(N + kN)*, 1/3 for *k*=2
- If share of *1/(1+N)*
  - Short buffer at AP: losses, but ACKs are cumulative
  - Large buffer at AP: longer RTT, limited by flow control

N downloads

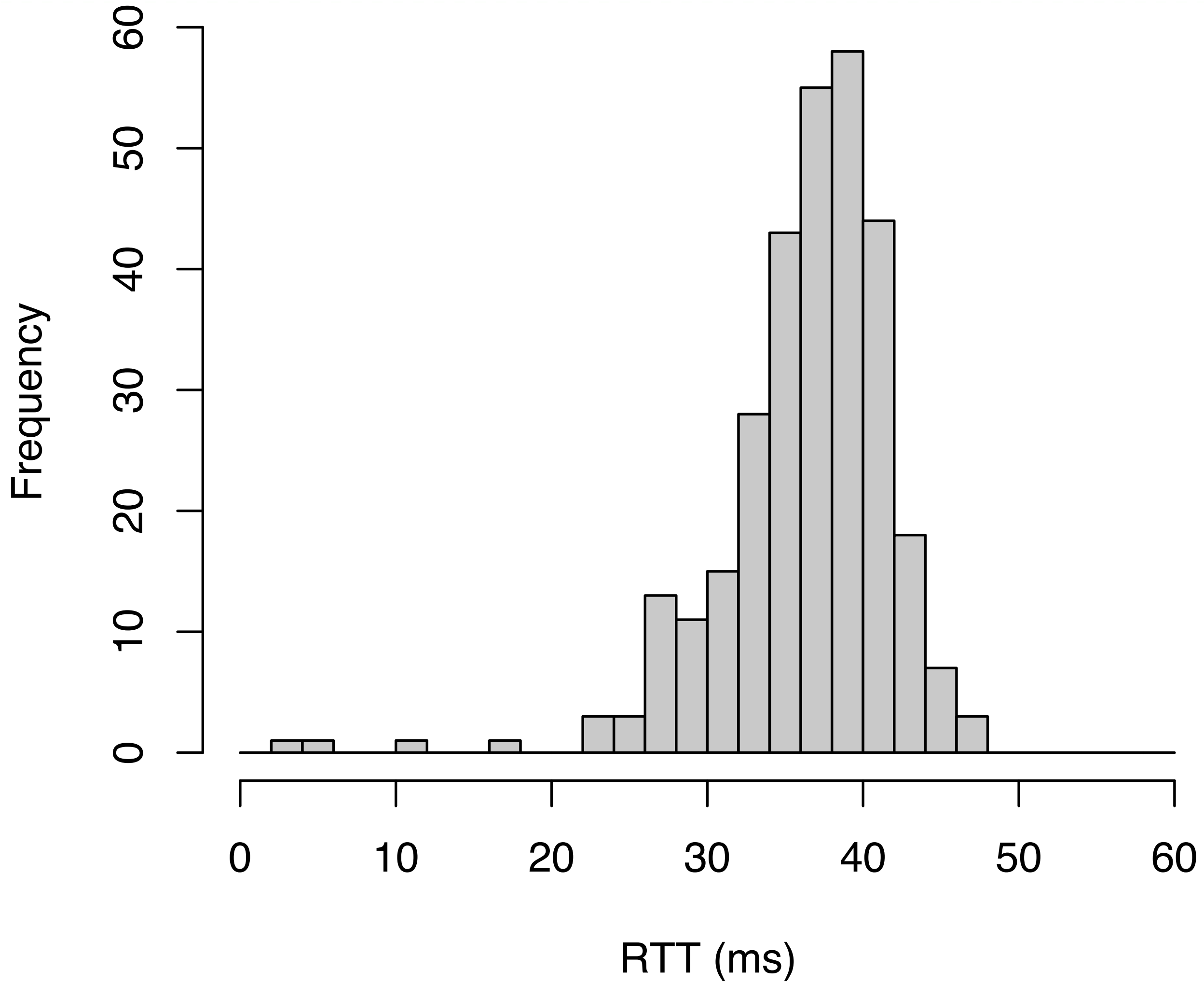


- *kN* data segments at AP, *N* ACKs at stations
- AP share needs to be *kN*/(*N* + *kN*), 2/3 for *k*=2
- If share of *1*/(*1*+*N*)
  - Short buffer at AP: loss, limited by congestion control
  - Large buffer at AP: longer RTT, limited by flow control

DCF; 4 uploads, 1 download



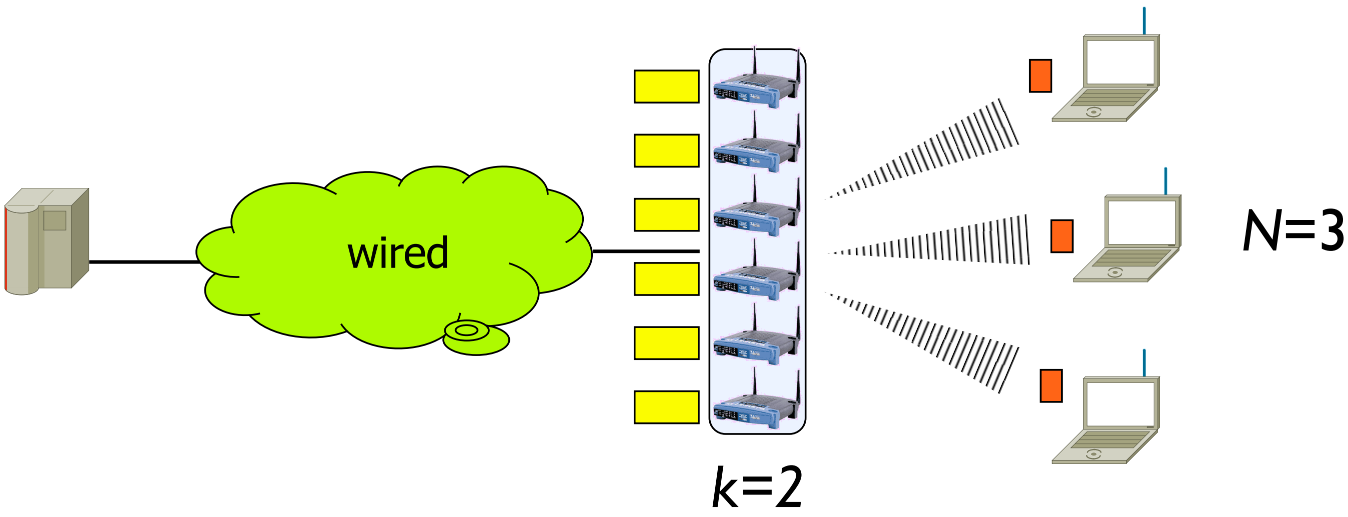
DCF; `ping` RTT vs. 4 downloads



Asymmetric AP Approach

- Give more channel access opportunity to AP
  - Asymmetric Access Point benefits from *k* more share than all stations in cell (or *kN* than any station)
  - Corresponds to the worst case (N downloads)
  - Increases performance in mixed upload/download scenario
  - keeps the AP buffer empty so that TCP connections become self-clocked by the destination (short RTT over the wireless part)

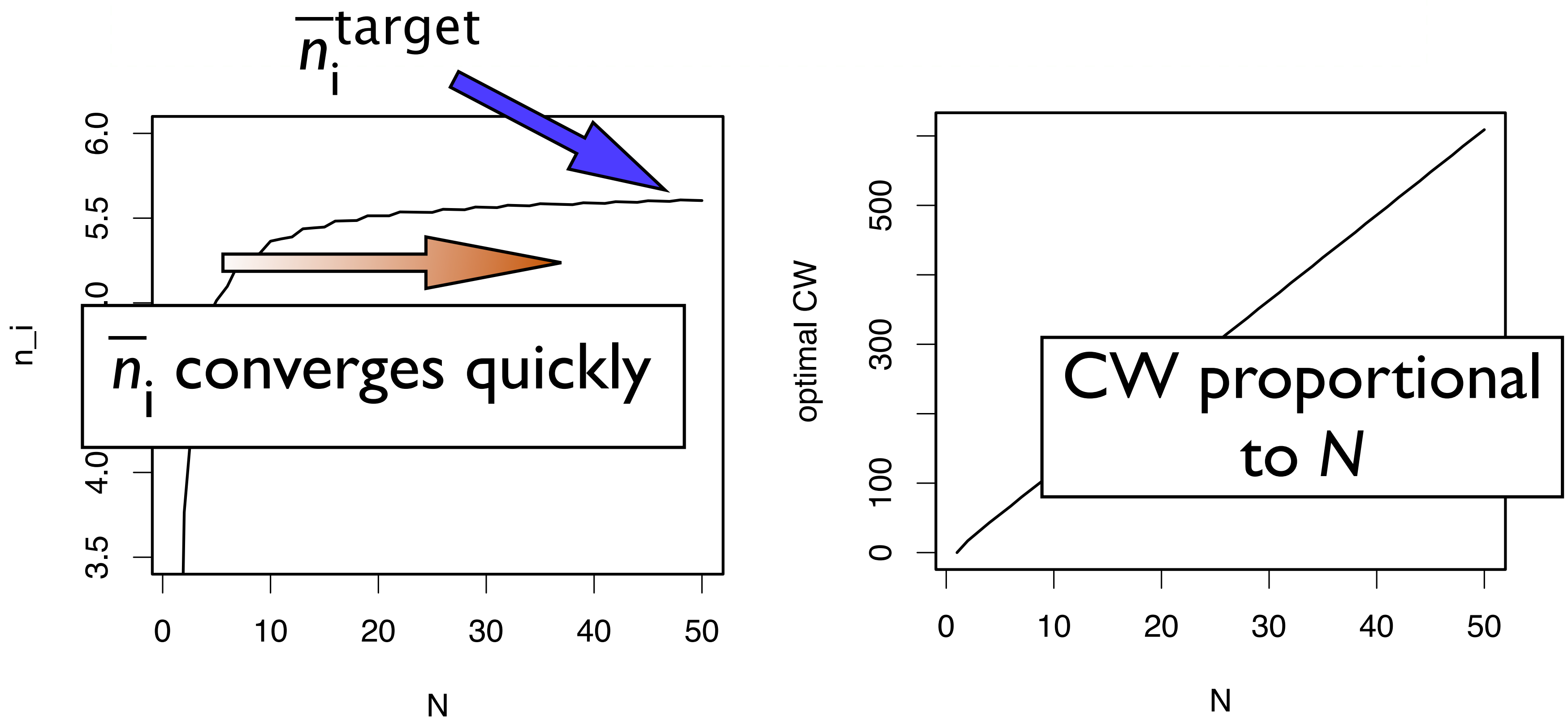
Asymmetric AP Approach



Implementing AAP

- Stations
  - Operate according to Idle Sense
  - Adapt CW to load conditions in the cell by observing the mean number of idle slots
- Asymmetric Access Point
  - Constant CW value, independent of N!
  - Derived for given *k* and 802.11 variant

Optimal CW



$\overline{n}_i$: average number of idle slots between transmission attempts

AAP

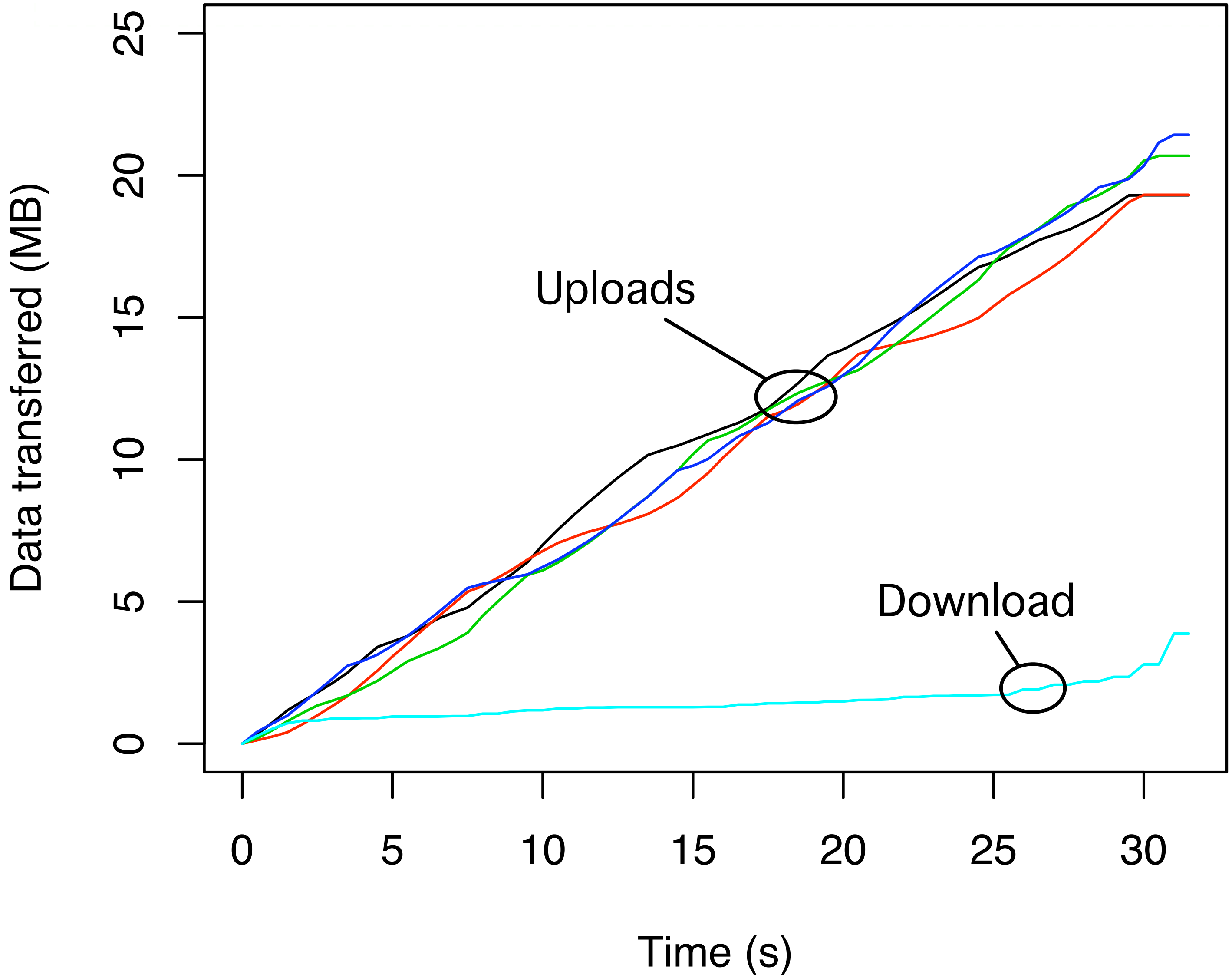
- *CW* proportional to *N*
- AP Access probability proportional to *N*
  - ➡ AP *CW* divided by *N* compared to STA *CW*s

➡ AP *CW* is a **constant**

Measurements

- Implementation of Idle Sense
  - Intel PRO/Wireless 2200BG 802.11 a/b/g cards
  - Modified firmware, operational cards
- AP - FreeBSD box
  - constant CW
- Stations close to AP, good channel conditions, 802.11**a** at 54 Mb/s

DCF; 4 uploads, 1 download



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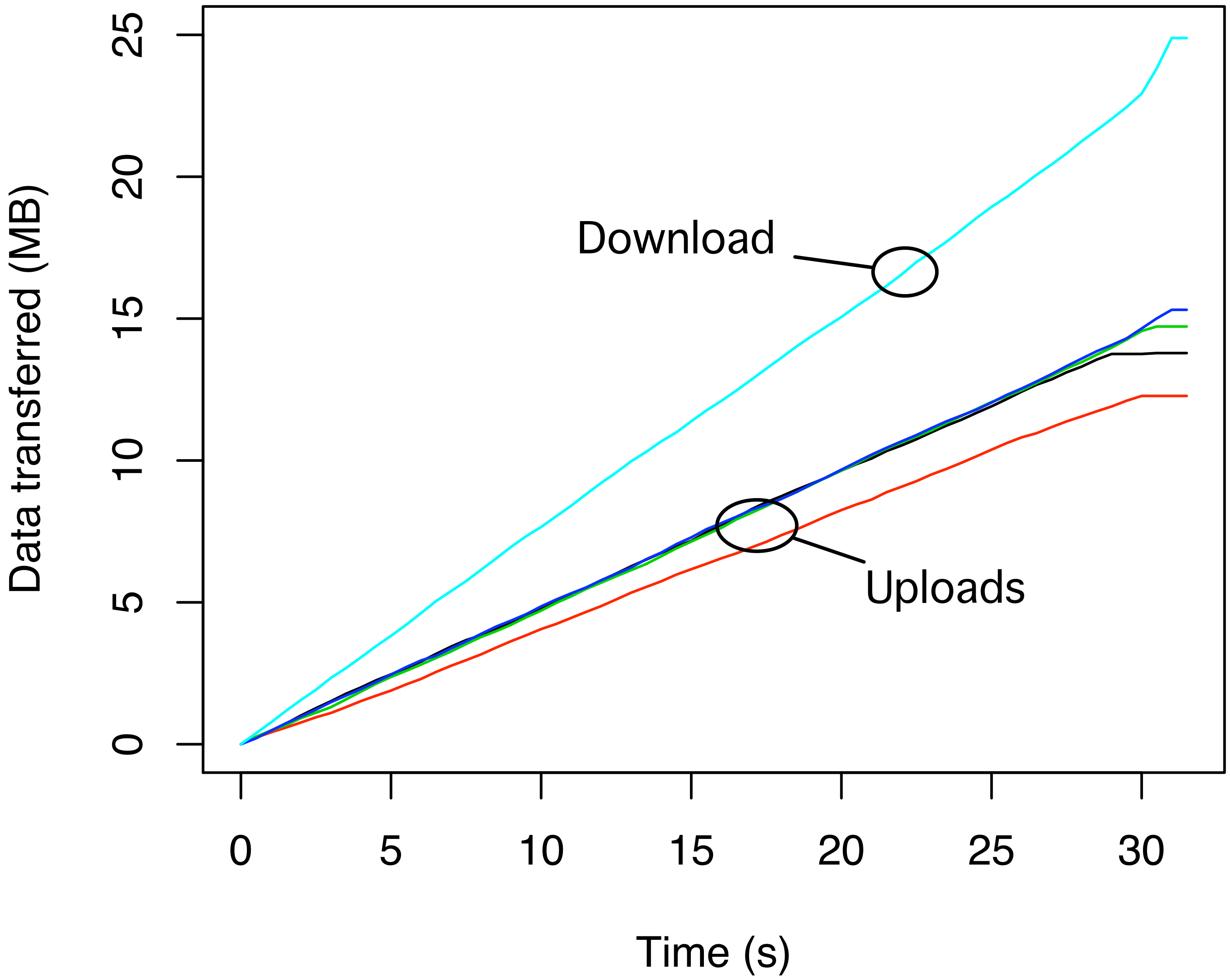

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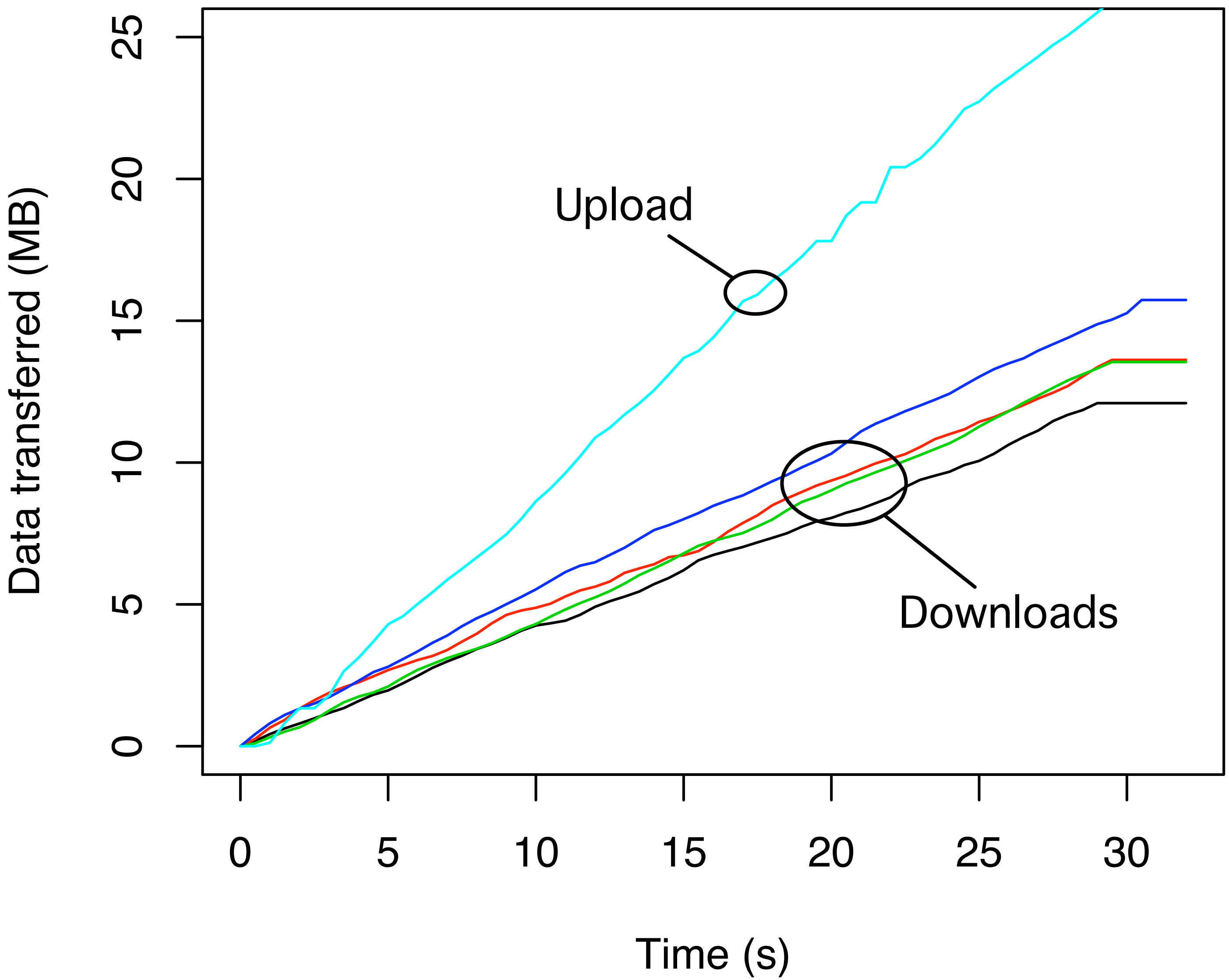

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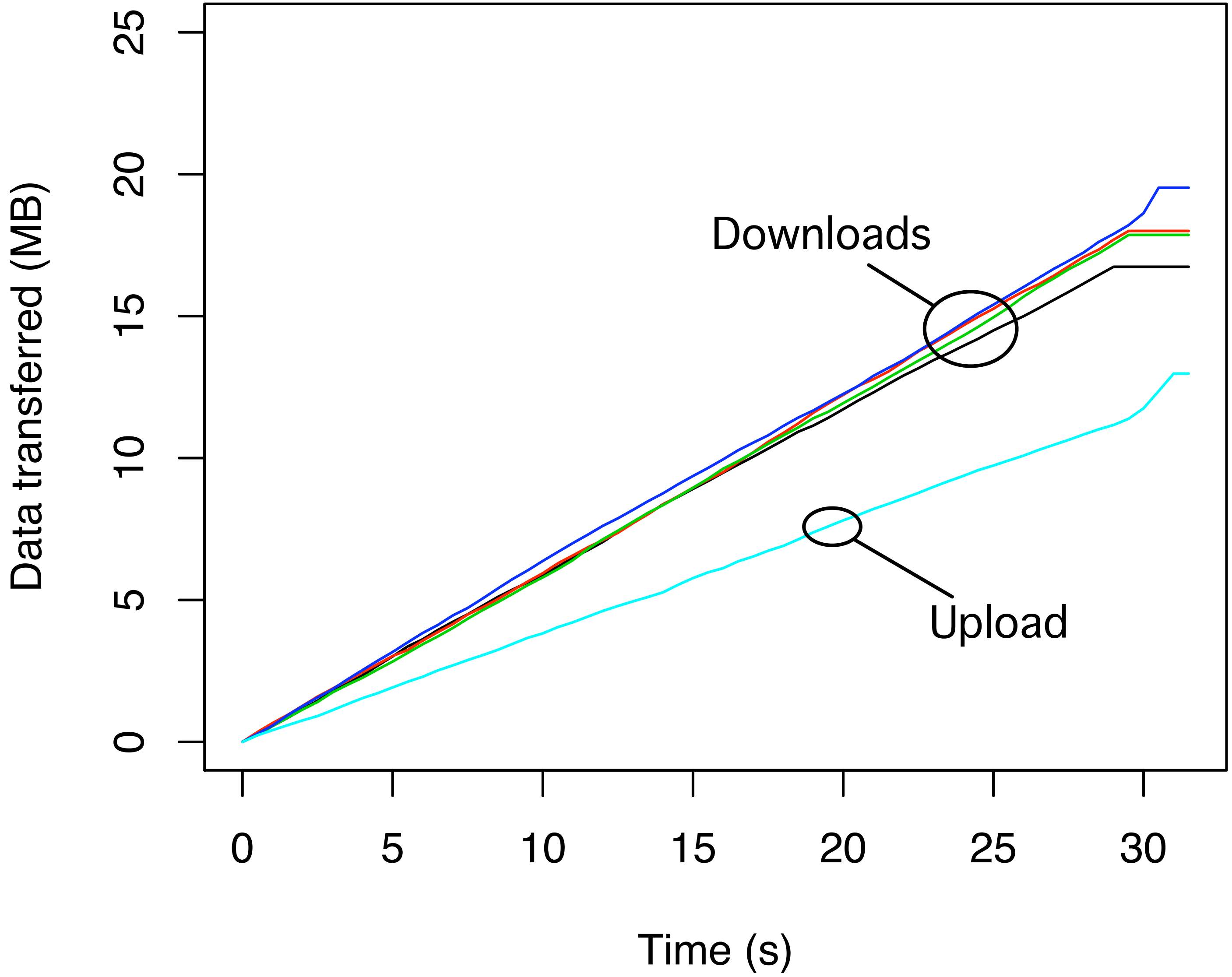

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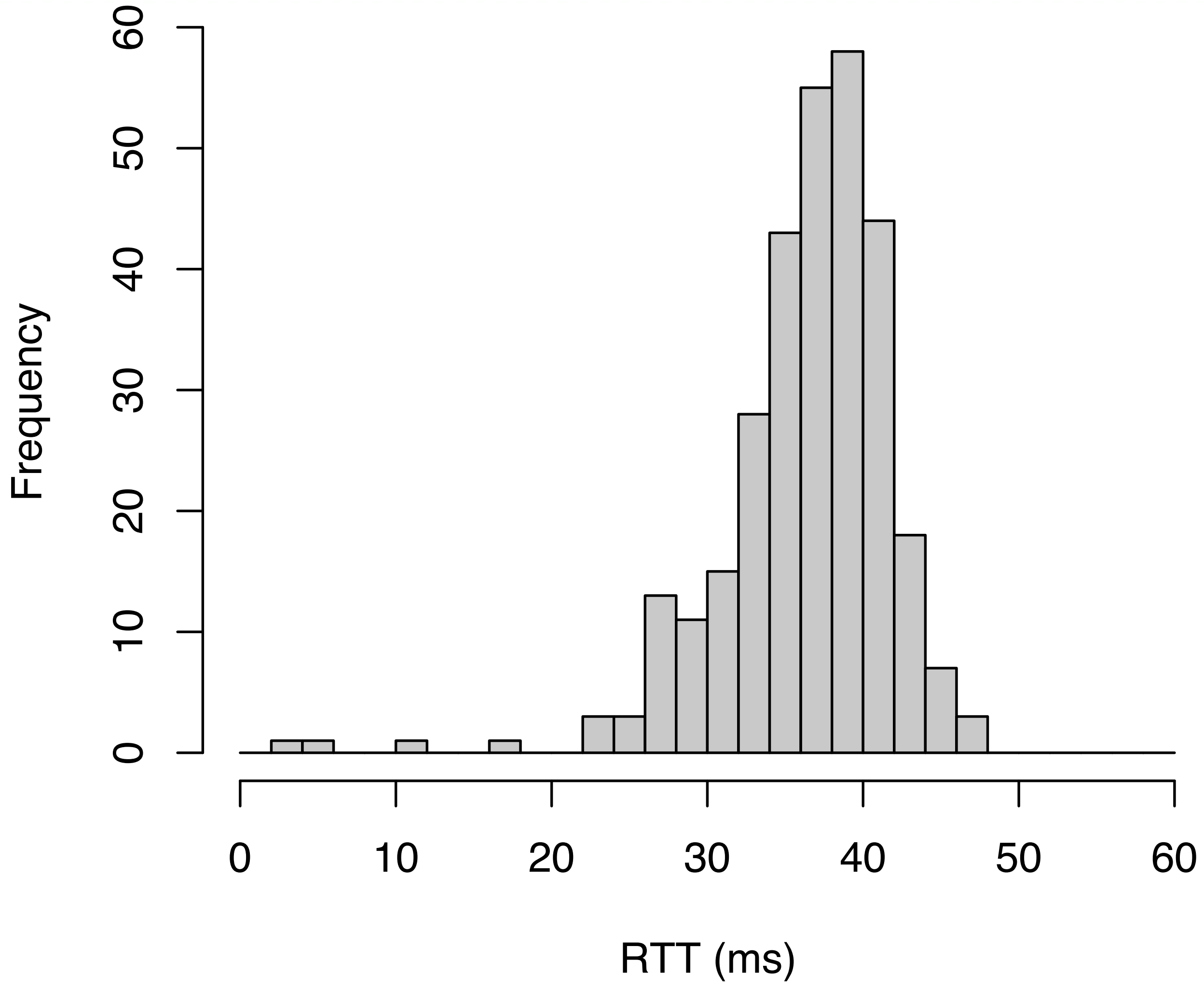

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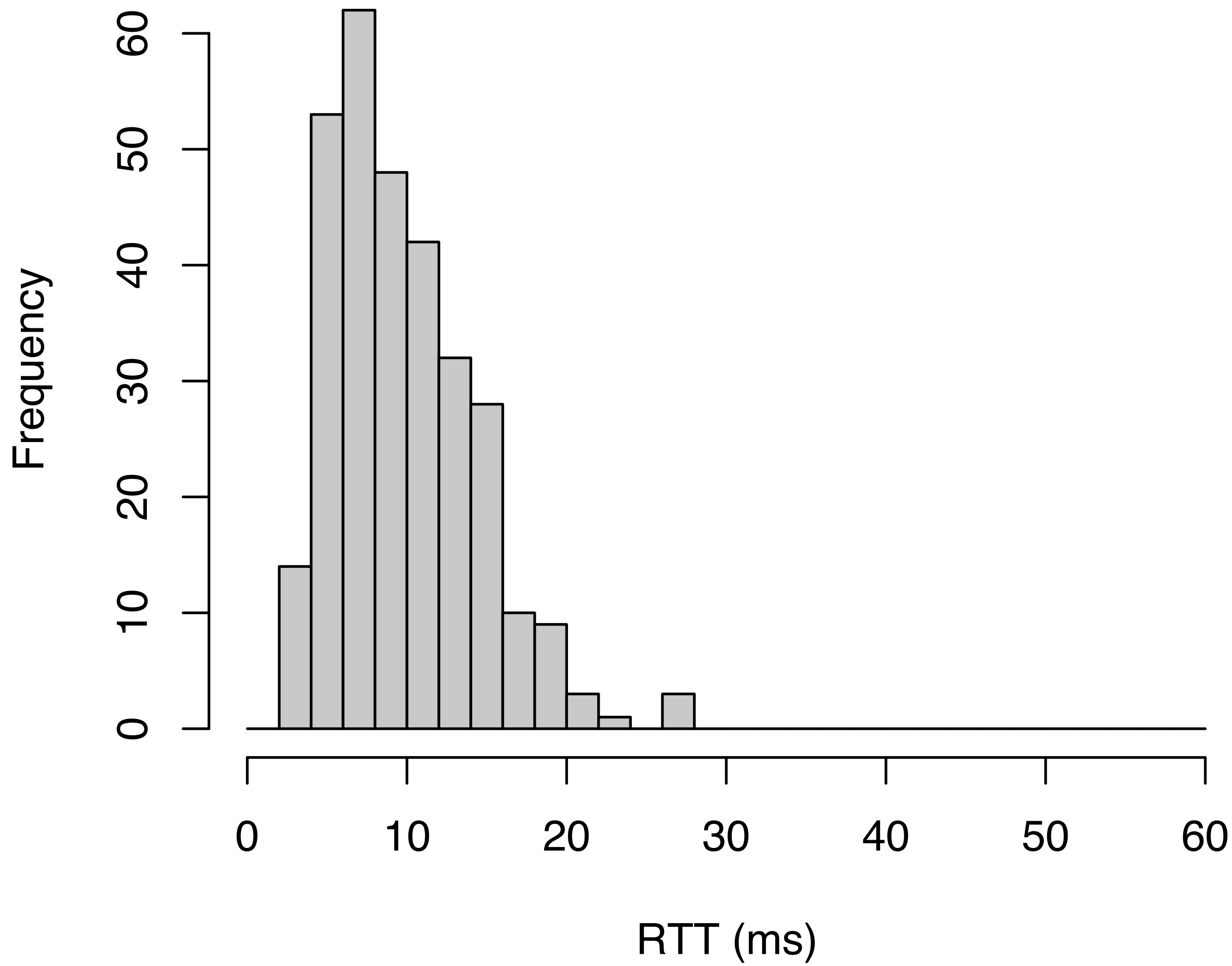

Conclusions

- Simple solution at MAC layer to the unfairness problem
  - Right shares of transmission opportunity
  - Correct operation of TCP over 802.11 - self-clocked flow control
  - Keeps empty buffer at AP - gives short delays
  - Always preference to download connections
- Optimal solution in mixed upload/download scenarios requires upper layer modification
  - Proper scheduling at IP/TCP layer