Uncovering a Hidden Wireless Menace: Interference from 802.11x MAC Acknowledgment Frames

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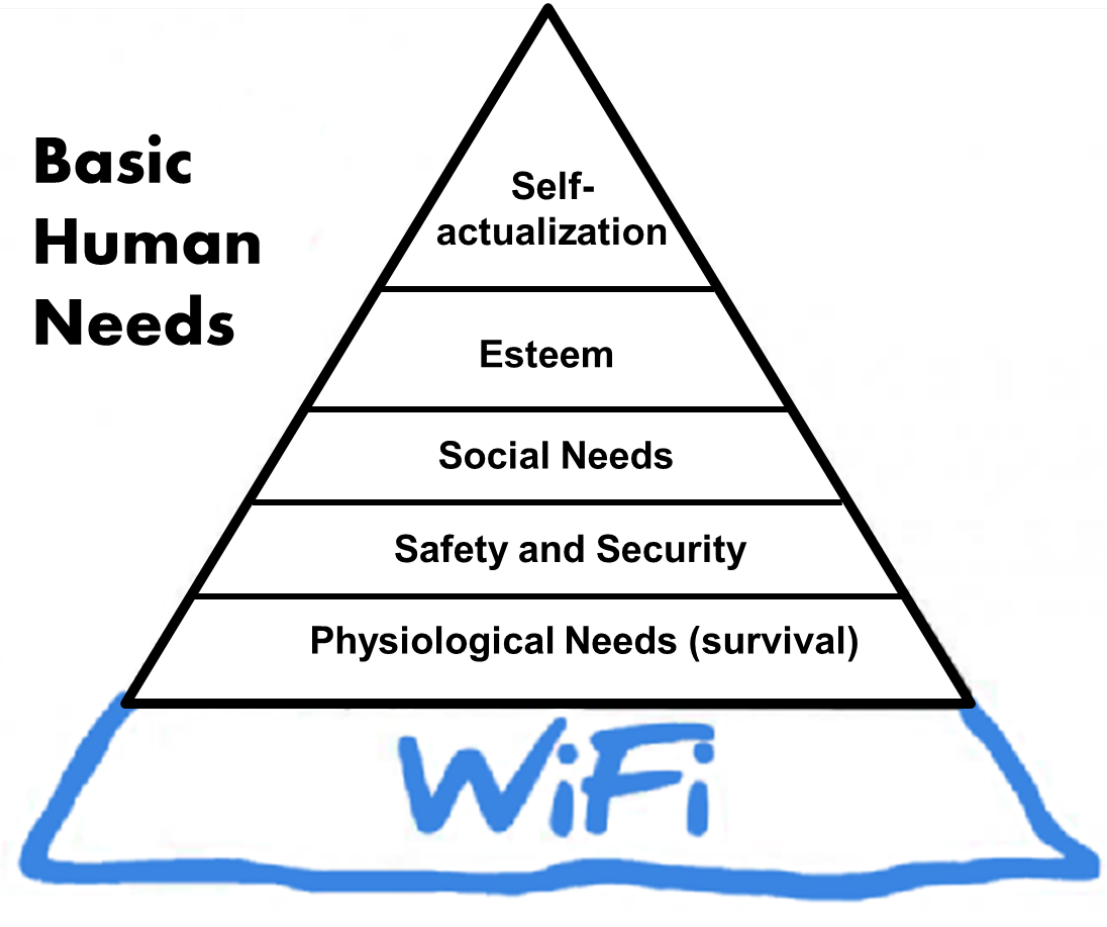
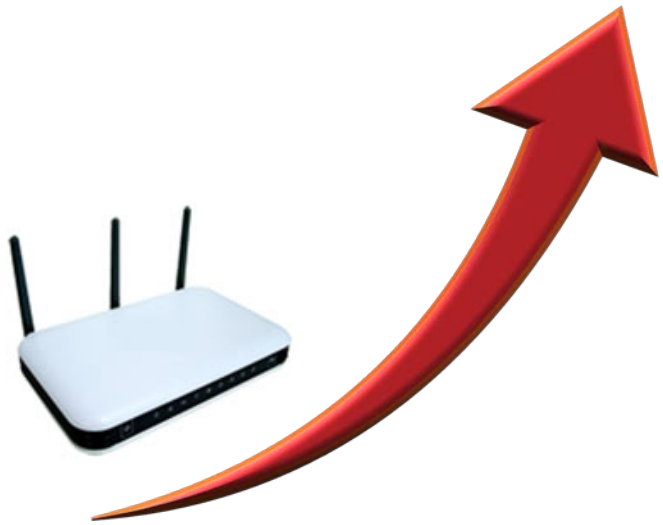
RISING DEMAND FOR WIFI



RISING DEMAND FOR WIFI

WiFi hotspot market:

Annual growth at **84%**



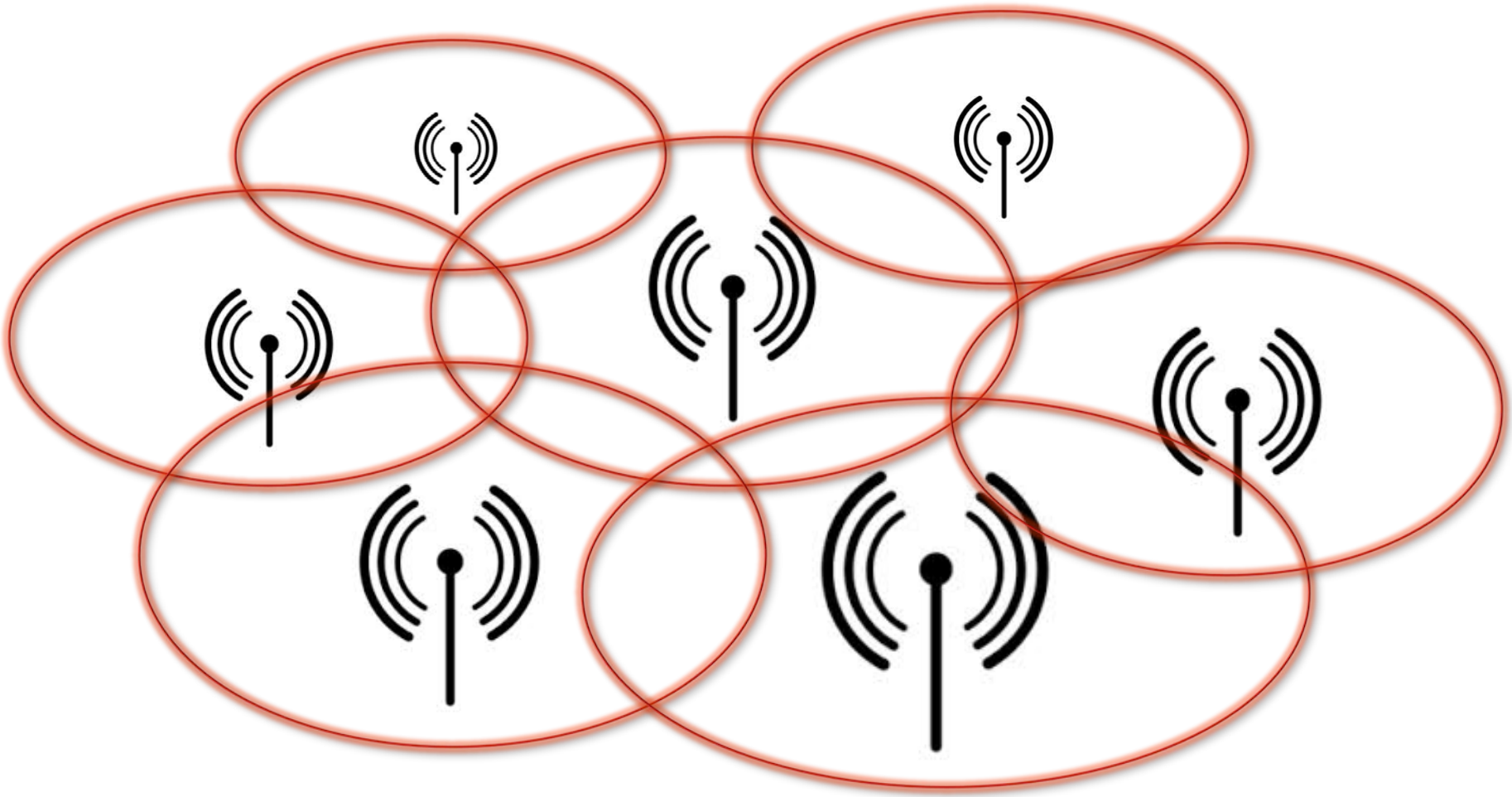
By the year of 2017

WiFi will make up **56%** of total Internet traffic

Global WiFi Hotspot Market 2012-2016, by Research and Markets

Cisco Visual Networking Index forecast, 2012-2017

DENSE DEPLOYMENT OF ACCESS POINT



AP DENSITY MEASUREMENT

War-walking

WAR-WALKING

Each 1-fe Identify AP speed 1 m/s SID in Beacon

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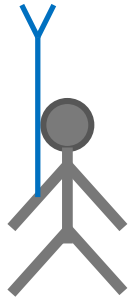
WiFi sniffer



WAR-WALKING

University campus

Commercial area

Residential area

AP DENSITY RESULTS

Scenarios	Median number of APs			
	Channel 1	Channel 6	Channel 11	Others
Commercial	**6**	**6**	**9**	**< 1**
University	**8**	**6**	**5**	**< 1**
Residential	**9**	**15**	**10**	**< 4**

INTERFERENCE MITIGATION

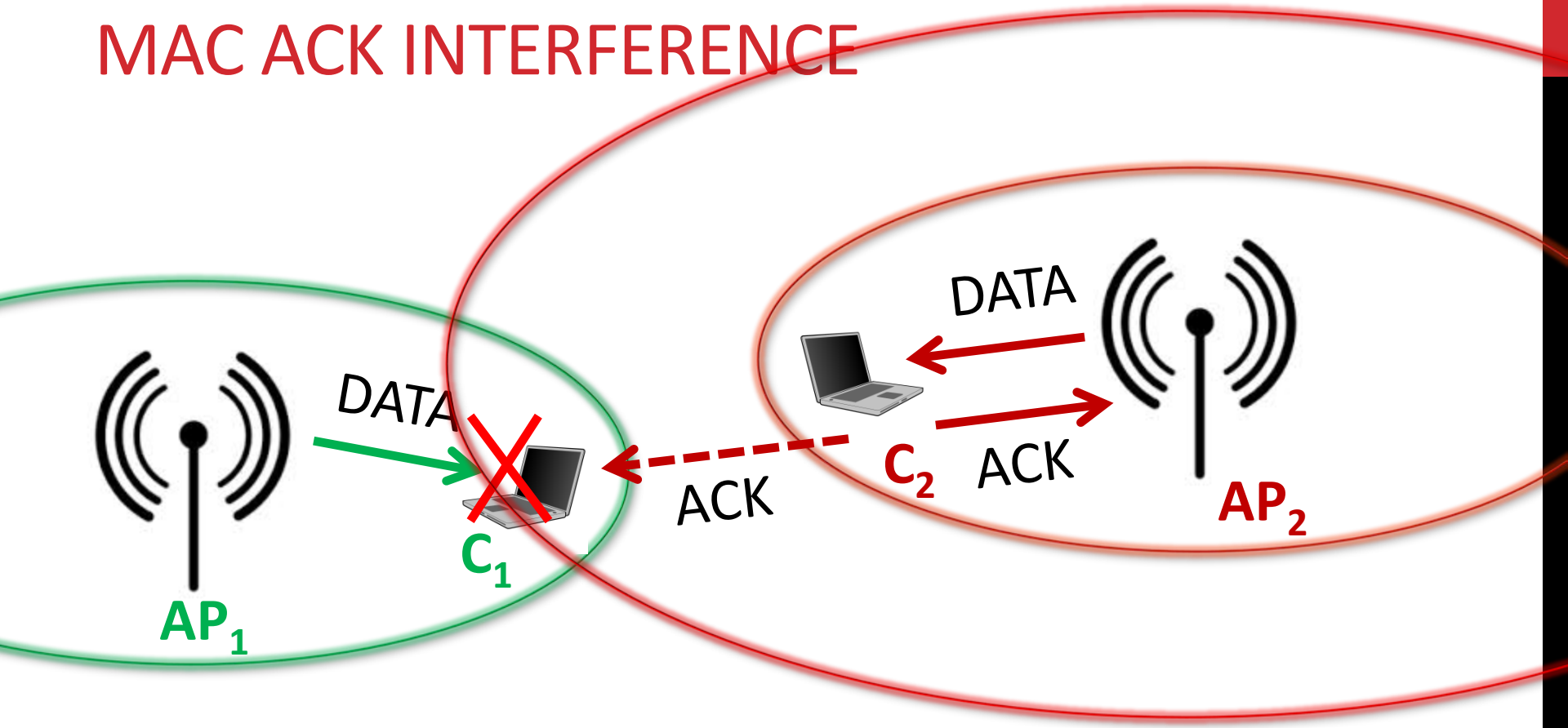
Current approaches:

- Regulate the tx power of the **MAC Data frames** from AP

Our key observation:

- **MAC Acknowledgment frames** from clients could also cause serious interference to neighbor cells

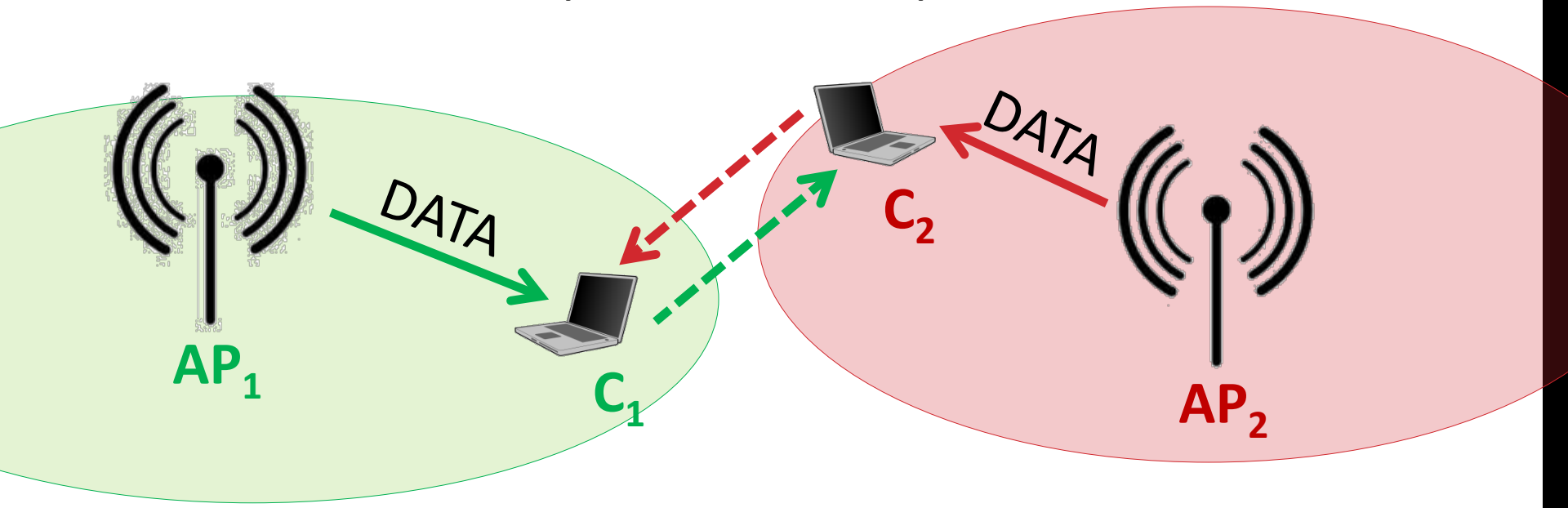
MAC ACK INTERFERENCE



MAC ACK frames effectively **extend the interference range** of a hotspot

MEASURE THE IMPACT OF ACK INTERFERENCE

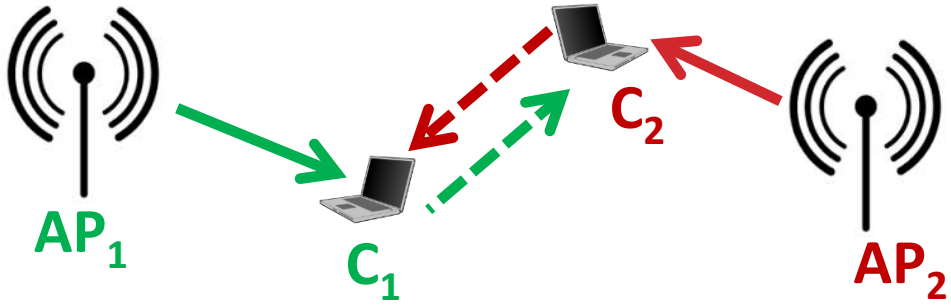
Experiment Setup

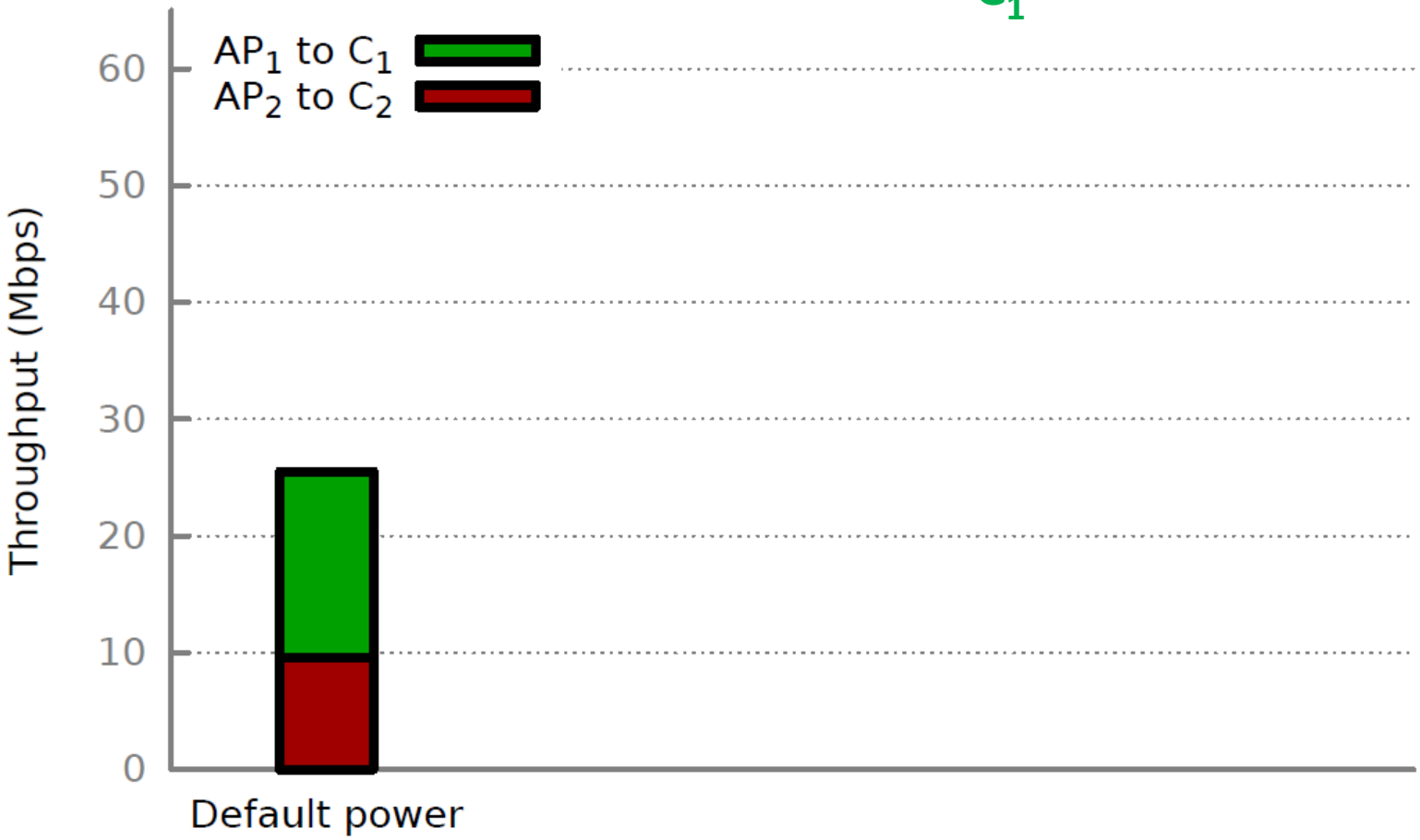


- **Campus WLAN**
  - Cisco AP (1140 series)
- **Clients with Atheros adapters**
  - 802.11a and 802.11n

IMPACT OF MAC ACK INTERFERENCE

11n vs. 11n, UDP





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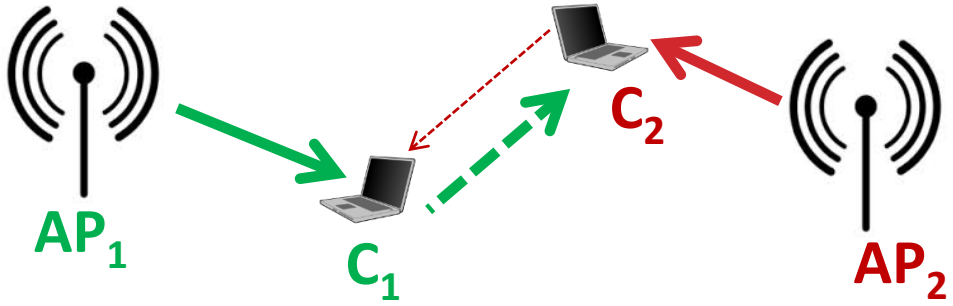

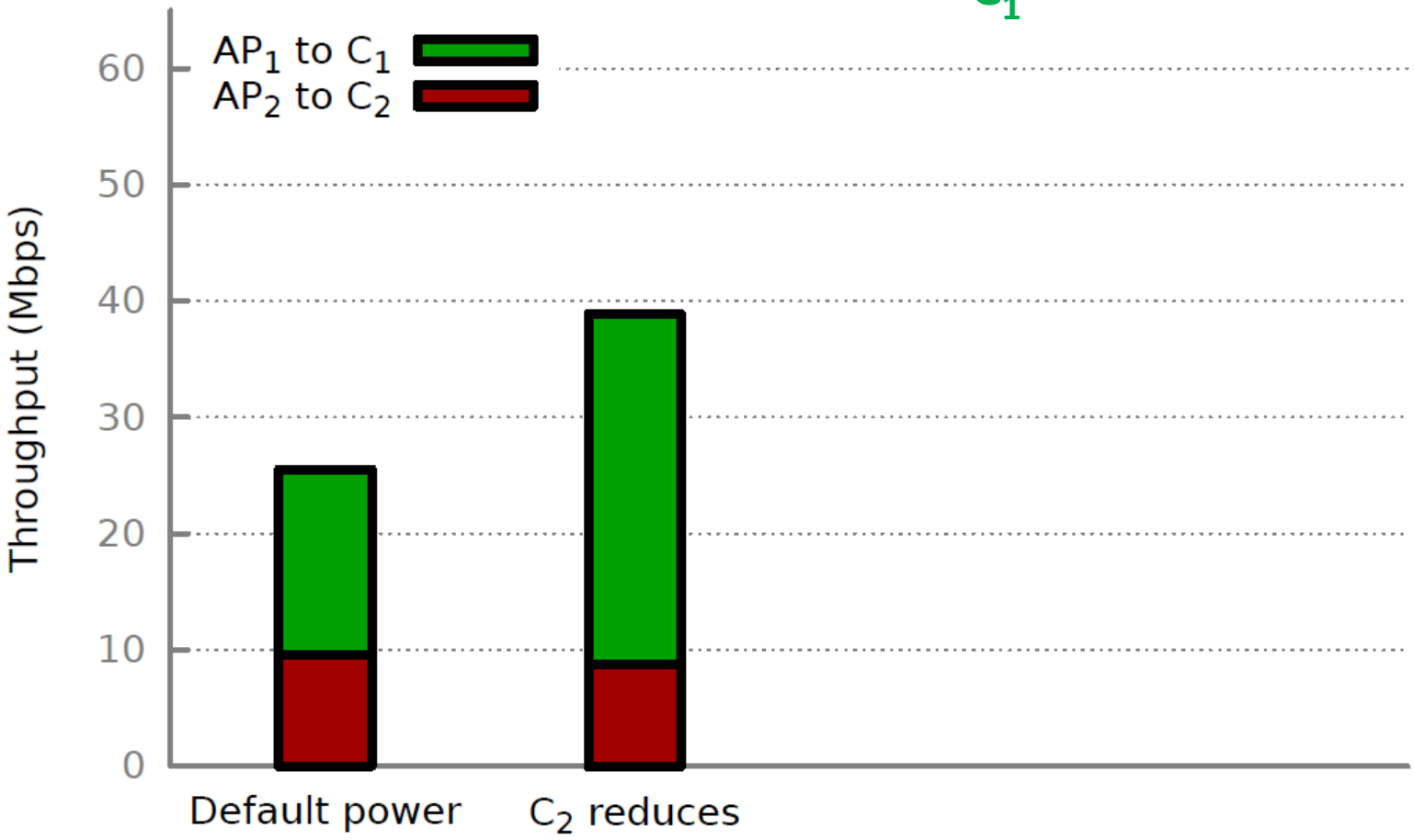

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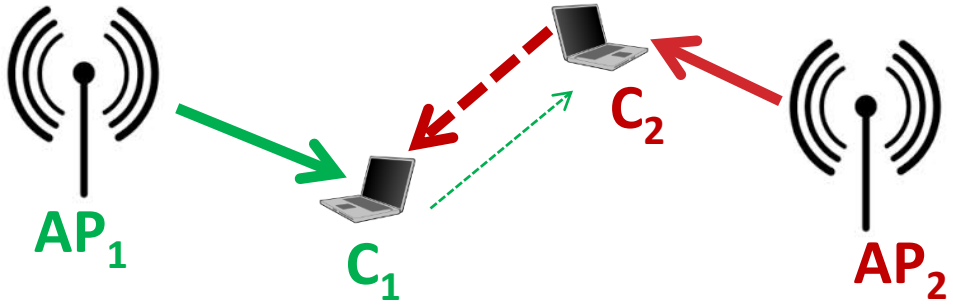

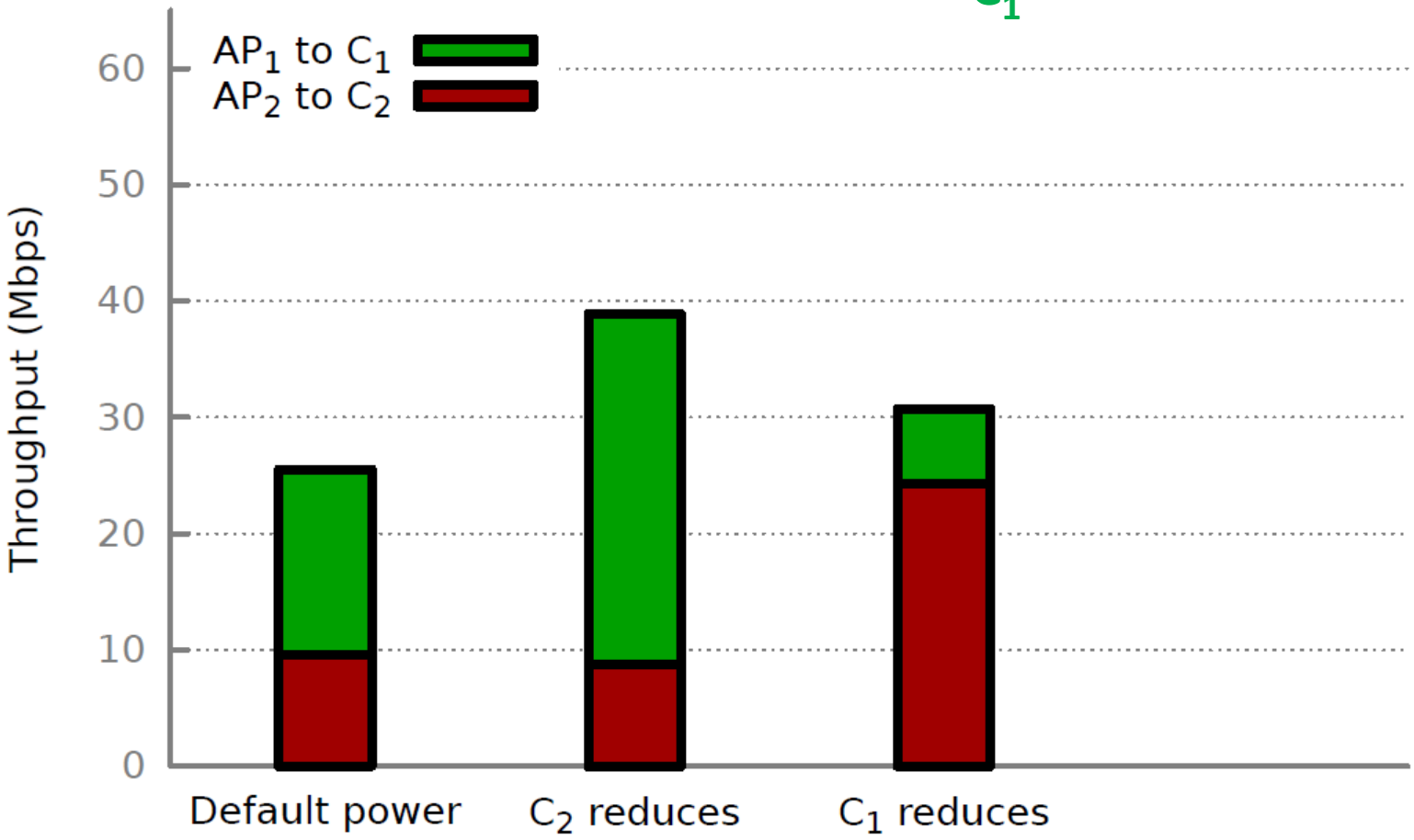

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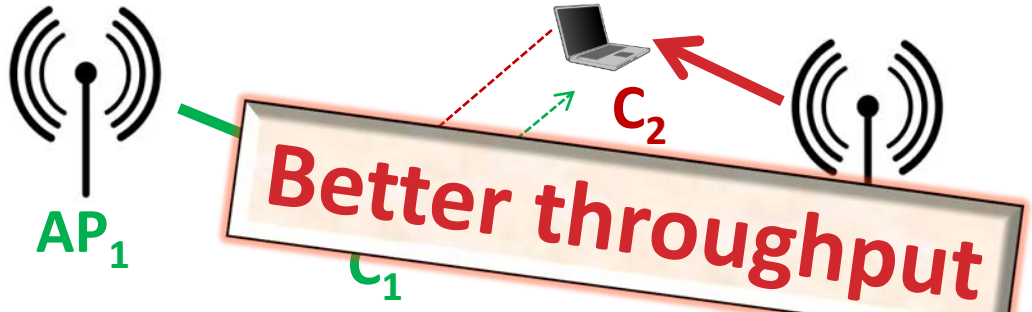
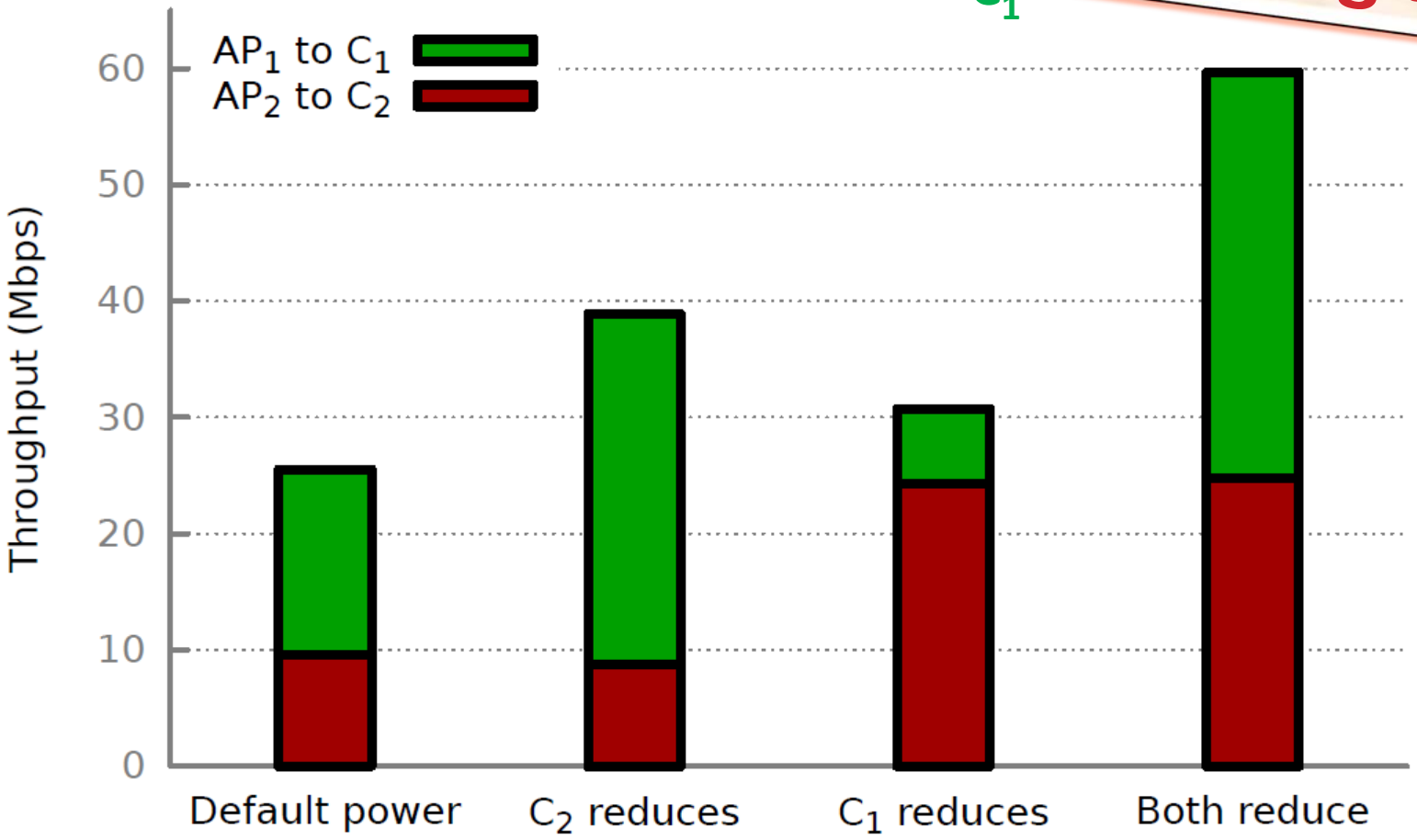
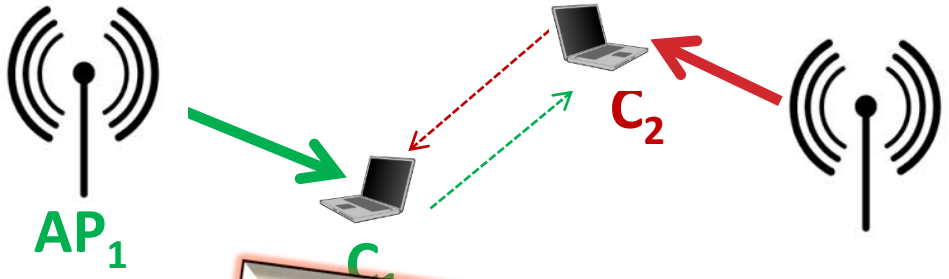
11n vs. 11n, UDP



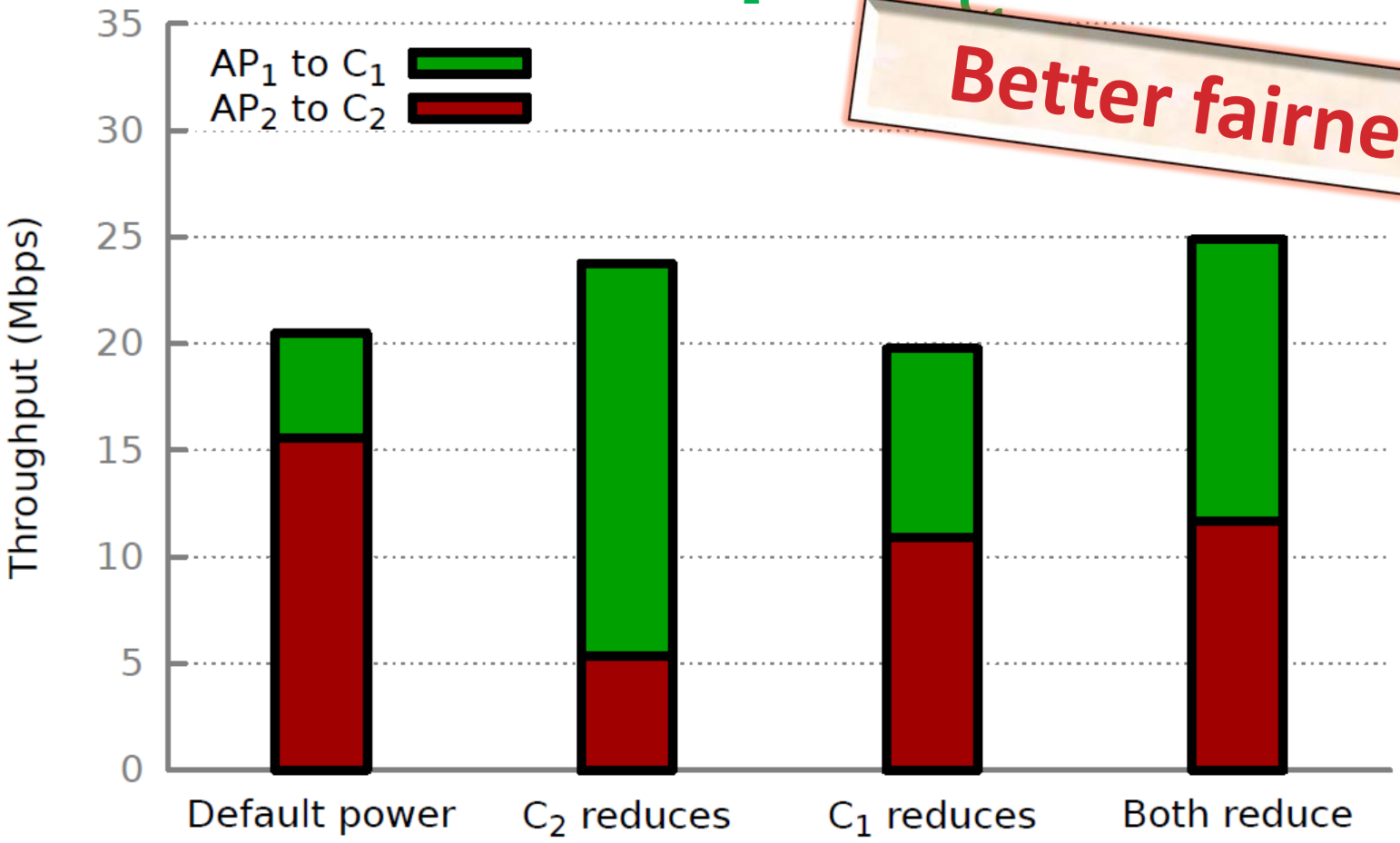


IMPACT OF MAC ACK INTERFERENCE

11n vs. 11n, TCP

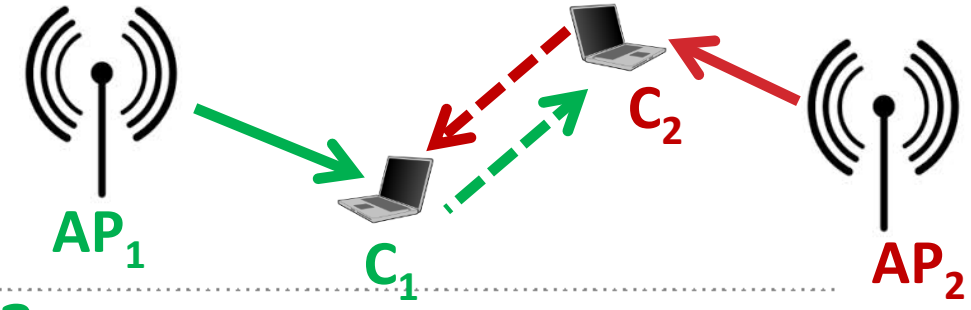


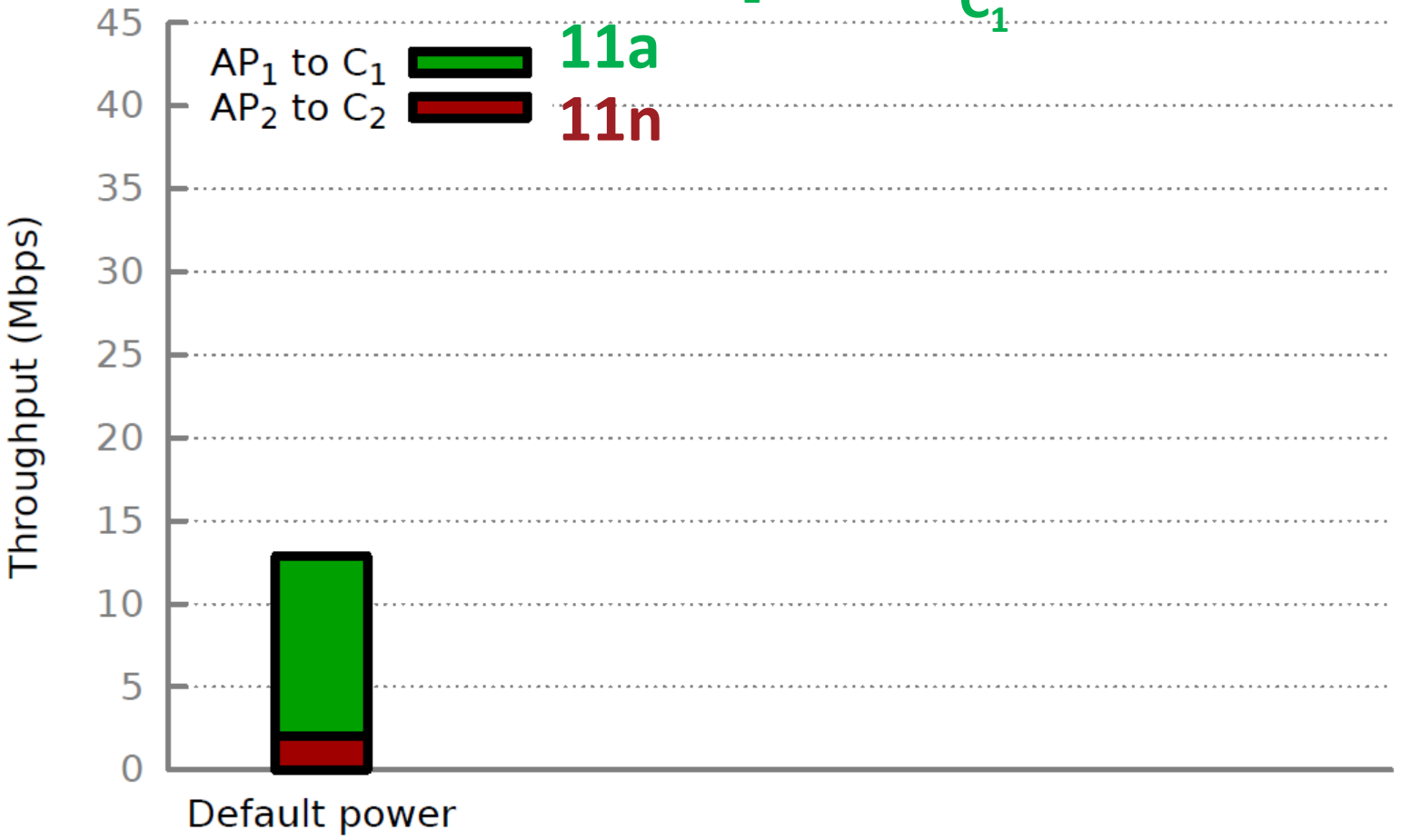
Better fairness



IMPACT OF MAC ACK INTERFERENCE

11a vs. 11n, UDP





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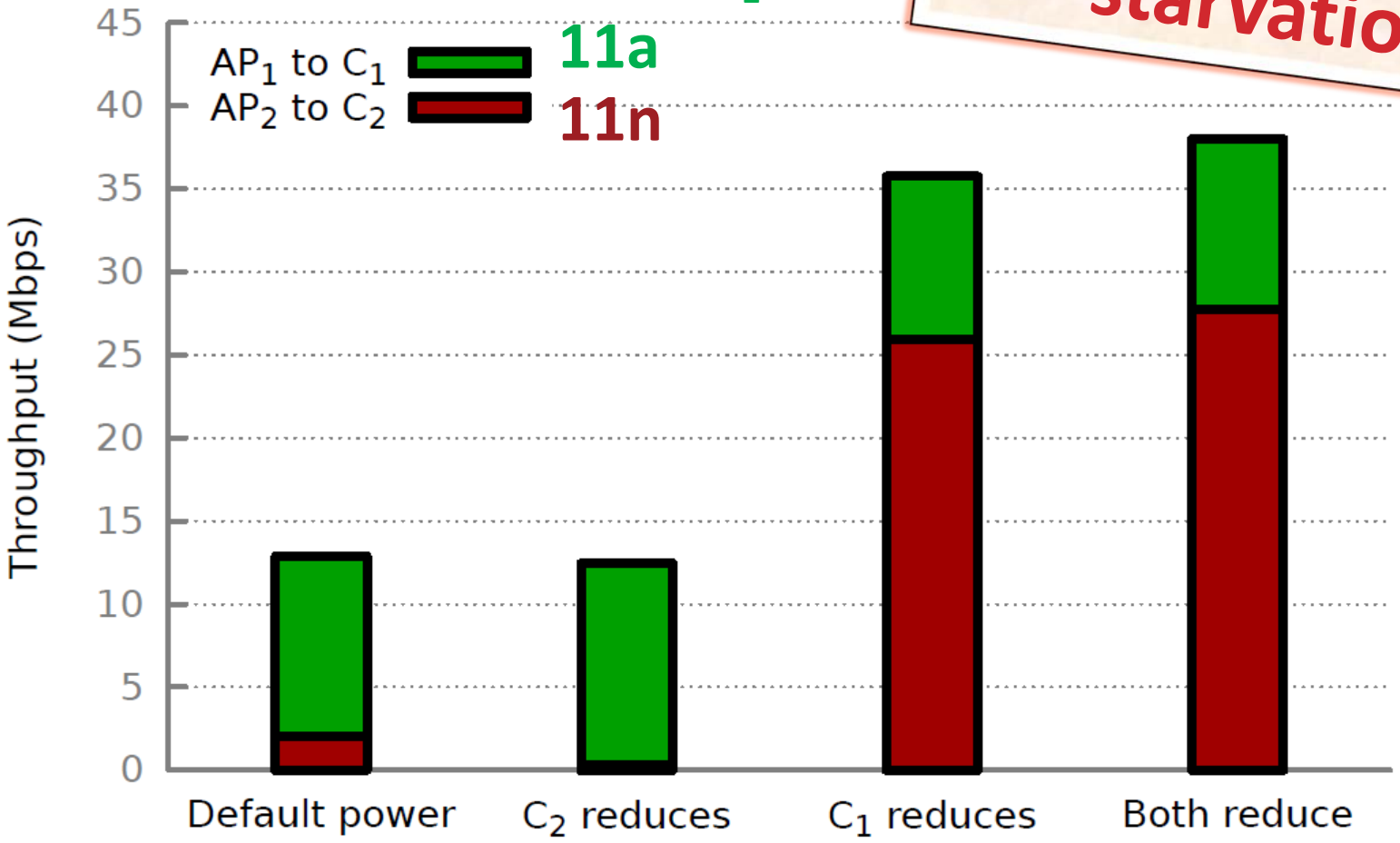
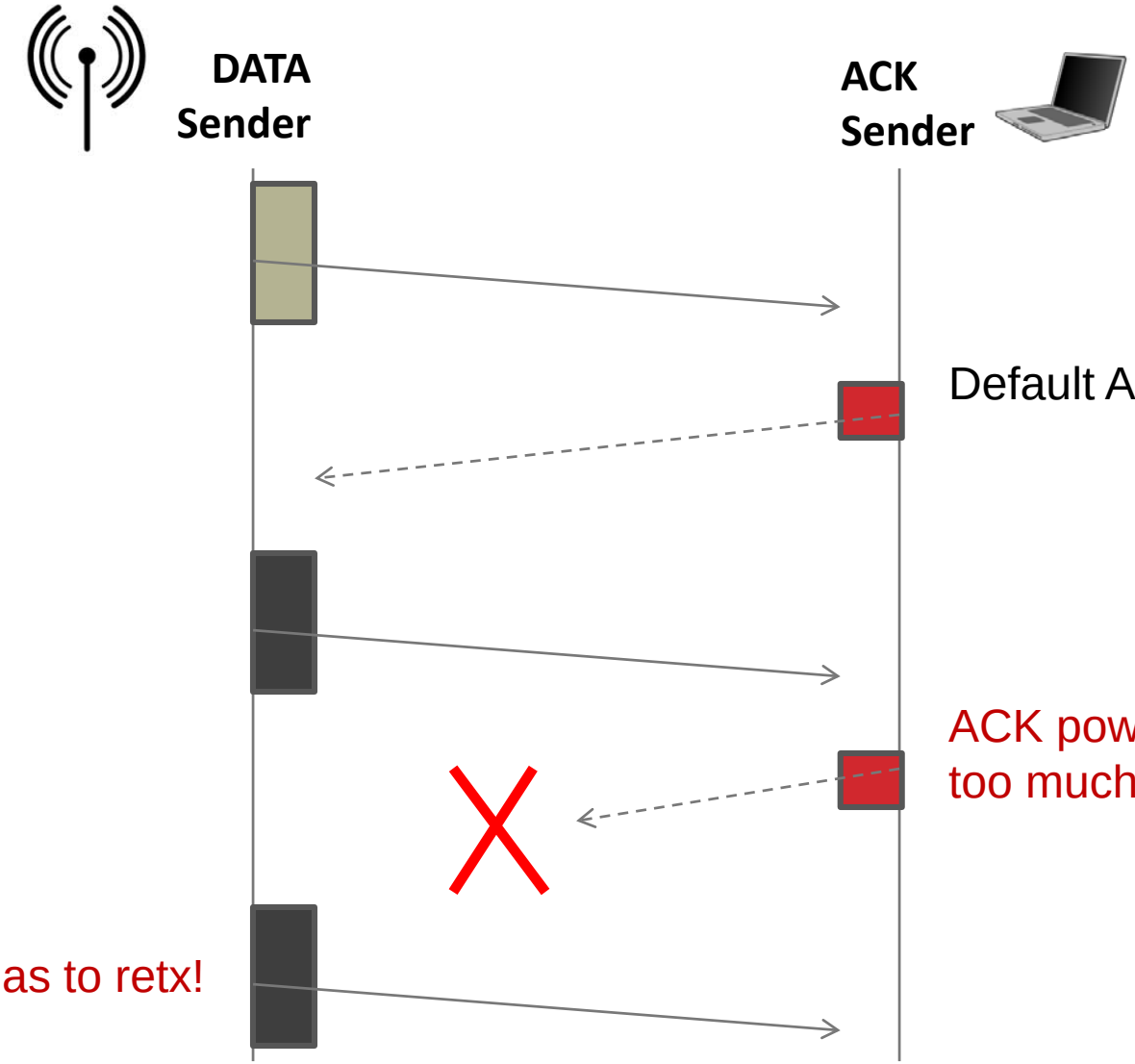


POWER CONTROL OF ACK



POWER CONTROL OF ACK

Key idea

Gradually reduce the power of ACK, until the point just before the success rate of ACK starts decreasing.

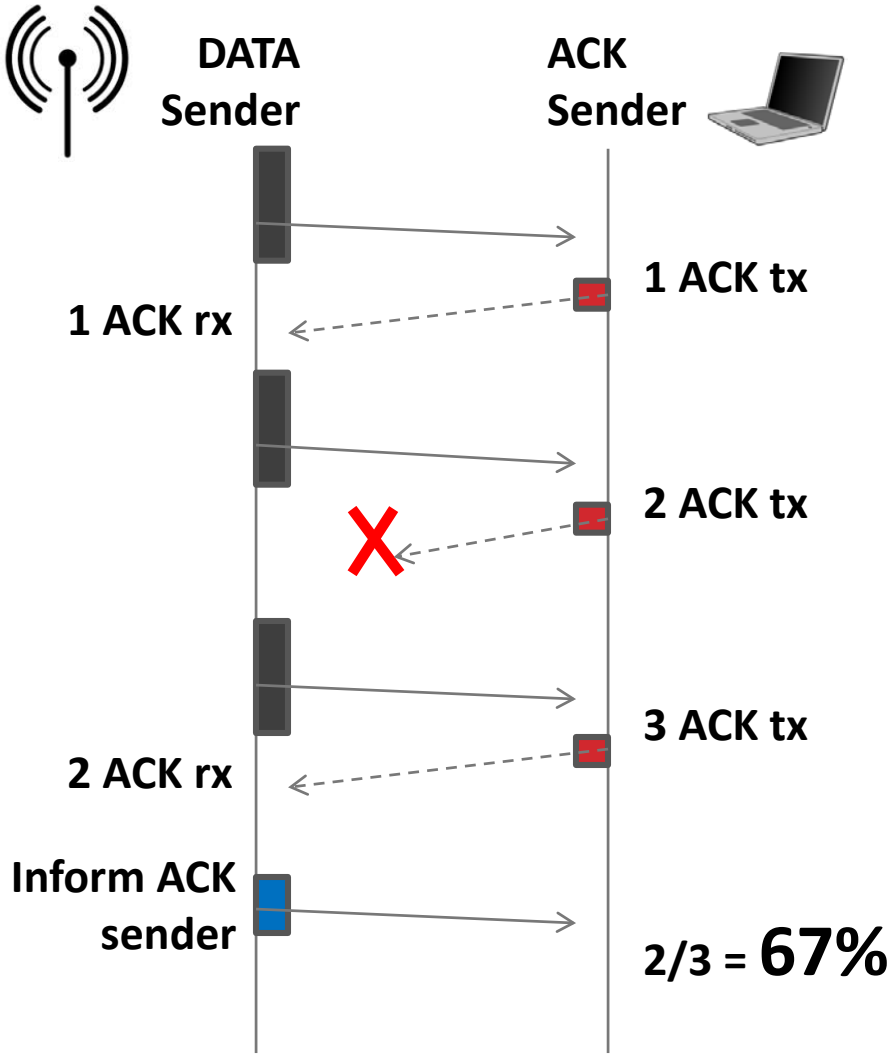
Called **Minimum Power for ACK (MinPACK)**

Challenge

How can the ACK sender accurately estimate the success rate of ACK?

ESTIMATION OF ACK SUCCESS RATE

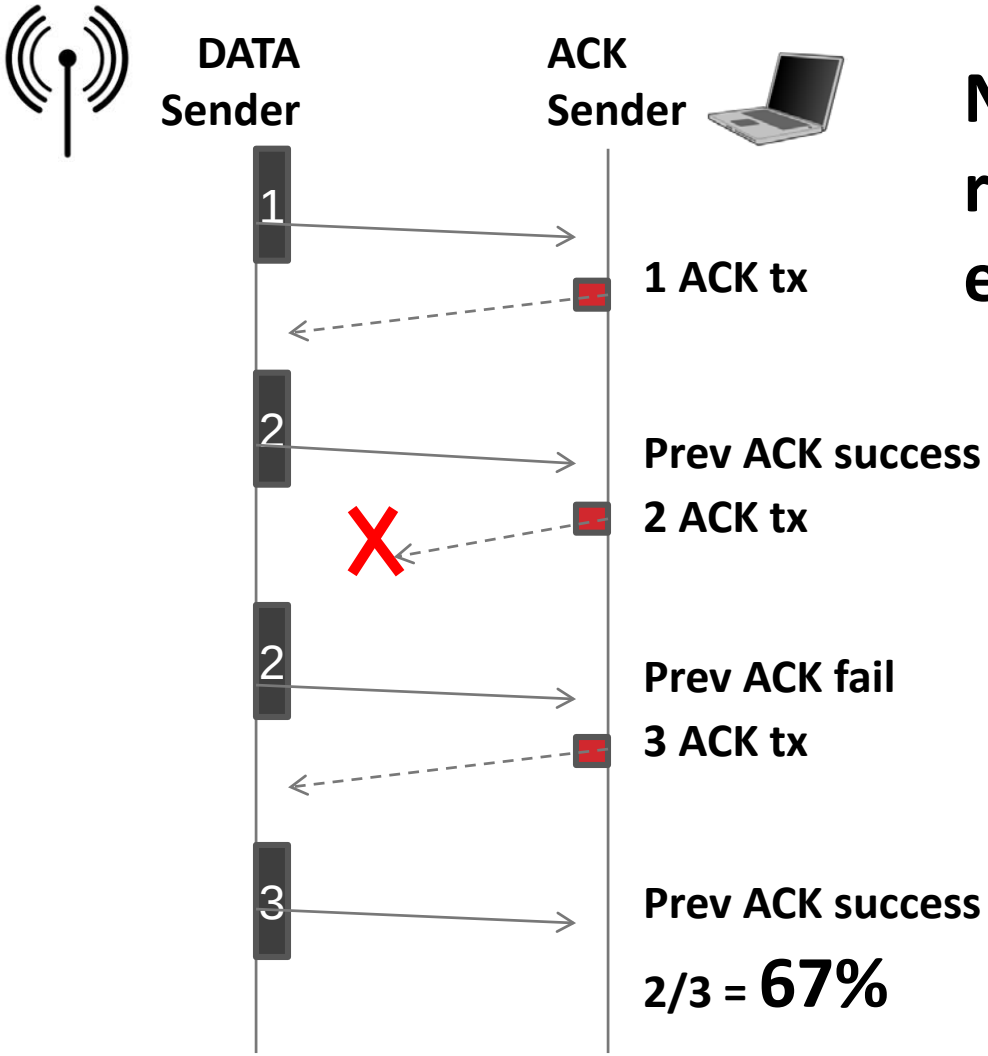
Feedback-based method



Accurate, but need to modify DATA sender!

ESTIMATION OF ACK SUCCESS RATE

Passive estimation method



Not perfect due to retx limit, but good enough in practice

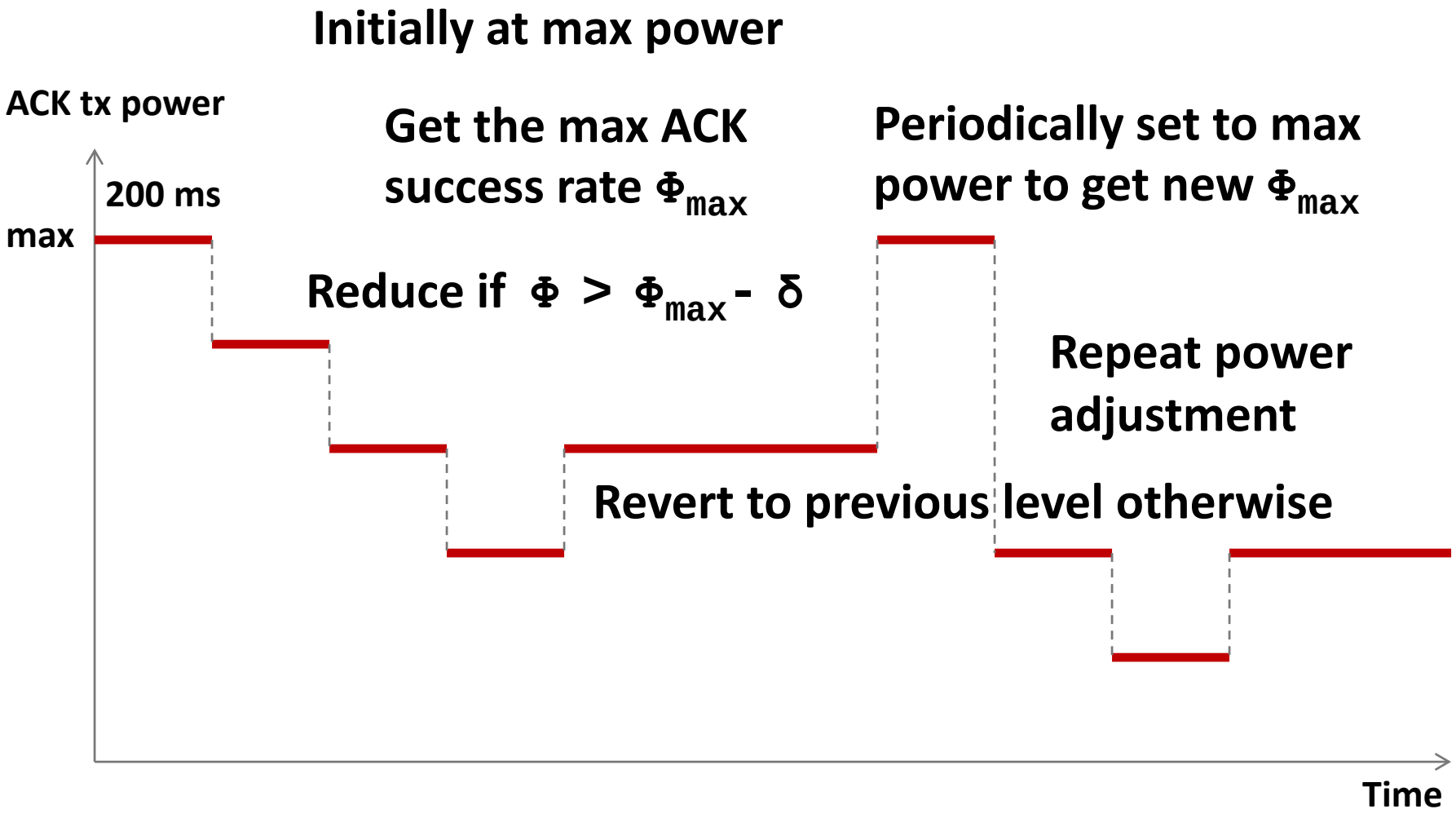
PASSIVE ESTIMATION FOR BLOCK ACK

Problem: DATA sender could send any frame that has not been acknowledged

Solution: ACK sender maintains a history of frames received

More details in the paper

MINPACK PROTOCOL



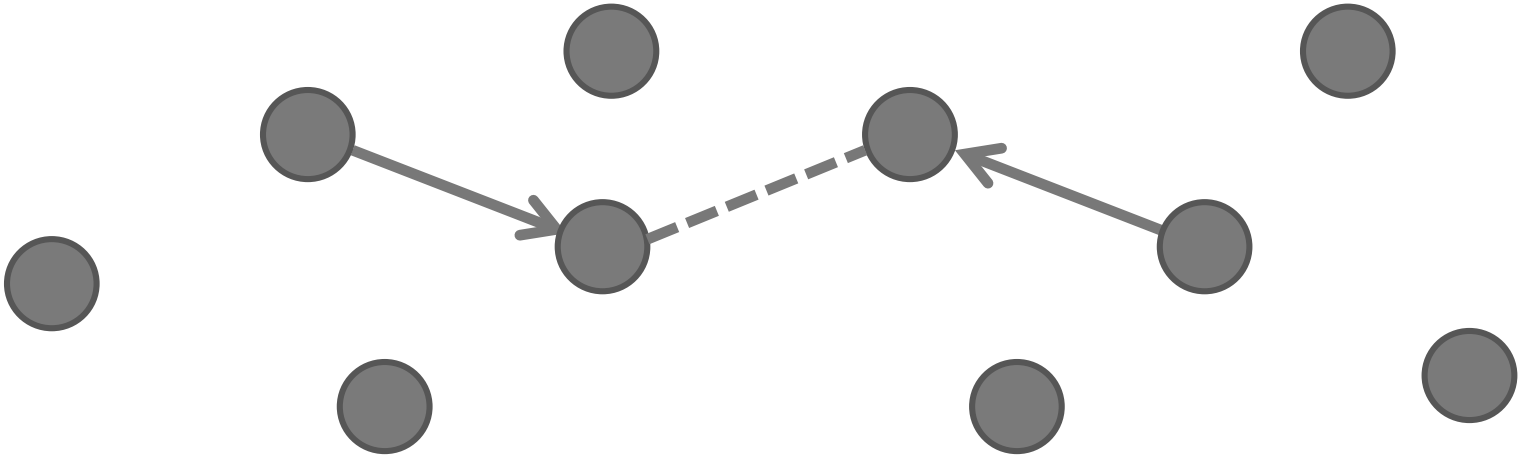
EVALUATION OF MINPACK

Outline

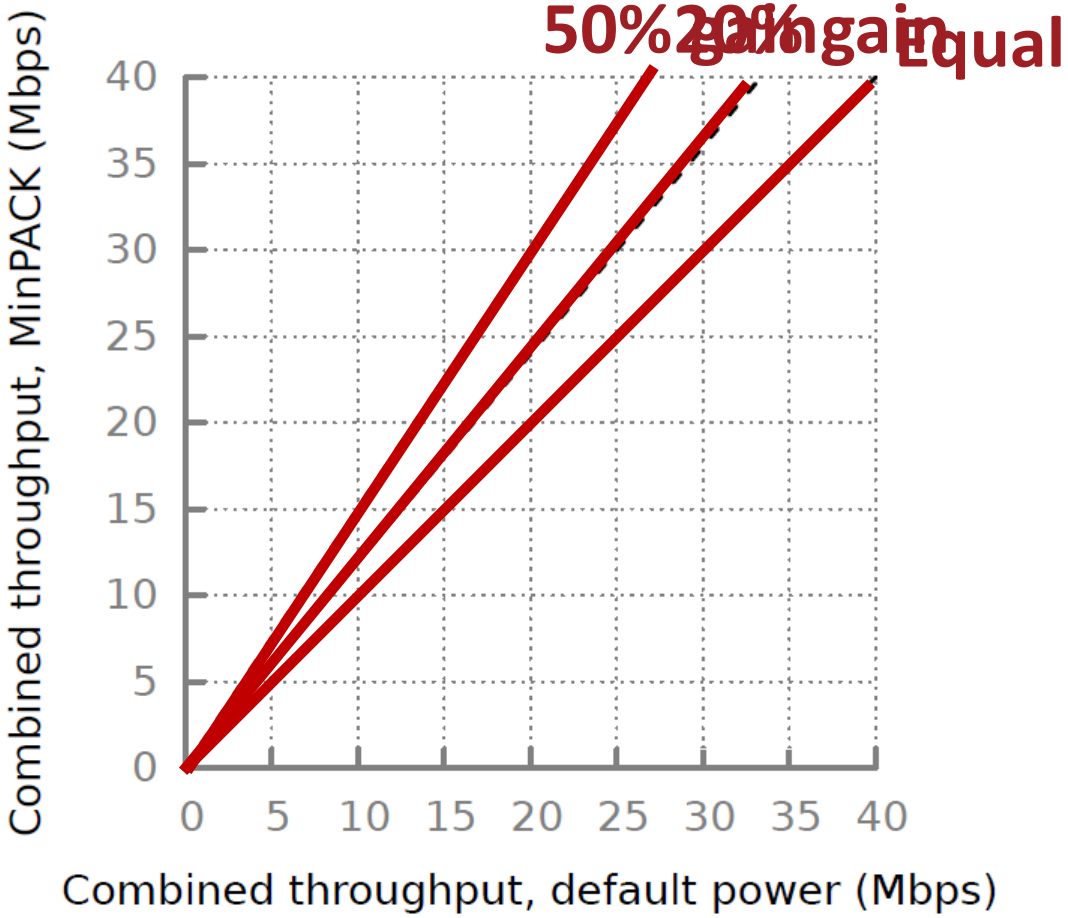
- Gain of MinPACK
  - 11a vs. 11a in 20-node testbed
  - 11n vs. 11n in campus WLAN
  - 11a vs. 11n in campus WLAN
- Interaction with DATA power control
- Adaptation to client mobility

GAIN OF MINPACK

- 20-node outdoor 802.11a testbed
- Arbitrarily select 38 pairs of competing links, with UDP traffic



THROUGHPUT GAIN



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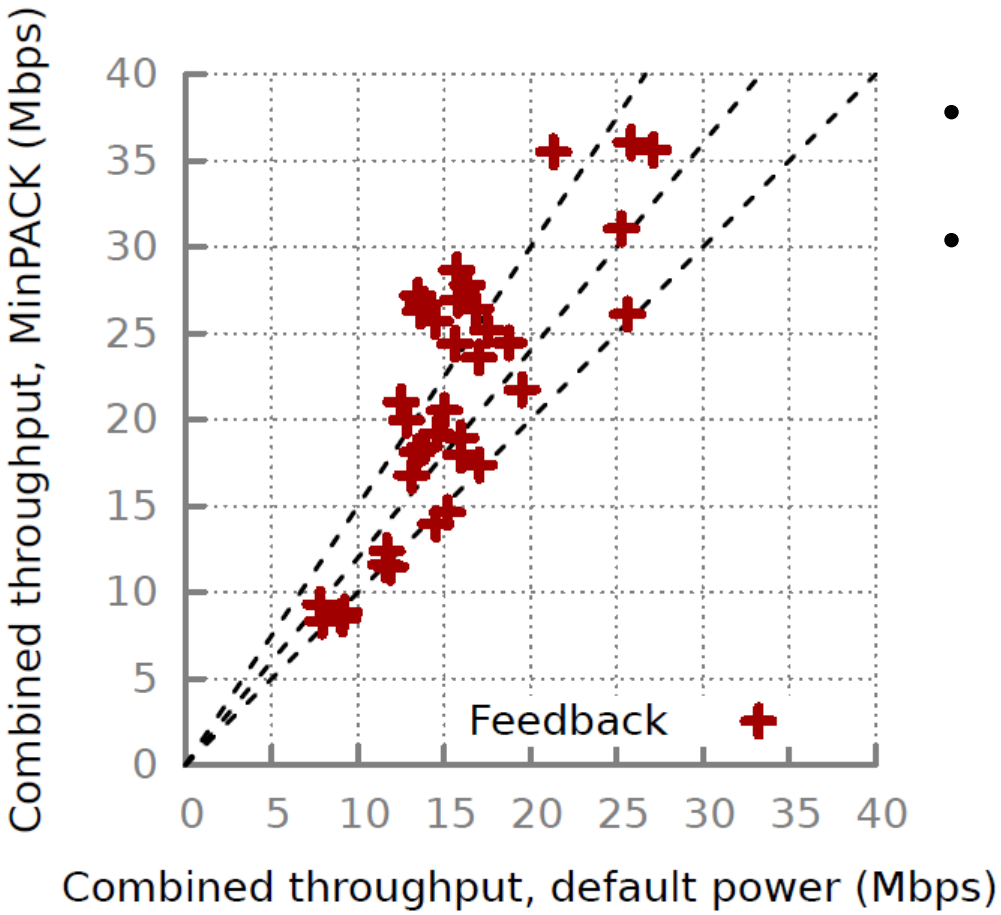
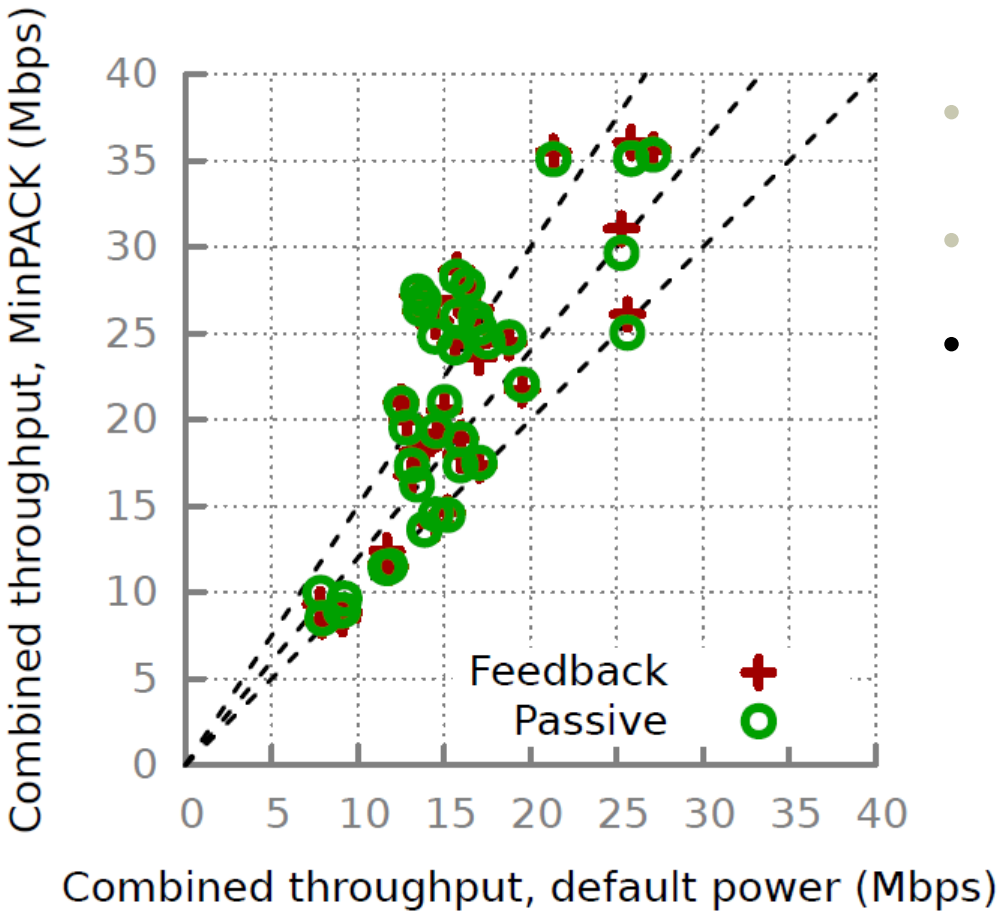


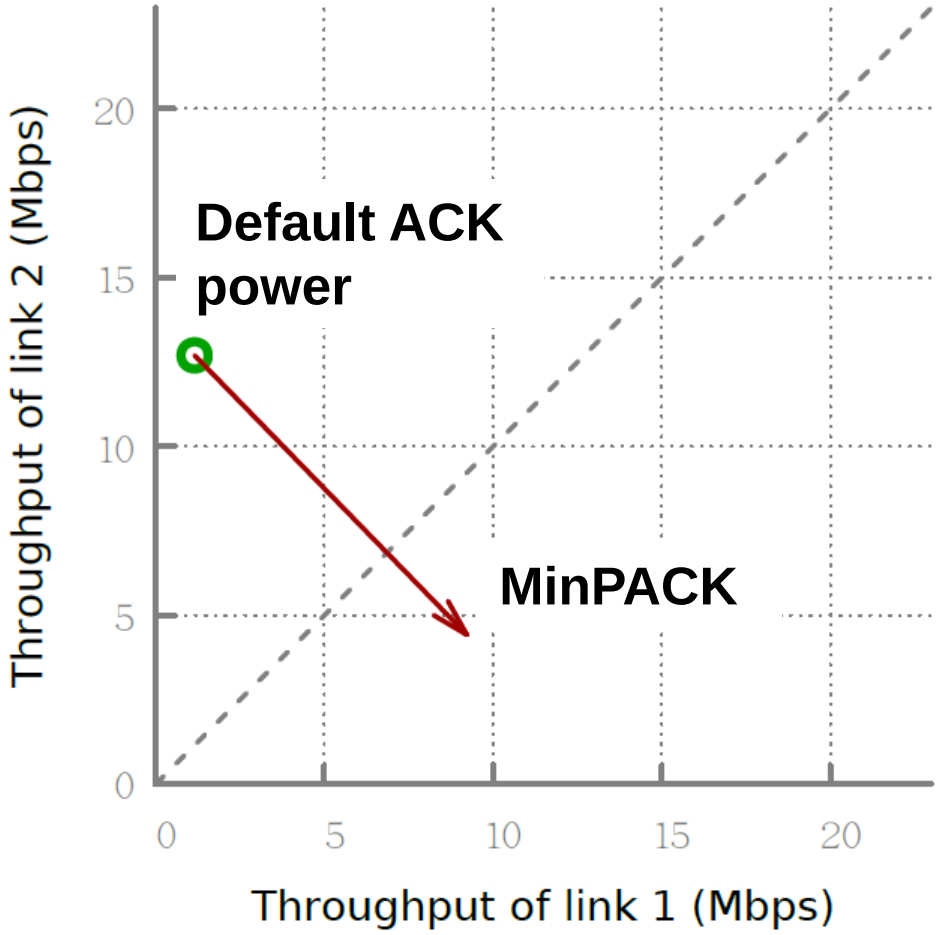
- **MinPACK does no harm**
- **Median gain is 31%**

THROUGHPUT GAIN



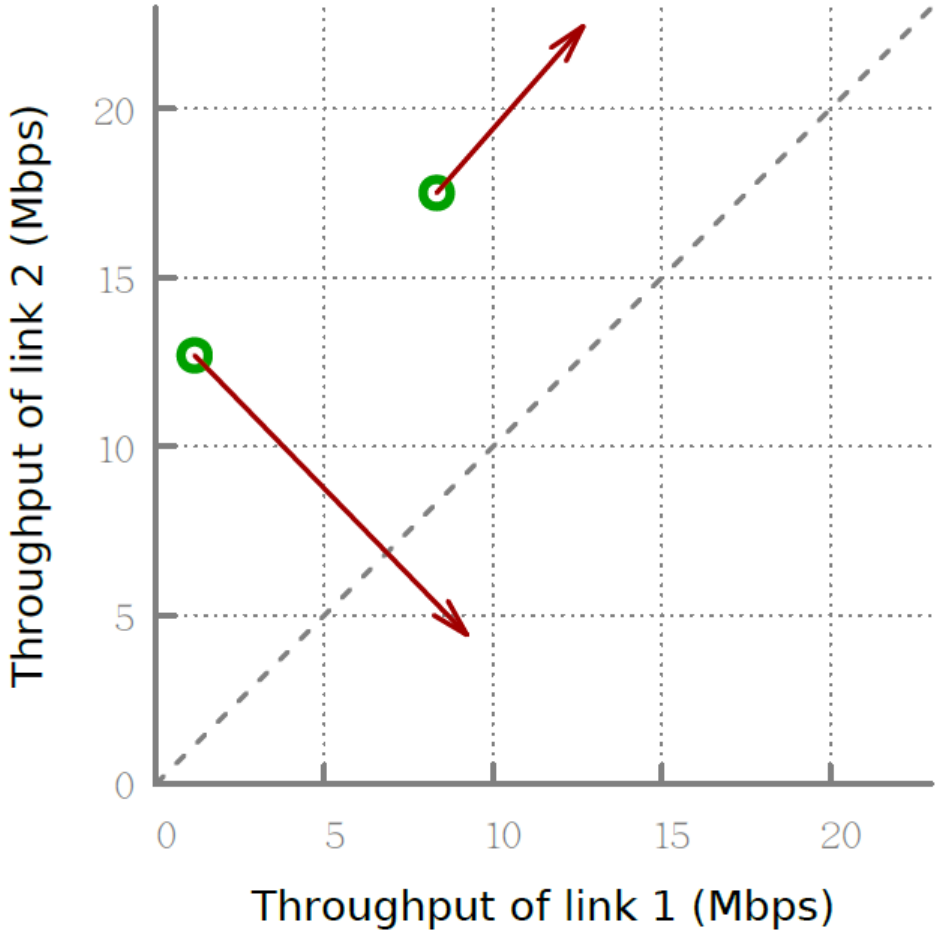
- MinPACK does no harm
- Median gain is 31%
- **Passive method achieves similar performance to Feedback method**

IMPROVEMENT OF FAIRNESS



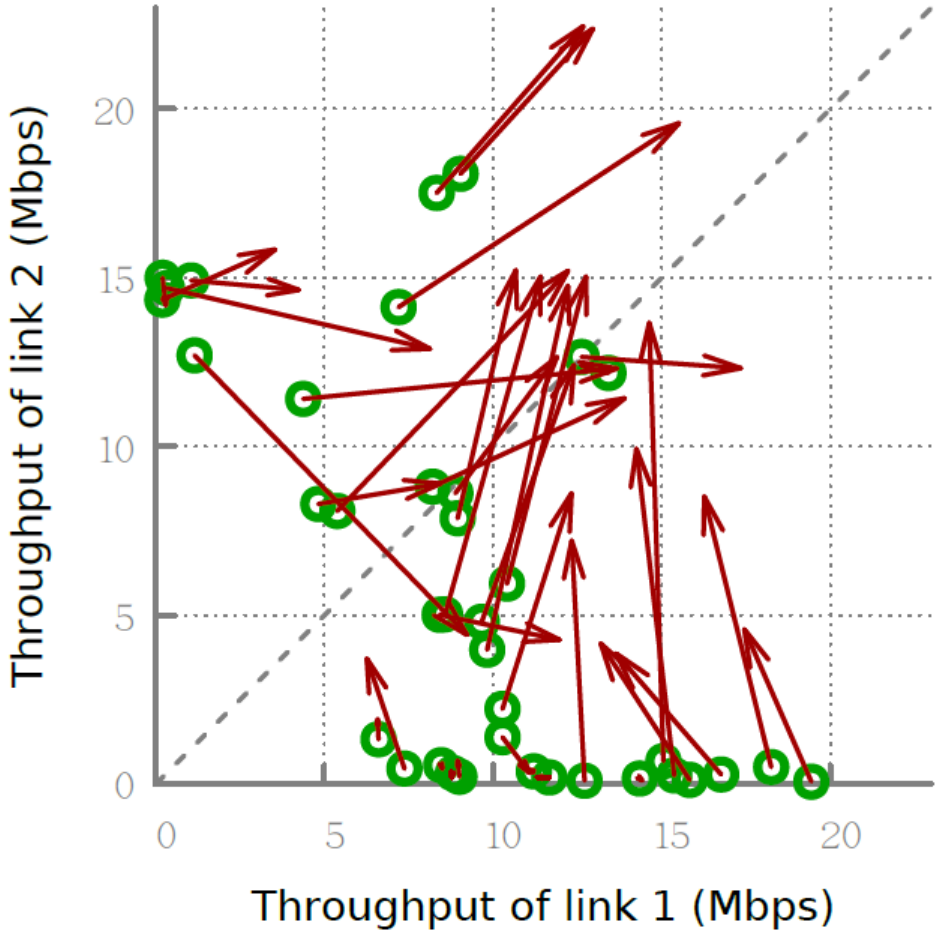
MinPACK achieves better fairness for this link pair

IMPROVEMENT OF FAIRNESS



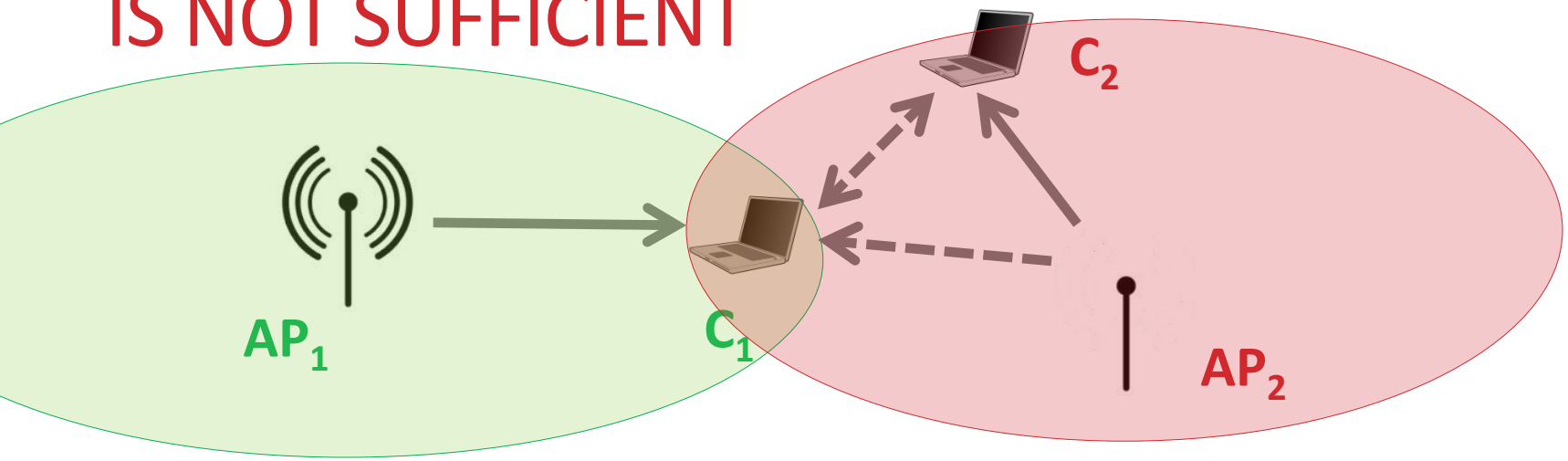
MinPACK achieves better efficiency for this link pair

IMPROVEMENT OF FAIRNESS



- **Fairness is improved for most link pairs.**
- **Some link pairs have fairness and efficiency both improved.**

POWER CONTROL OF DATA FRAMES IS NOT SUFFICIENT



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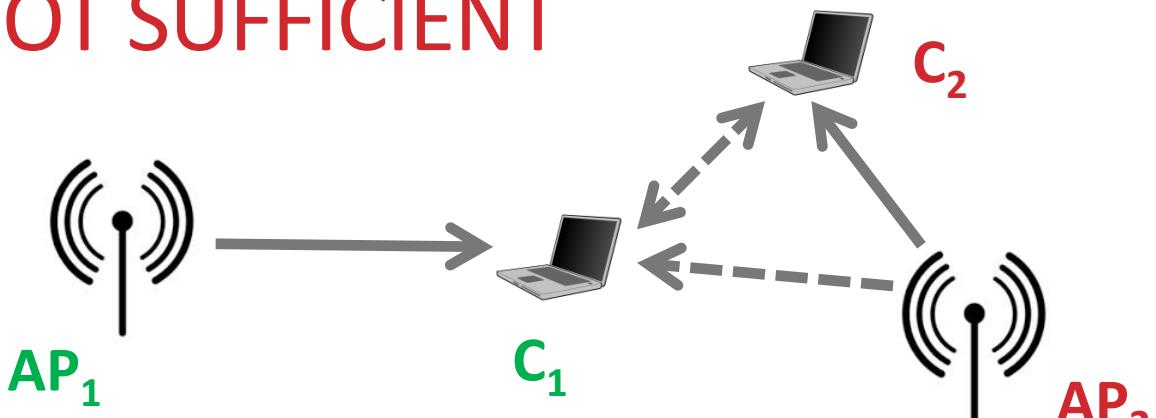
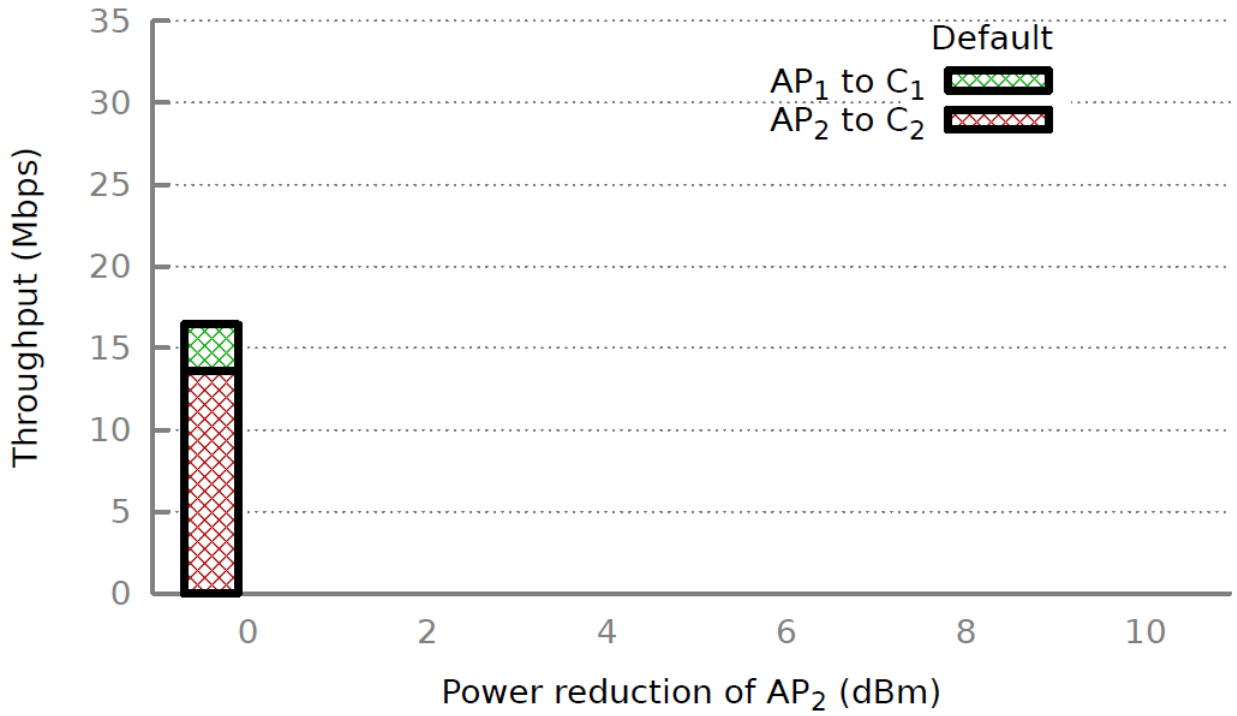


Default ACK power



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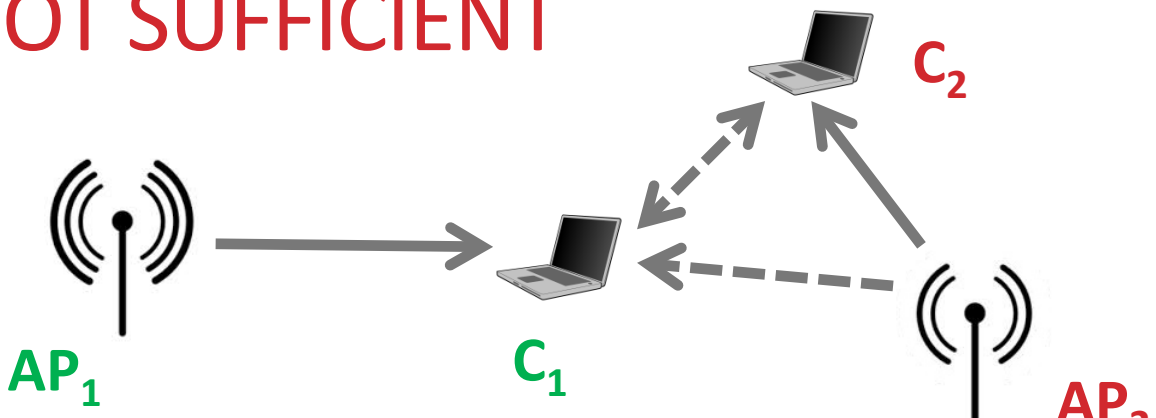

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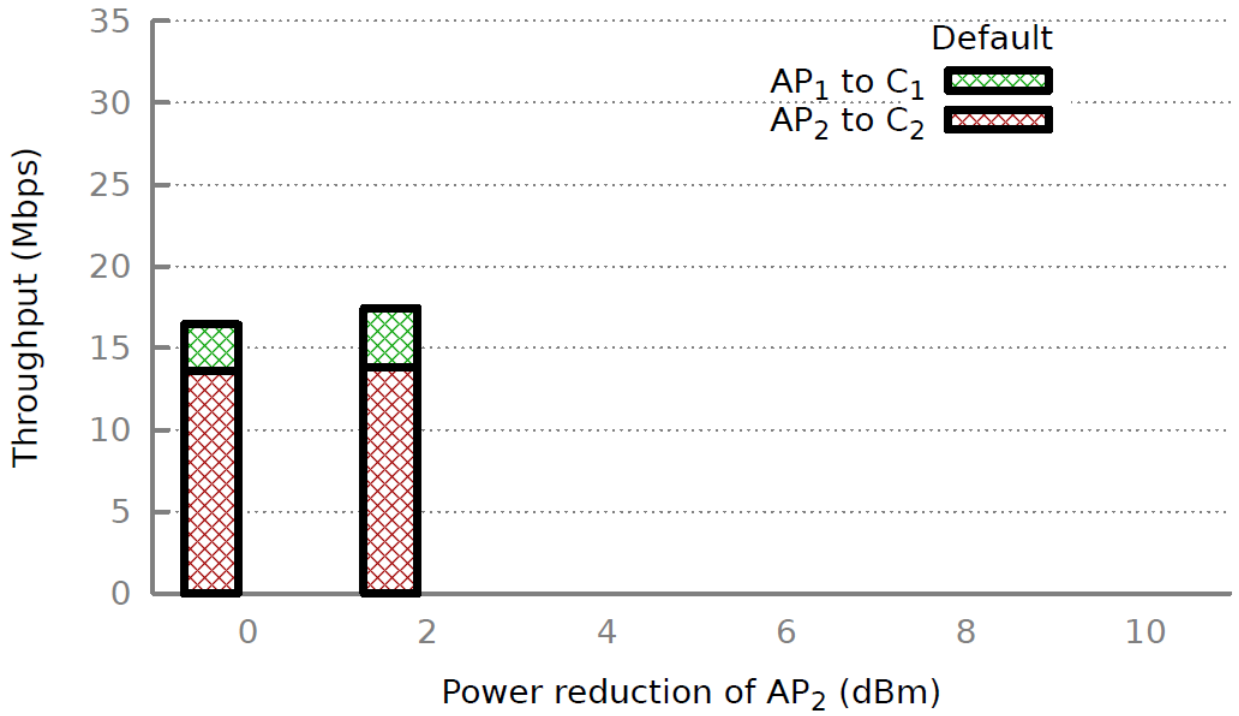

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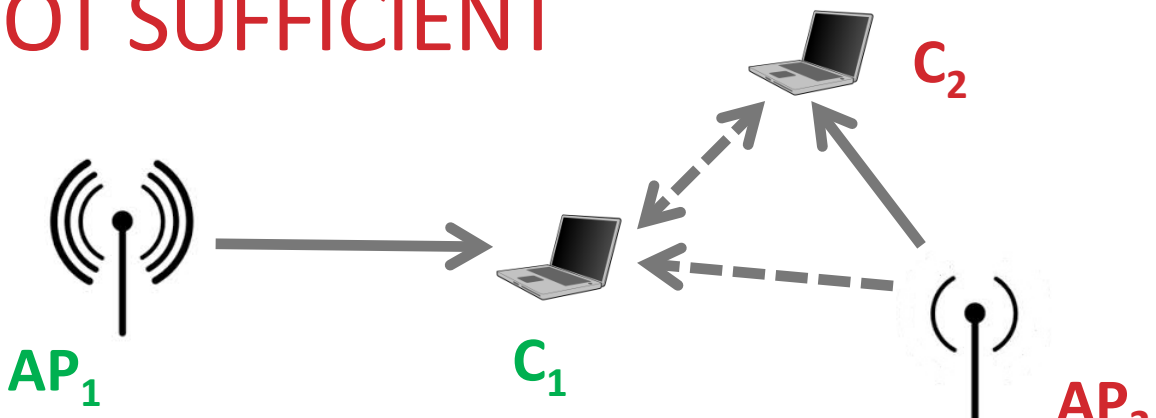

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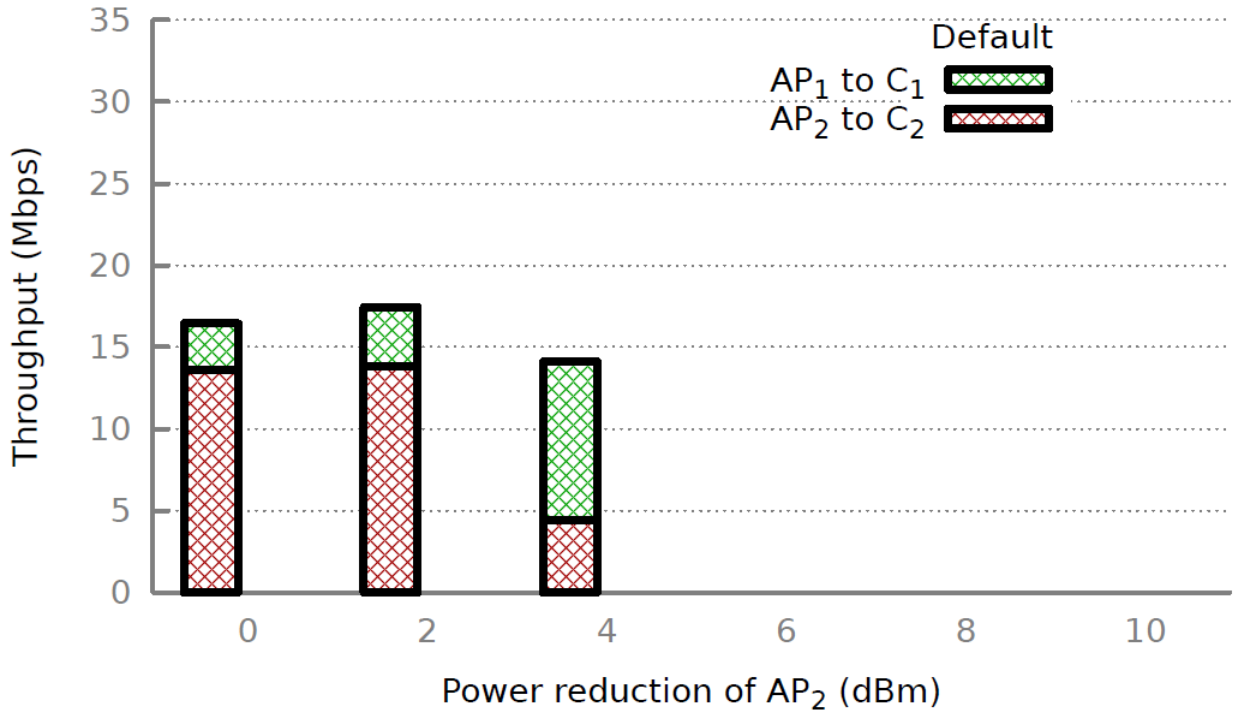

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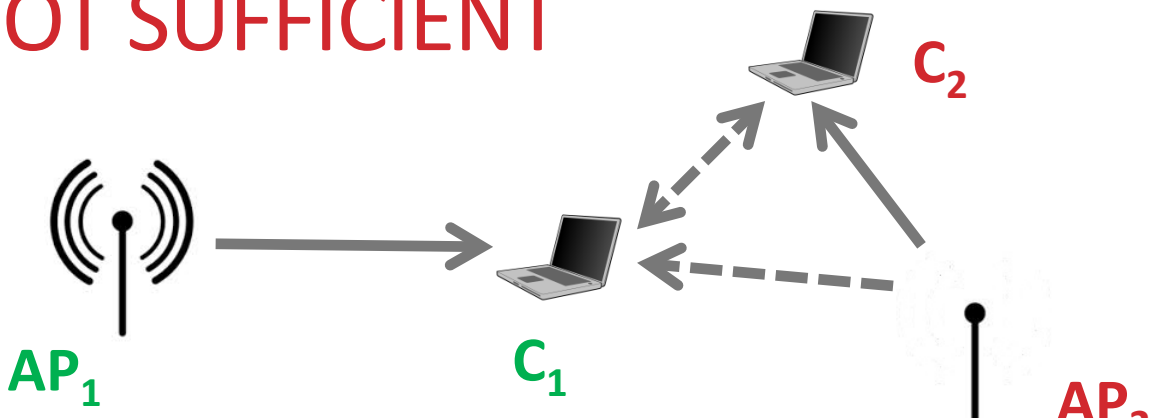

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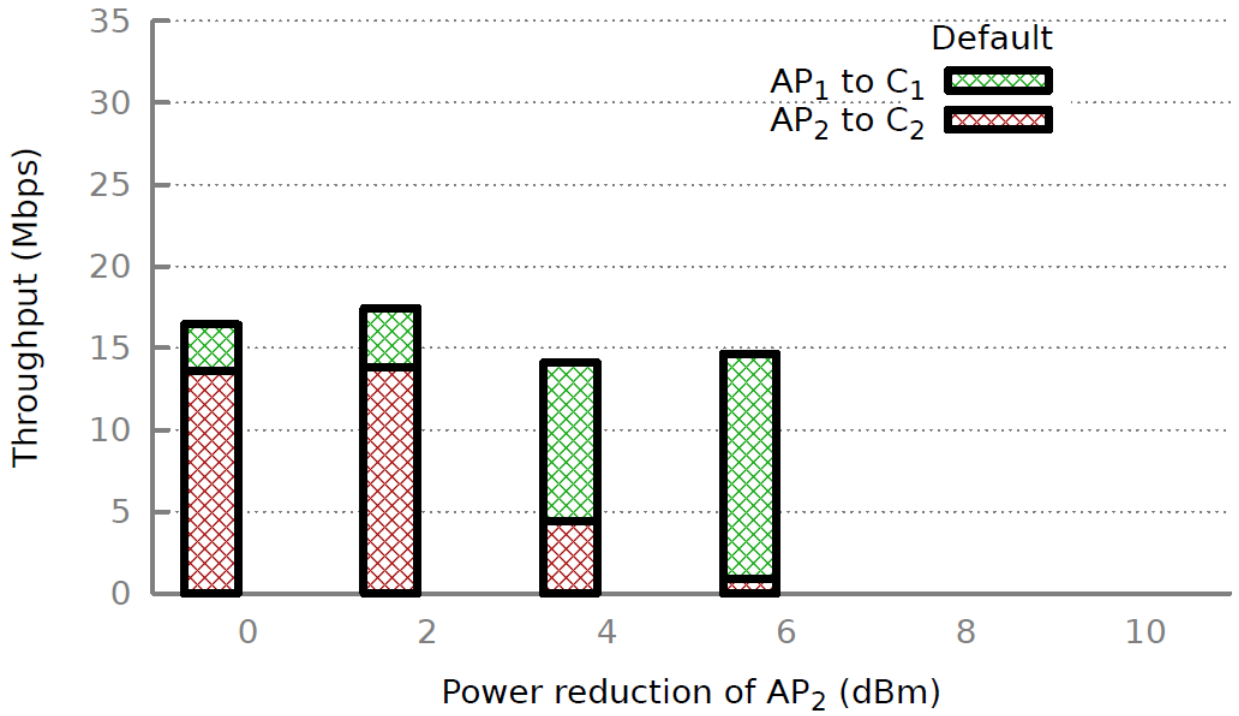

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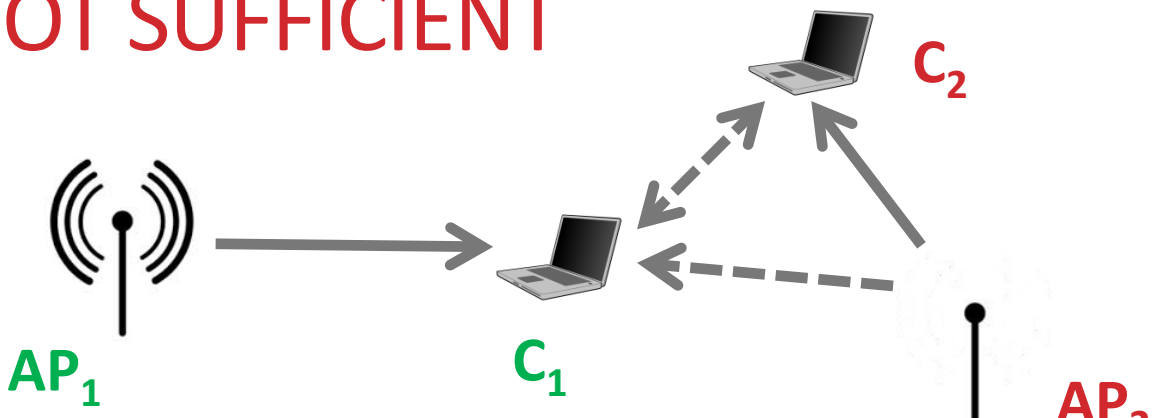

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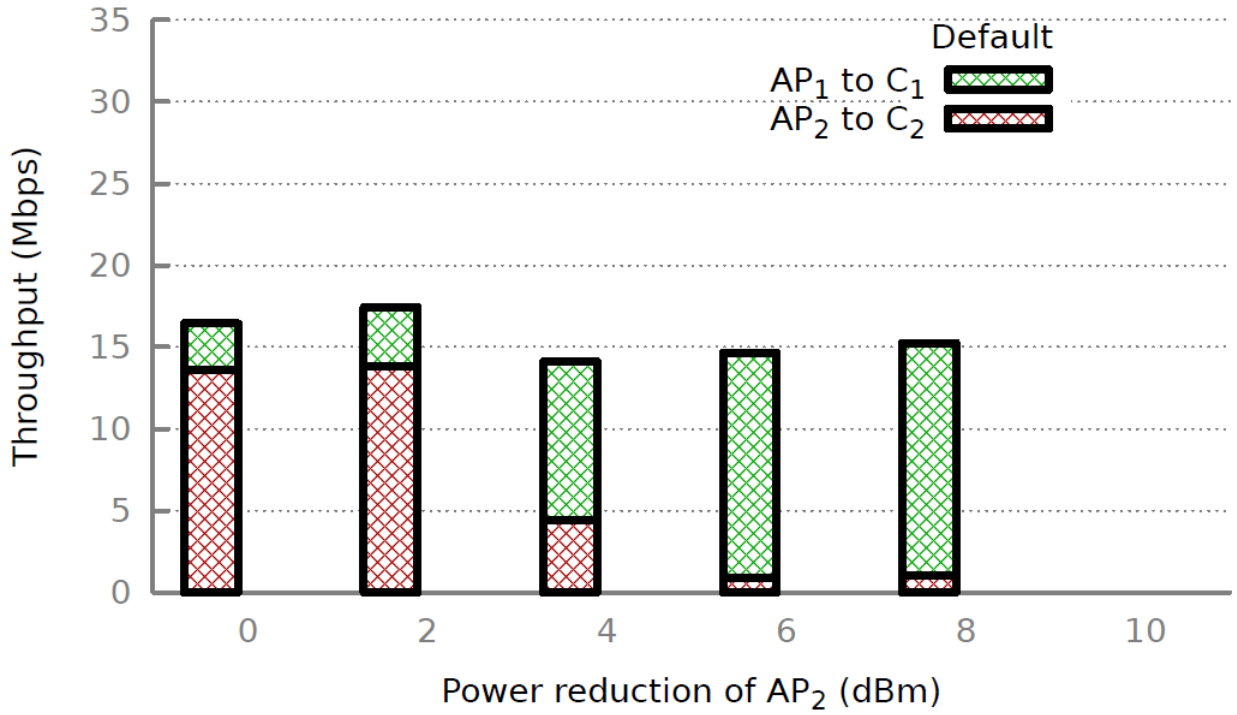

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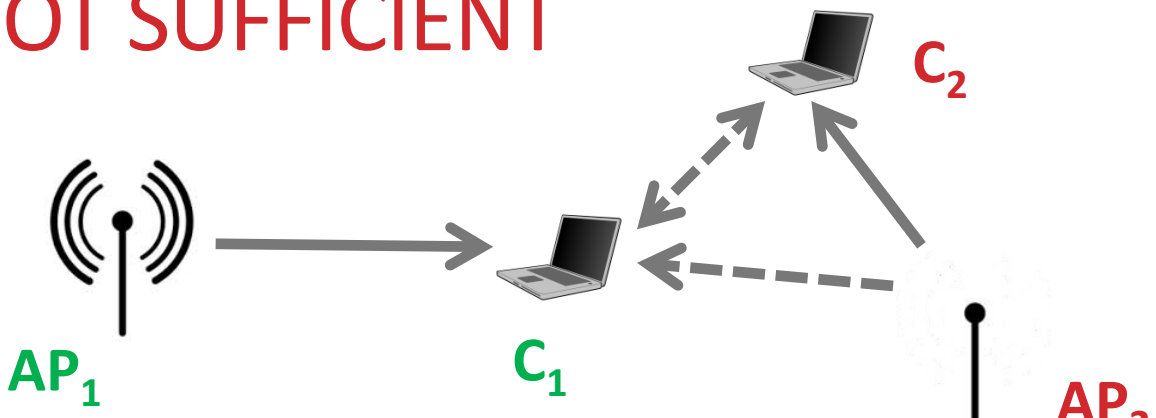

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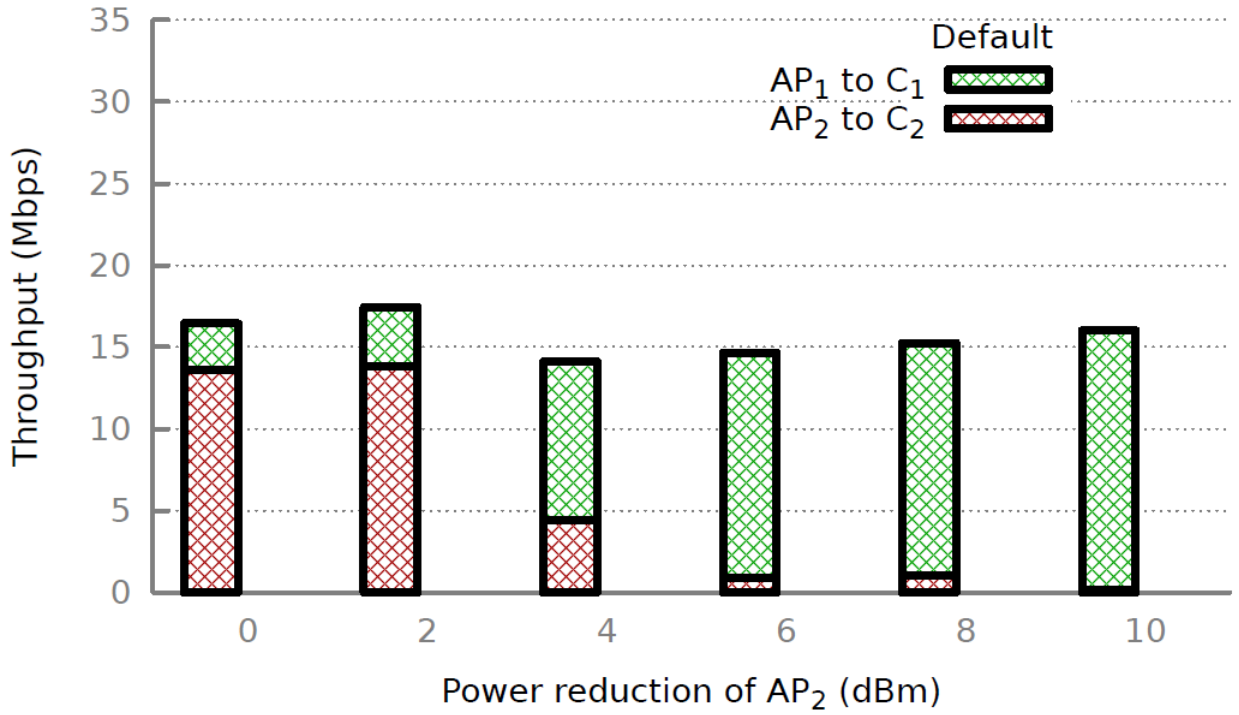

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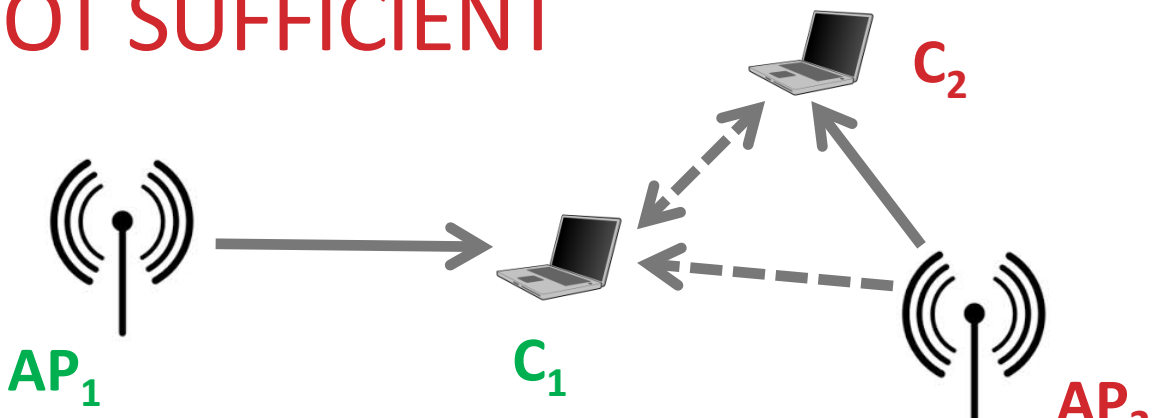
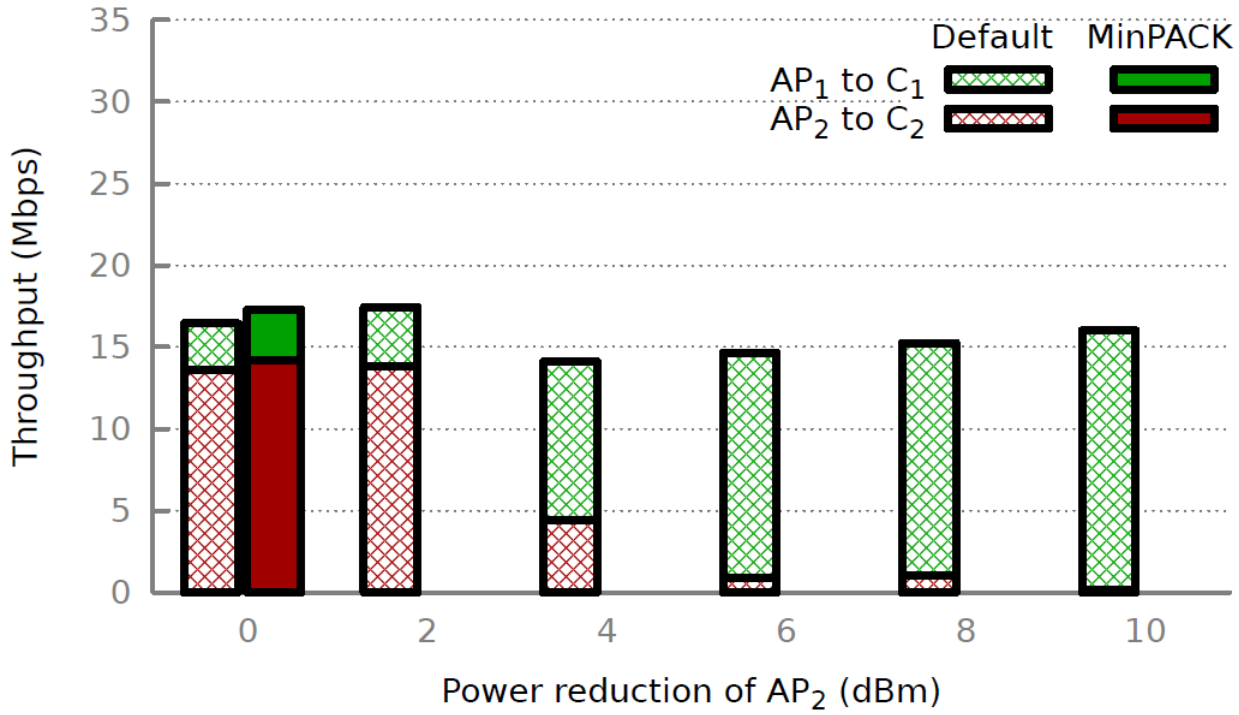


Default ACK power vs. **MinPACK**



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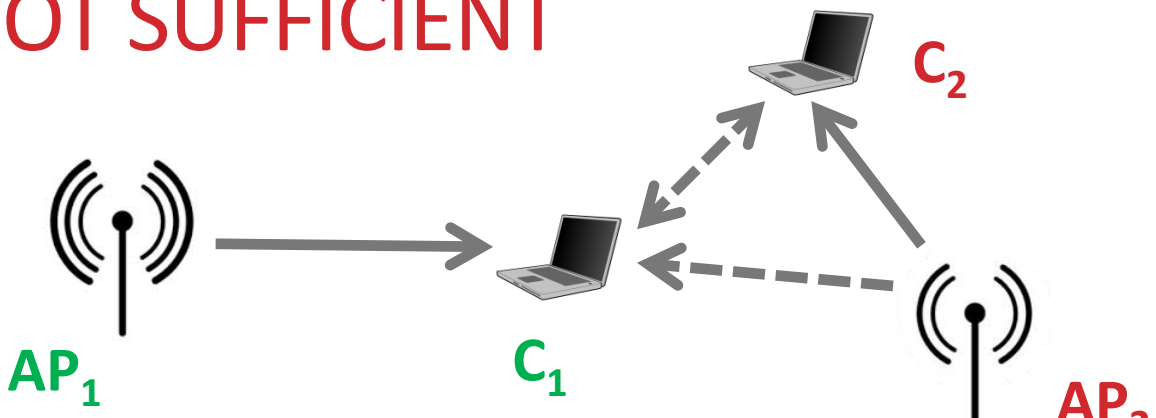

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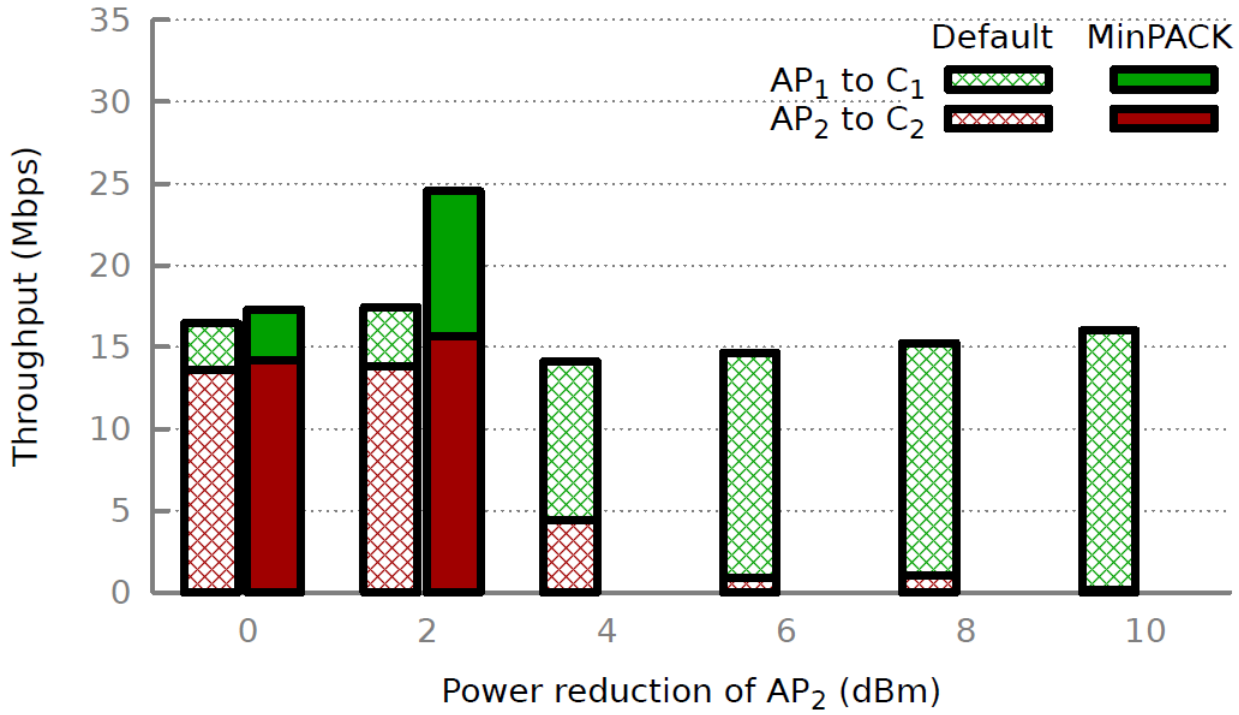

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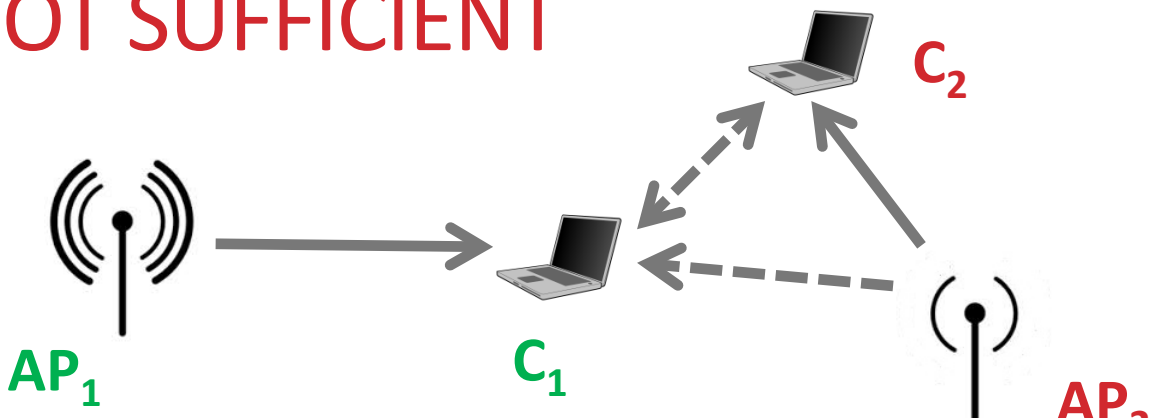
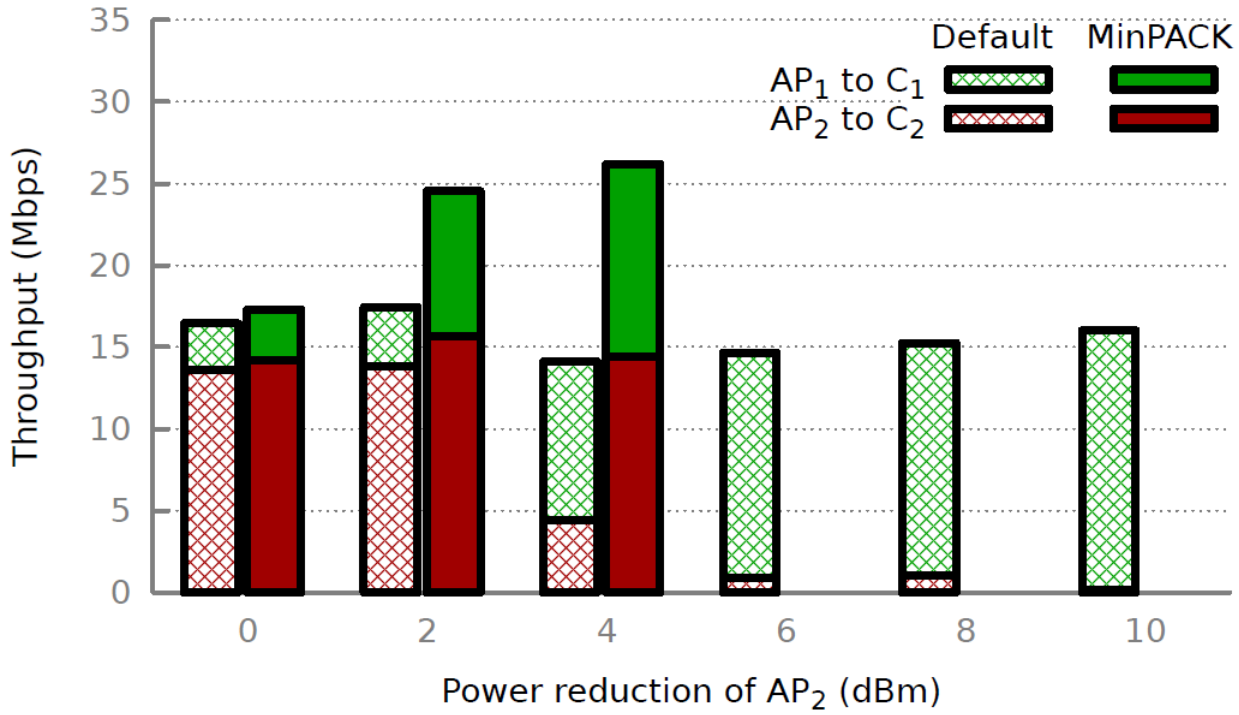
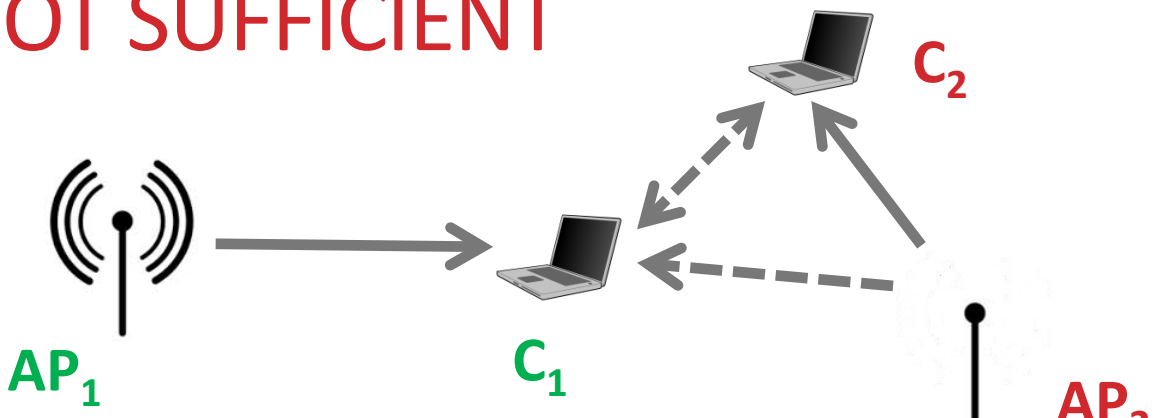


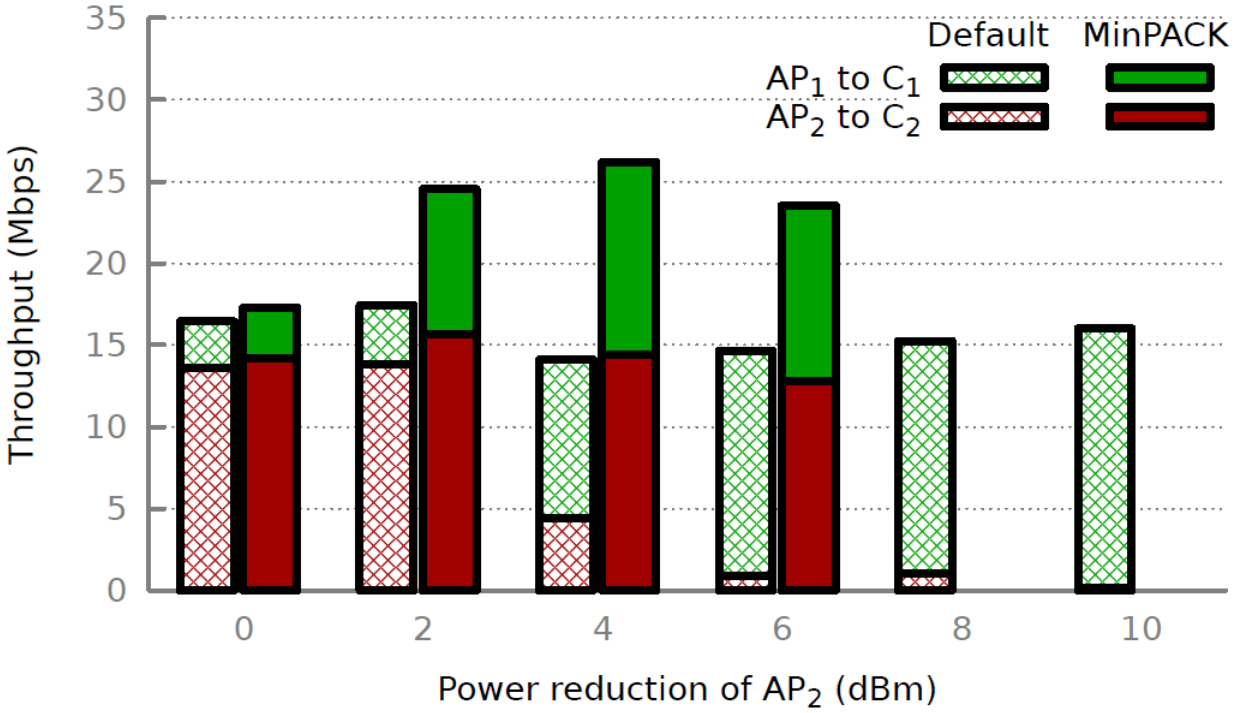
Default ACK power vs. **MinPACK**



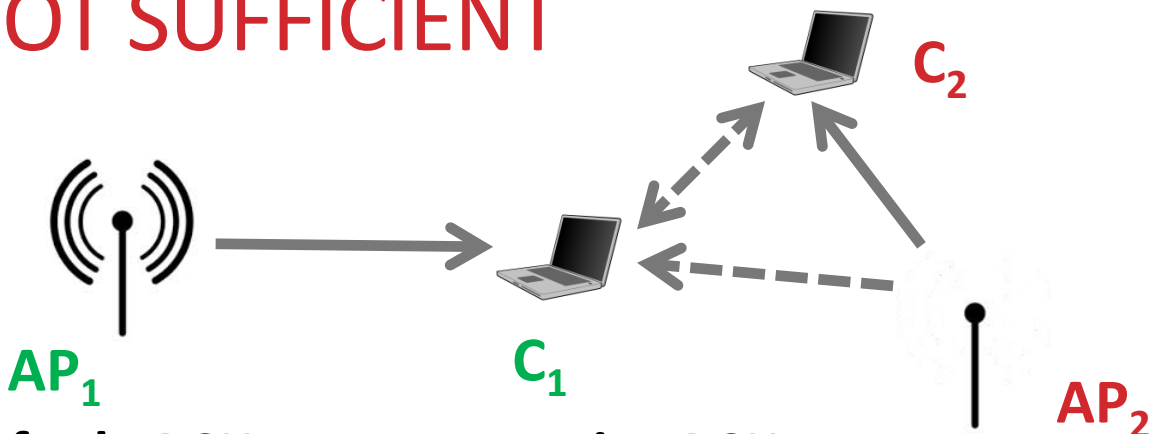
POWER CONTROL OF DATA FRAMES IS NOT SUFFICIENT



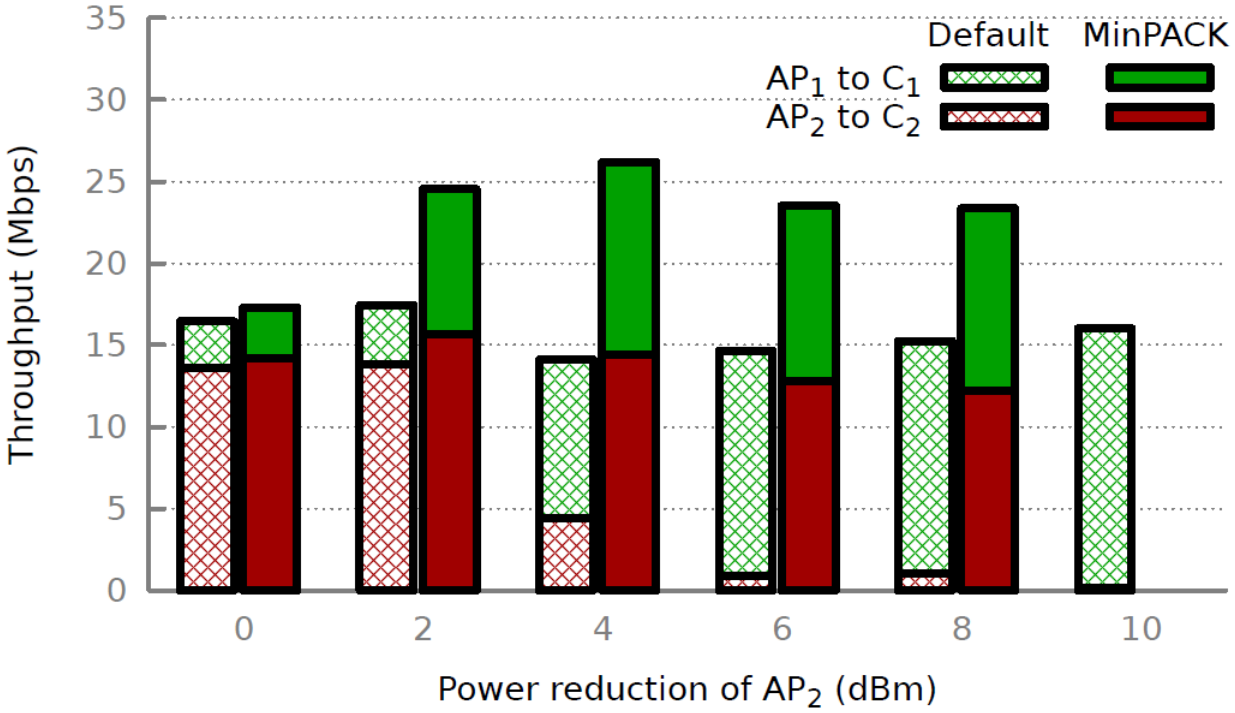
Default ACK power vs. **MinPACK**



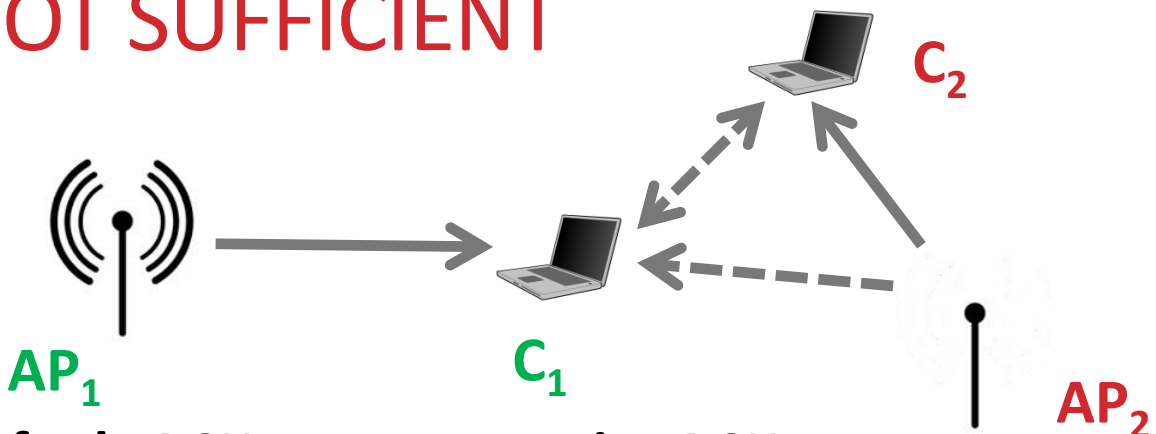
POWER CONTROL OF DATA FRAMES IS NOT SUFFICIENT



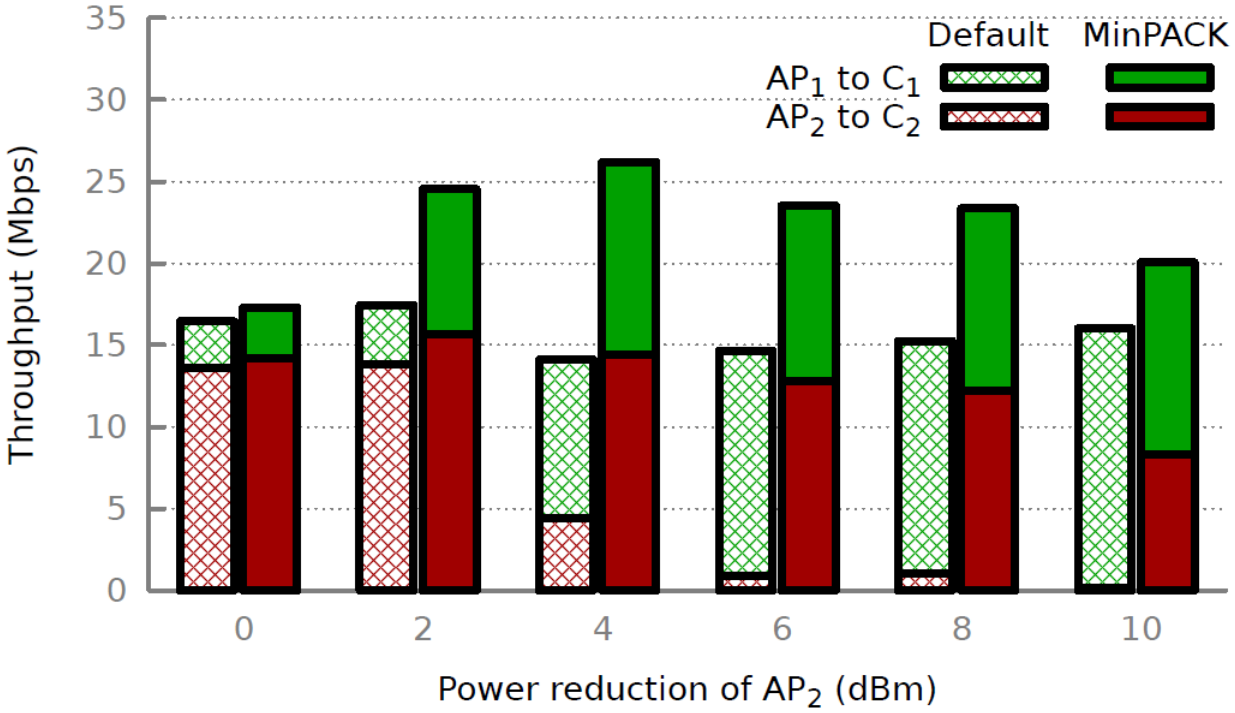
Default ACK power vs. **MinPACK**



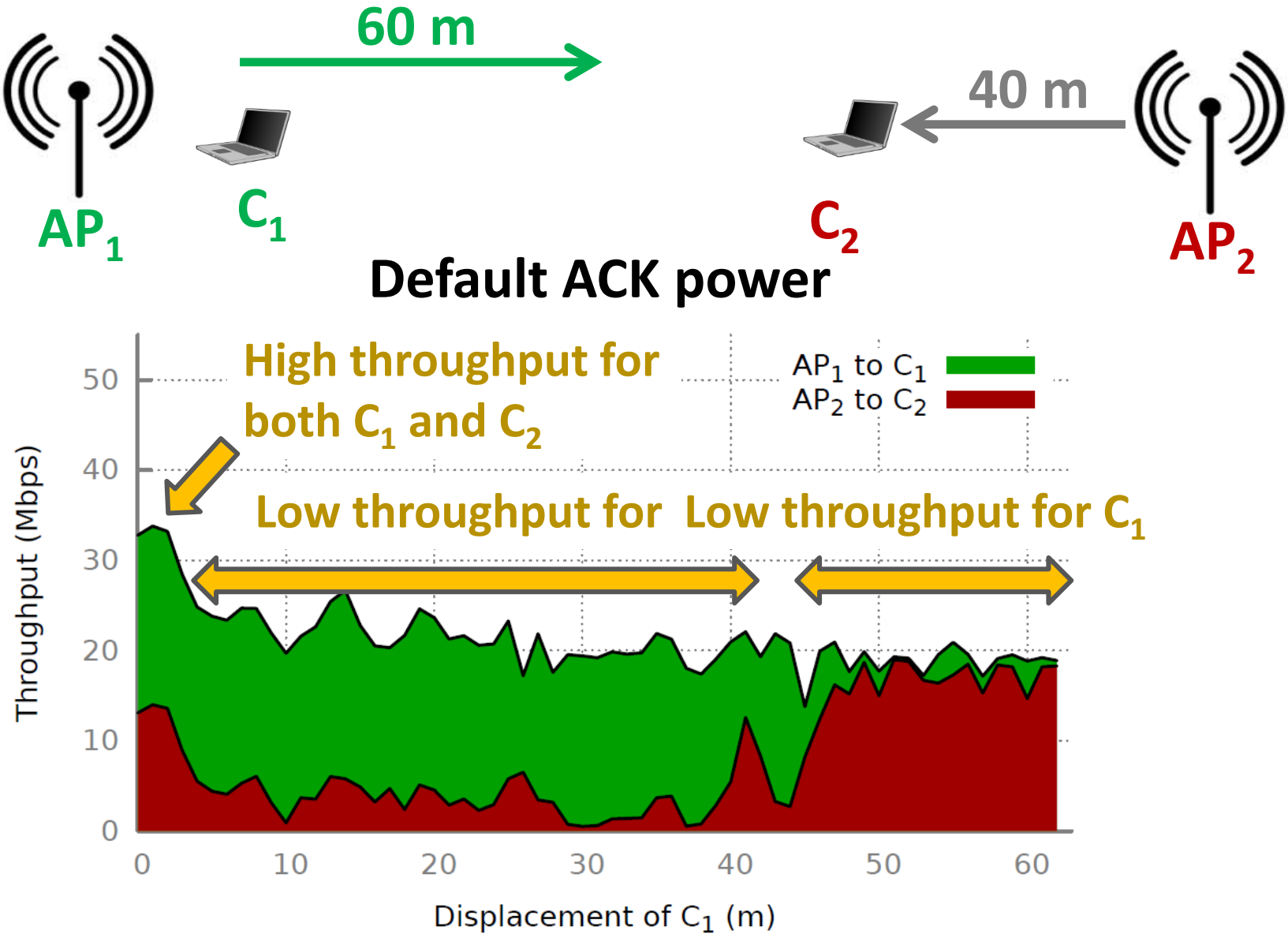
POWER CONTROL OF DATA FRAMES IS NOT SUFFICIENT



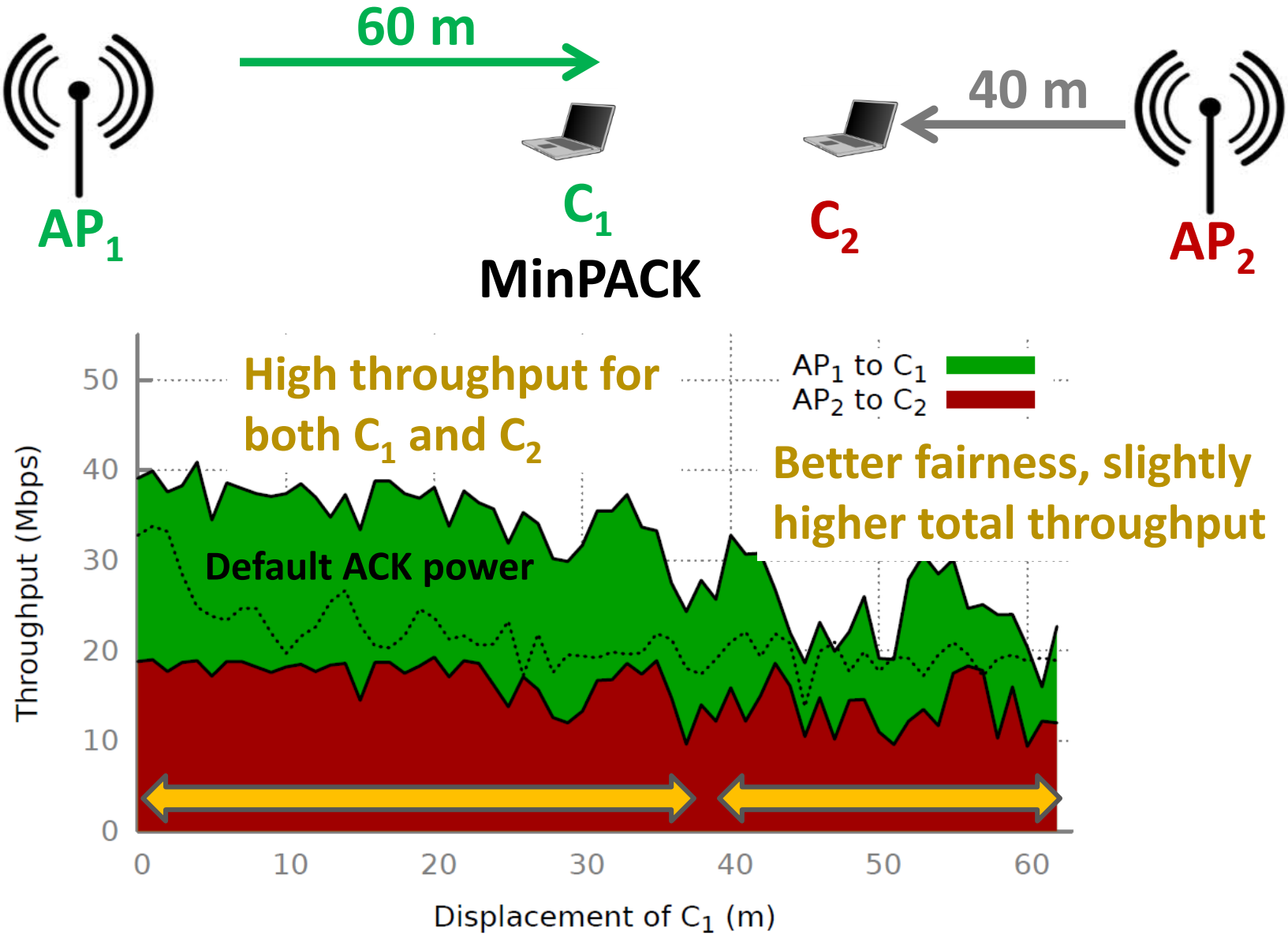
Default ACK power vs. **MinPACK**



MOBILITY


60 m
40 m
AP1
C1
C2
AP2
Default ACK power
High throughput for both C1 and C2
Low throughput for
Low throughput for C1
AP1 to C1
AP2 to C2
Throughput (Mbps)
0
10
20
30
40
50
0
10
20
30
40
50
60
Displacement of C1 (m)

MOBILITY


60 m
40 m
AP1
C1
C2
AP2
MinPACK
High throughput for both C1 and C2
AP1 to C1
AP2 to C2
Better fairness, slightly higher total throughput
Default ACK power
Throughput (Mbps)
0
10
20
30
40
50
60
Displacement of C1 (m)

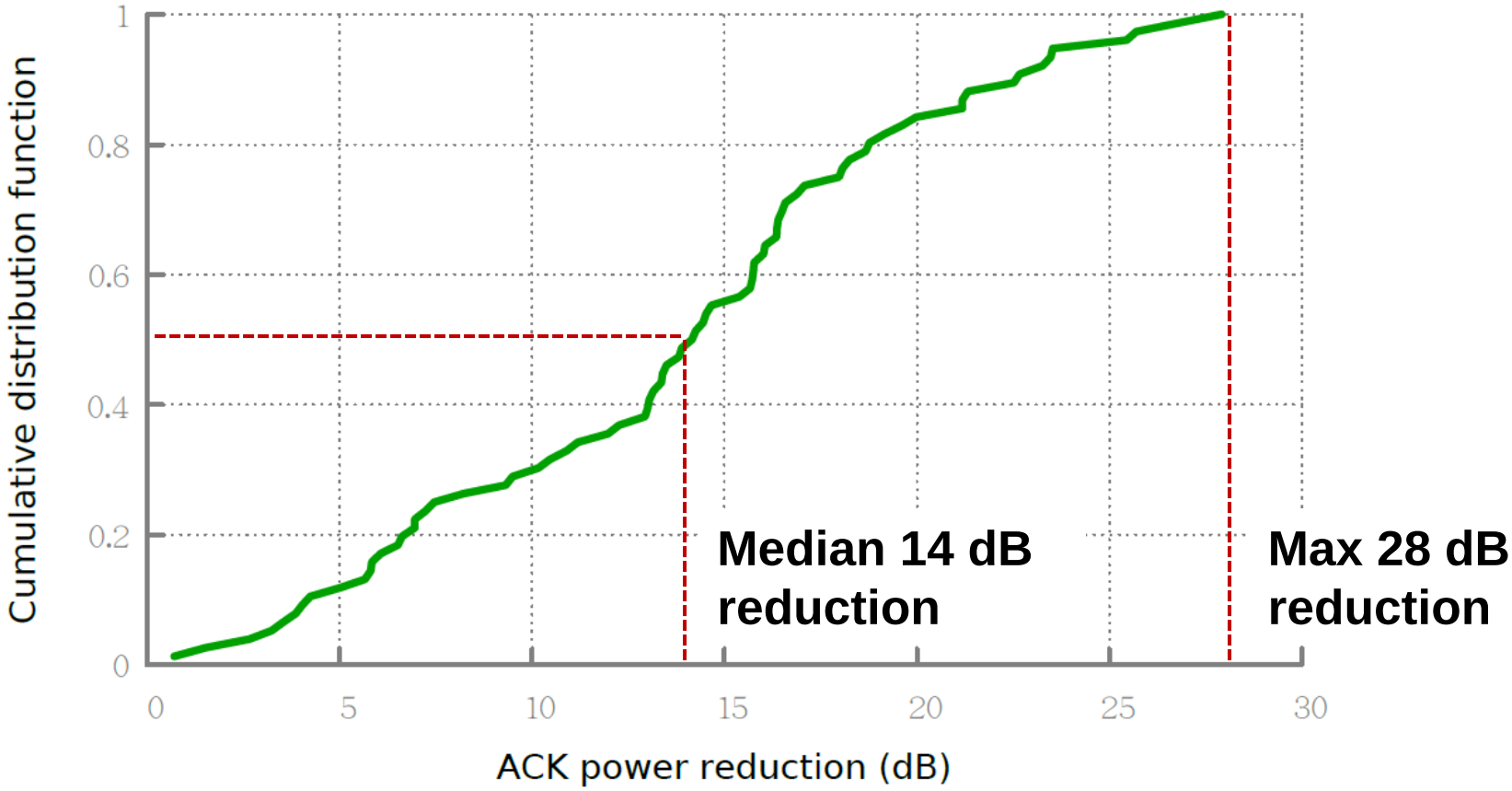
CONCLUSION

- MAC ACK interference is common and serious
- MinPACK
  - Improve total throughput and/or fairness
  - Complementary to tx power control of DATA frames
  - Adaptive to mobility
  - Applicable to commercial hardware adapters

THANK YOU!

BACK-UP SLIDES

DISTRIBUTION OF ACK POWER REDUCTION



ACK is small, sent at low rate, and protected by EIFS

Number of ap for each channel or what? (make it clearer) How about other channels(ie. 2-5)?

Impact of mac ack interference: no need animation, add to next page at the corner, put 11/a and 11/n at the legend label, adjust color of the histogram, 'how does ' to 'how can'

Estimation of ack success rate: break up the animation, highlight the data sender is AP(hard to modify, put a pic here)

Passive estimation for block ack: 'the extra' to 'solution'

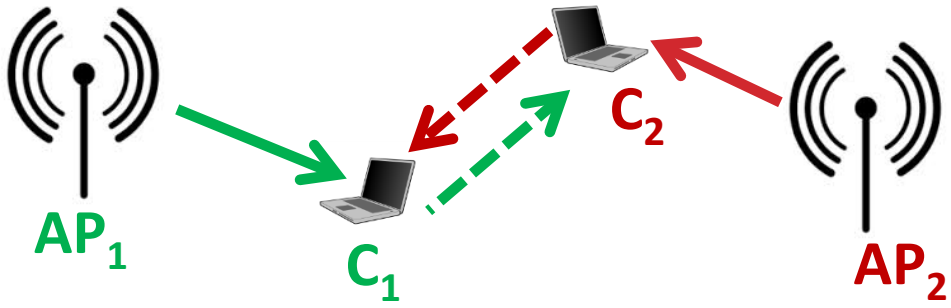
Evaluation of minpack: make the point direct to audience

Throughput gain: make lines darker, add animation to make it clearer

Distribution of ack power reduction: font problem to be fixed, power reduction important? Consider removing this slide

Power control of data frames is not enough: make it more natural to audience, use more solid pattern(hart to see), no need to say words at every step

Mobility: prepare for the doubt of c1 performance decrease, draw the location of c2 in the graph, draw the total throughput(prev vs. now)


AP1
C1
C2
AP2