

ACORN: Managing Interference in 802.11n WLANs

Mustafa Arslan, Konstantinos Pelechrinis, Ioannis Broustis,
Srikanth Krishnamurthy, Sateesh Addepalli, Dina Papagiannaki

ACM CoNEXT 2010

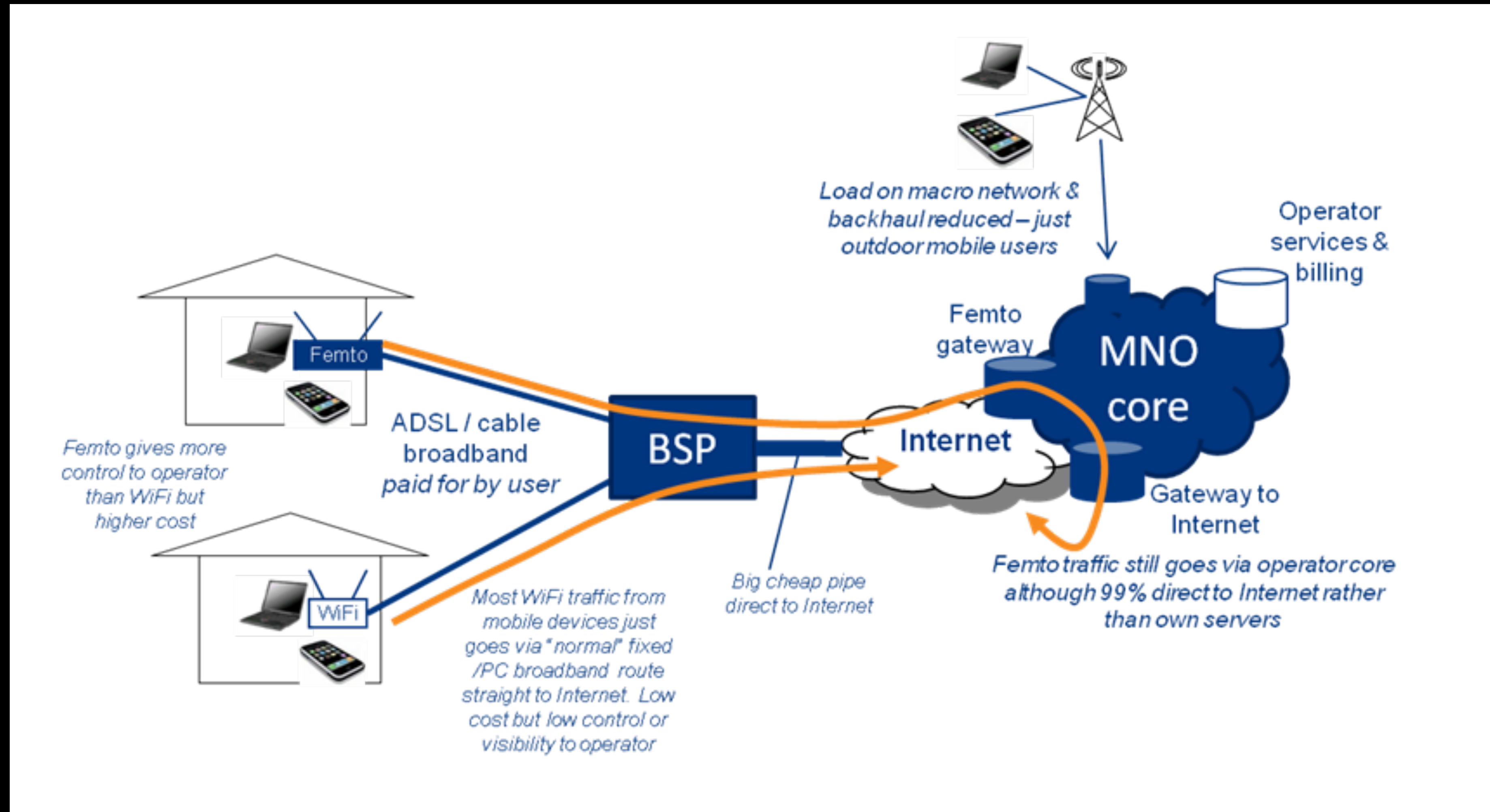
Interference Problem



- Delivering high data rates in wireless networks is challenging.
- *Interference: Degradation in wireless network performance due to the noise generated by other devices in the spectrum.*

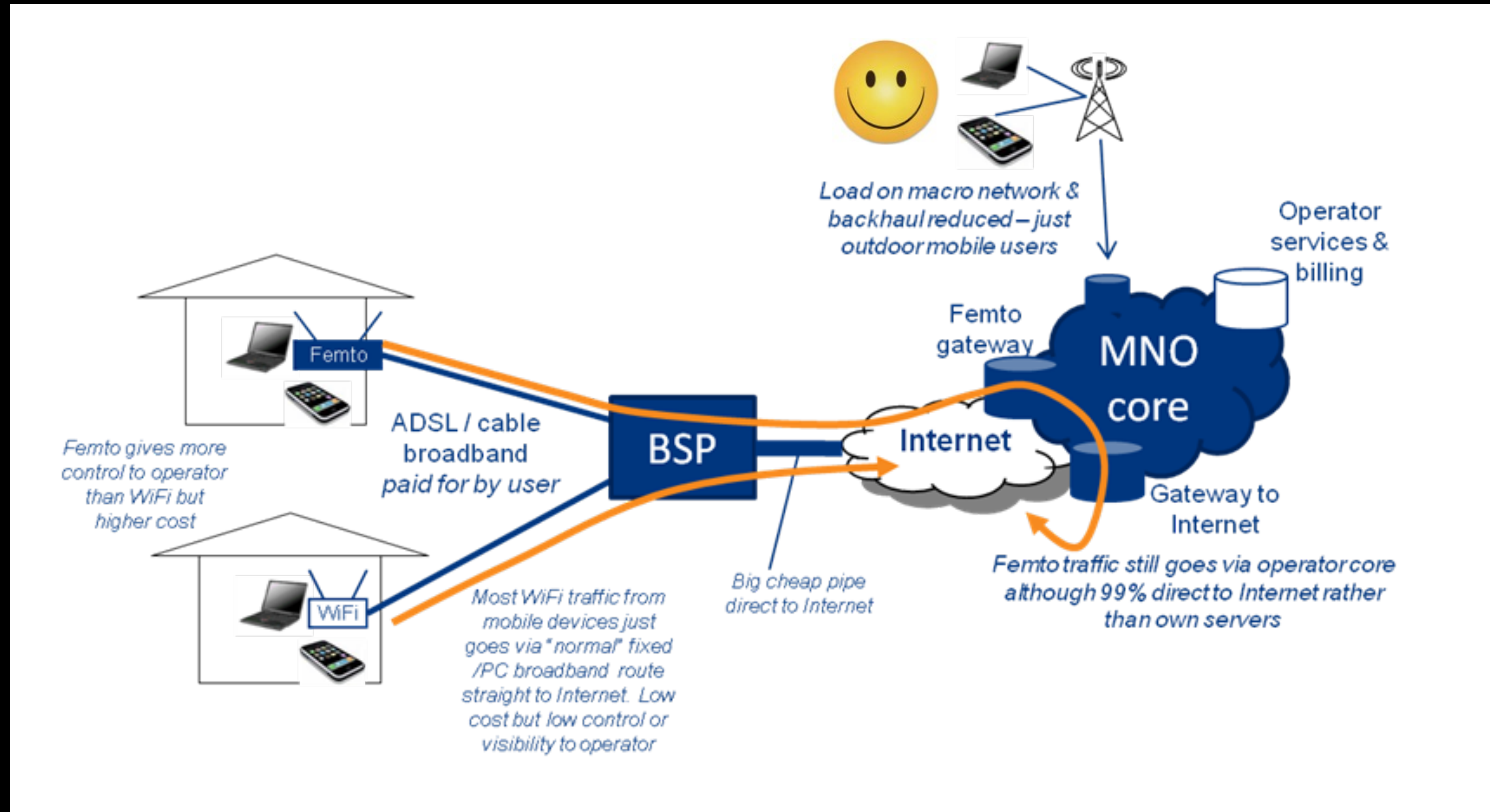
Indoor Wireless Networks

Source: telco2research.com



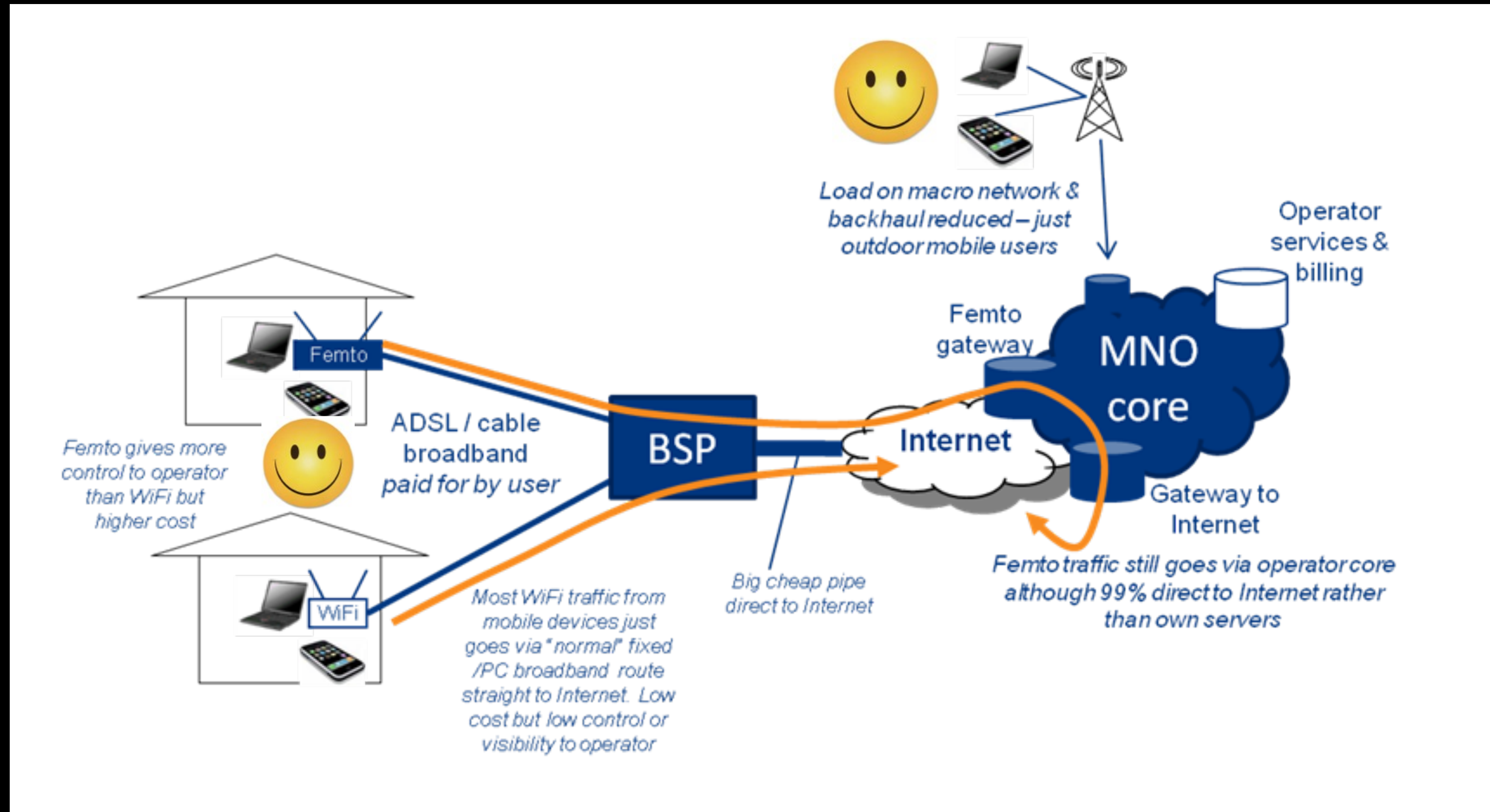
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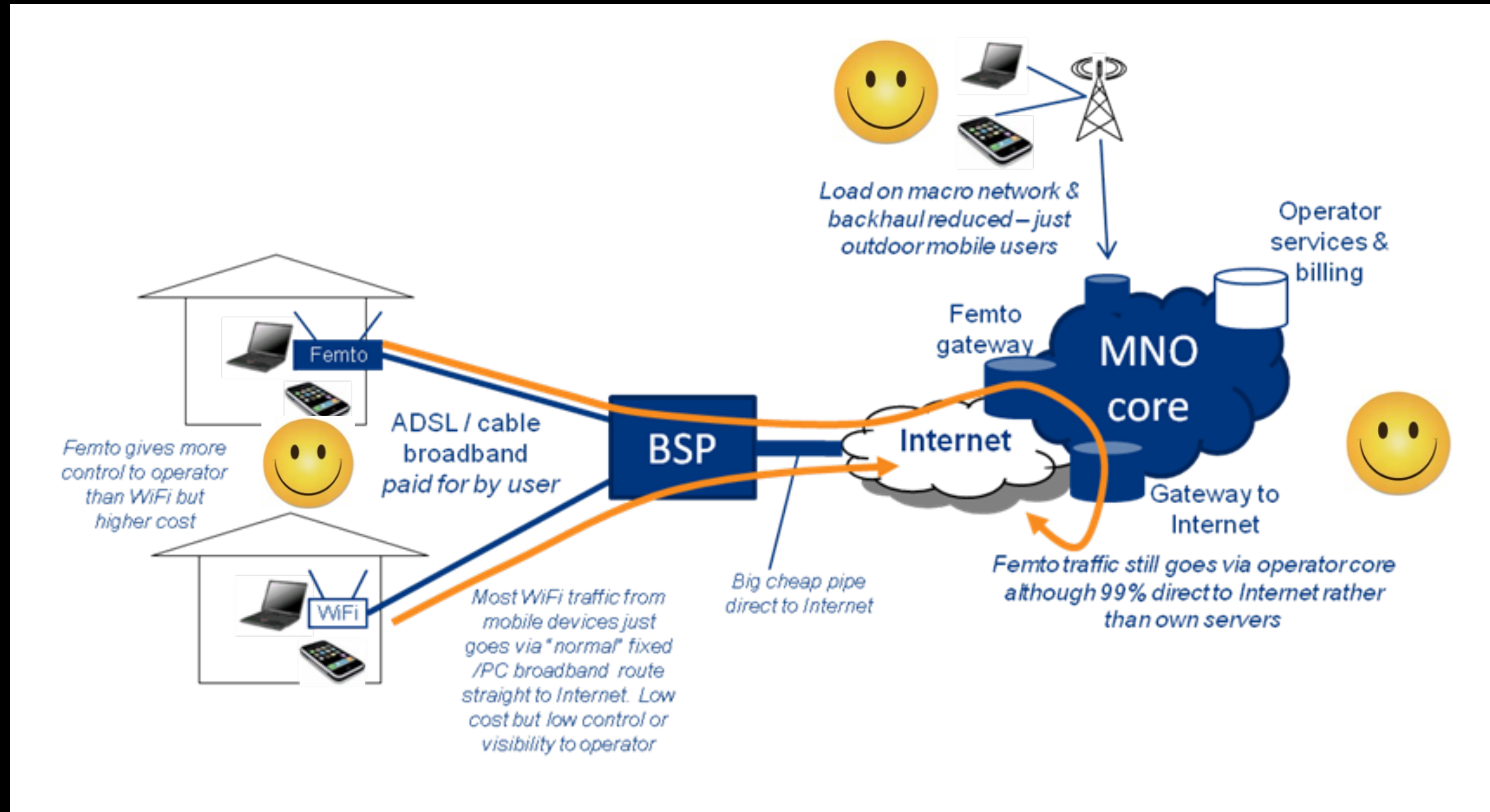
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The Case of Noisy Neighbors

CNET:

9:37 a.m.: Google is asking attendees to turn off their cell phones, as the interference has ground this demonstration to a halt. Awkward.

The Case of Noisy Neighbors

CNET:

NETWORK WORLD
Security | LANs & WANs | UC / VoIP | Cloud Computing | Infrastructure Mgmt | Wireless | Software | Data Center
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Coping with Wi-Fi's biggest problem: interference

By David Callisch, VP of marketing, Ruckus Wireless, Network World
August 02, 2010 01:45 PM ET

... guys
see the demo
Go ahead, jus

1. Public Enemy Number One: Your Neighbors' Wi-Fi Networks

"I'd say the biggest source of interference today for most people is their neighbors' Wi-Fi networks," says Kalle. The problem is that most existing Wi-Fi equipment operates on the crowded 2.4GHz band. "There are basically three nonoverlapping channels. I always describe it as a three-lane road that's really, really busy," Kalle adds.

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Got Interference? Data-Crowding Problems Loom for Wi-Fi

Robert Lemos 07.17.07

... in the city of Riverside, California, just got a
ded.
y 9, the city switched on its municipal
& delivering free internet service to more
e miles of the downtown area. According
ireless service provider that teamed up
d the network, the ad-supported service
ps download speeds to each resident in
nd
the inland empire's capital city, the
us, it's a burden. The new network
s of interference to the already

The Case of Noisy Neighbors



- How can we deal with interference in indoor wireless networks?
 - *Using resource allocation to manage the spectrum.*
- The goal is to restore the true potential of indoor wireless networks by mitigating interference and hence, enabling high data rates.

Wireless 101

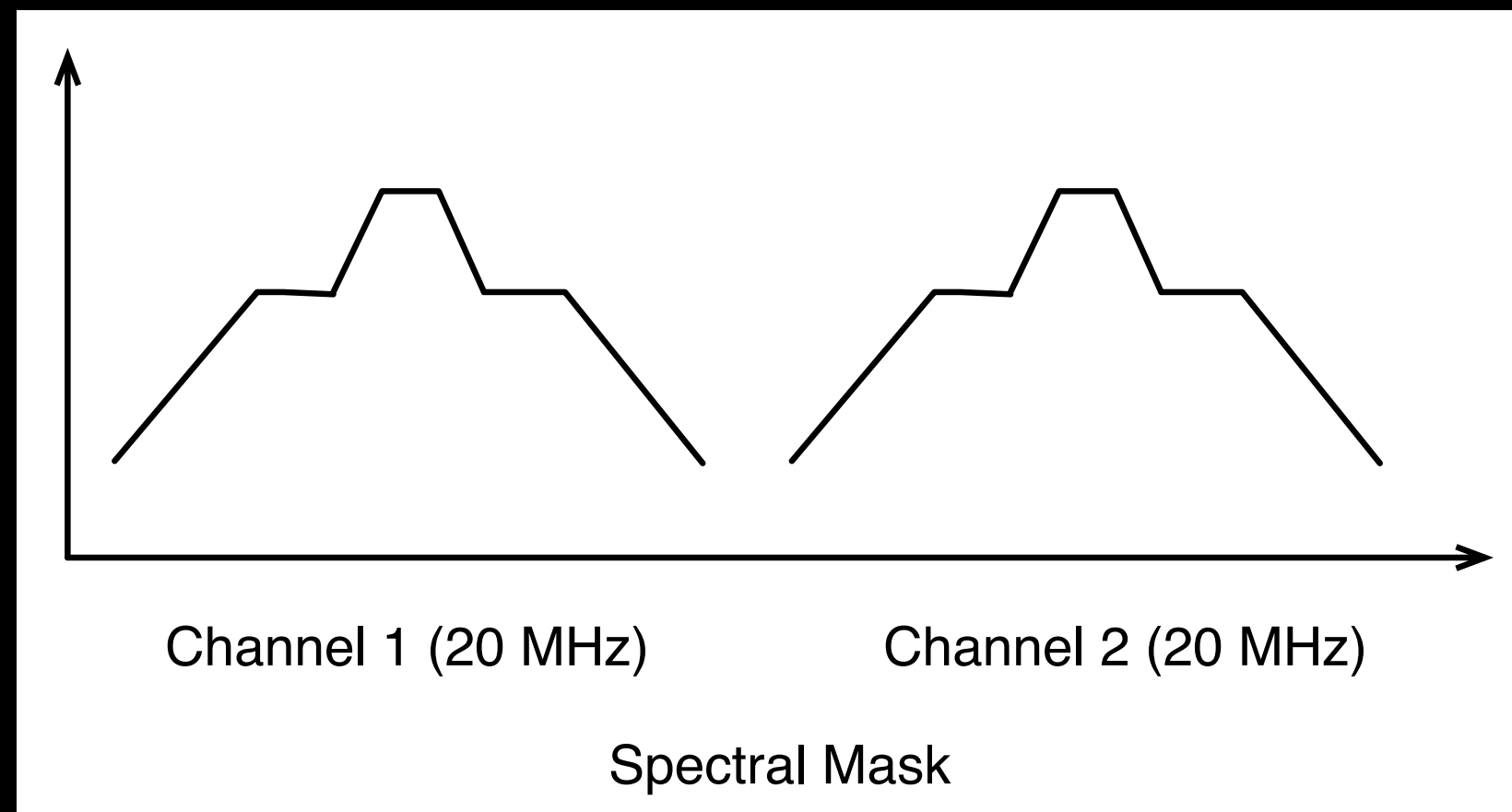
- SINR: Signal to Interference+ Noise Ratio:
 - How strong is your received signal?
 - Noise + interference results in poor reception.
 - *Interference is generated by other transmissions.*
- Modulation: the rate at which you encode and transmit bits
 - Higher mod (higher SINR required) \implies higher data rate.
- The effect of interference
 - *Low SINR \implies low modulation \implies low data rate on the link.*

802.11n Channel Bonding (CB)

- Goal of CB is to combine two adjacent 20 MHz channels to double the bandwidth (raw transmission rate)

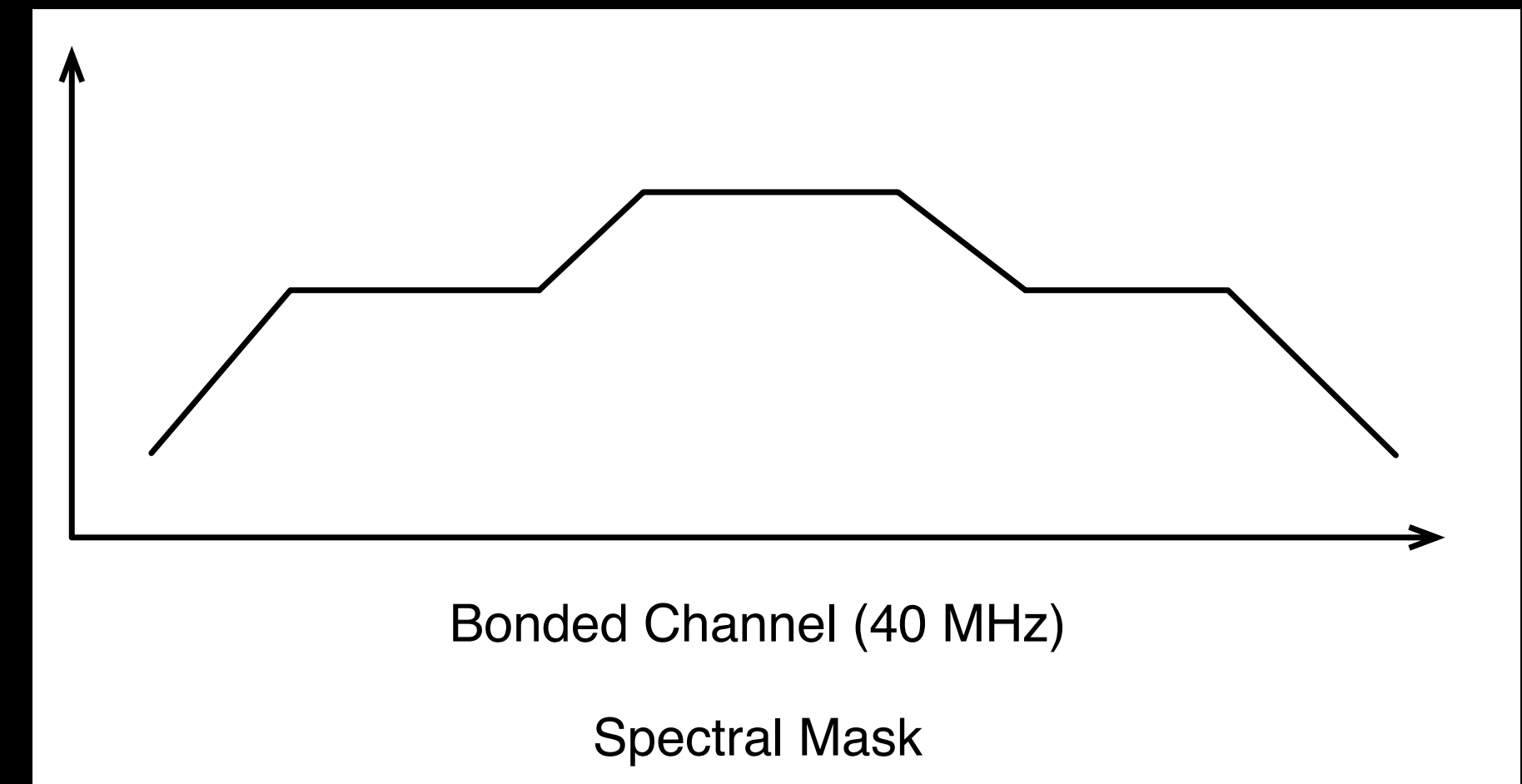
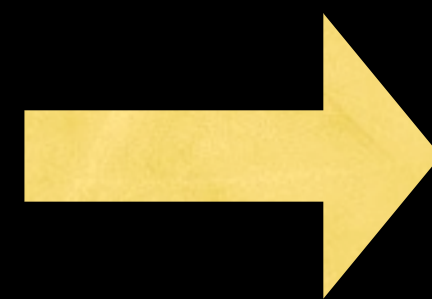
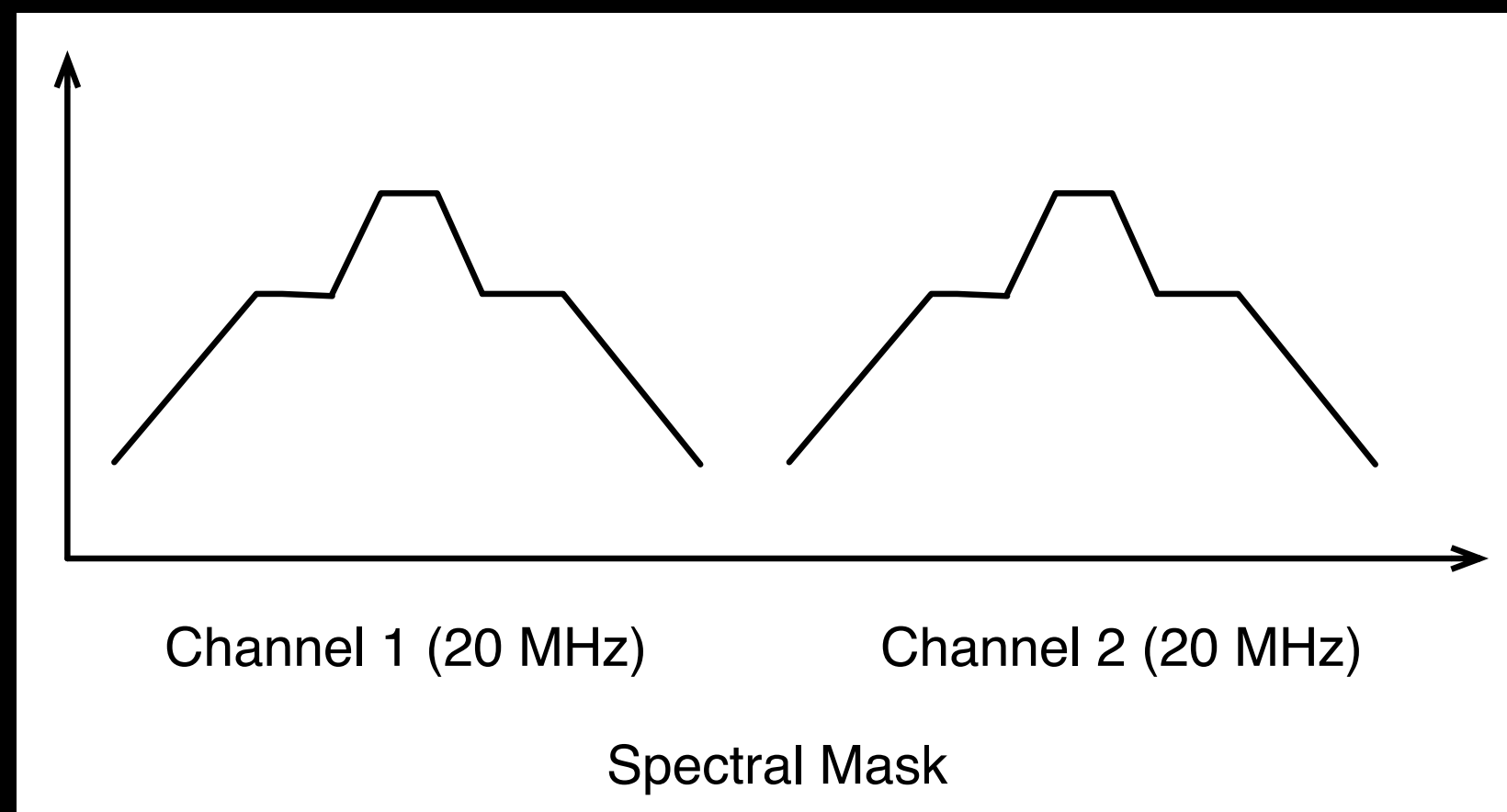
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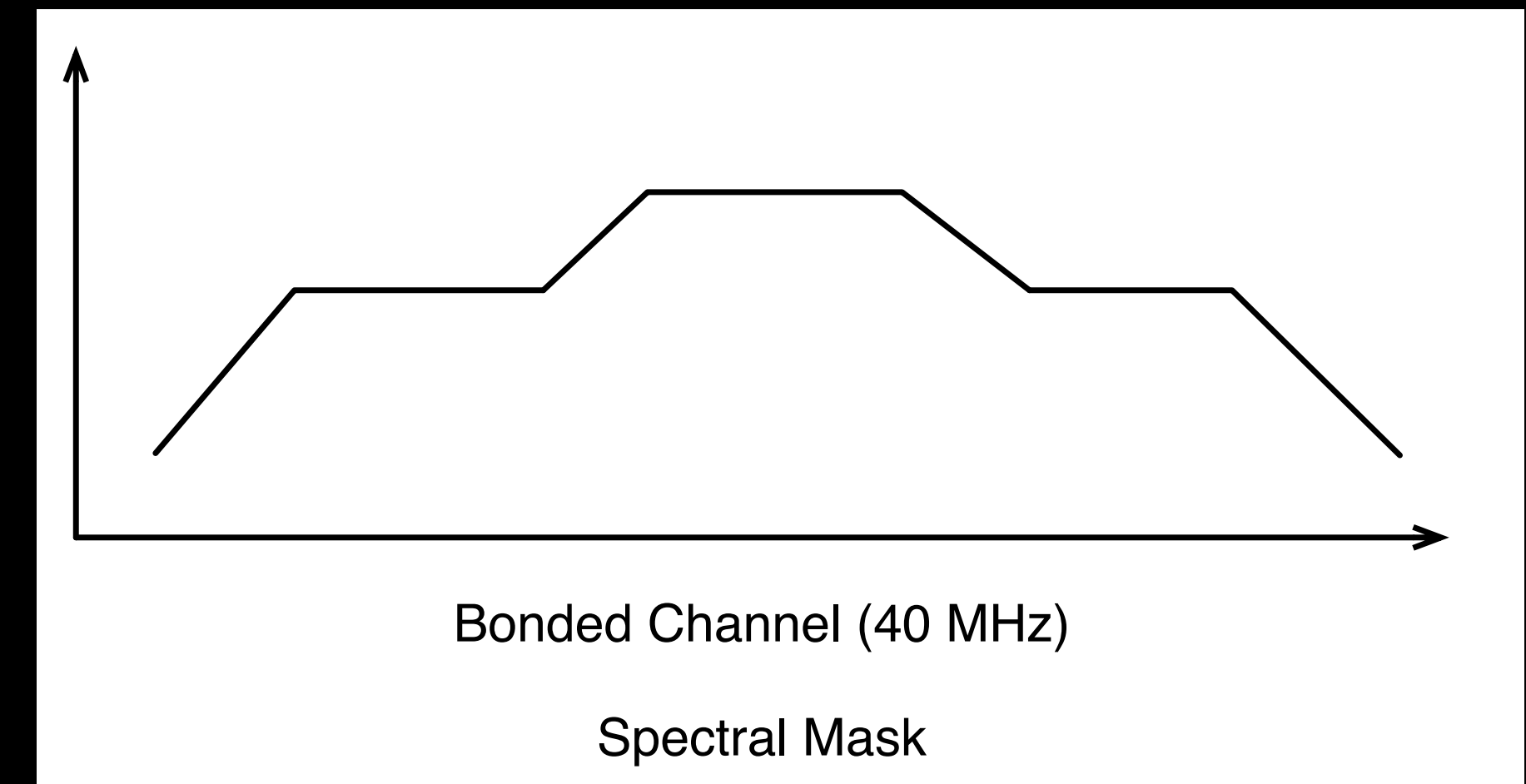
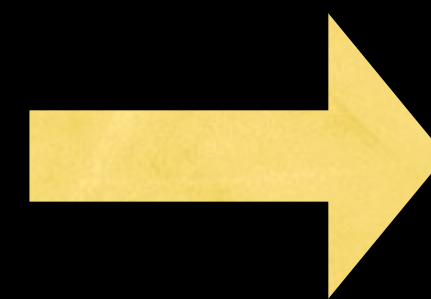
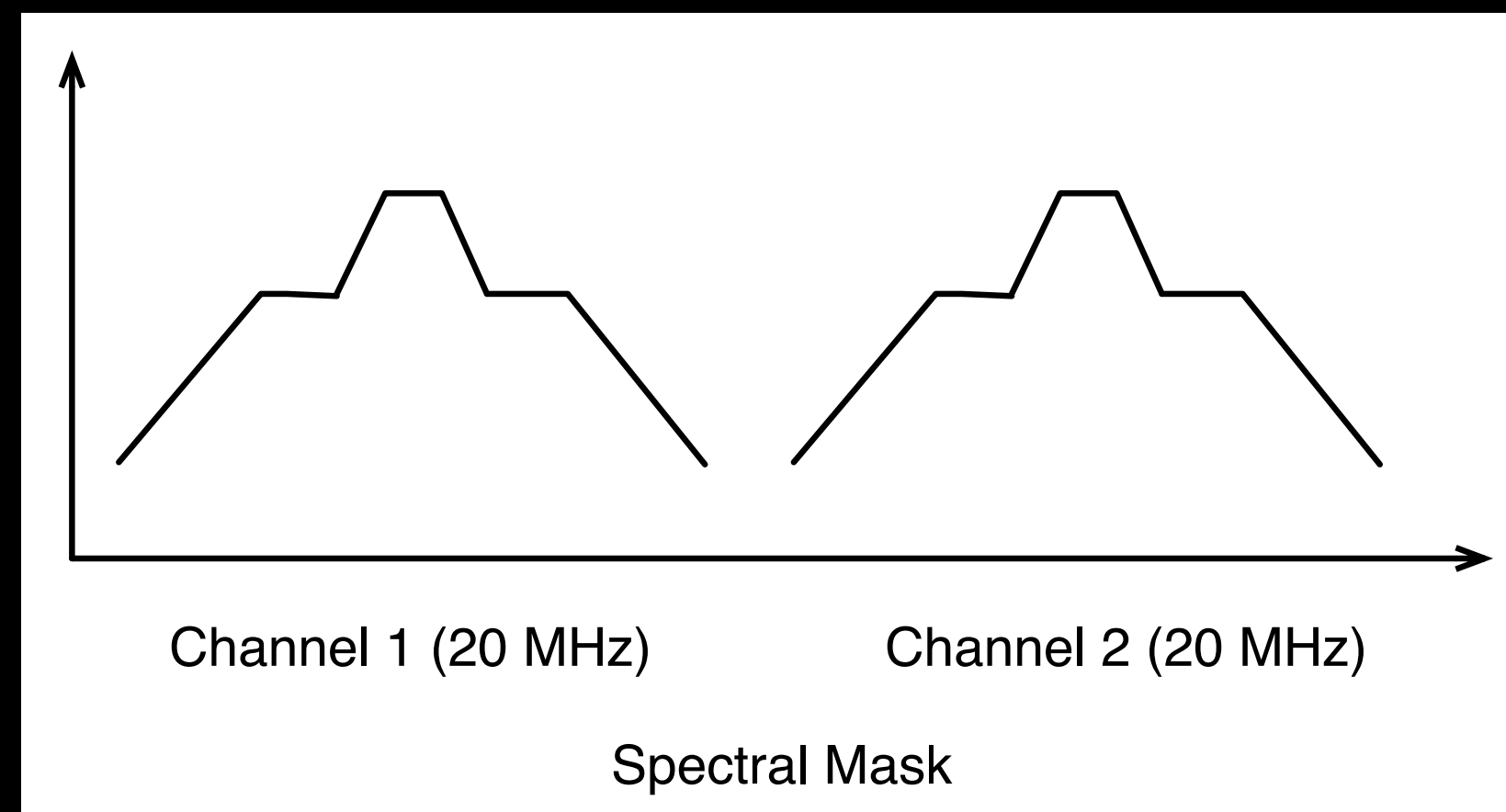
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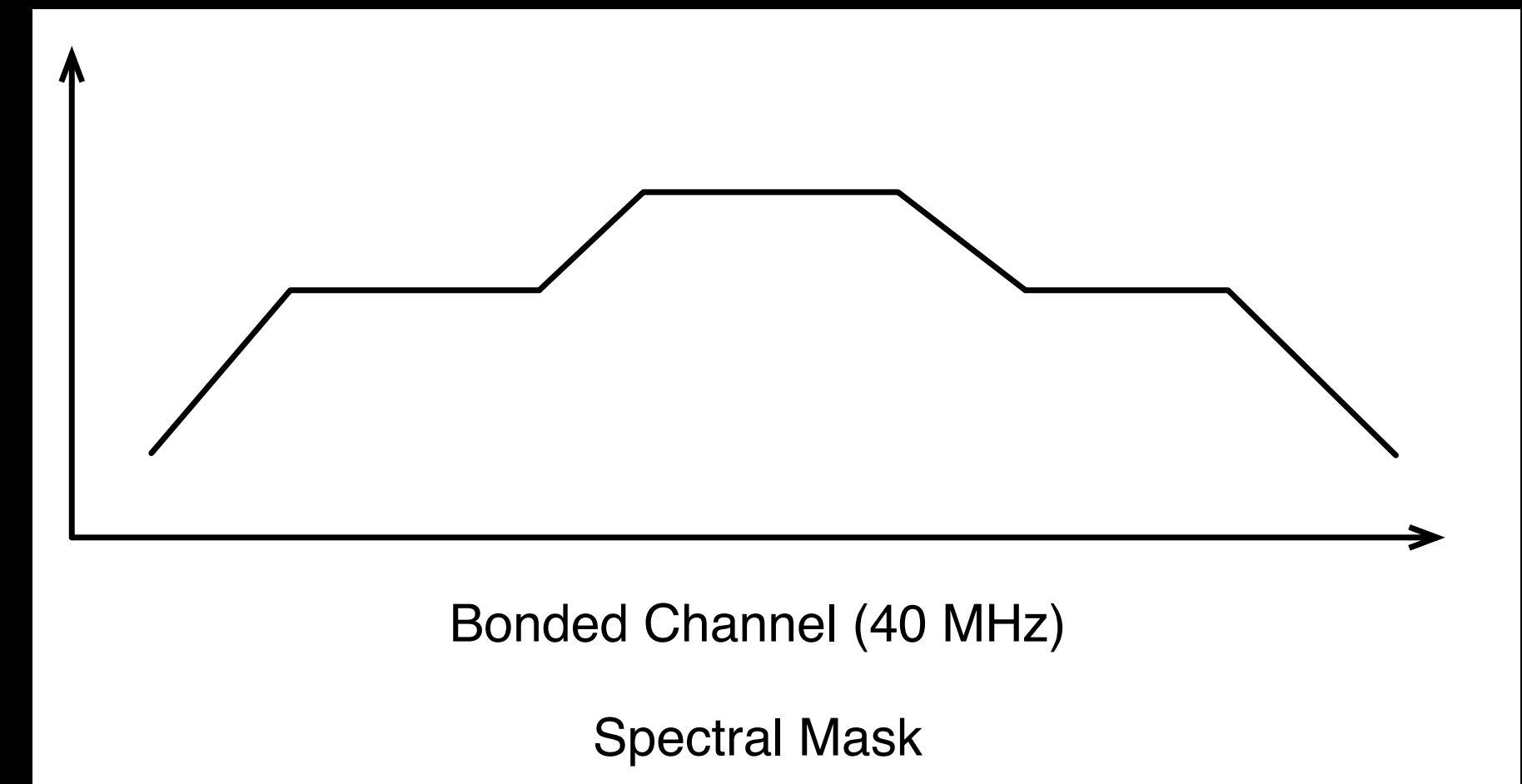
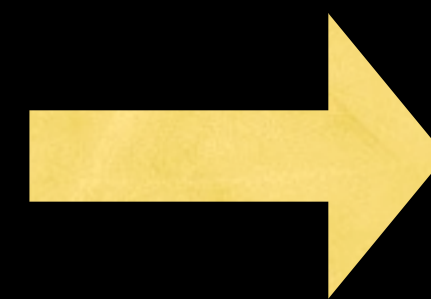
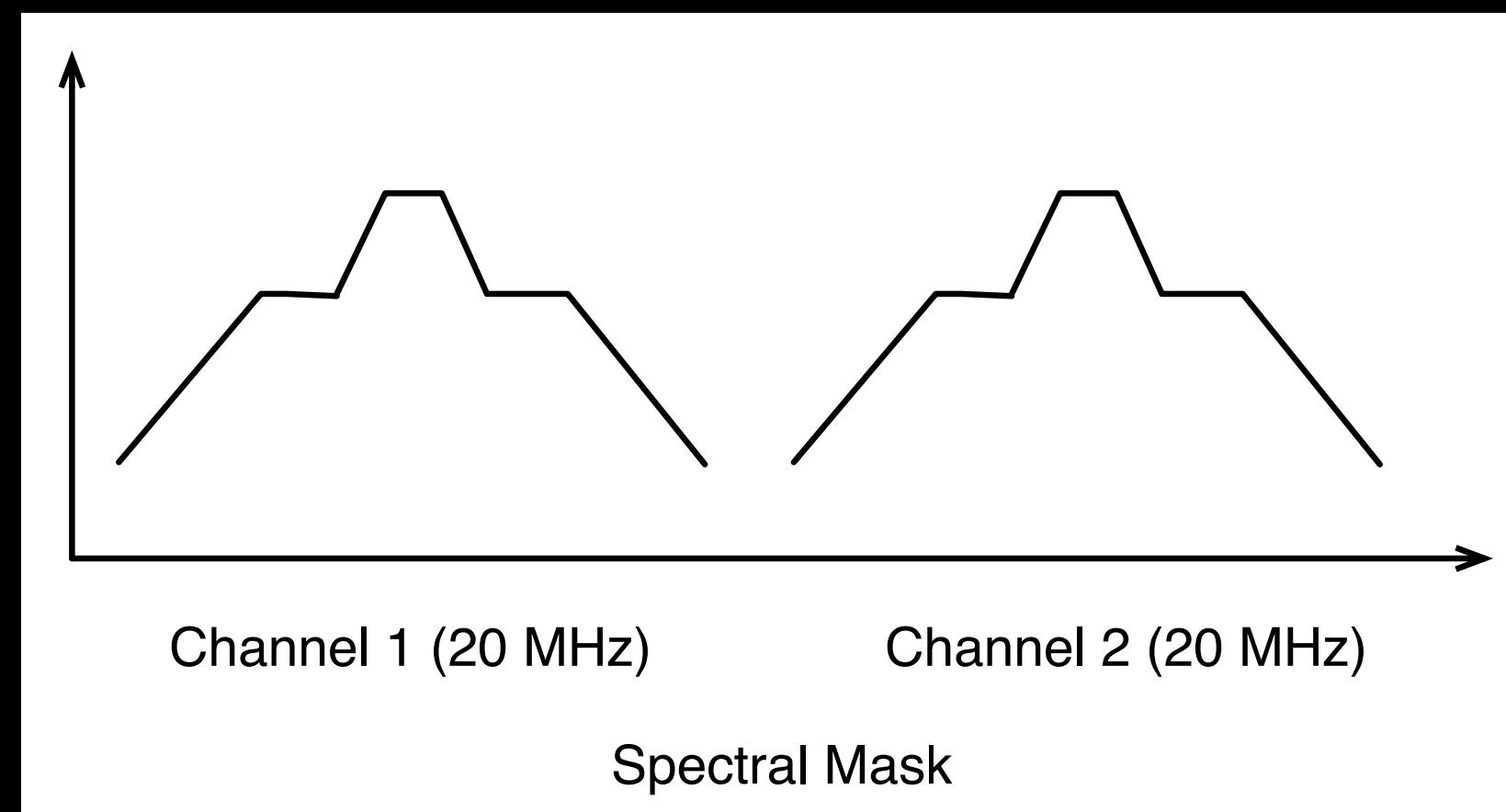
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Fact: CB increases interference (Pelechrinis et. al, Shrivastava et. al.)

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Fact: CB increases interference (Pelechrinis et. al, Shrivastava et. al.)

Public belief: CB always gives throughput benefits in isolation.

Common Belief About CB

- CB is advertised to be “just great”!

The Ruckus Room
Rants and Raves about Wi-Fi and its Role in the Mobile Internet Revolution

[« The Shape of Things to Come? | Main | Demo Diva Raises Ruckus at CableLabs... »](#)

March 01, 2008

802.11n without Channel Bonding is Just Stupid

802.11n is a good choice. 802.11n without channel bonding is not.

Perhaps the most important thing (in addition to MIMO and frame aggregation) that makes 802.11n 802.11n is 40Mhz channelization, aka channel bonding.

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RUCKUS WIRELESS

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- A PUBLIC APOLOGY
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Contributions

- Common belief: CB always gives throughput benefits.

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- Fact: CB, when blindly applied, may hurt throughput!
 - Extensive measurements led to PHY and MAC observations.

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- Common belief: CB always gives throughput benefits.
- Fact: CB, when blindly applied, may hurt throughput!
 - Extensive measurements led to PHY and MAC observations.
- Auto-COnfiguRation of 802.11N WLANs
 - ✓ First system targeted for 802.11n
 - ✓ 1.5x - 6x throughput gain per AP



Roadmap

- CB - why and when does it fail?
 - Experiments to reveal fine-grained observations.
- Designing ACORN
 - User association, channel selection
- Key evaluation results

CB at the PHY

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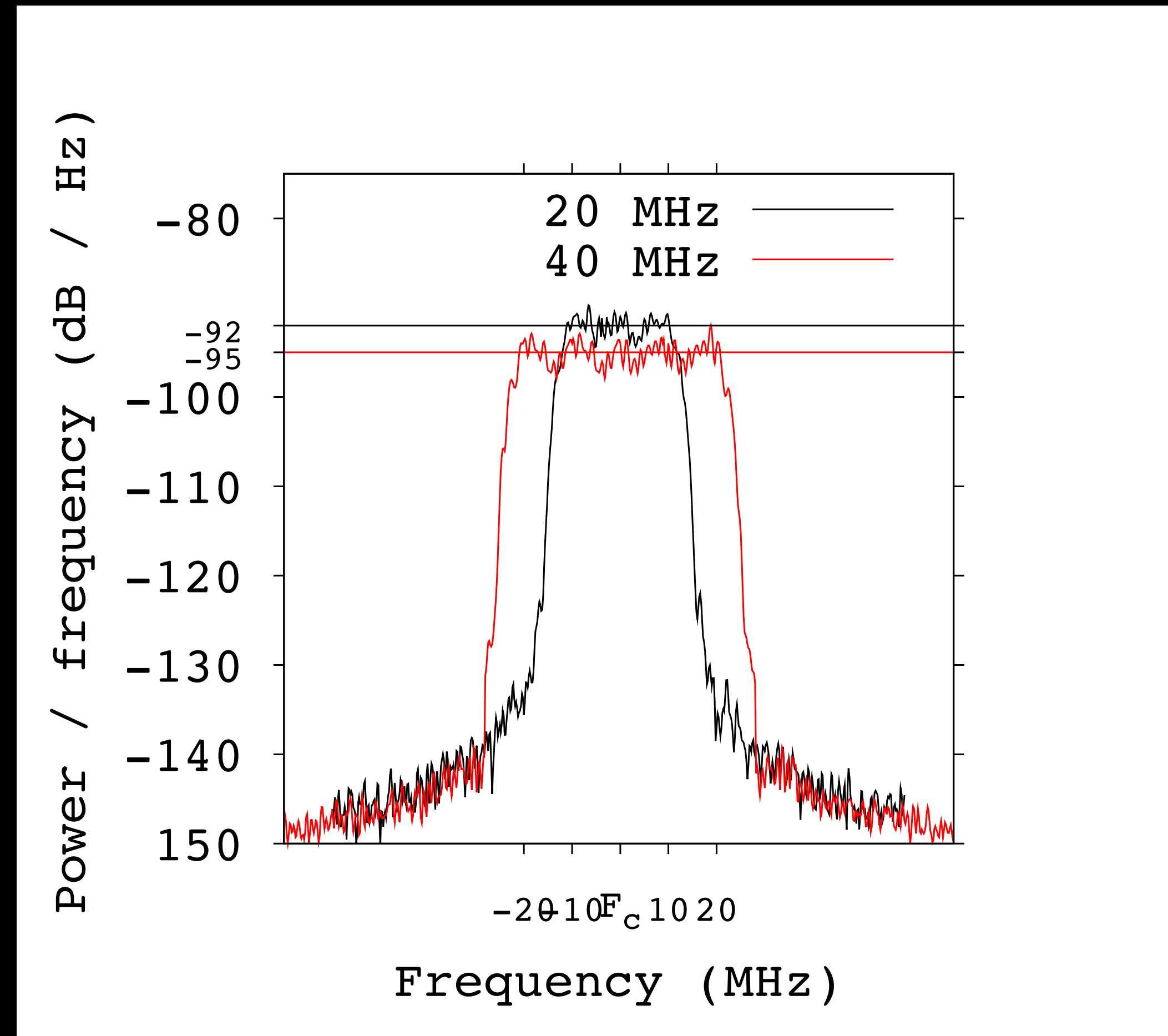
CB at the PHY

- 20 MHz vs 40 MHz (twice the sub-carriers in a symbol with CB)
- Sub-carrier energy
 - For a given TX power, *energy per sub-carrier* is halved.

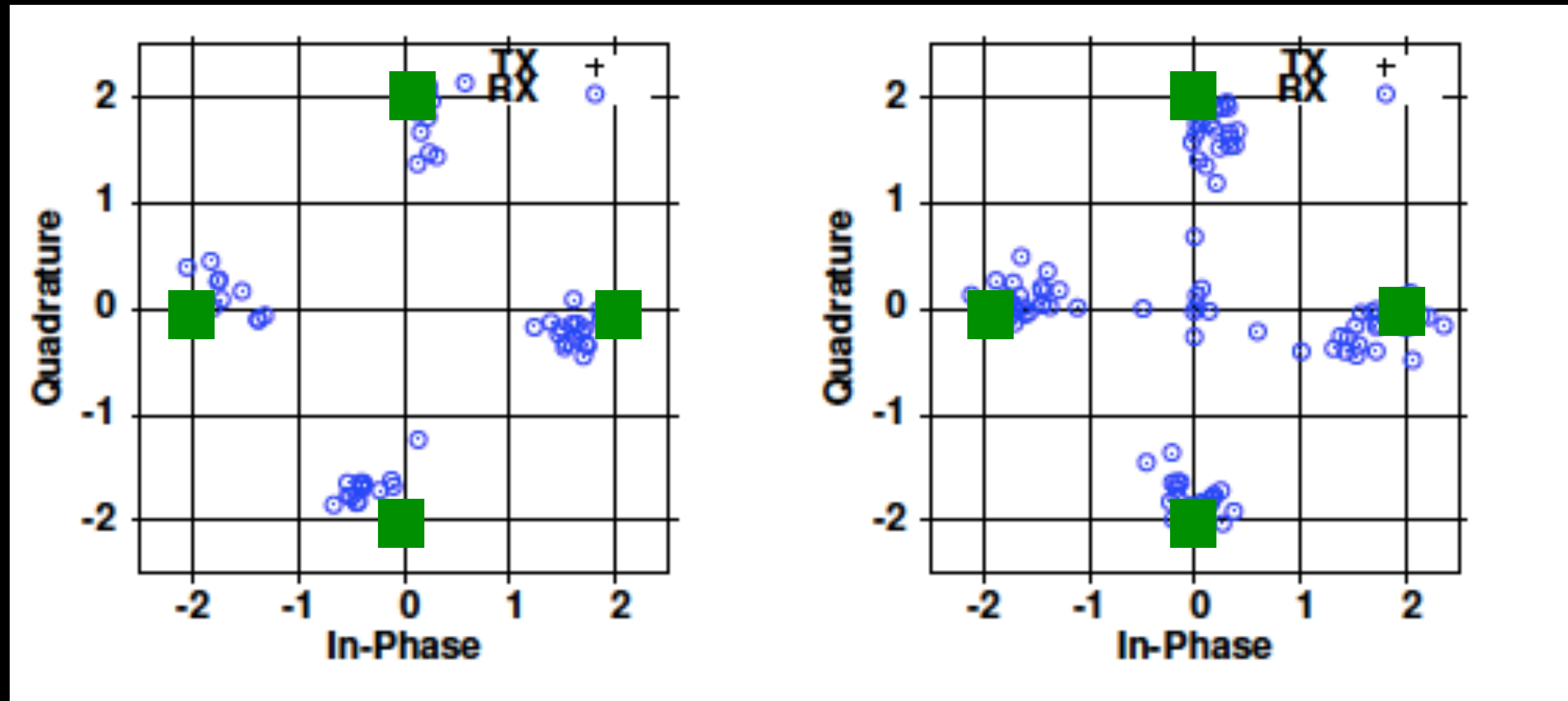
CB at the PHY

- 20 MHz vs 40 MHz (twice the sub-carriers in a symbol with CB)
- Sub-carrier energy
 - For a given TX power, *energy per sub-carrier* is halved.
- P_1 : energy with 20 MHz and P_2 : energy with 40 MHz.
 - $10 \cdot \log_{10}(P_1/P_2) = 3$ dB loss in transmitted energy.

Measured Power Spectral Density



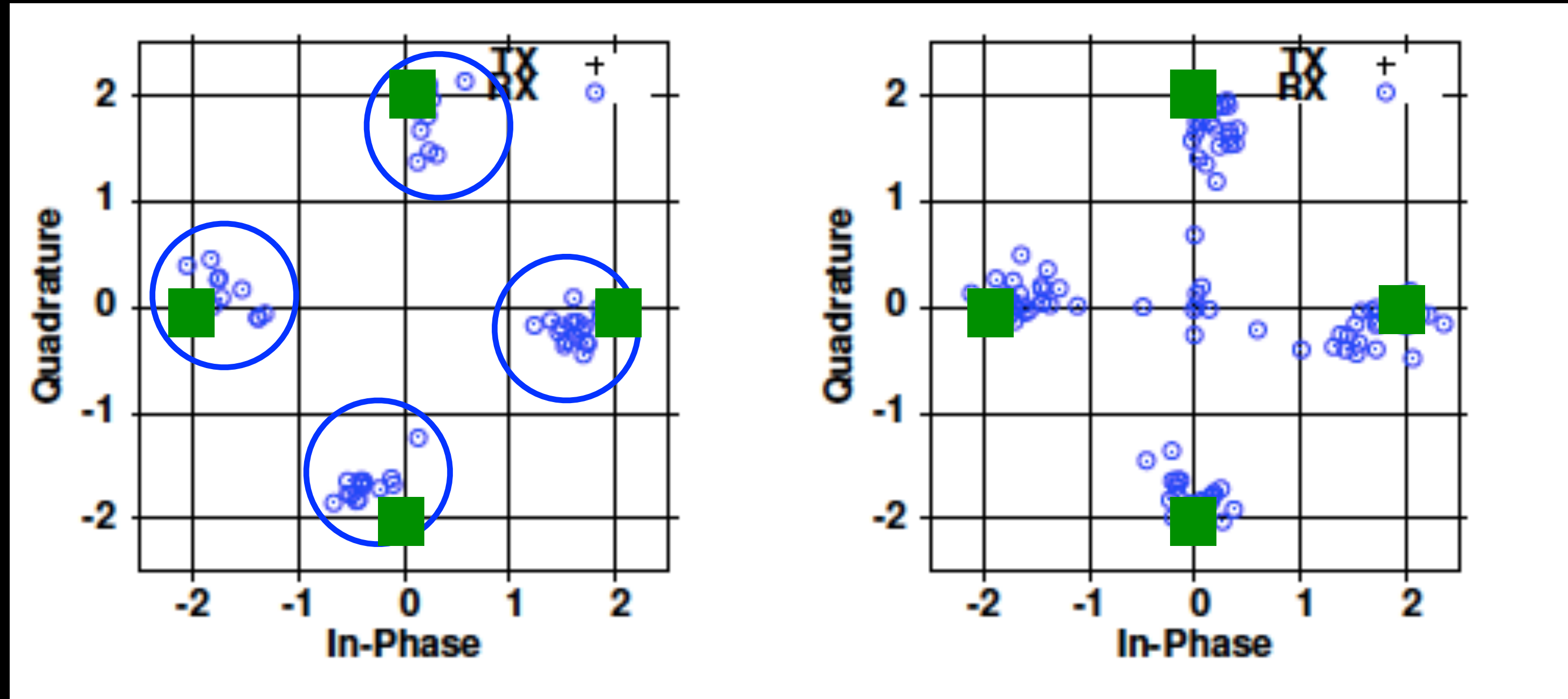
Measured impact on received signals



a) without CB

b) with CB

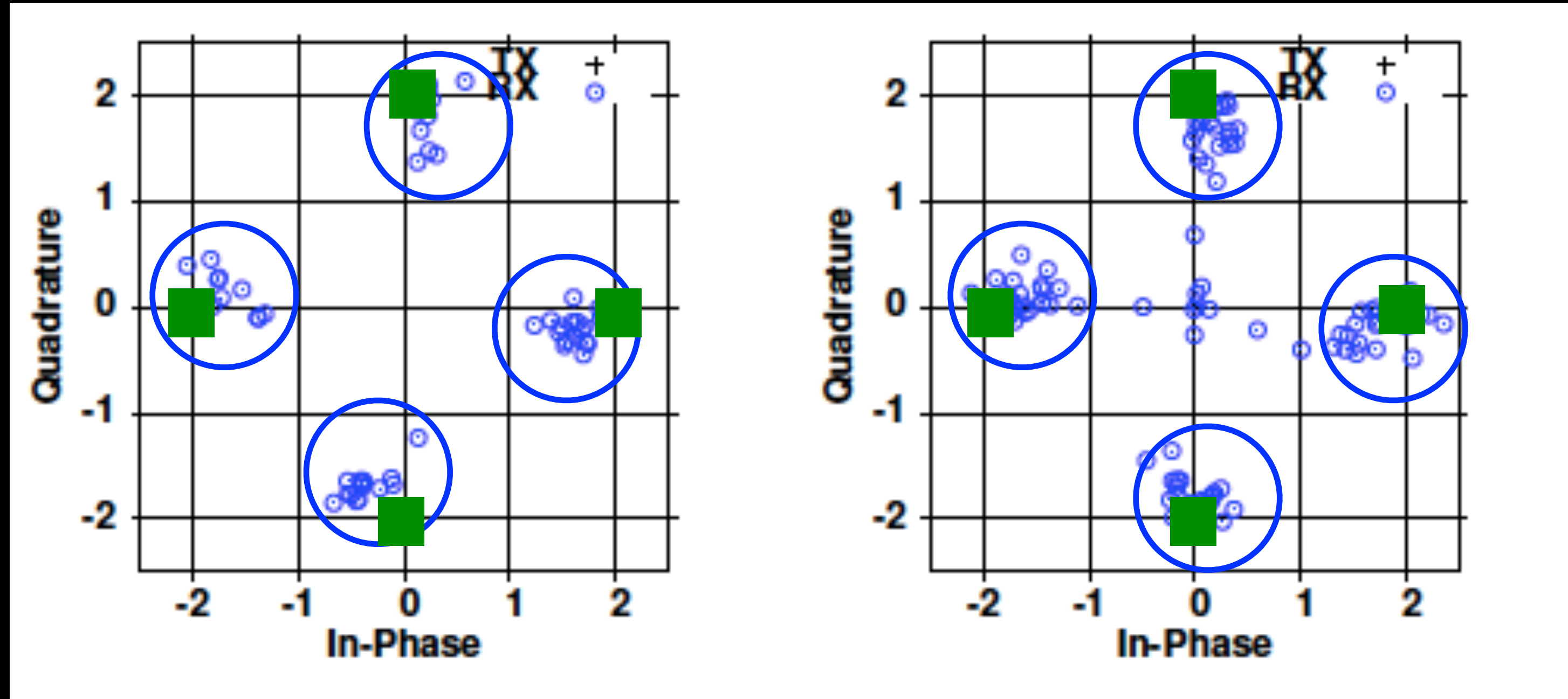
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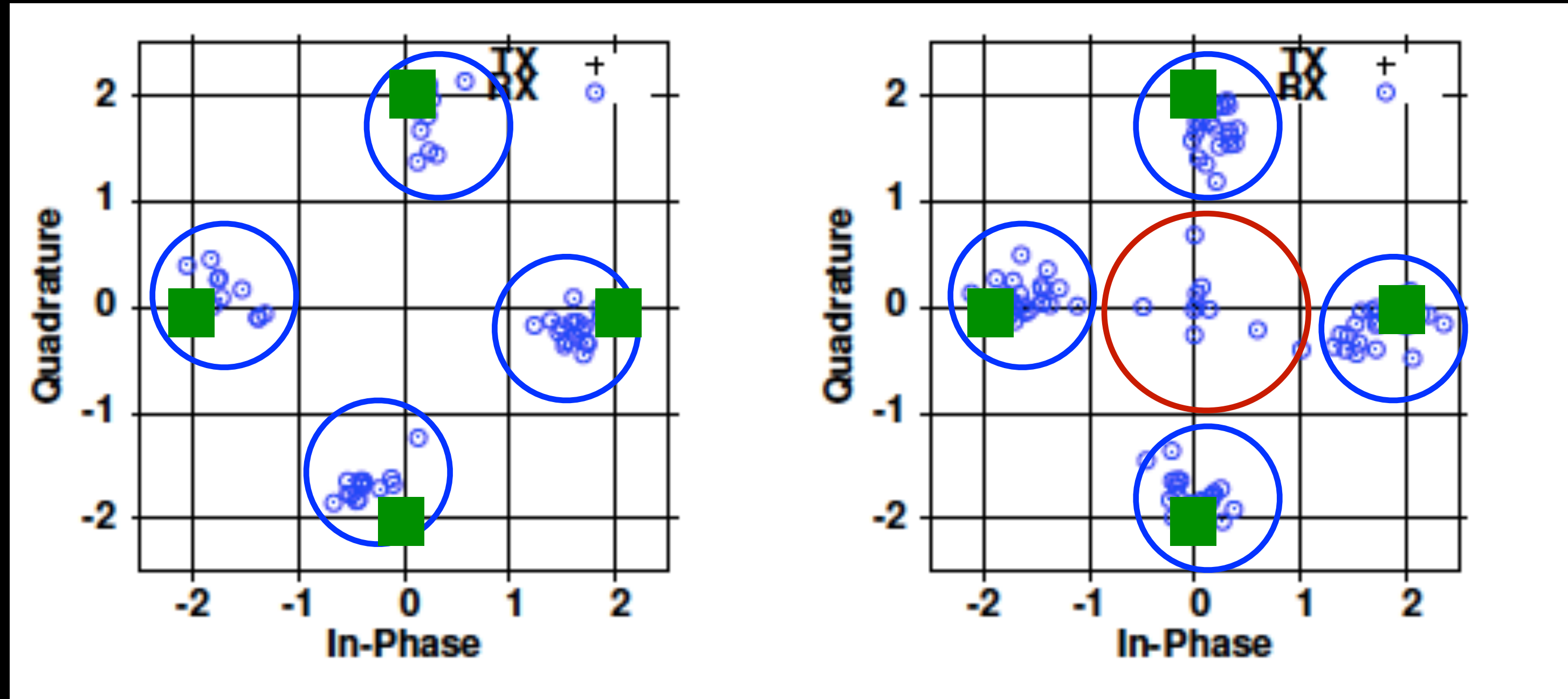
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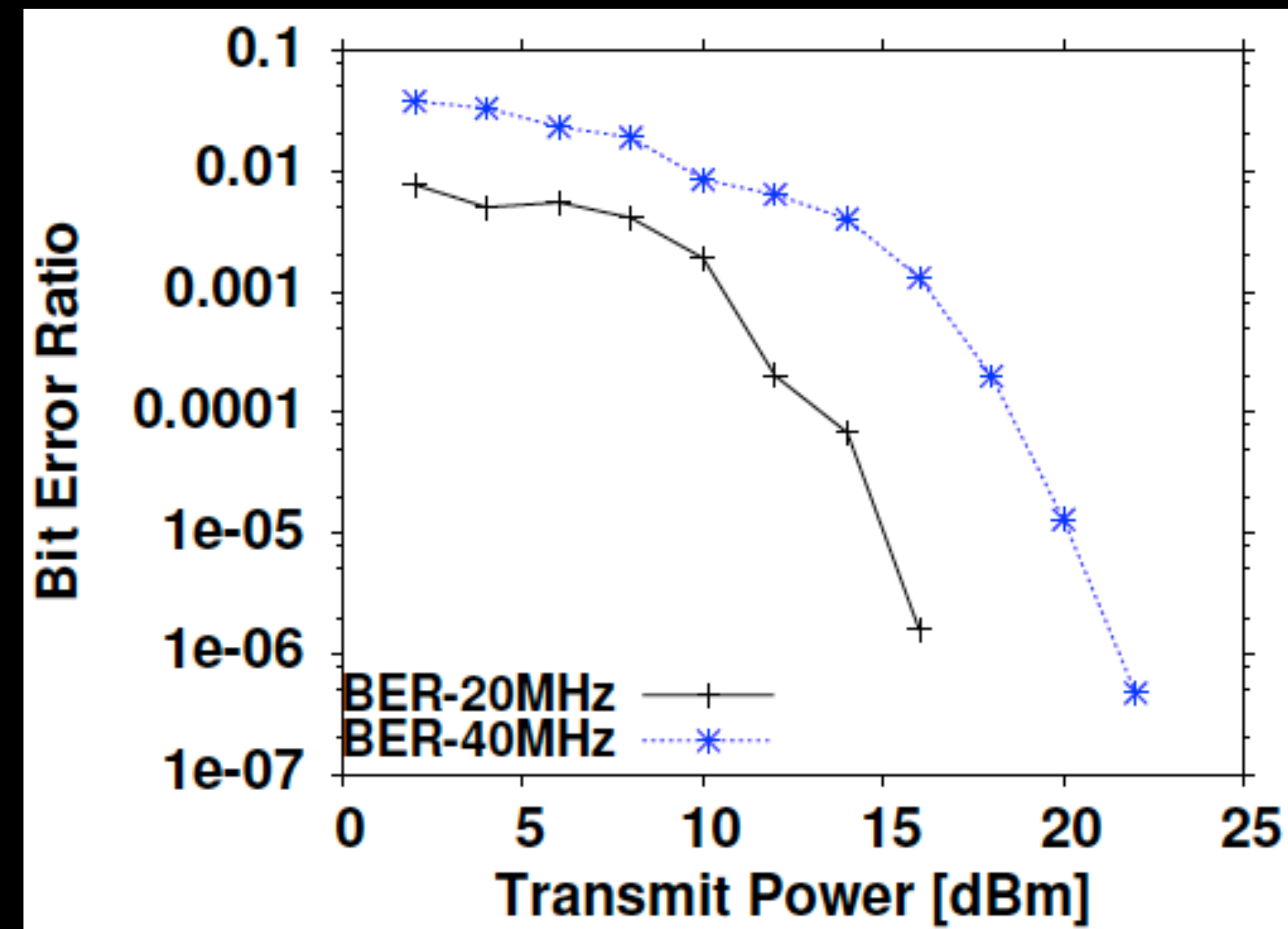


a) without CB

b) with CB

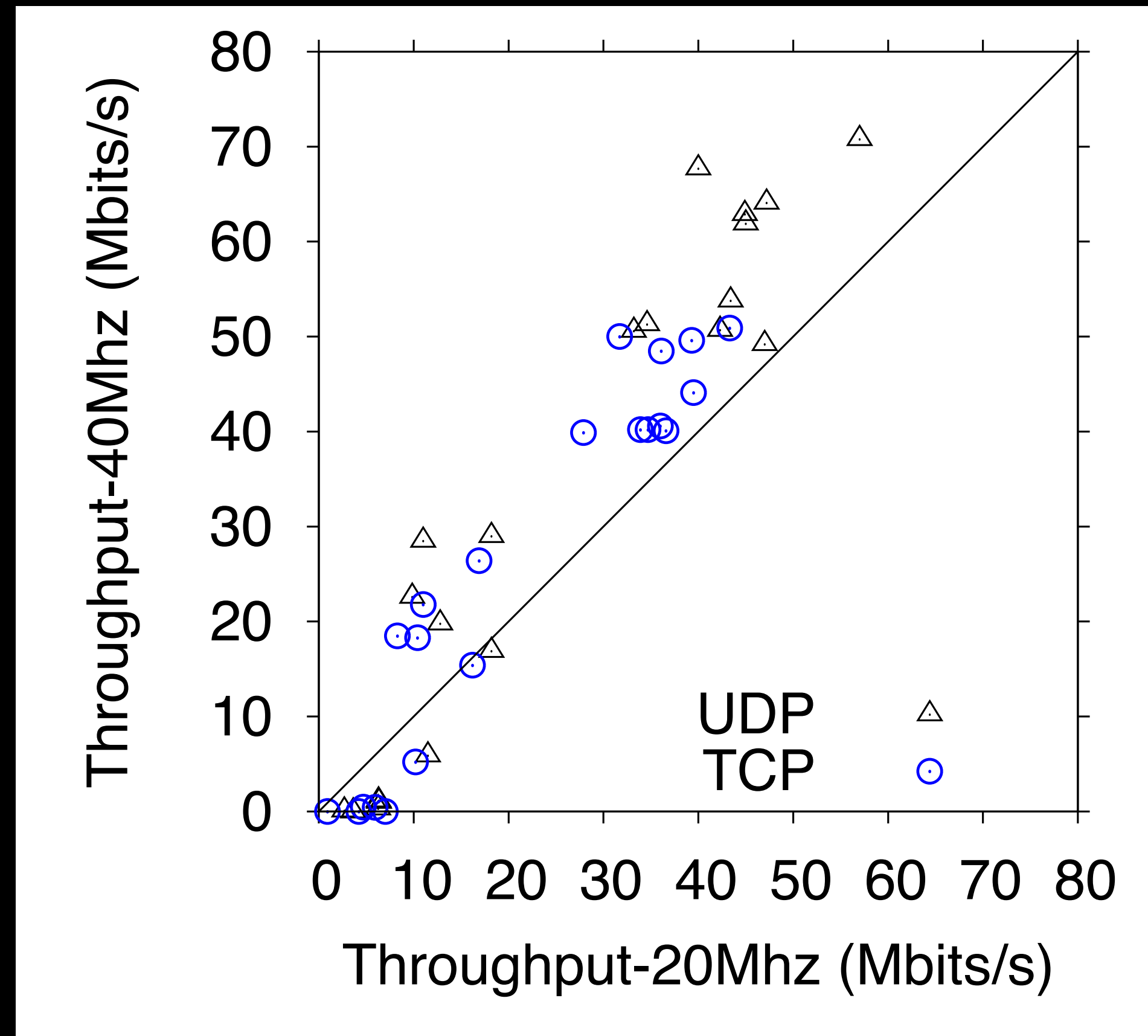
CB increases baud error rate → increase in BER

Measured Bit Error Rates with CB

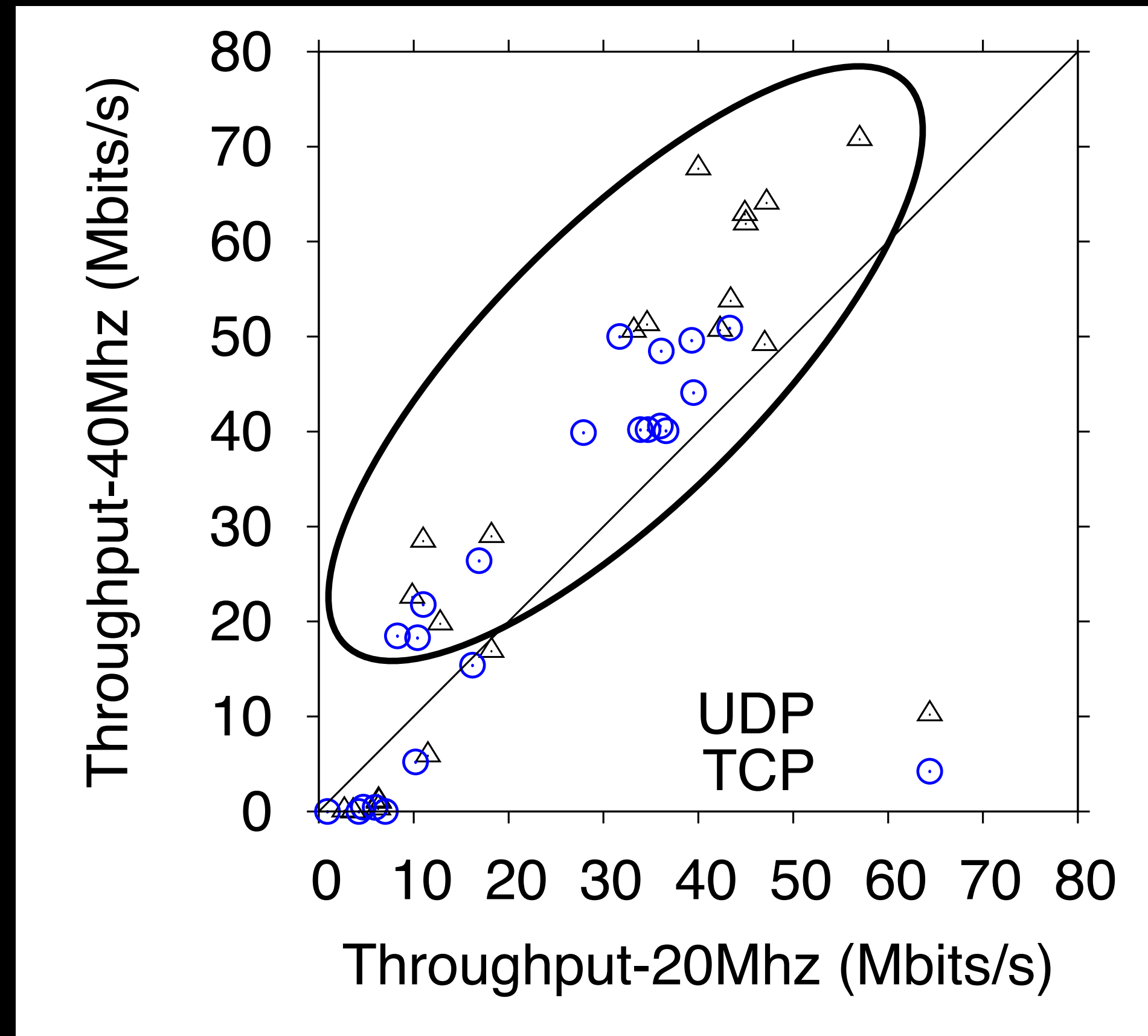


- For a given TX power, BER is higher when CB is employed.

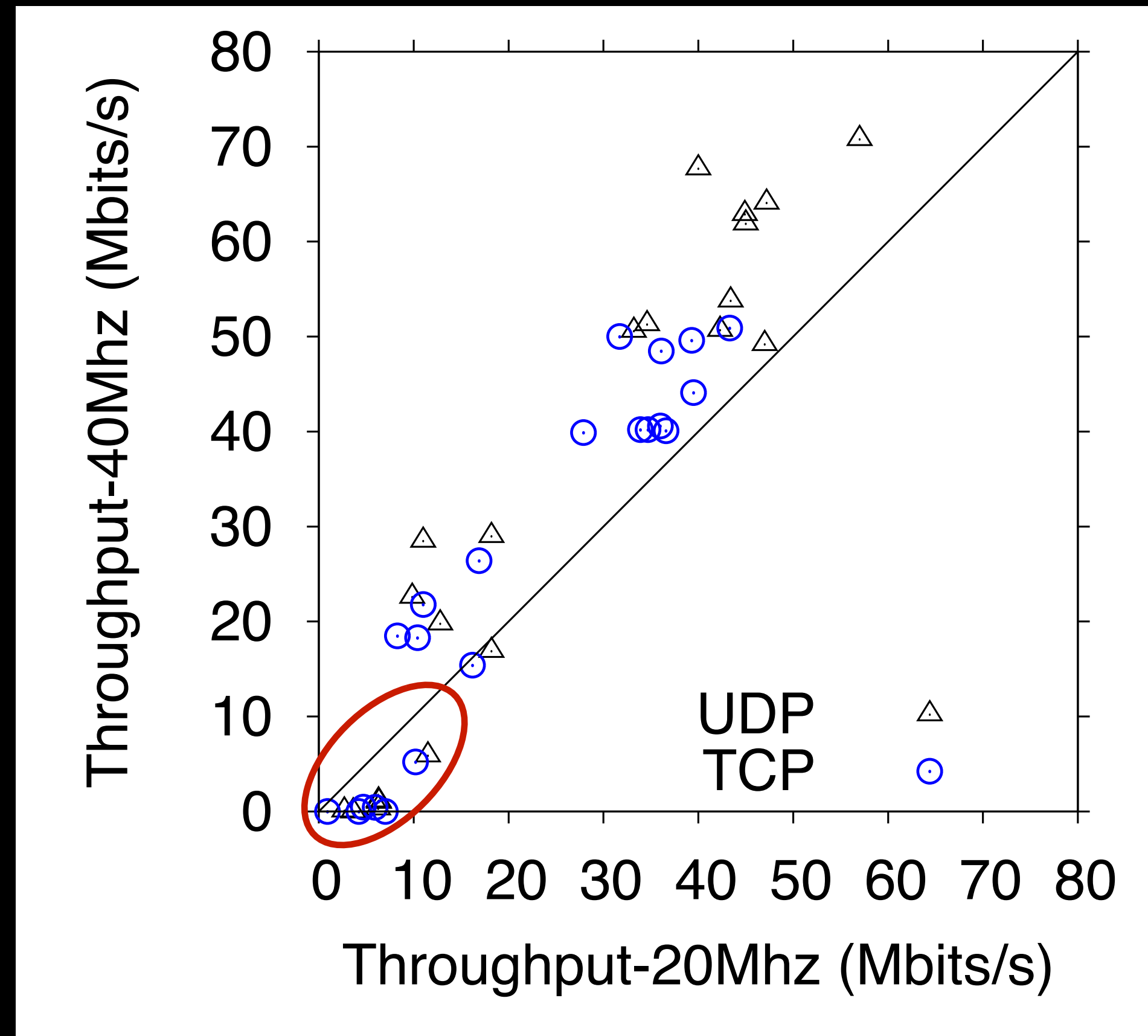
CB effect as seen by the user: lower thruput



CB effect as seen by the user: lower thruput



CB effect as seen by the user: lower throughput



CB reduces throughput for low-SINR links!

A “bad” node affects everybody’s performance

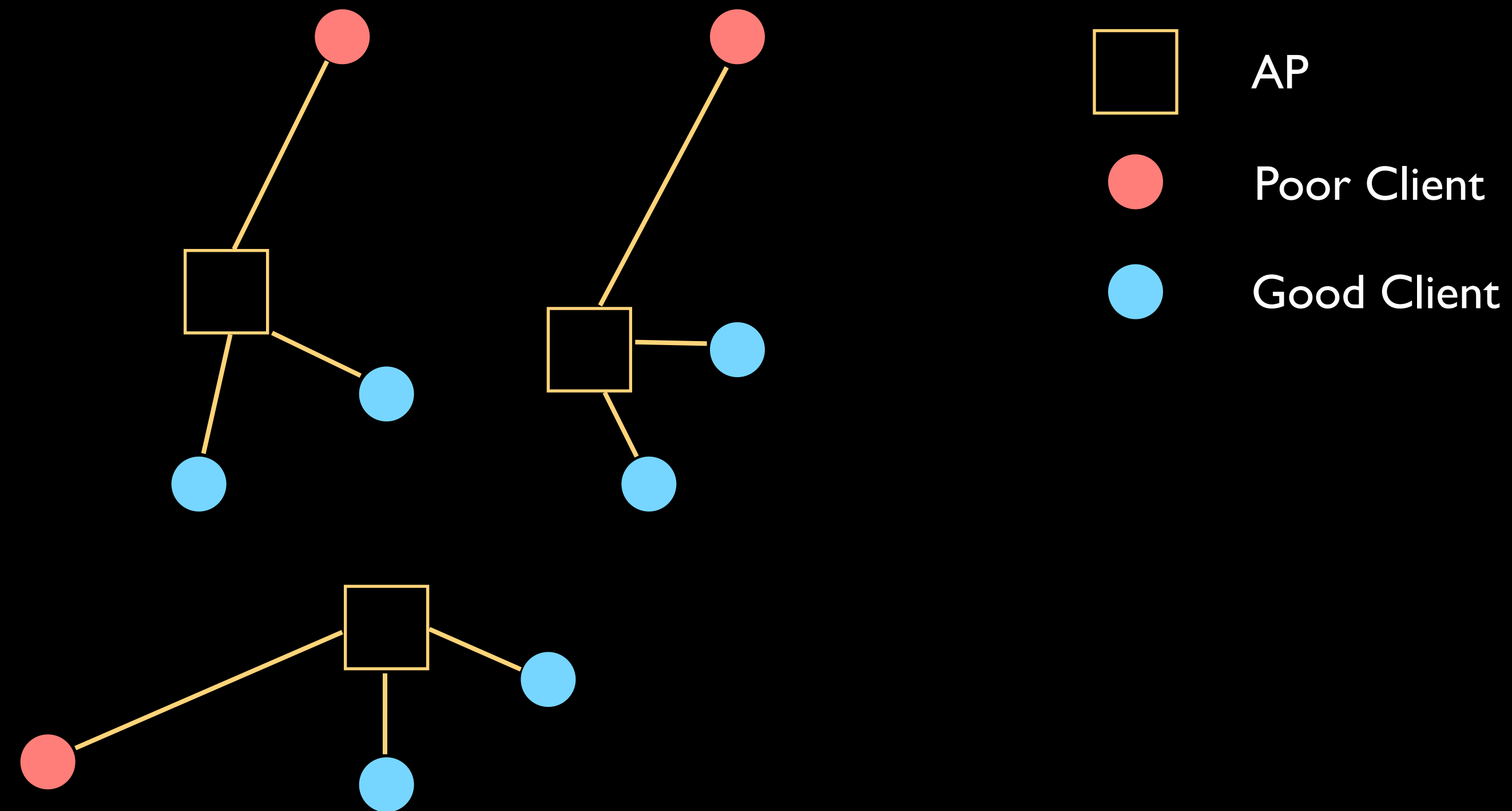
- Assume one AP and multiple clients connected to it.
 - AP serves each client in a fair manner in the long term (equal opportunities for access).
- A low data rate client (i.e. low SINR) has high service time.
 - Reduces the long-term throughput of other clients of the AP.
- How can we address this?
 - Use ACORN!

What is ACORN ?

- ACORN manages interference in IEEE 802.11n WLANs.
- It assigns 20 MHz or 40 MHz bands to base stations intelligently.
- It performs intelligent user-association
 - wherein clients are assigned to appropriate cells to aid frequency band allocation (as above).
- ACORN's key idea:
 - *Prevent low SINR clients from joining APs with 40 MHz*

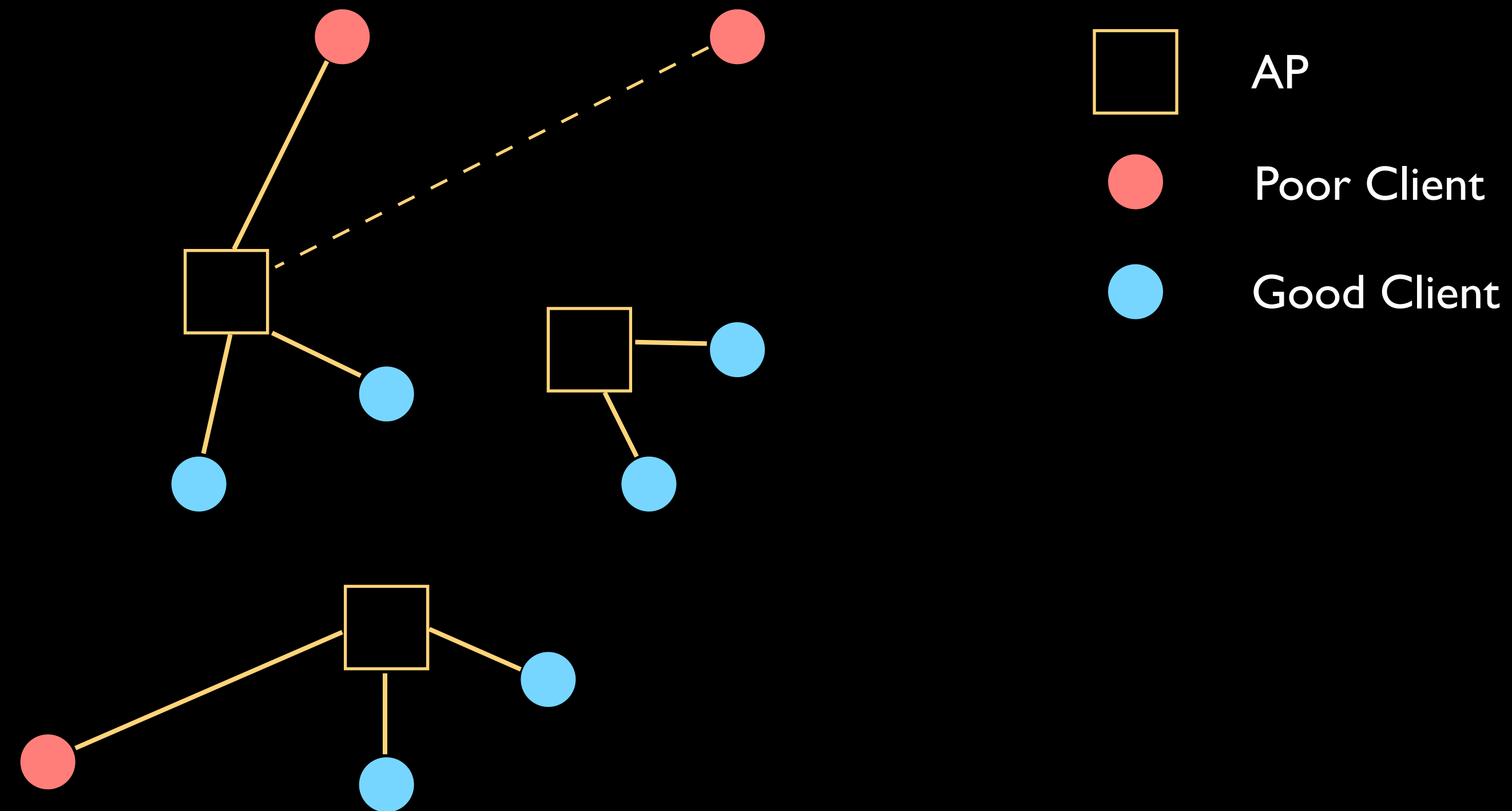
ACORN's User Association

- *Key idea: group similar quality clients in a cell*



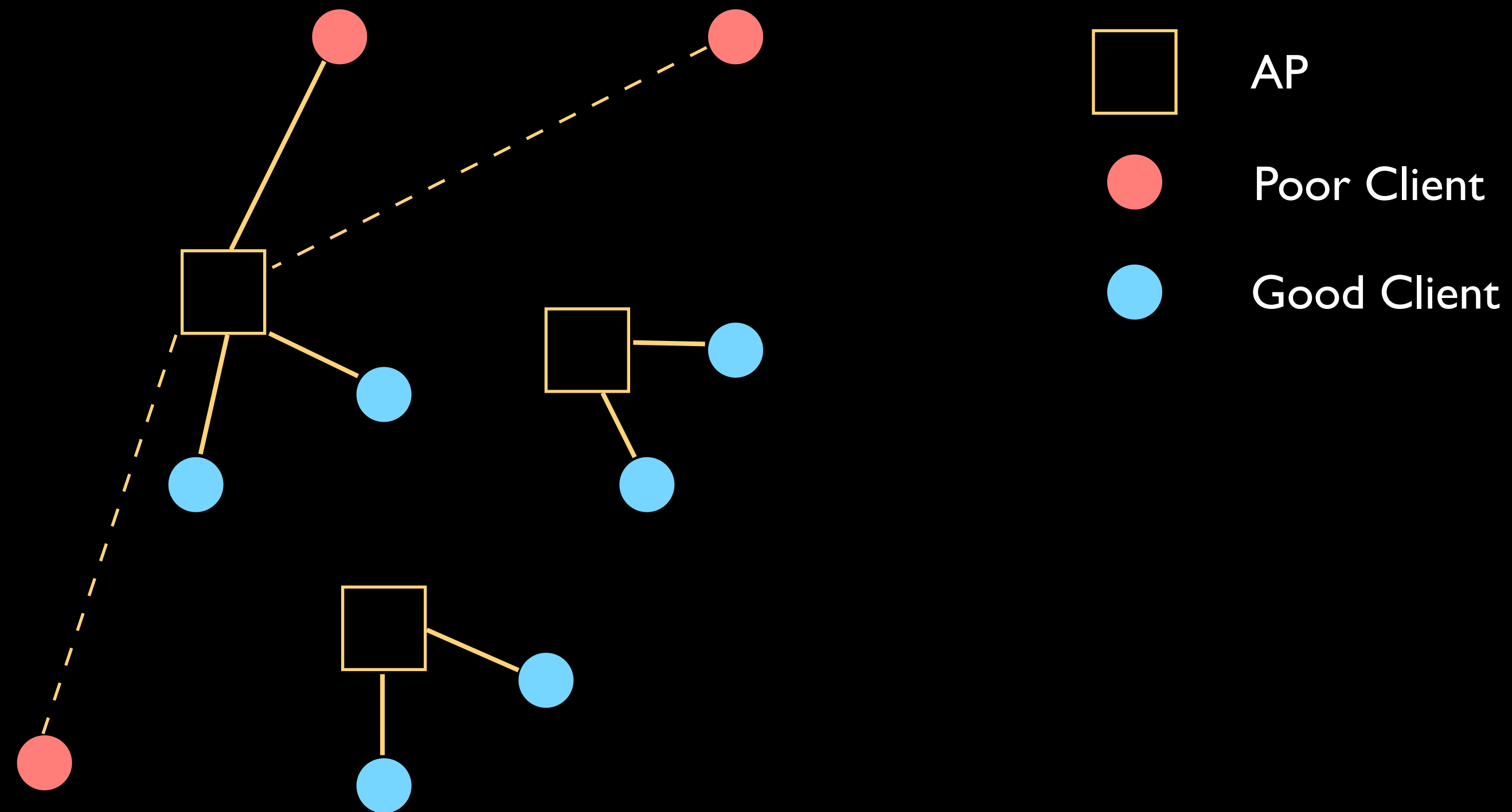
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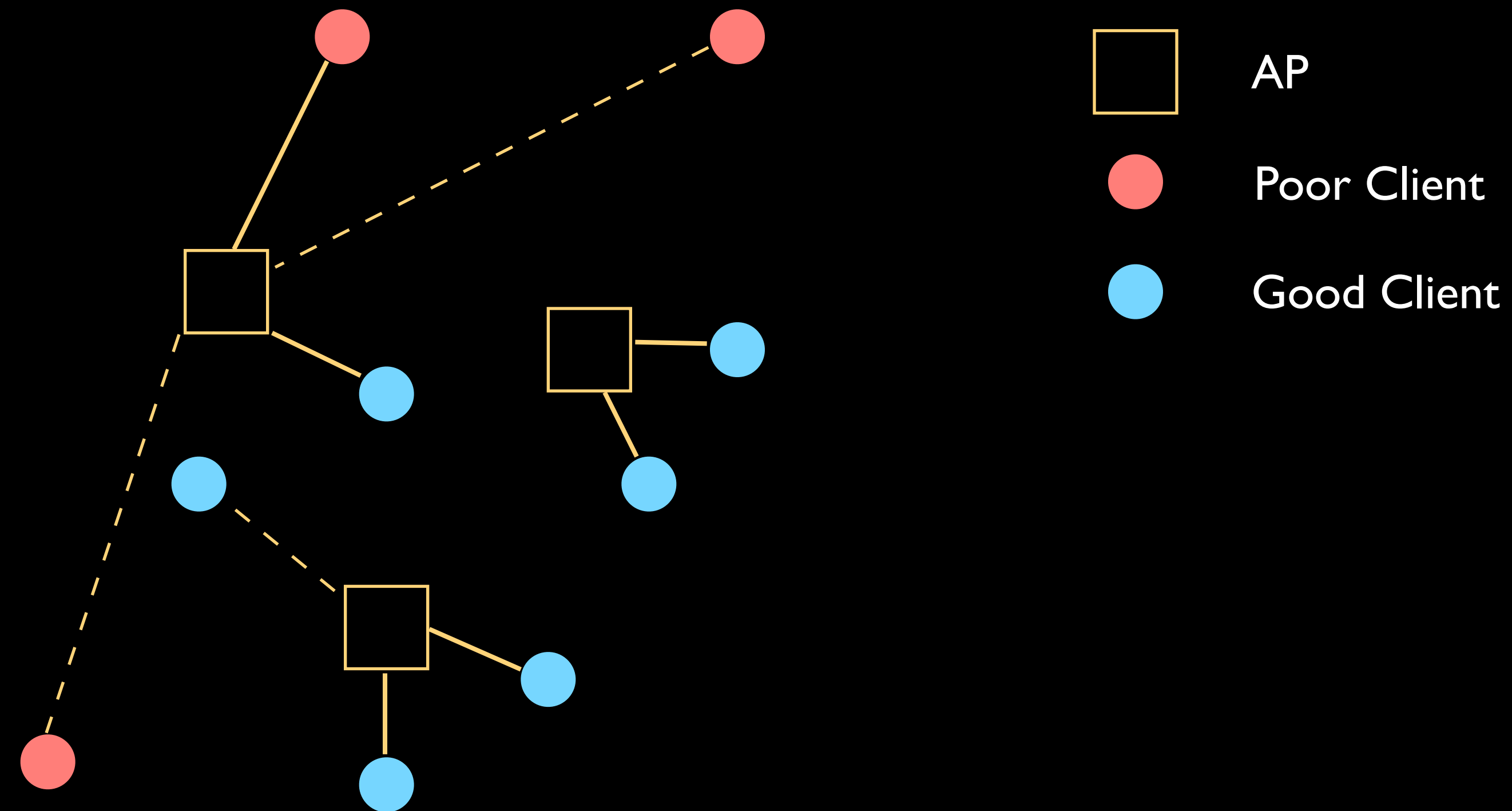
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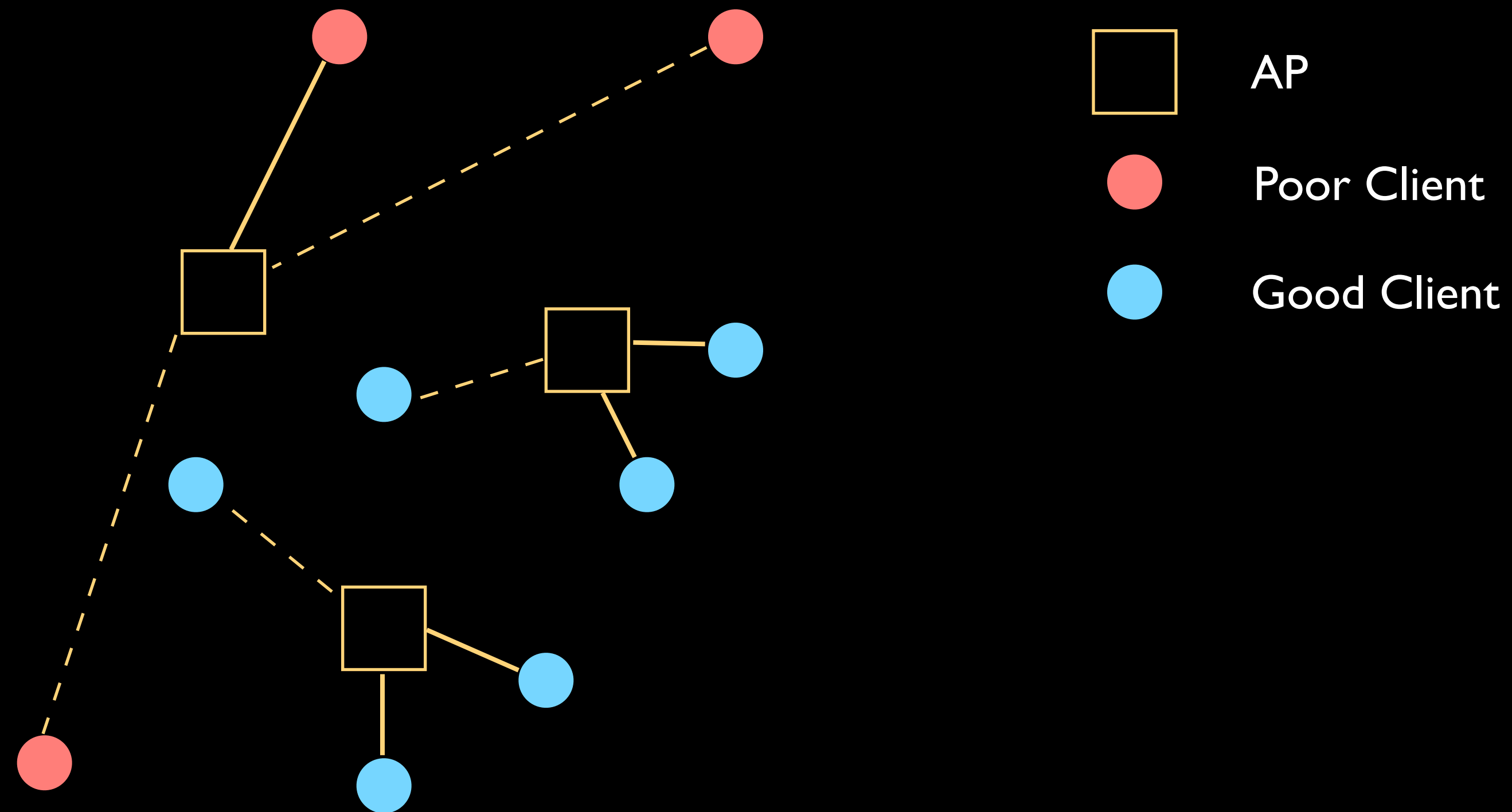
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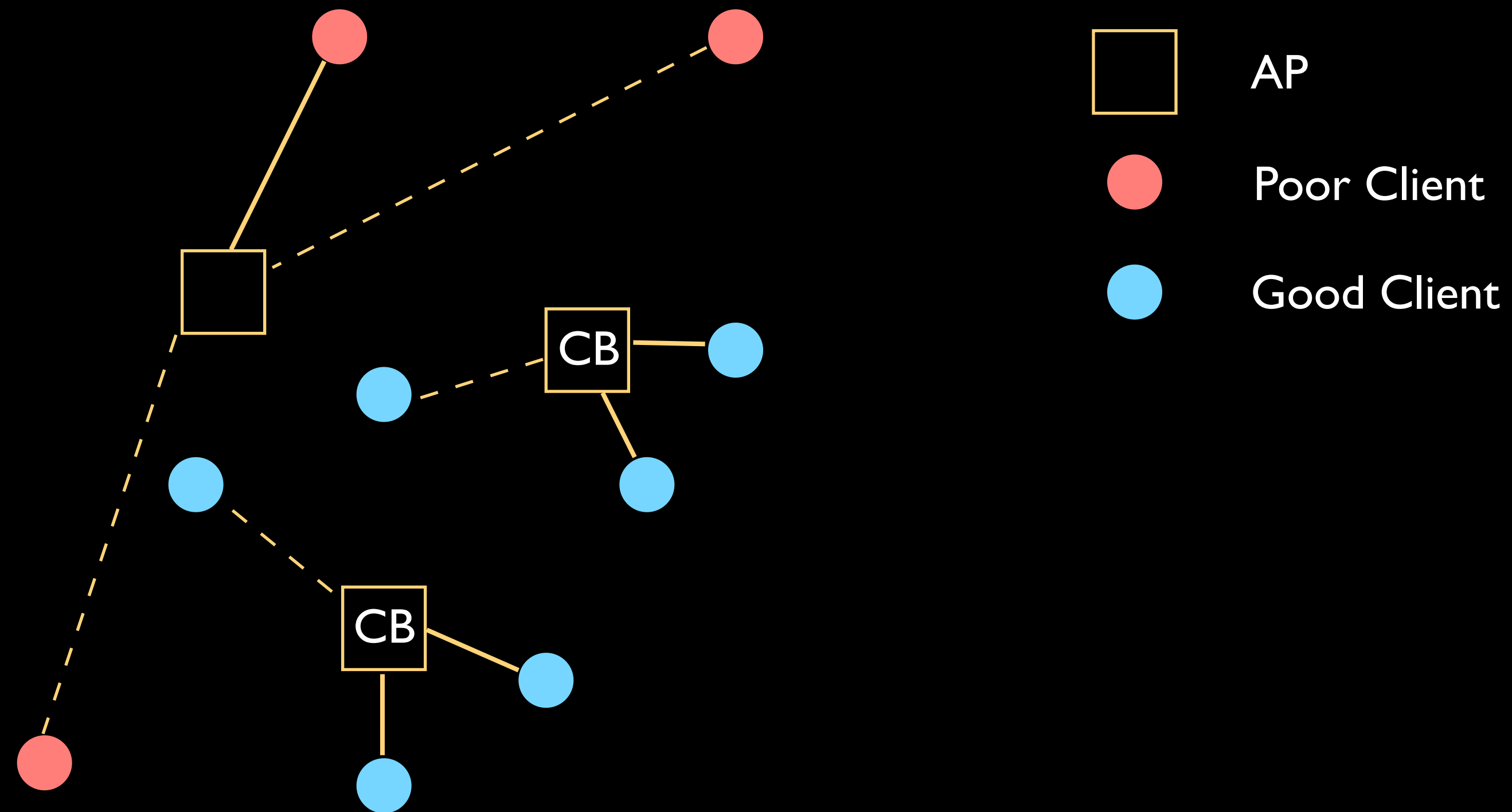
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ACORN's Channel Selection

- Problem: given a network of APs, assign channels s.t. the aggregate network throughput is maximized.
- reduces to graph coloring \implies NP-hard
- Iteratively assign each channel to the AP that has the best throughput increase with that channel.

ACORN's Channel Selection

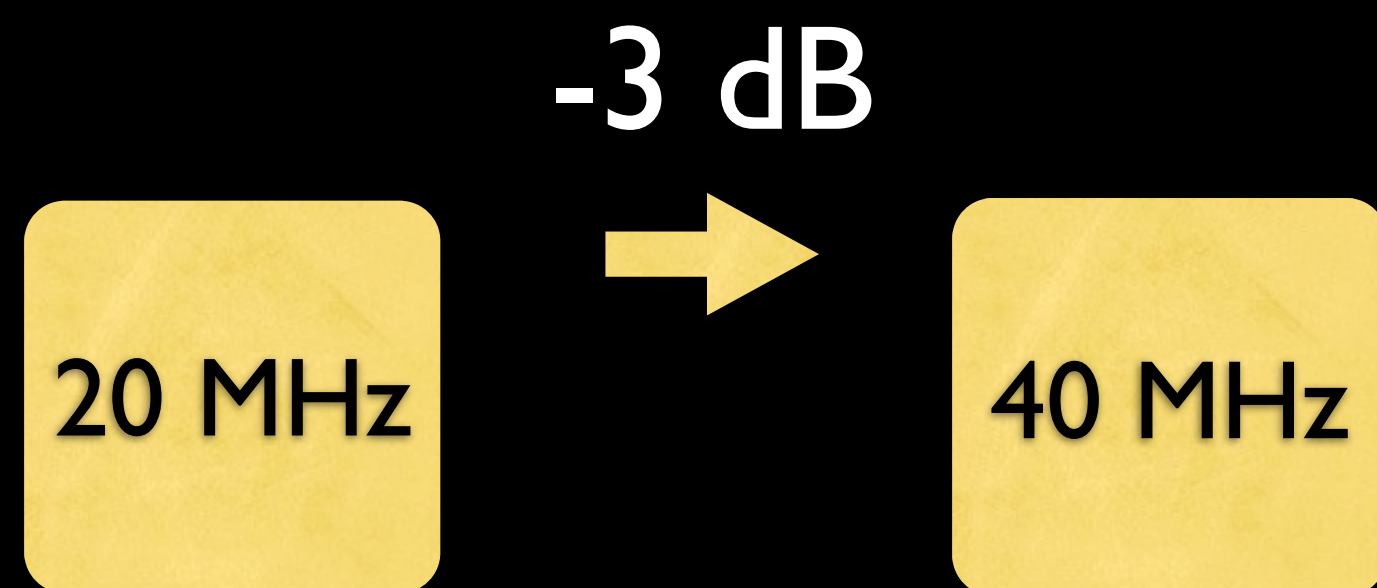
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20 MHz

40 MHz

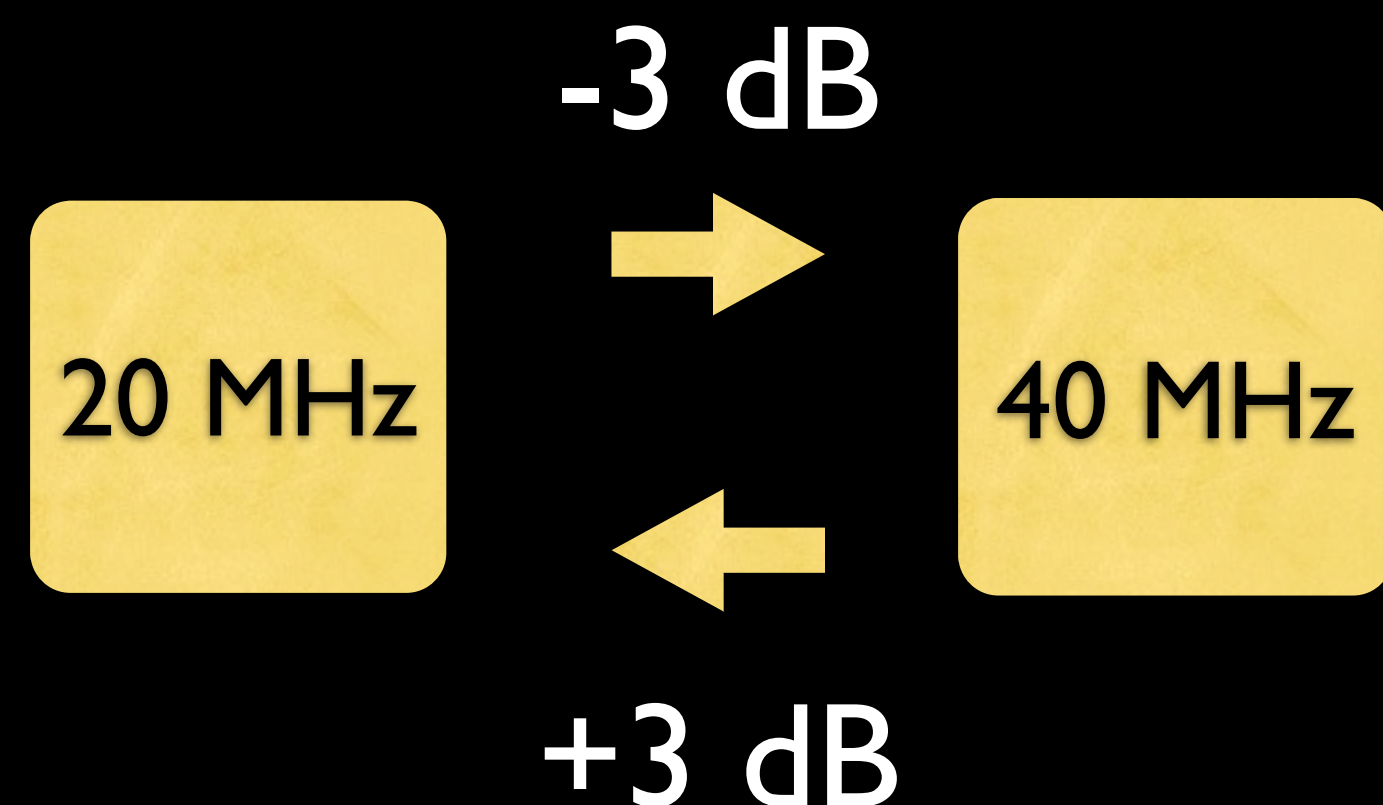
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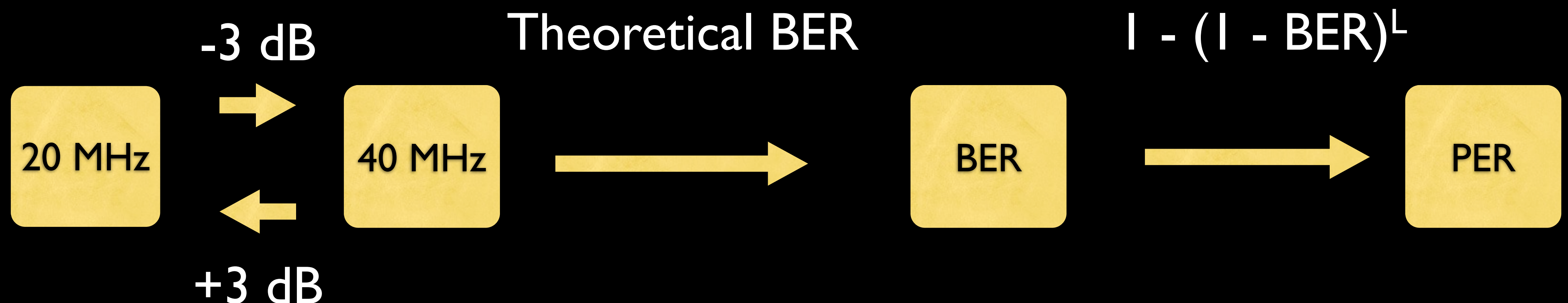
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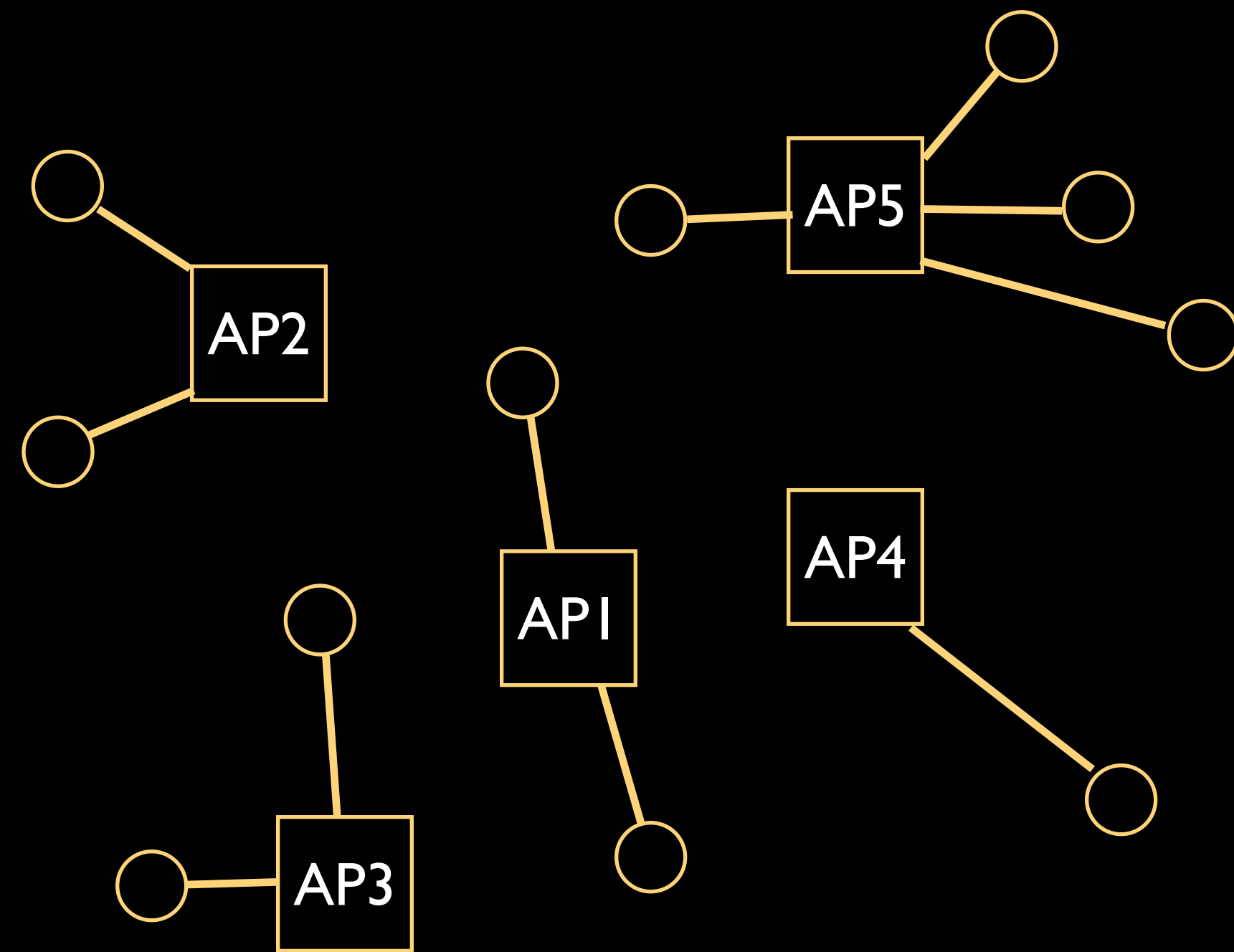
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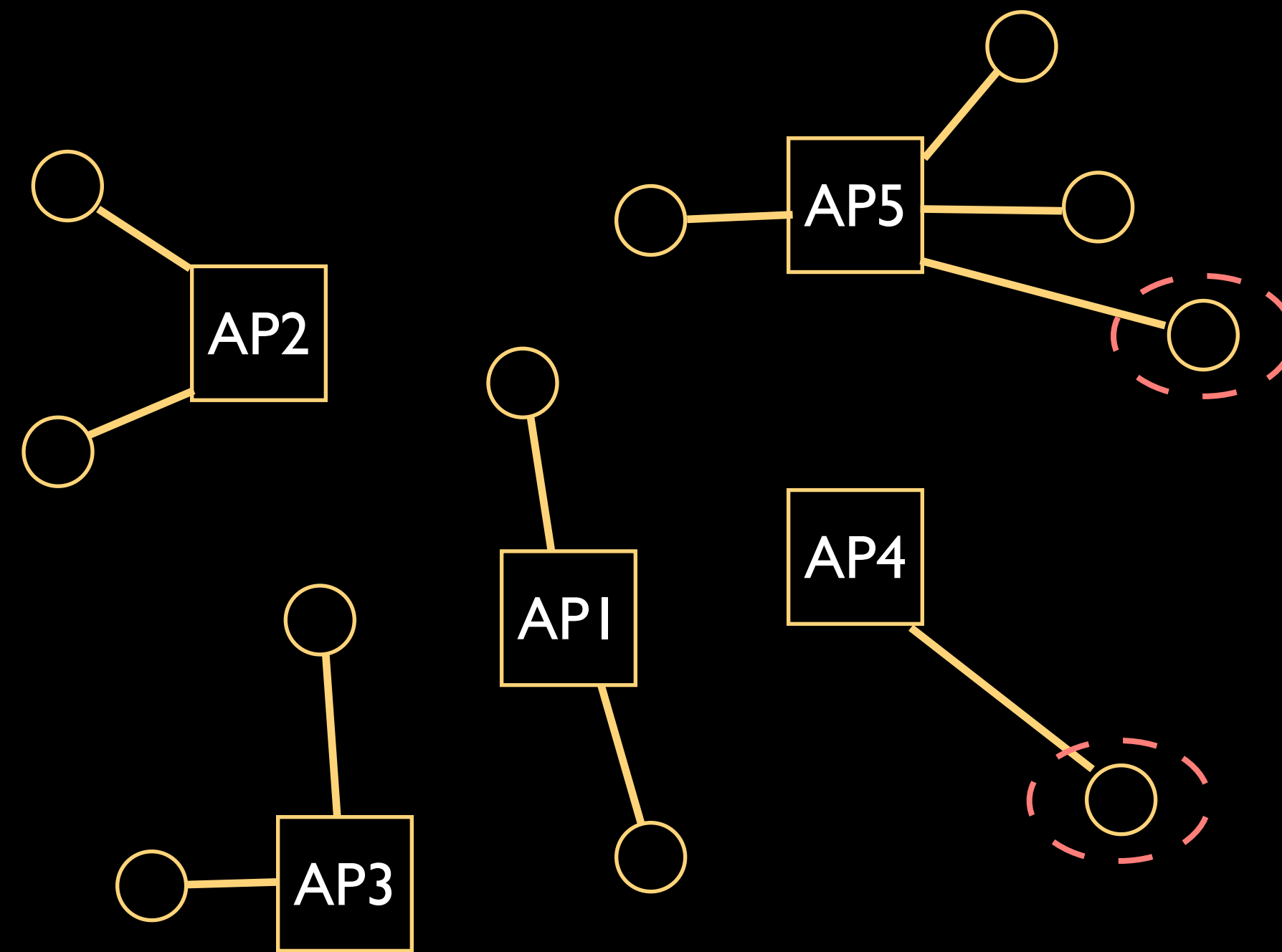
Evaluation through implementation

- 18 node 802.11n testbed.
- Comparison with a legacy auto-configuration system
 - Kauffmann et. al. - Infocom'07
 - Legacy user association
 - Minimize total transmission delay.
 - Legacy channel selection
 - Each AP selects a channel with the least interference.
 - Pick 40 MHz channels all the time (mimic public belief).

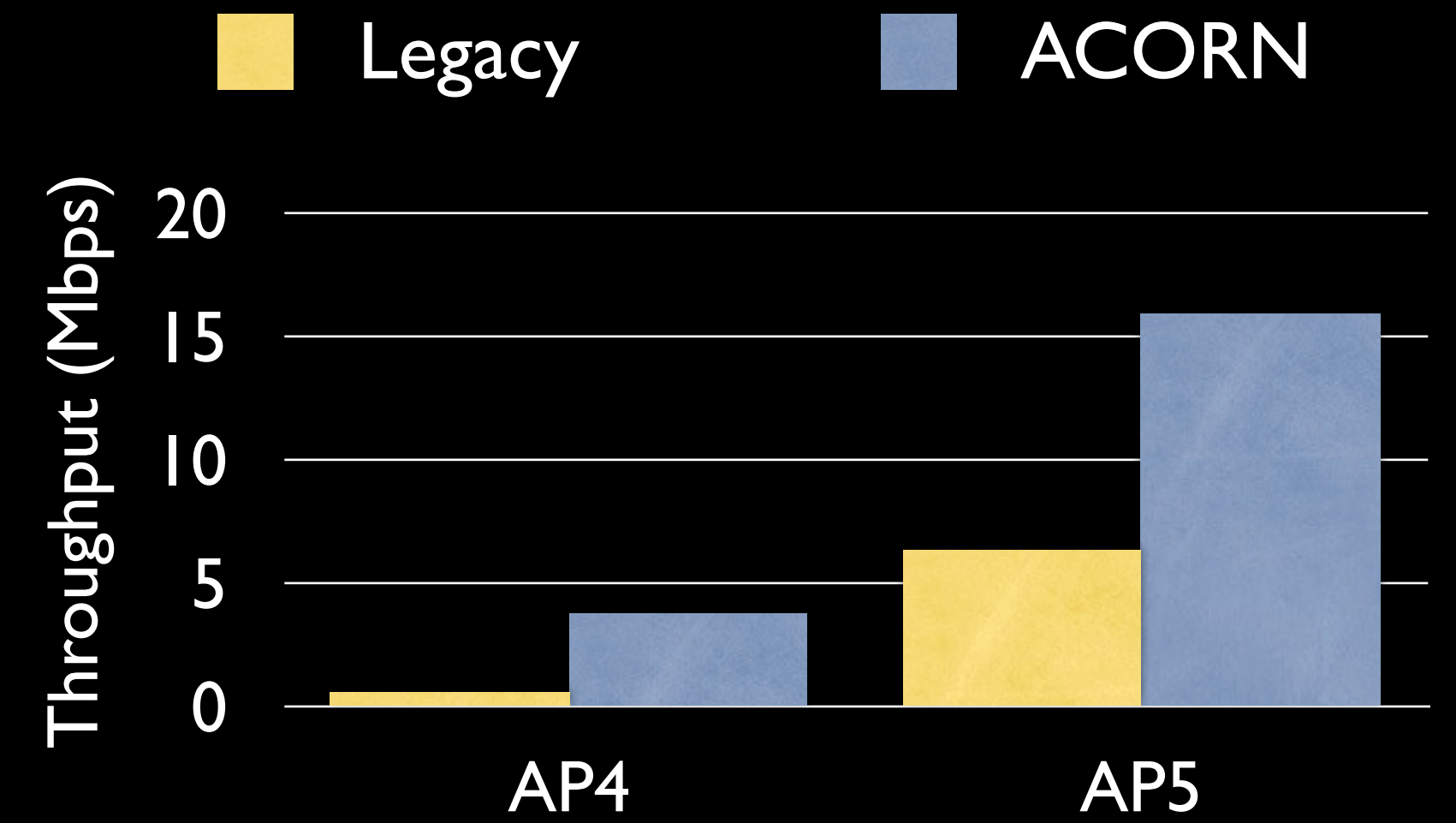
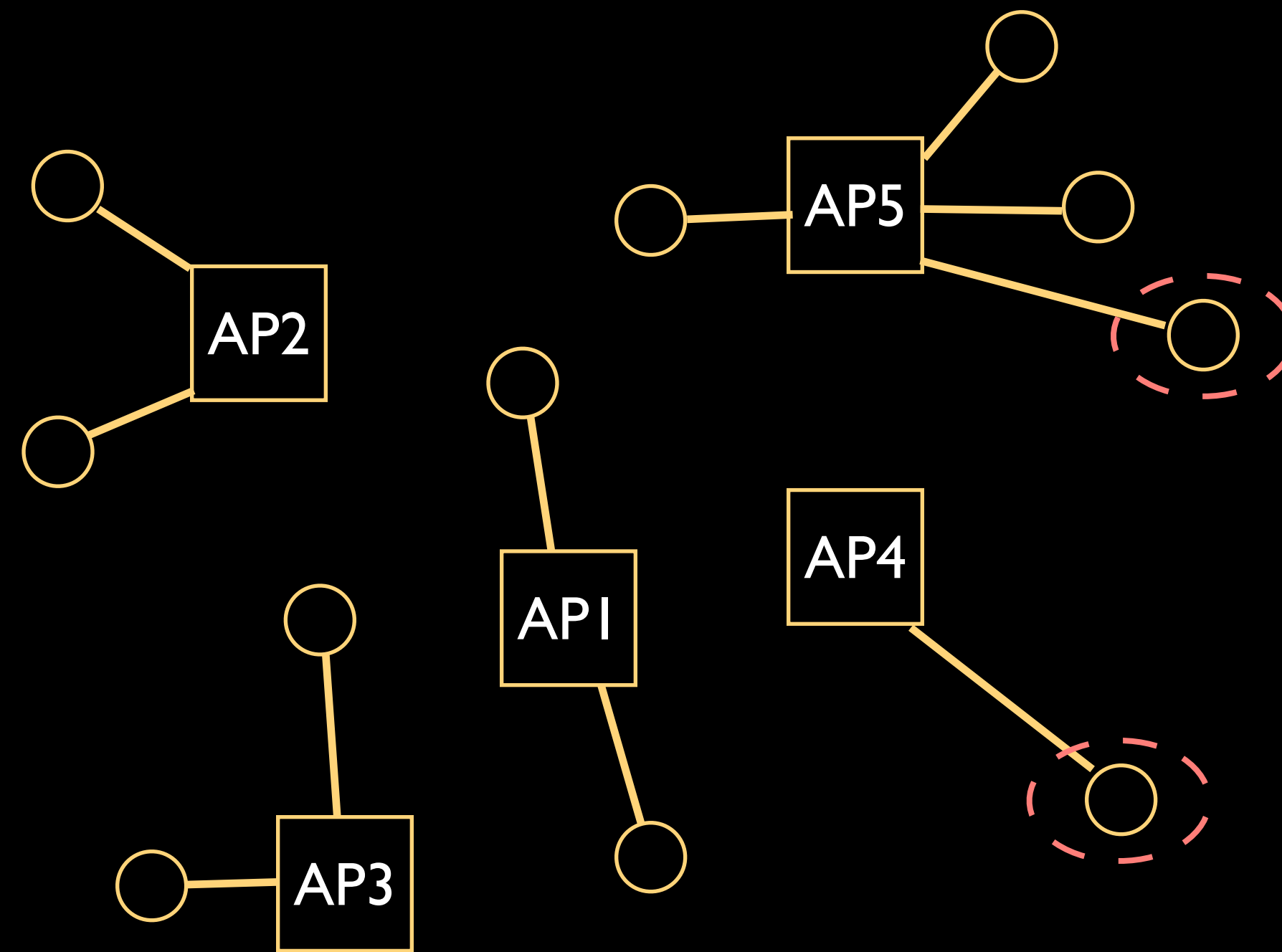
Evaluation



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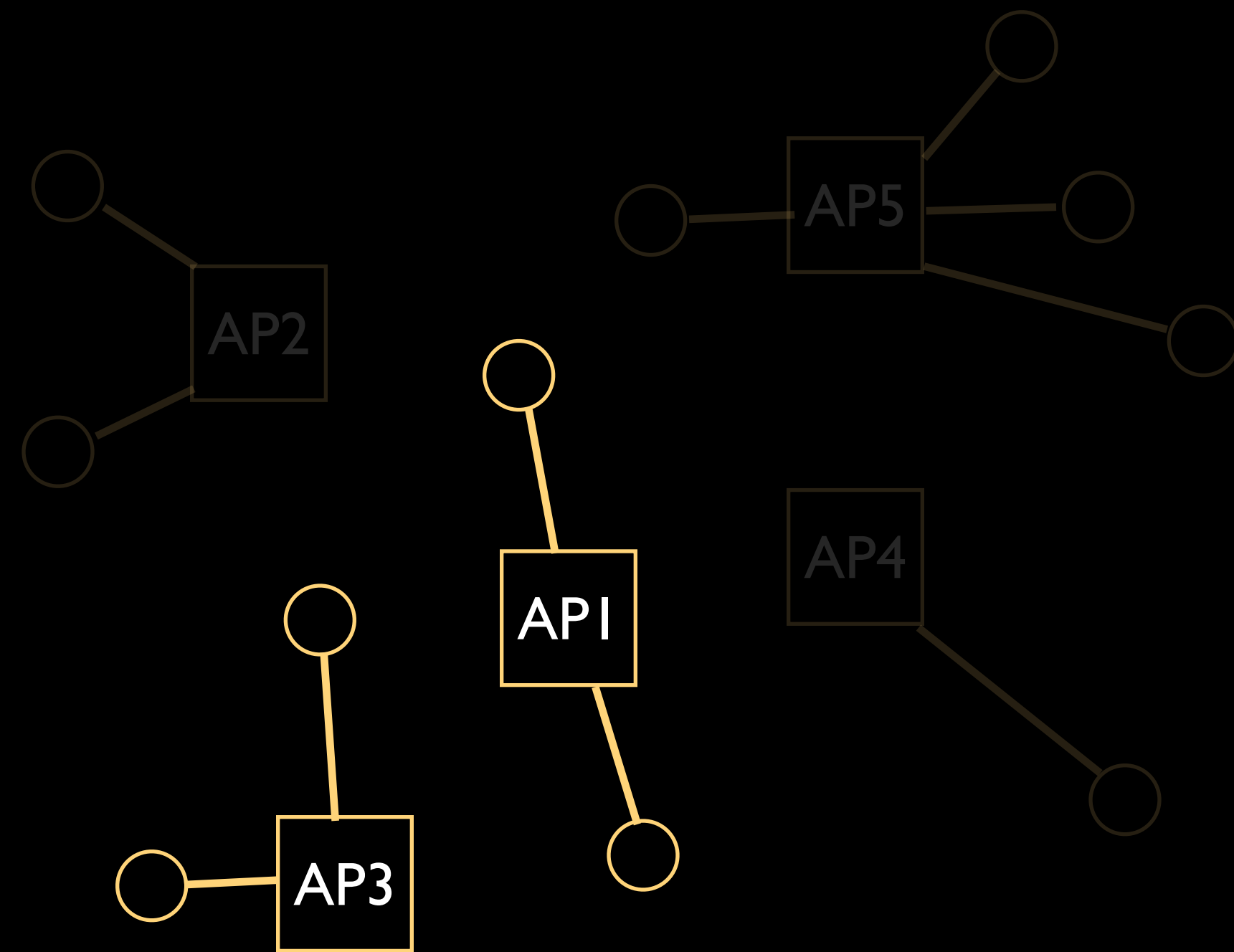


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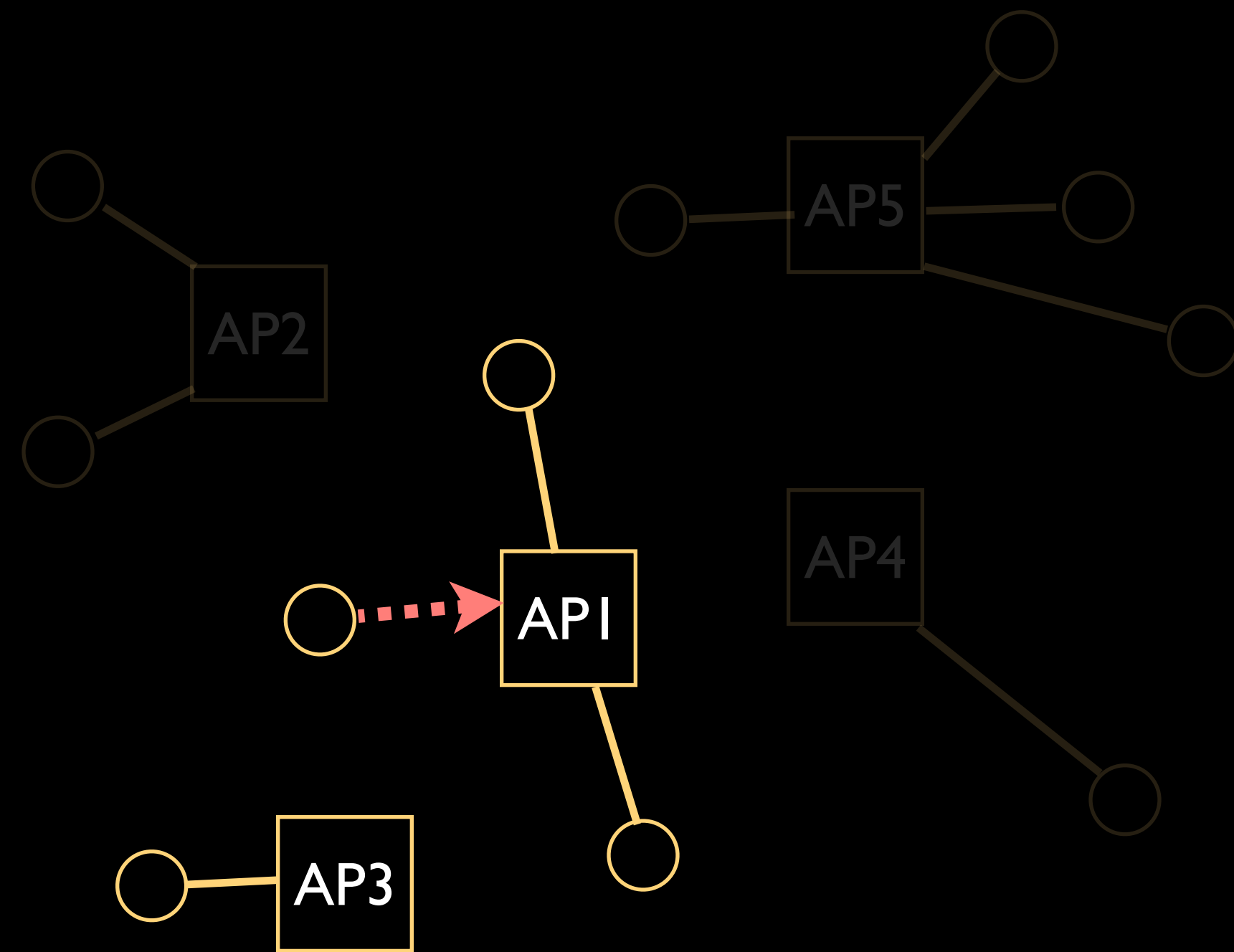


CB avoided due to low-SINR clients.

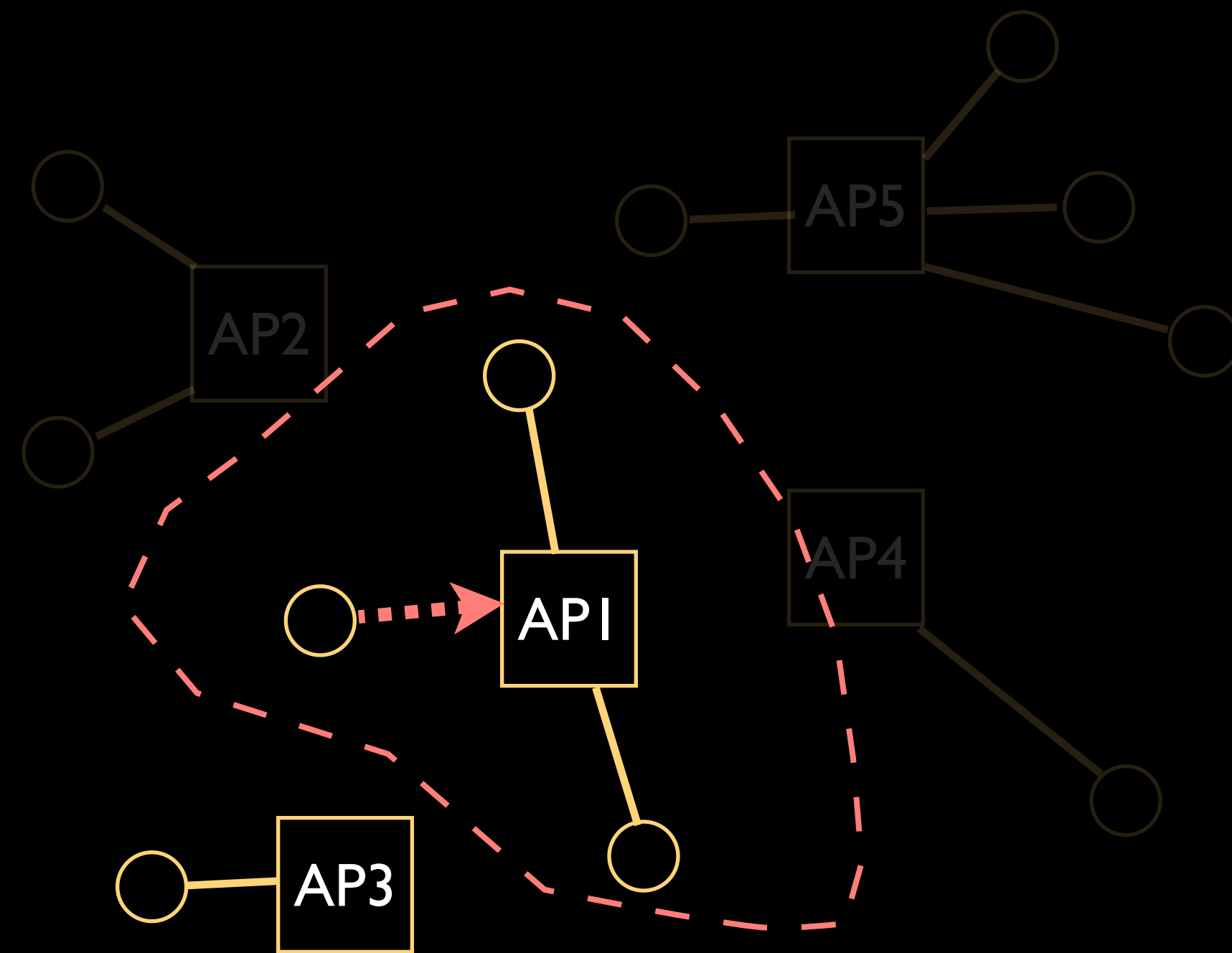
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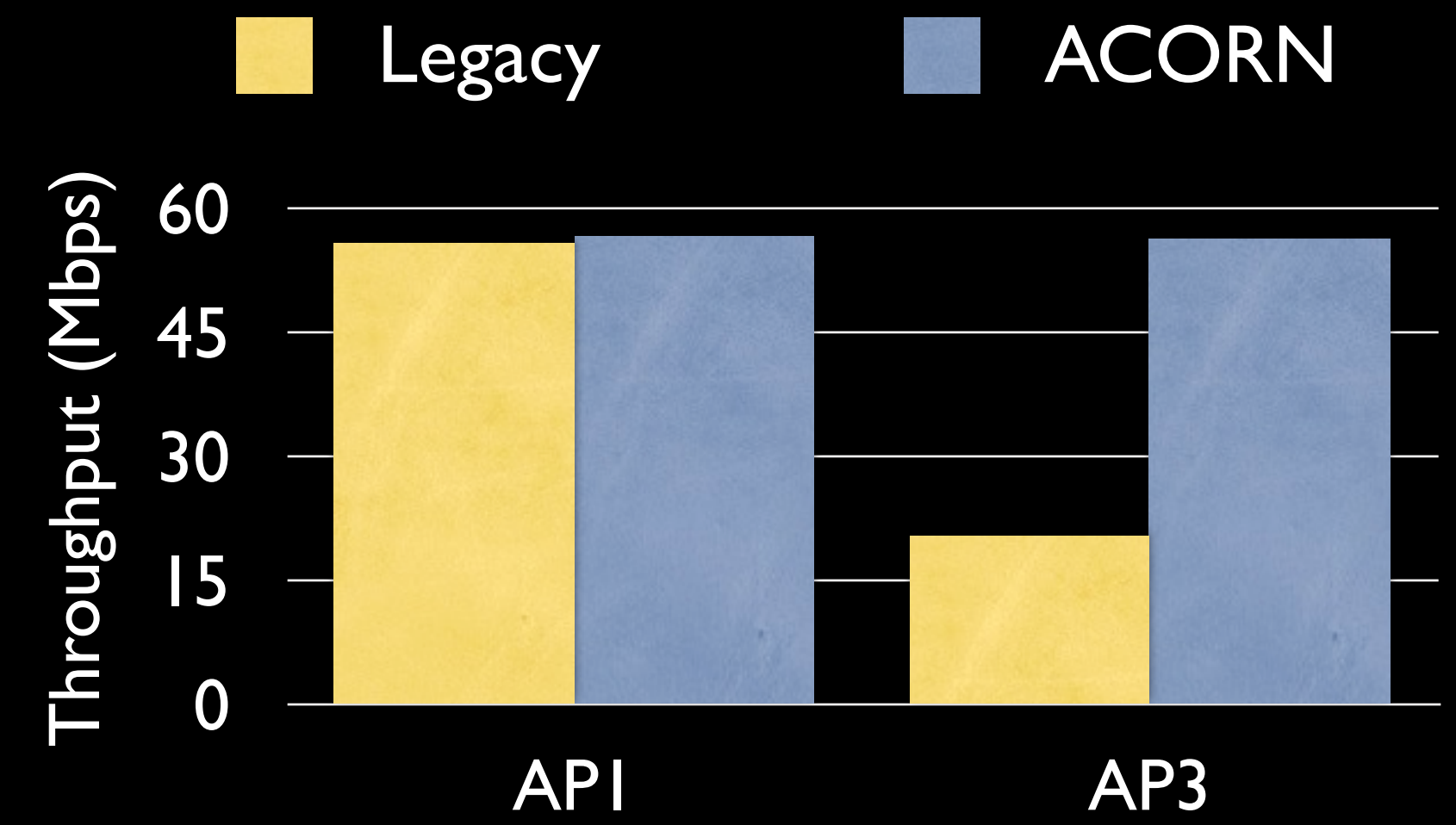
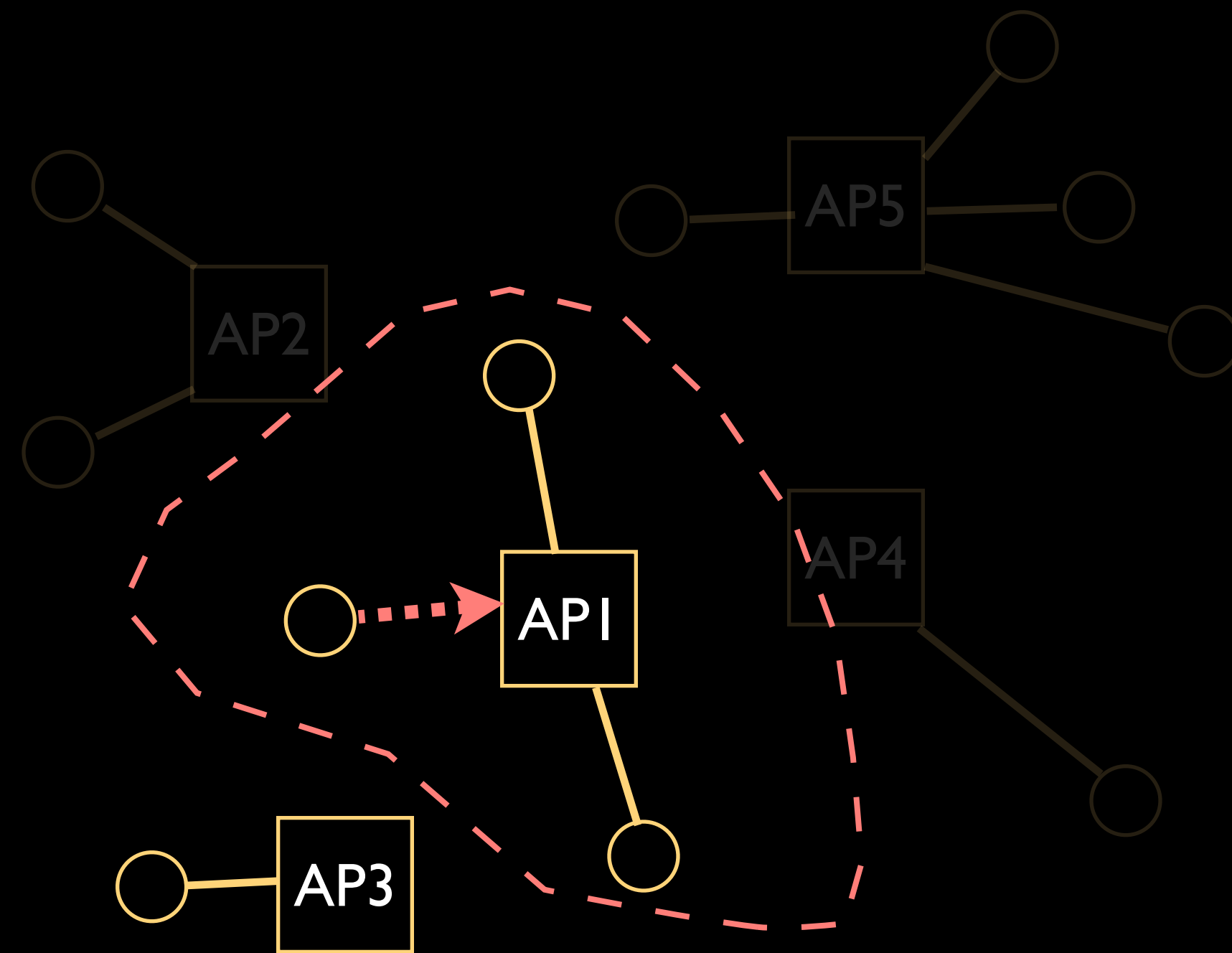


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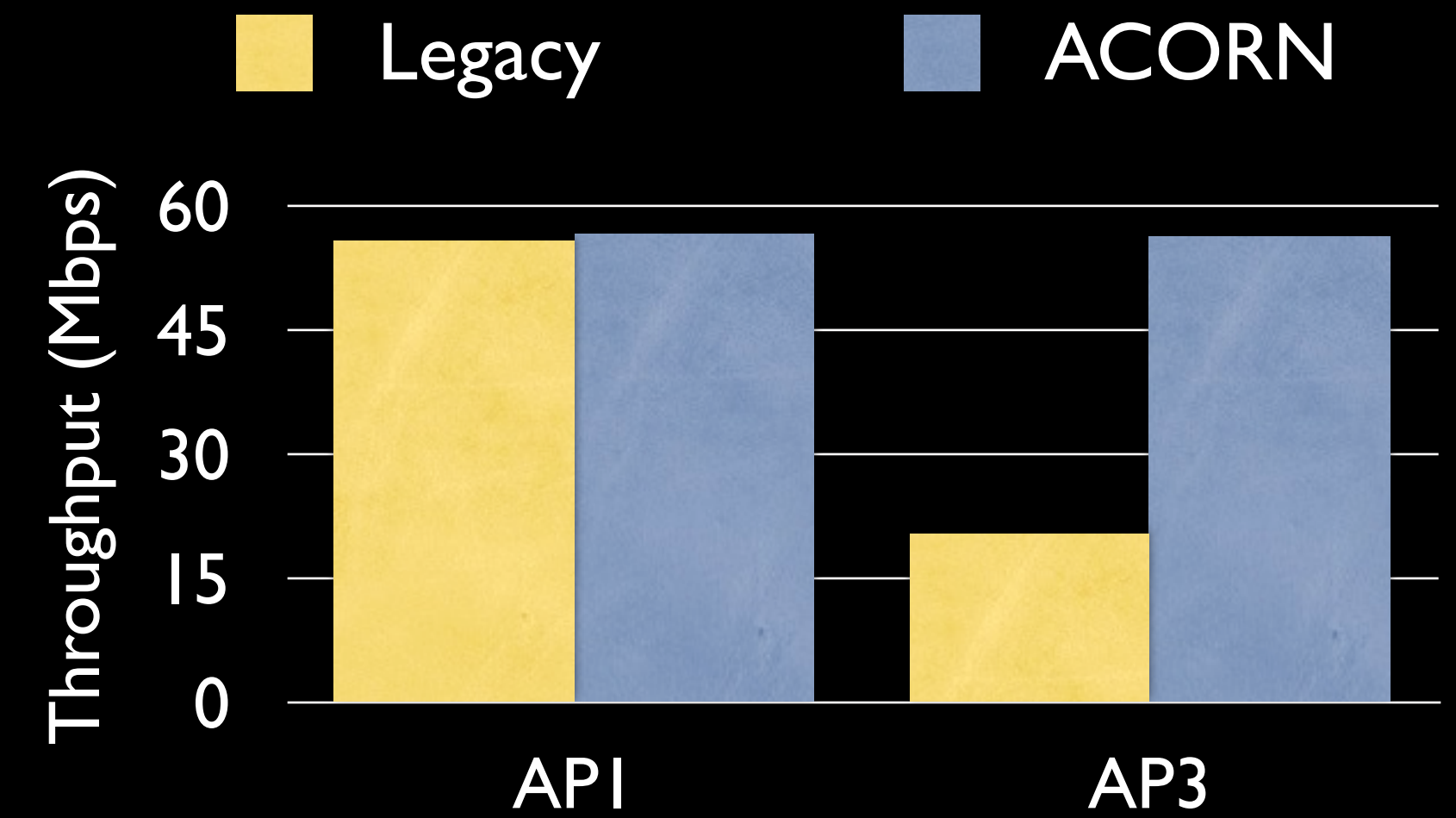
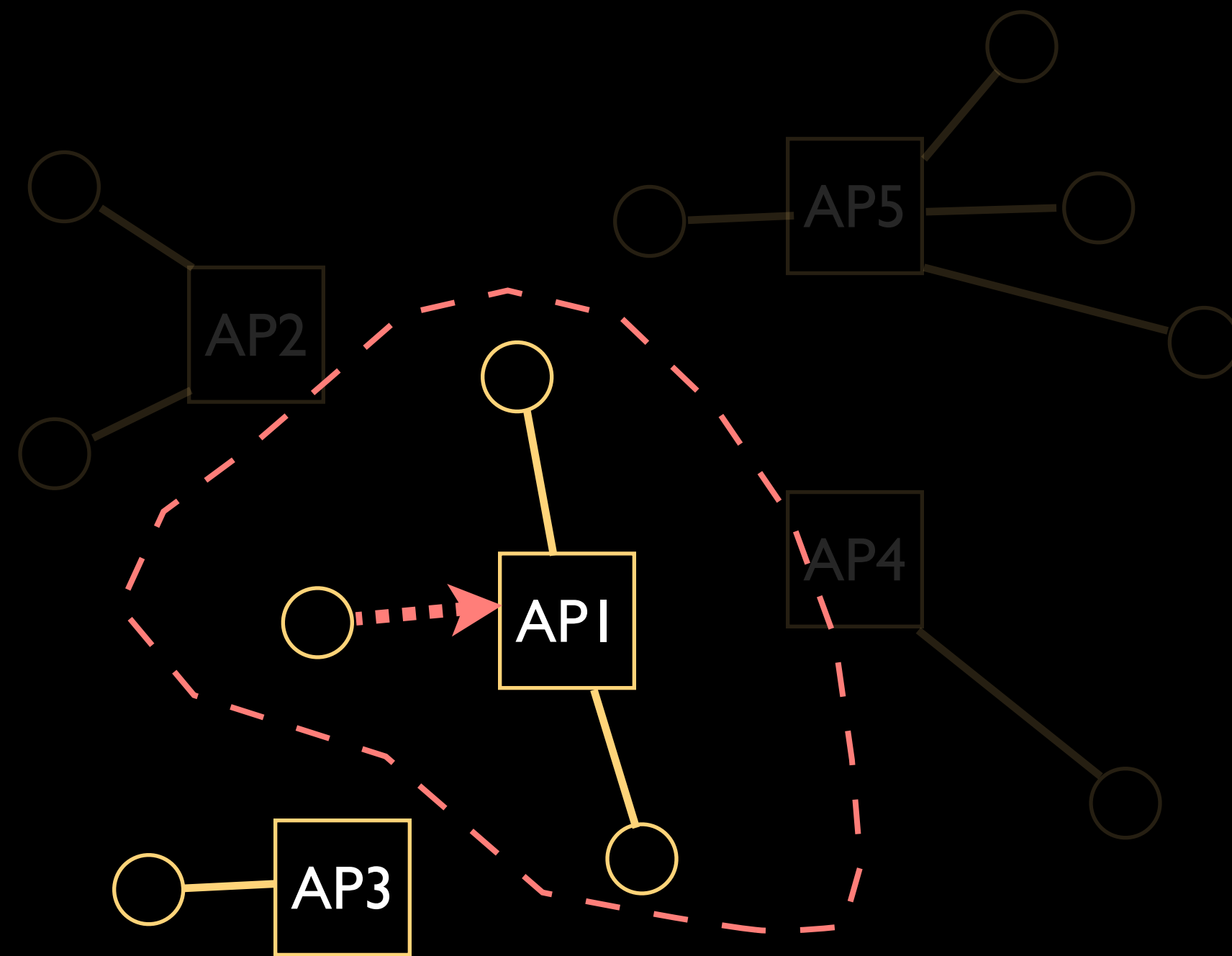


Mid-quality client group - AP3 serves one good client

Evaluation



Evaluation



With ACORN, higher congestion at AP1 (per-client throughput is reduced) but *aggregate throughput* does not change!

Conclusion

- Demonstrated that CB may hurt throughput even in isolation.
 - User association becomes critical and is coupled with channel width selection.
- ACORN performs both functions in tandem
 - the goal is to maximize network throughput (NP-hard).
 - outperforms state-of-the-art by as much as 6x via careful selection of channel width.