No Time to Countdown: Backing Off in Frequency Domain

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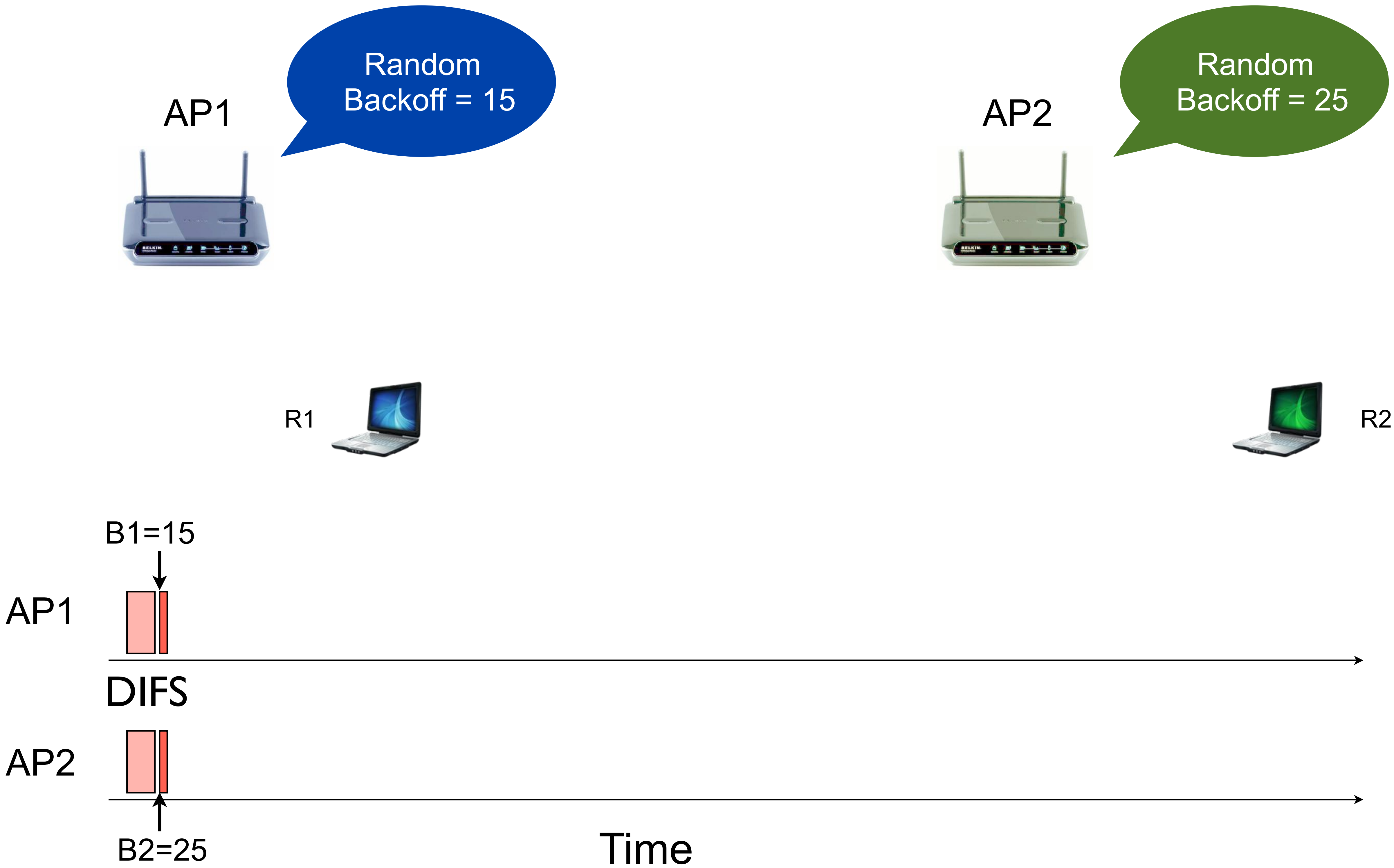
Current WiFi Channel Contention



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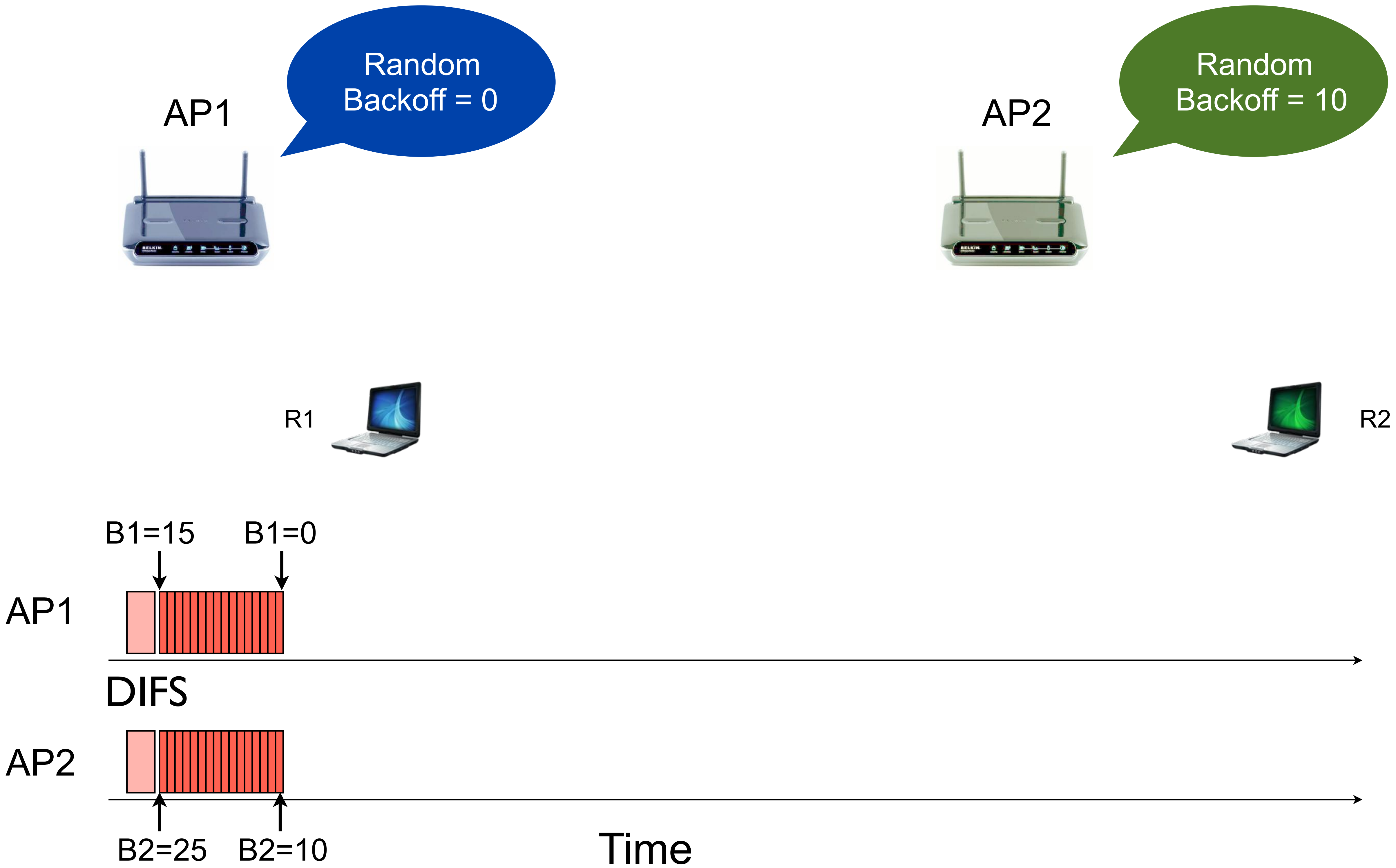

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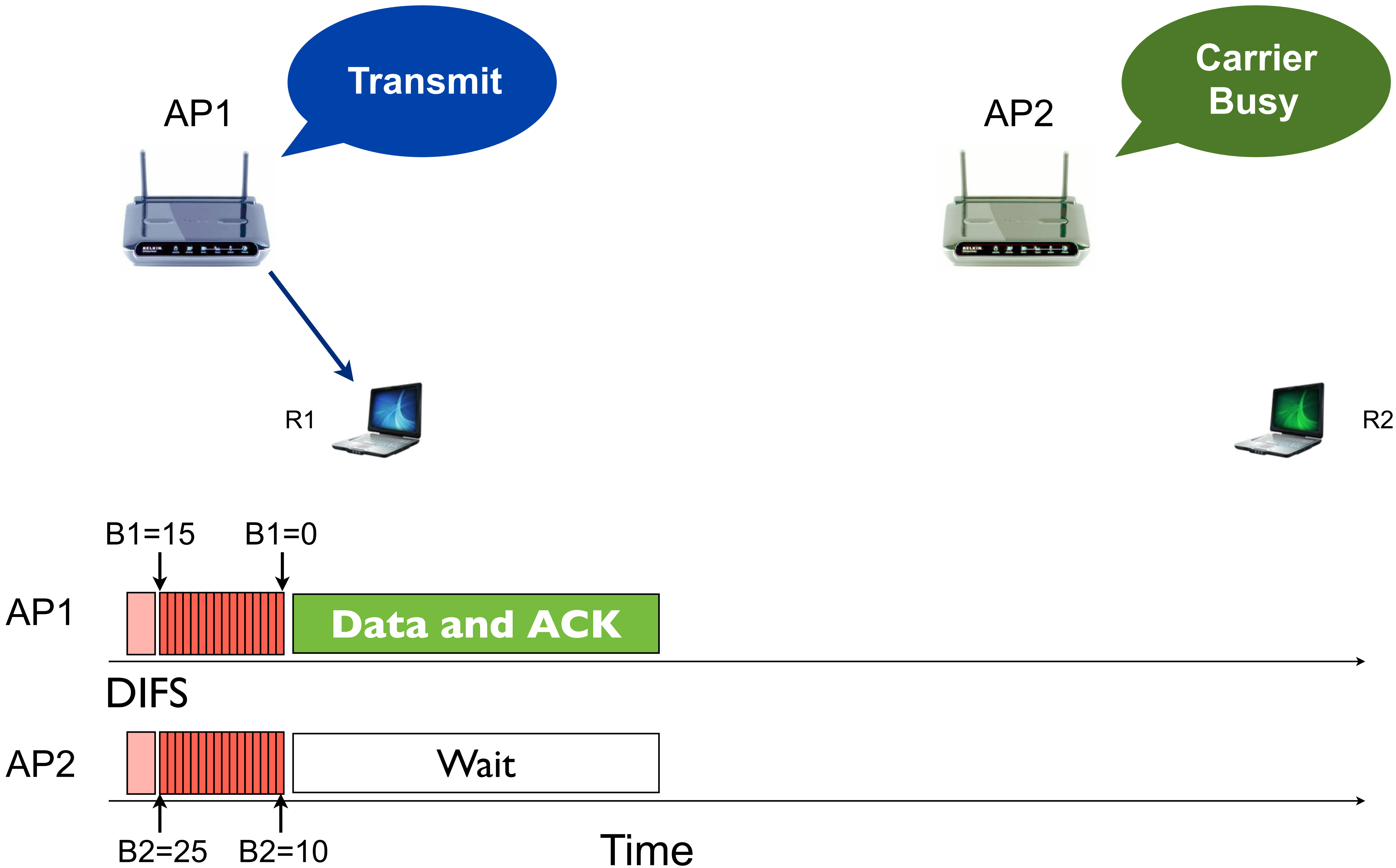

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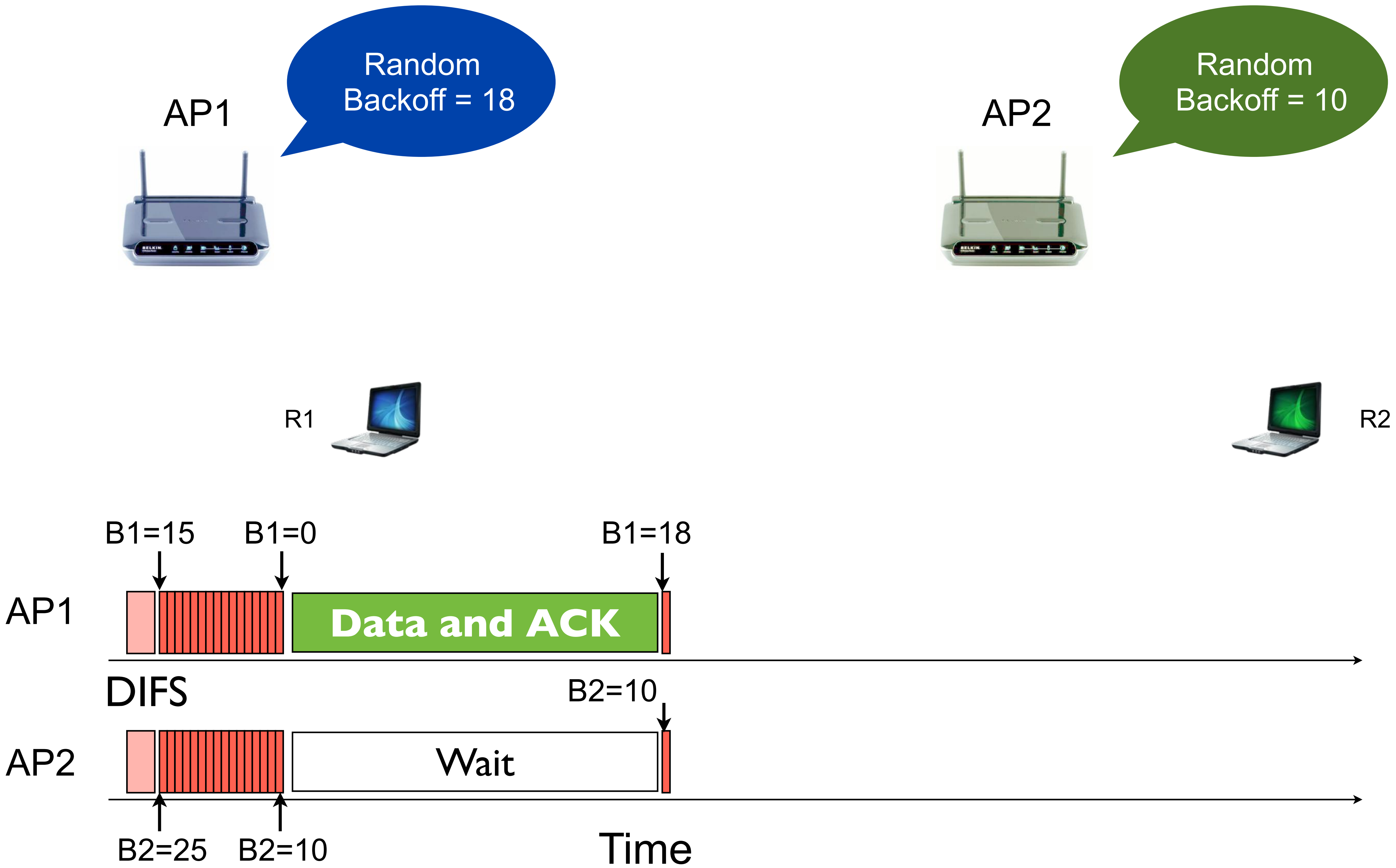

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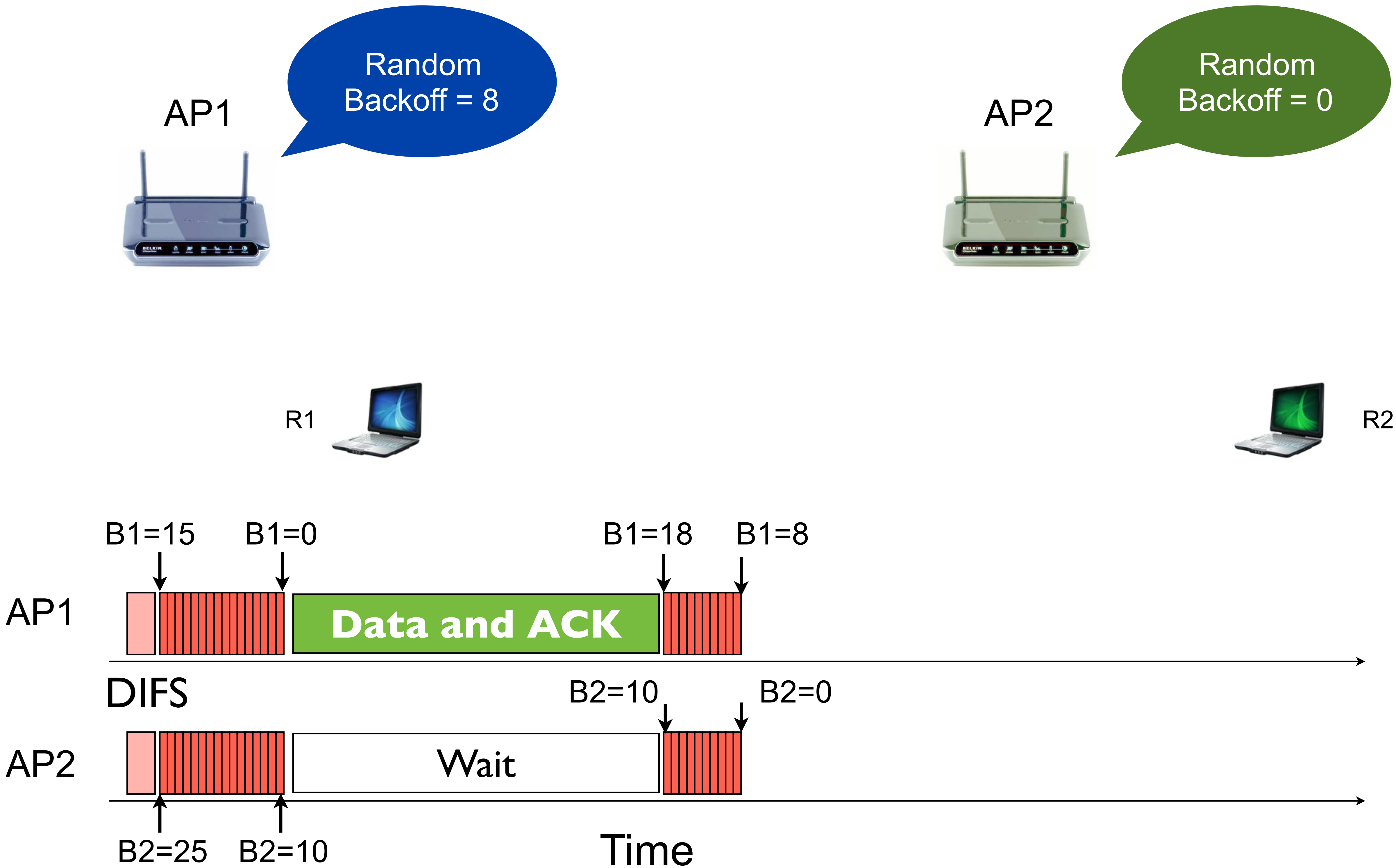

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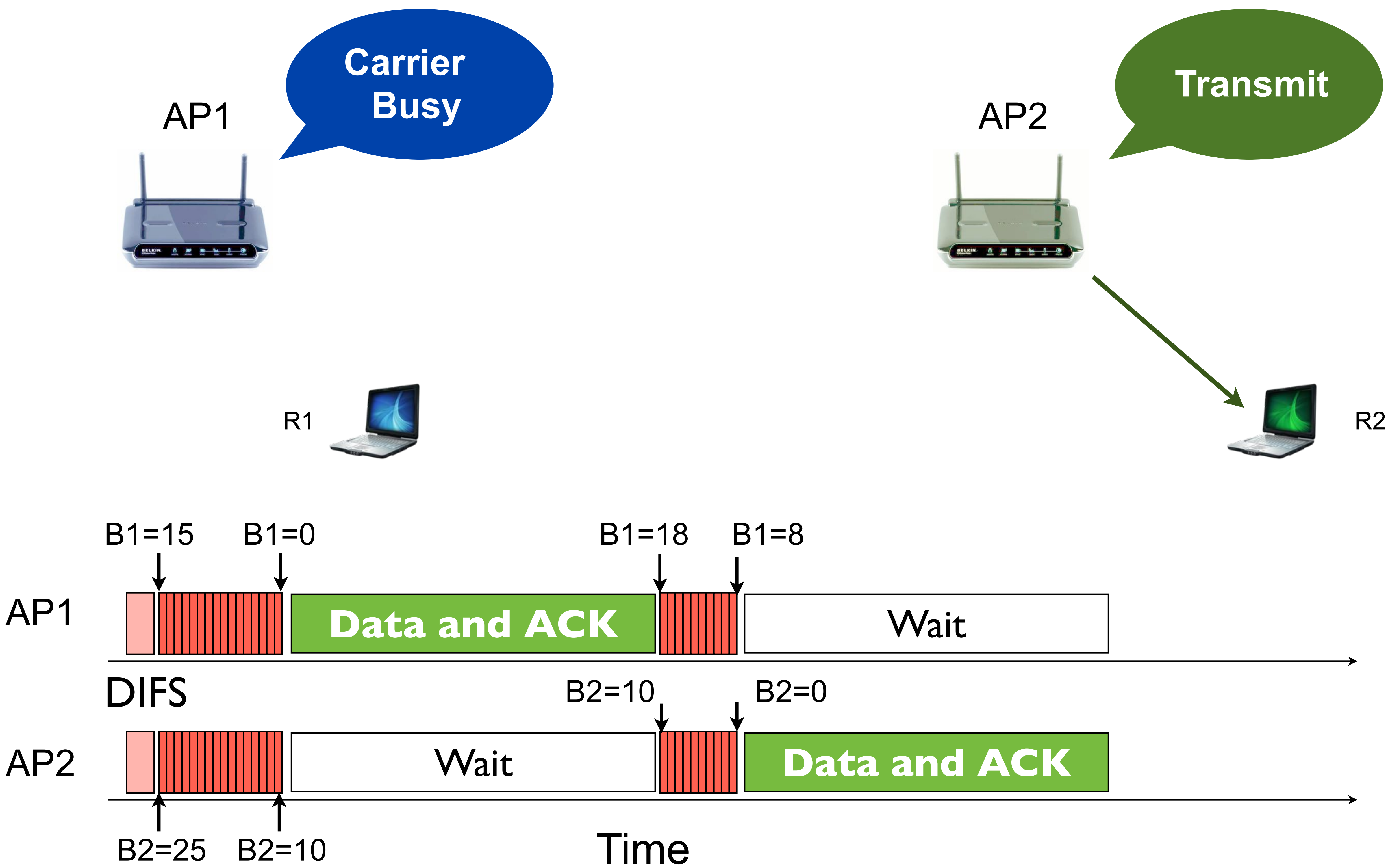

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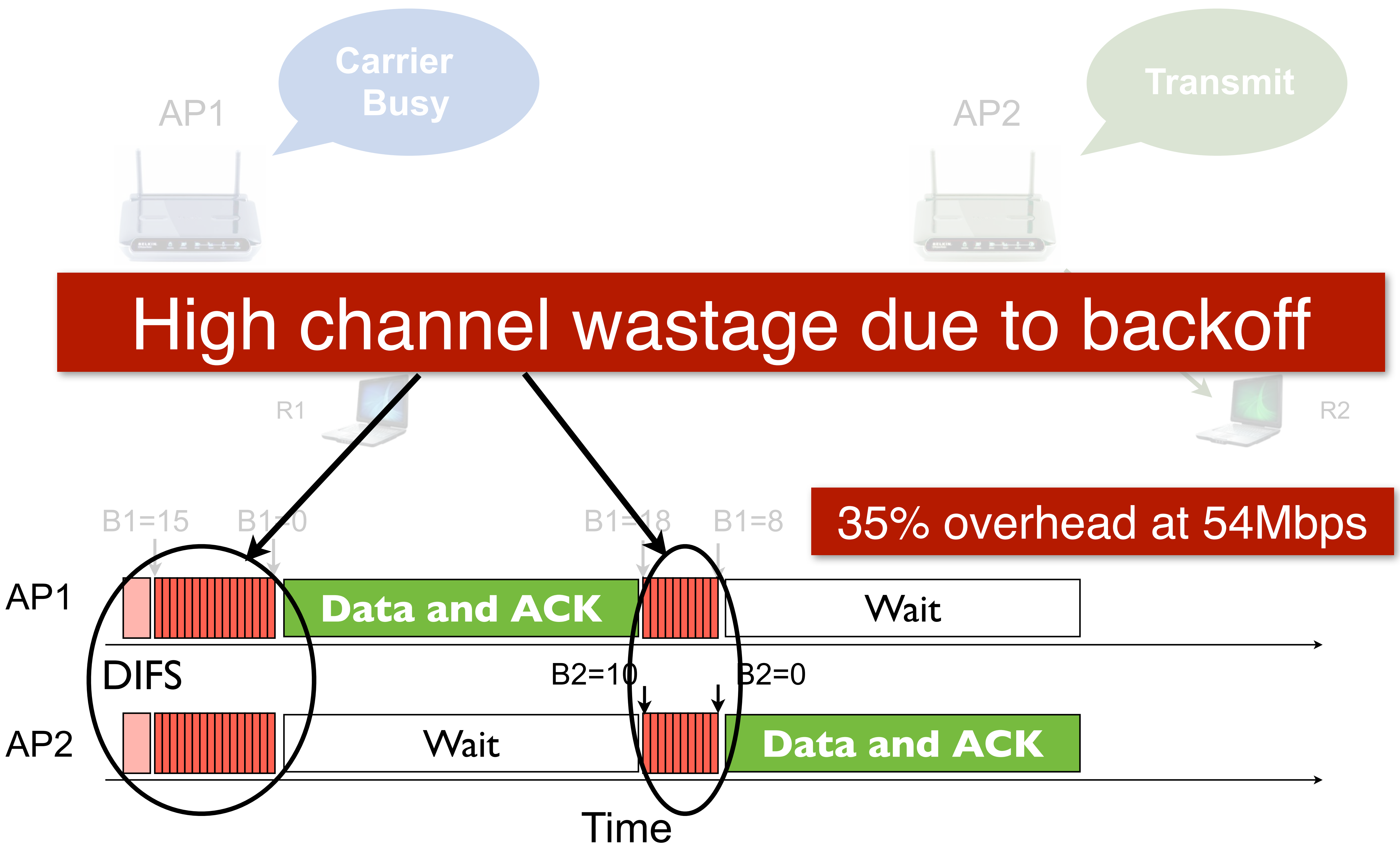
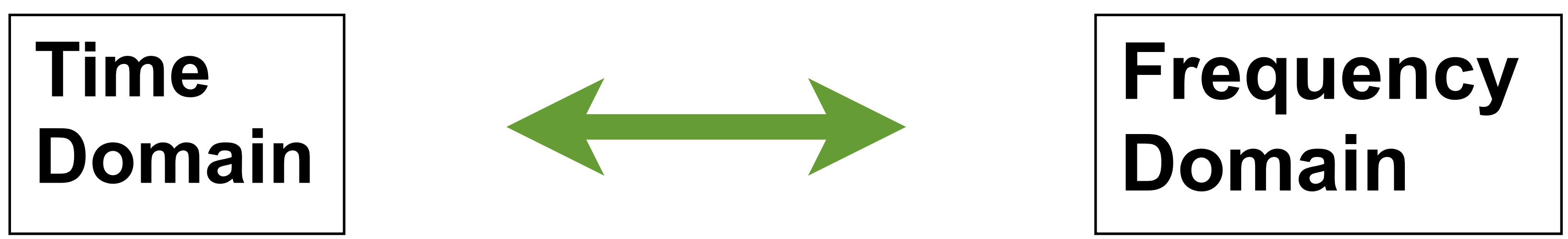


Current WiFi Channel Contention

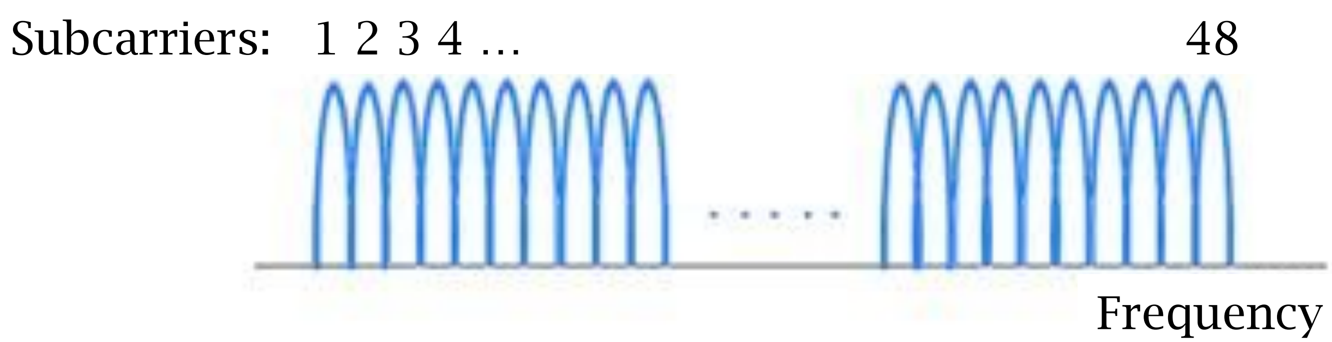
- Backoff is not fundamentally a time domain operation
  - Its implementation is in time domain



**Can we implement backoff in frequency domain?
Are there any benefits in doing so?**

Frequency domain contention resolution

- 802.11 a/g/n PHY adopts OFDM
  - Wideband channel divided into 48 narrowband subcarriers
  - Copes better with fast, frequency selective fading
  - Purely a PHY motivation

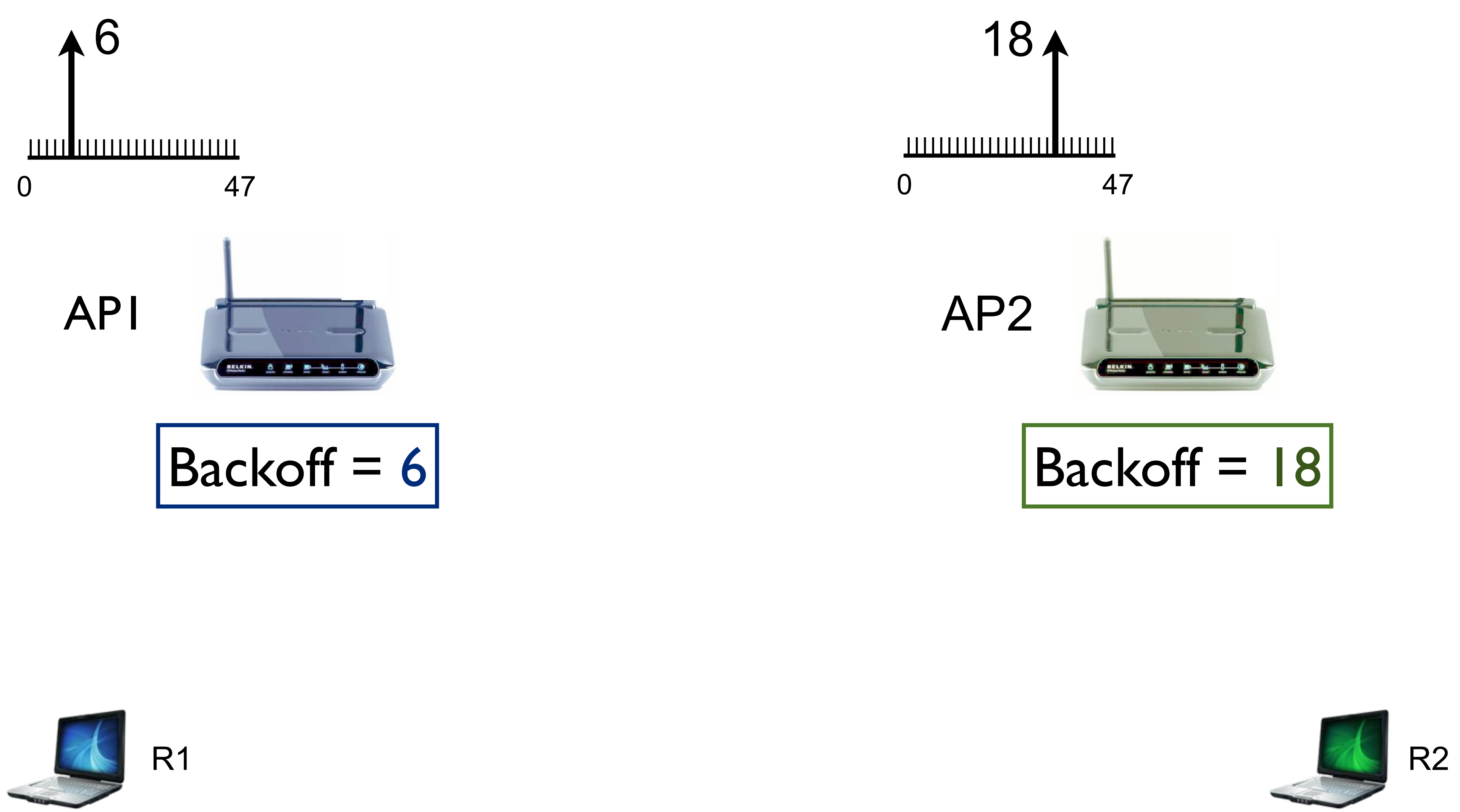


We propose Back2F

- MAC Opportunity: Pretend OFDM subcarriers as integers
- Emulate randomized backoff

Back2F: Main Idea

- Replace temporal with subcarrier transmission



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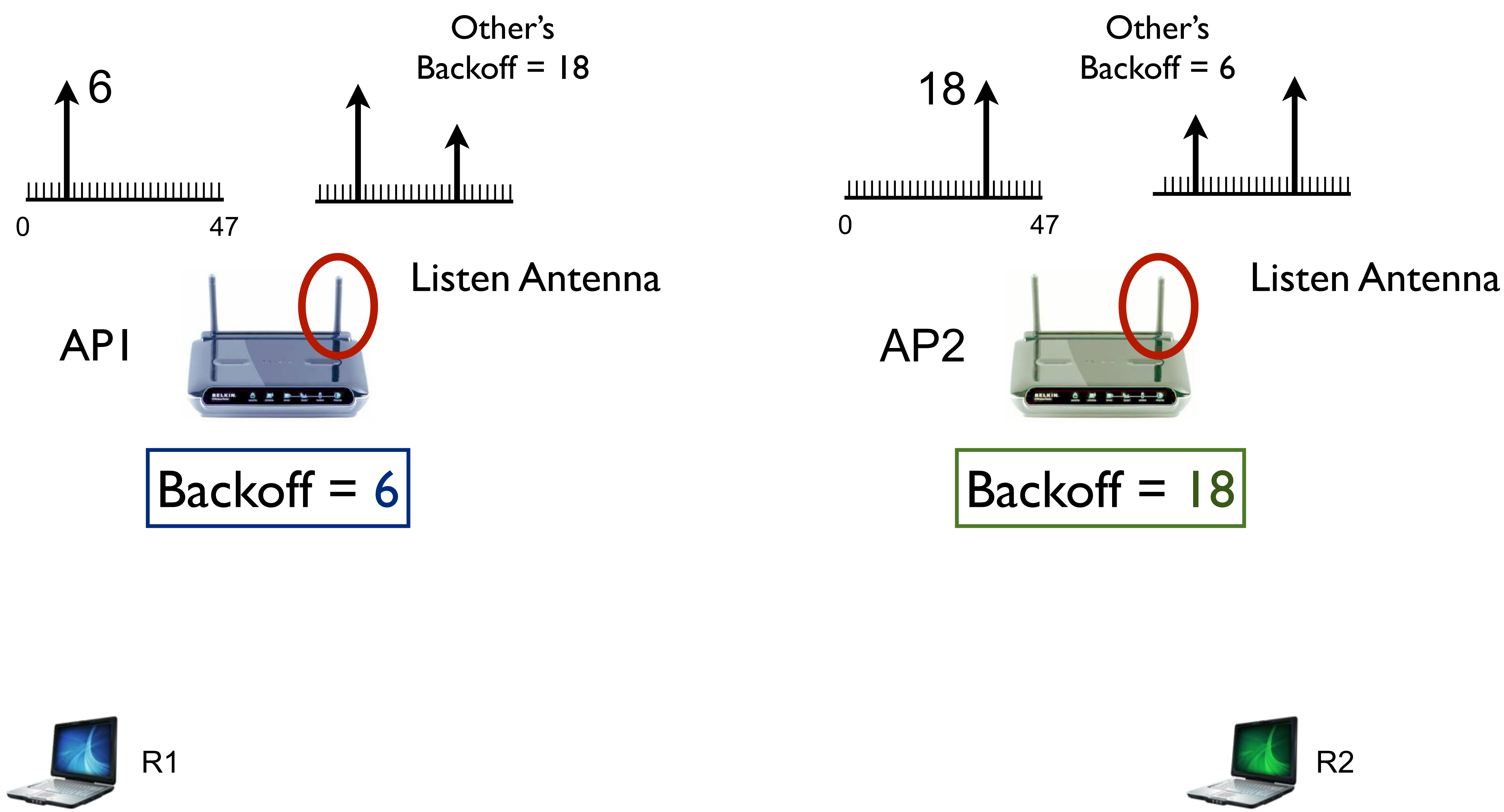
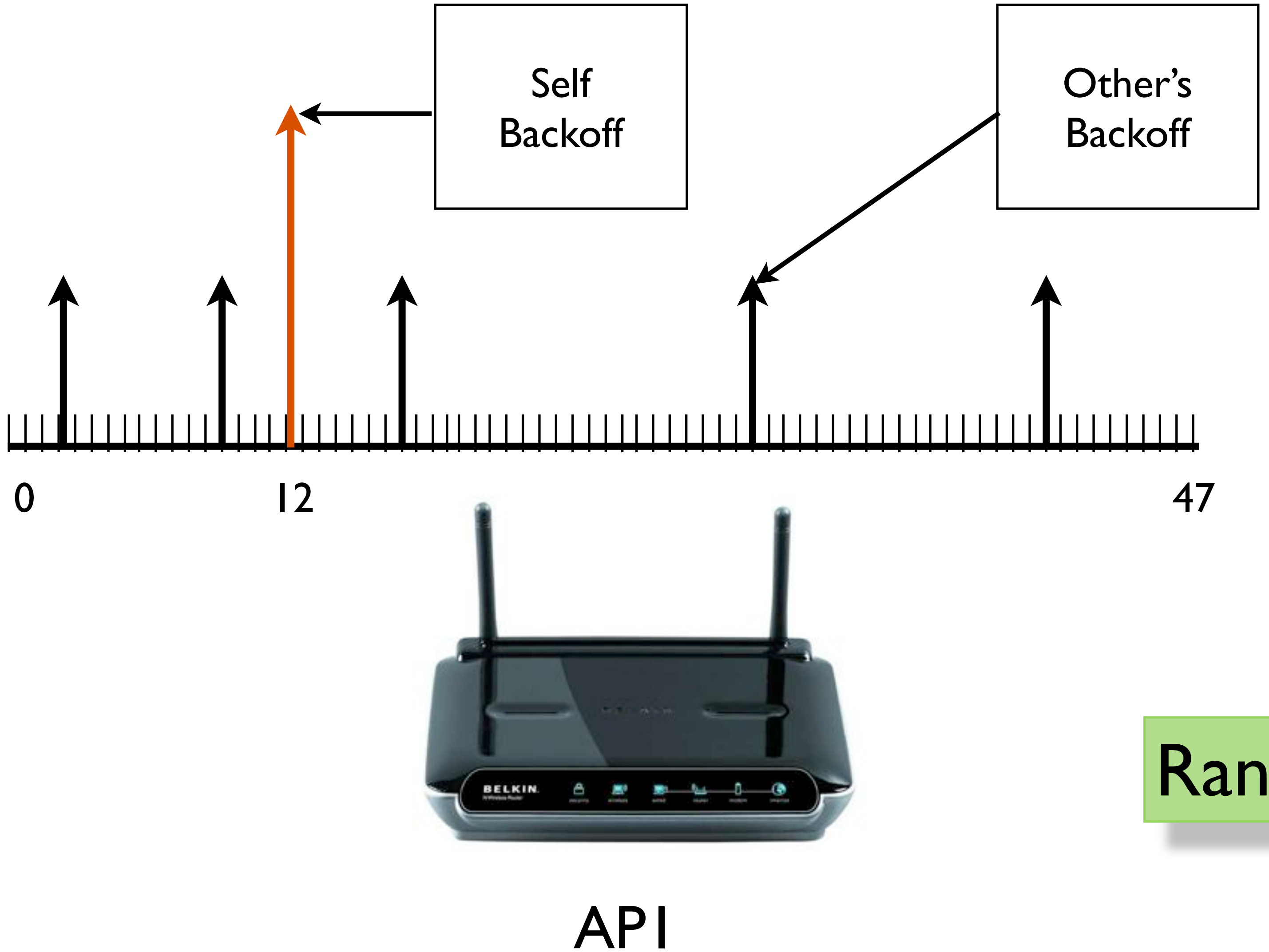


Both APs learn AP1 is the winner

Back2F: Scheduled Transmission

- Active subcarriers imply backoff chosen by other APs
  - Each AP knows its rank in the sequence
  - Enables back to back TDMA like transmission



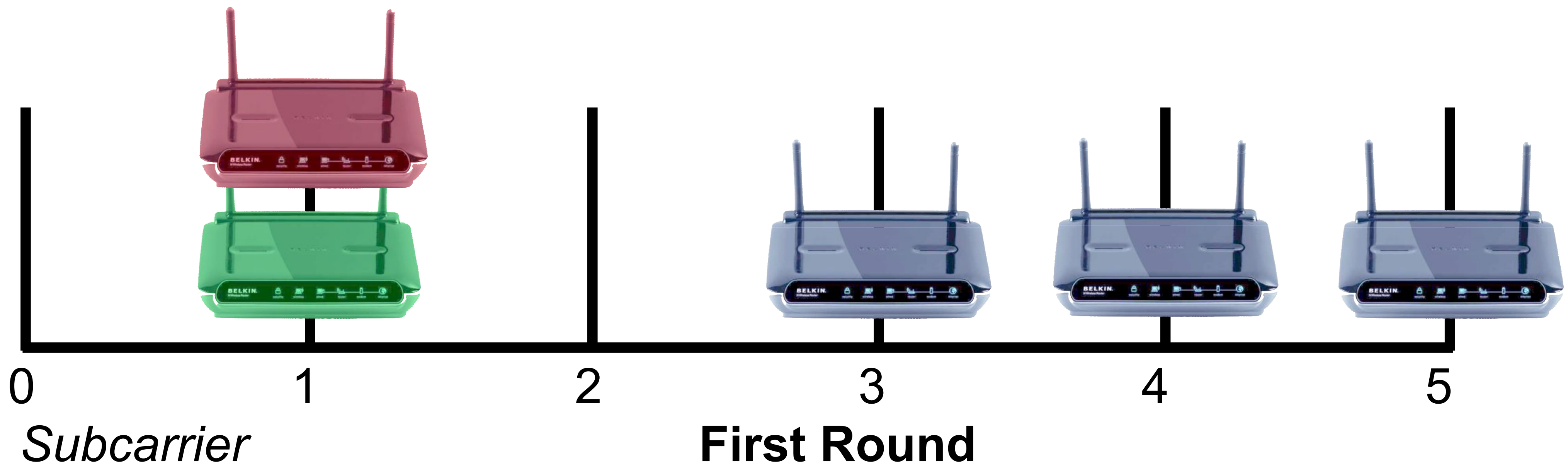
Rank in TDMA: 3

Is there a benefit with frequency domain backoff?

- 1500 bytes at 54Mbps ~ 250 micro sec.
- Avg. temporal backoff ~ 100 micro sec.
- Frequency backoff = 1 OFDM symbol = 4 micro sec

Will APs Collide During Contention?

- Introduce a second round of contention
  - Winners of first go to second



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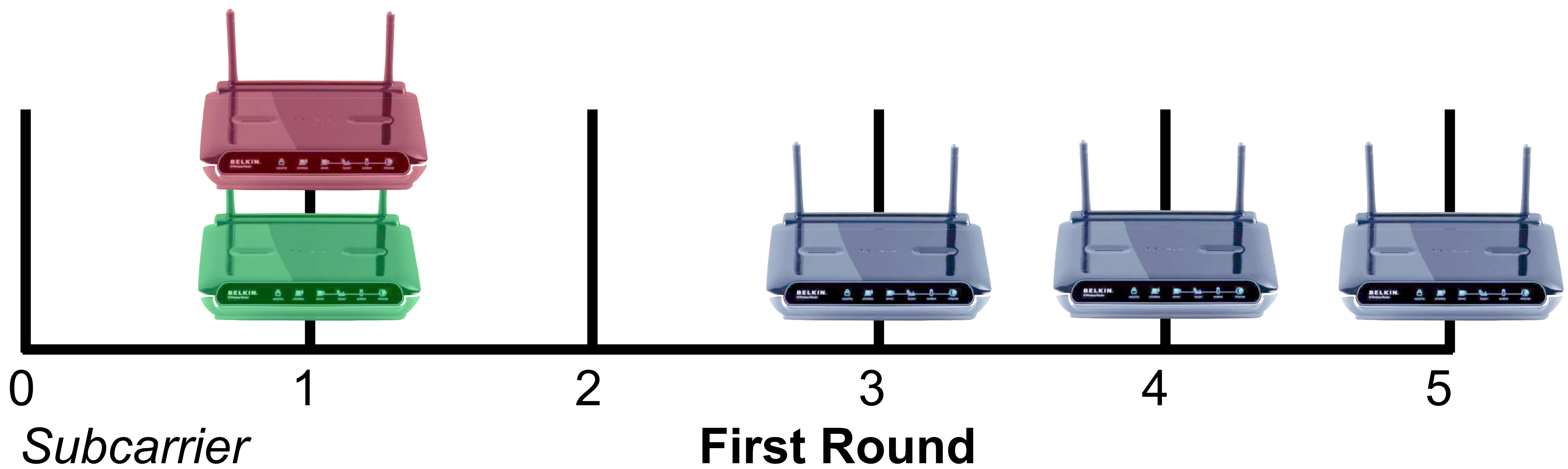
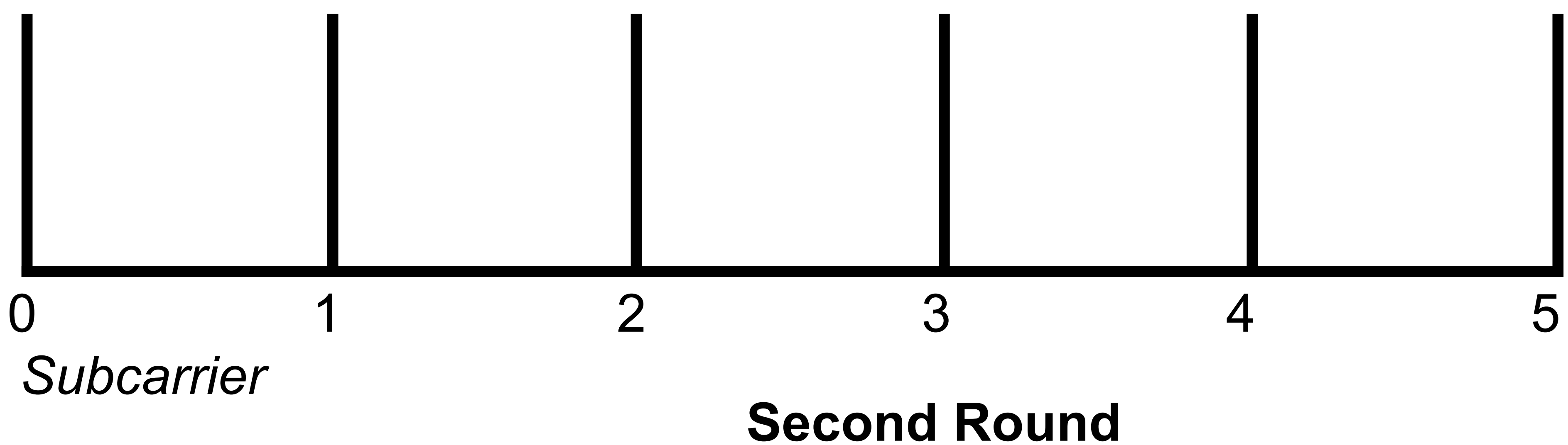


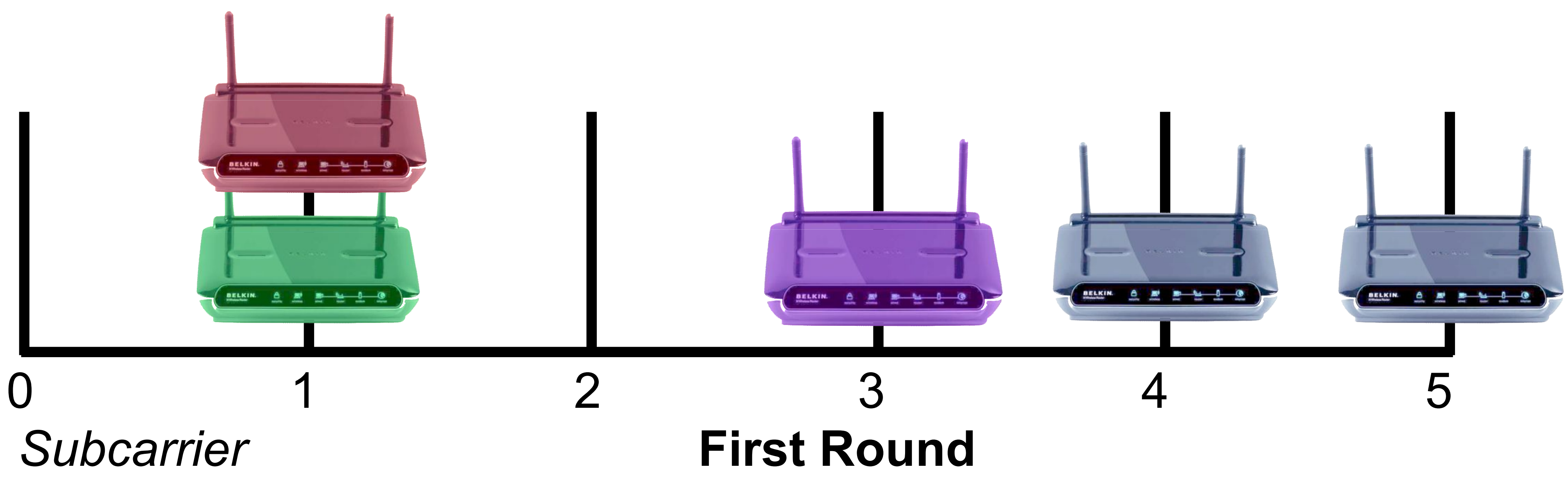


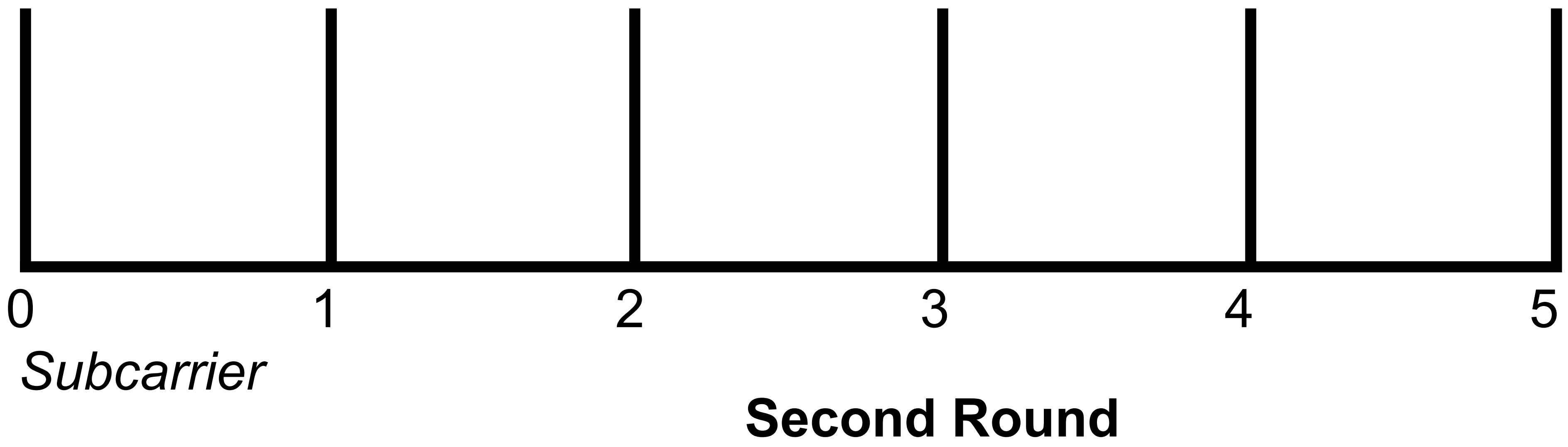
Only a Few APs in Second Round?

TDMA will not be effective

Optimize for TDMA

- Instead of only winners, a few more APs to second round





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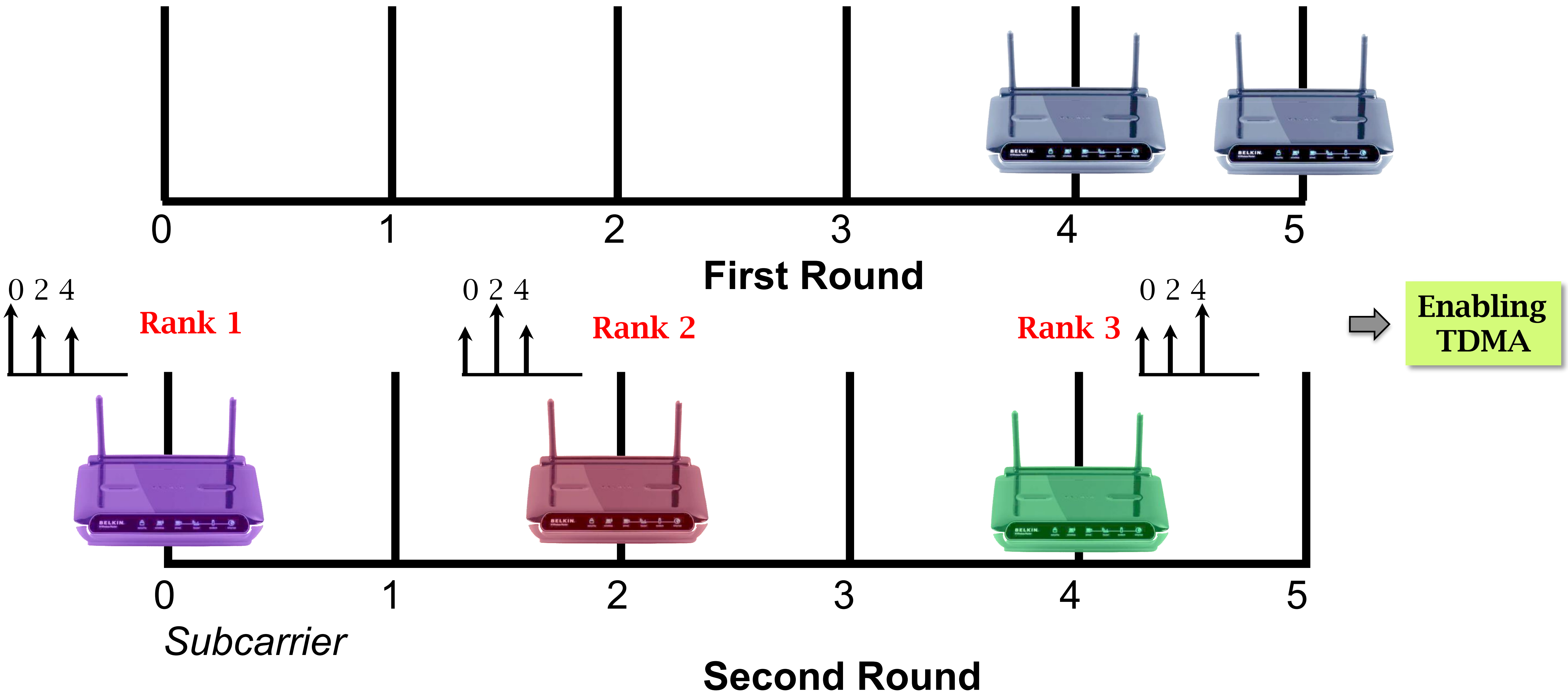
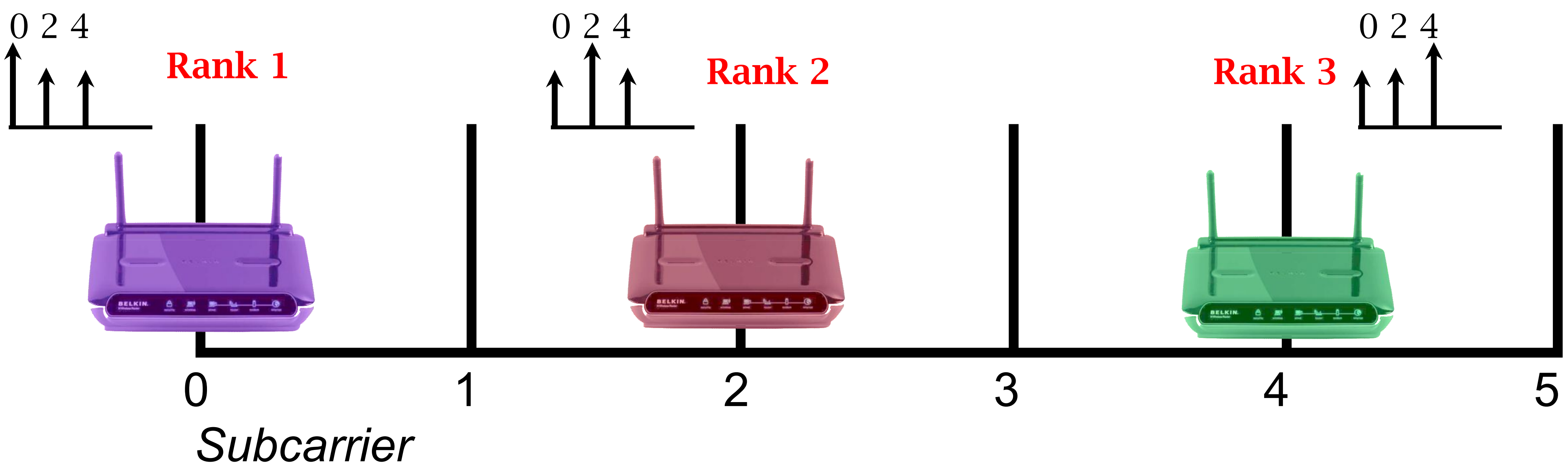
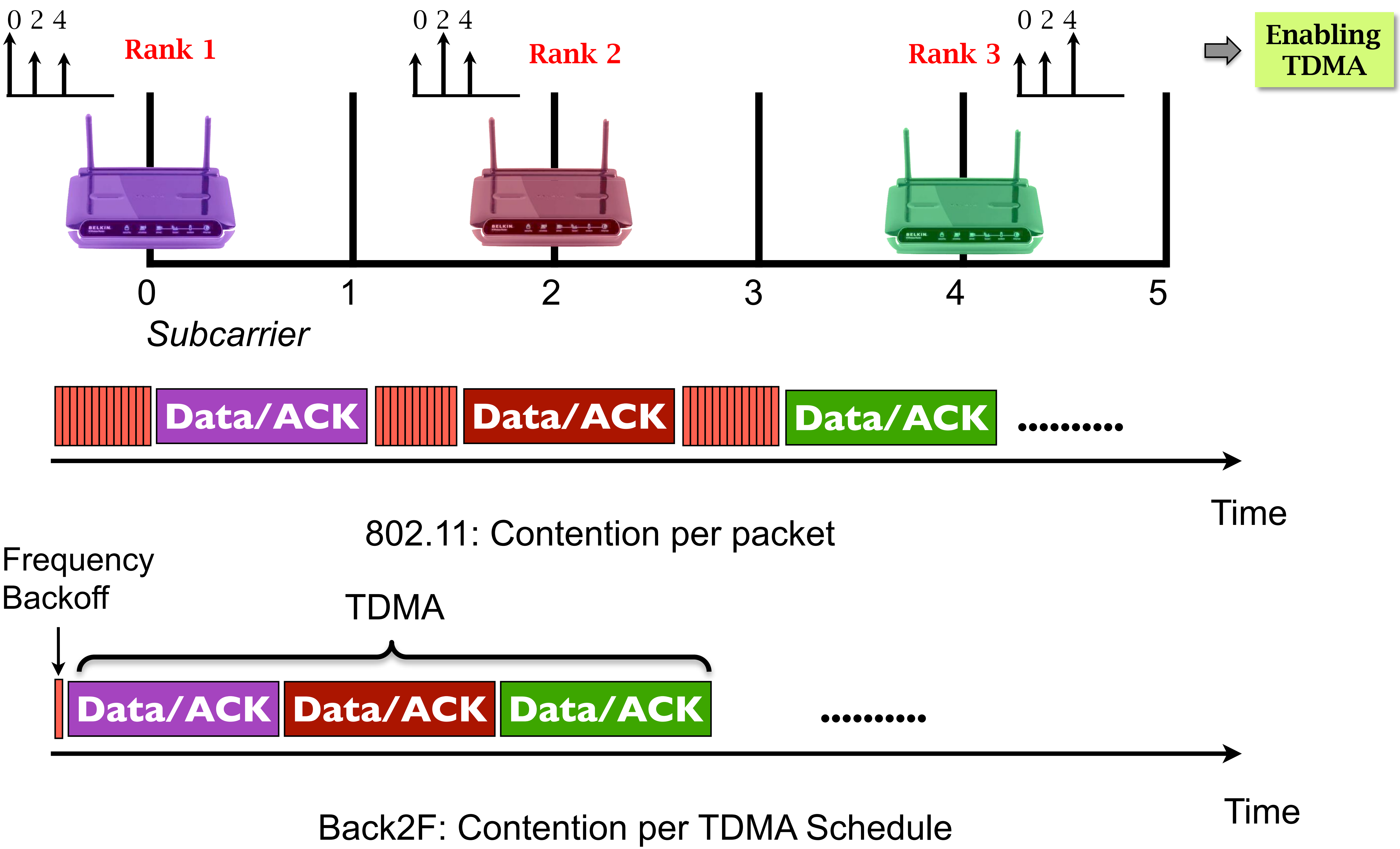


Improved Channel Utilization



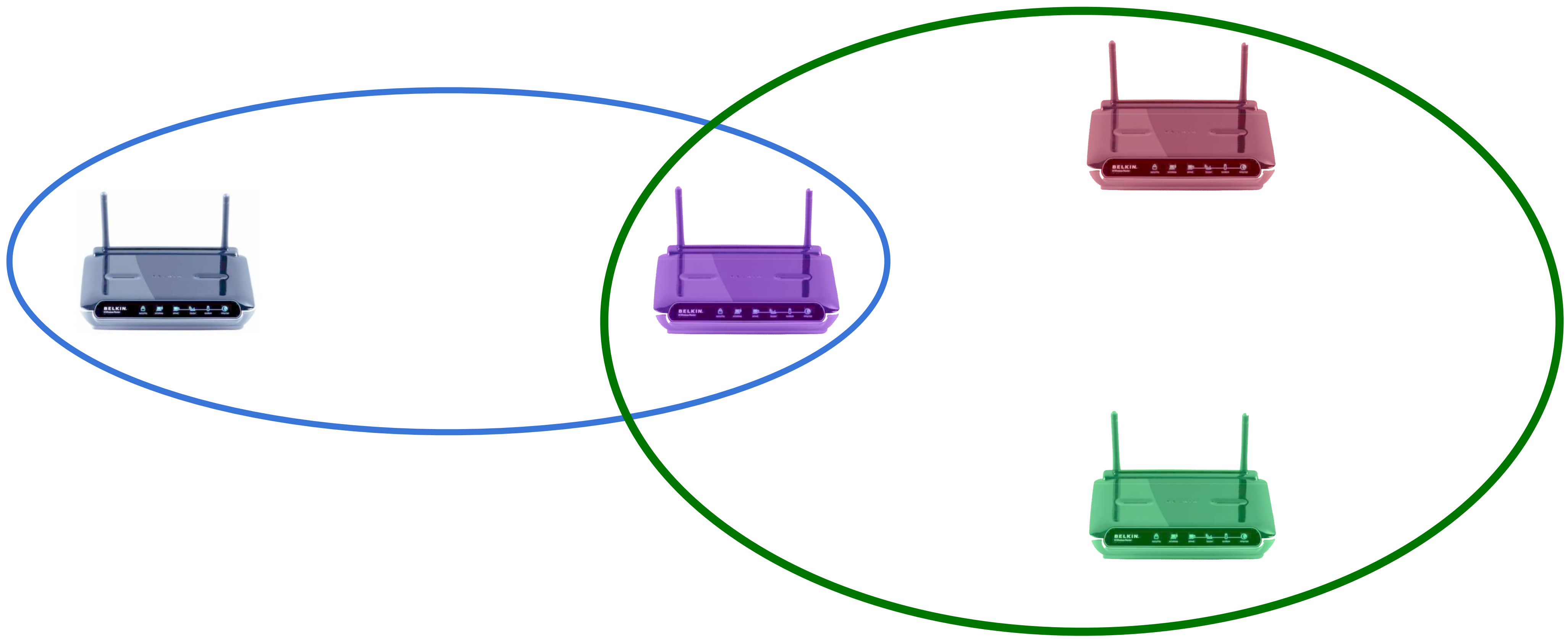
Enabling TDMA

Improved Channel Utilization



Multiple Collision Domains

- Does Back2F work with real-world scattered APs?



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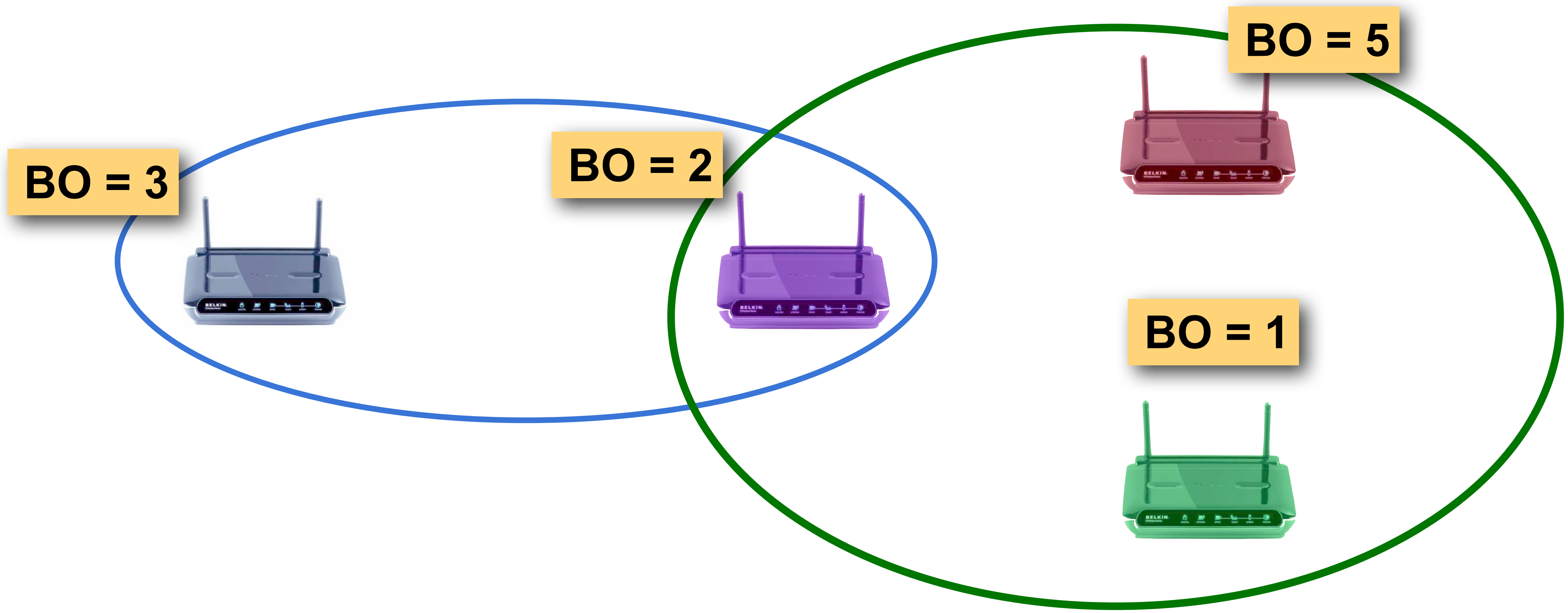

- **Blue** waits for **Purple**, but **Purple** waits for **Green**
- But Blue and Green should transmit simultaneously
  - **Lost transmission opportunity**
  - **However 802.11 does not suffer from this problem**
  - Blue will wait for DIFS, continue counting down and eventually transmit

Multiple Collision Domains

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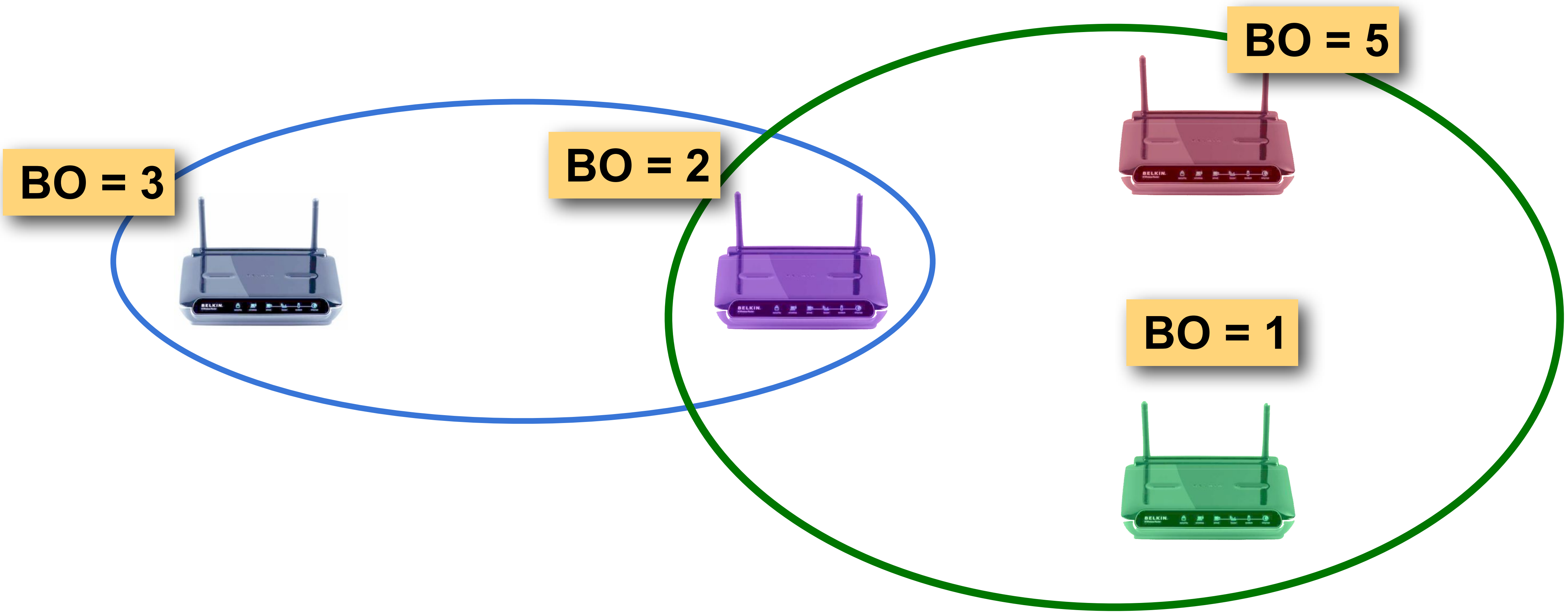

- Blue waits for Purple, but Purple waits for Green
- But Blue and Green should transmit simultaneously

Back2F Solution: Emulate 802.11

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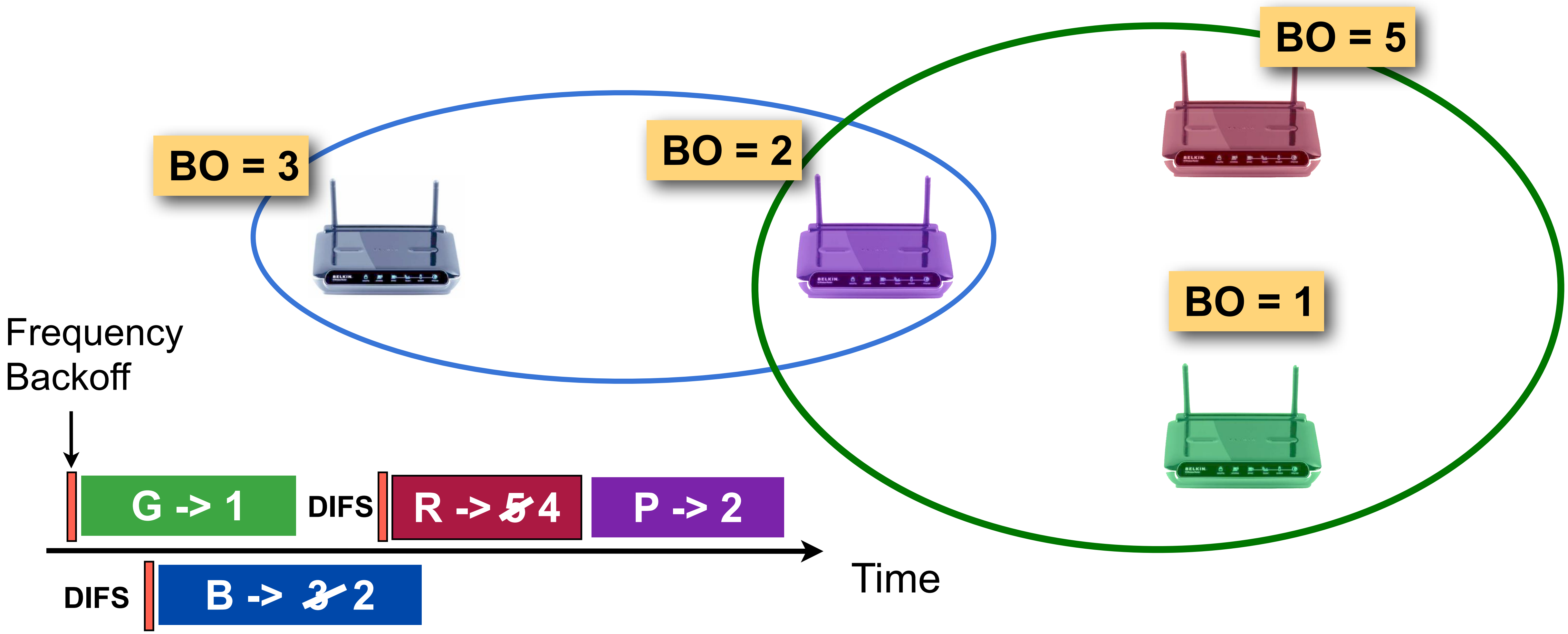
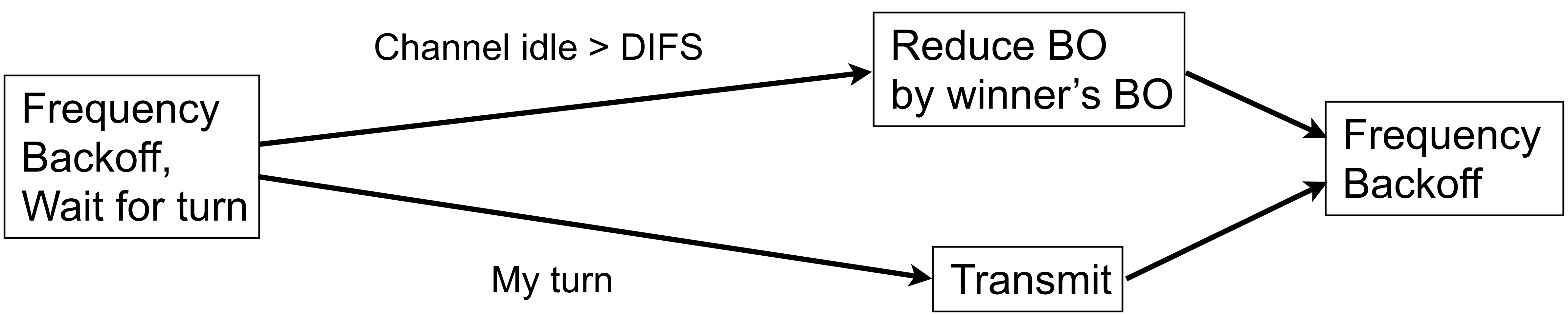
  - Blue will wait for DIFS, continue counting down and eventually transmit

Multiple Collision Domains





Back2F: Performance Evaluation

- Three important questions:
  - Can Back2F detect subcarriers reliably?
  - What is Back2F's collision probability?
  - How much throughput gain over 802.11?

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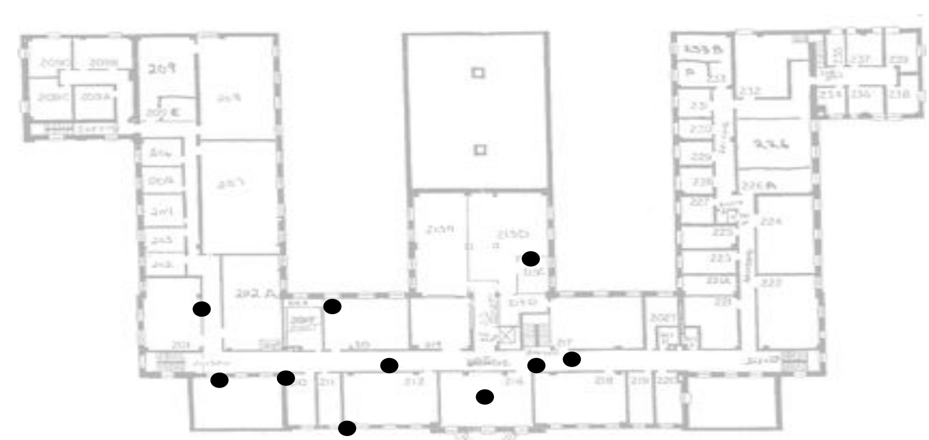
    - **Evaluated on USRP/Gnuradio**



  - What is Back2F's collision probability?
  - How much throughput gain over 802.11?
    - **Evaluated using traces at 65 locations**

Back2F: Performance Evaluation

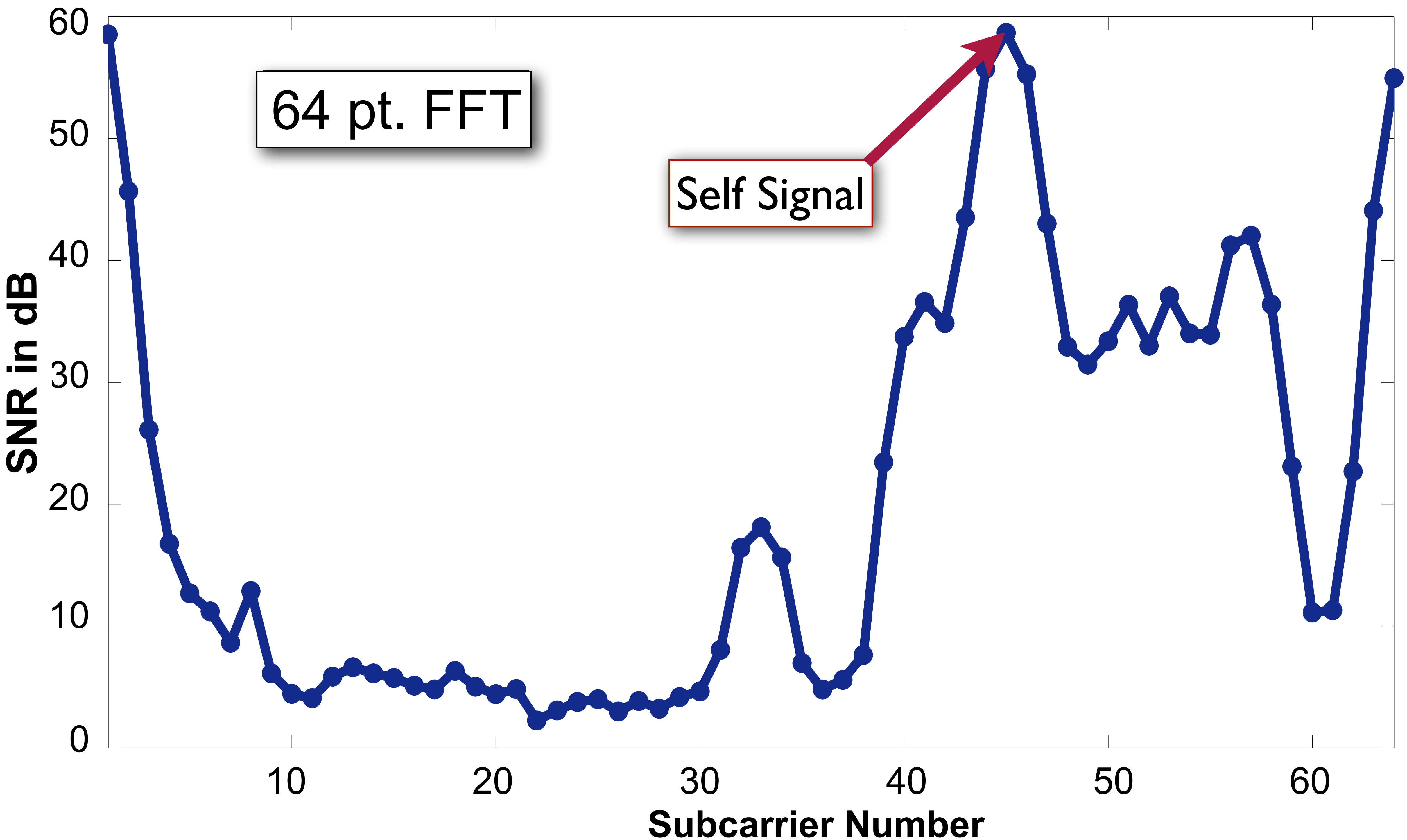
- Three important questions:
  - Can Back2F detect subcarriers reliably?
    - **Evaluated on USRP/Gnuradio**

Practical Challenge: High Self Signal

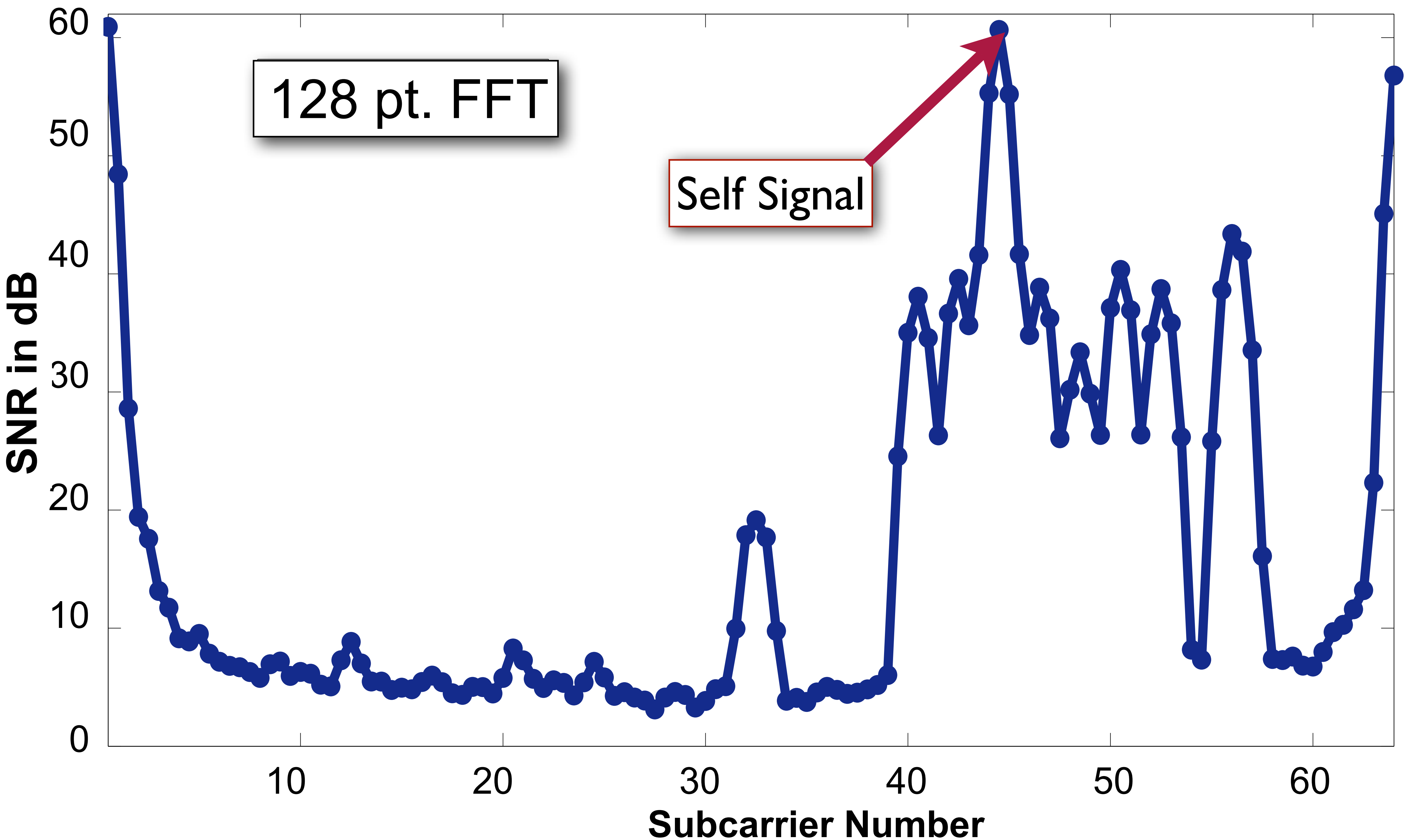
Transmit Antenna

Listen Antenna

Self Signal Overflows into Adjacent Subcarrier



Solution: Use a Higher Point FFT



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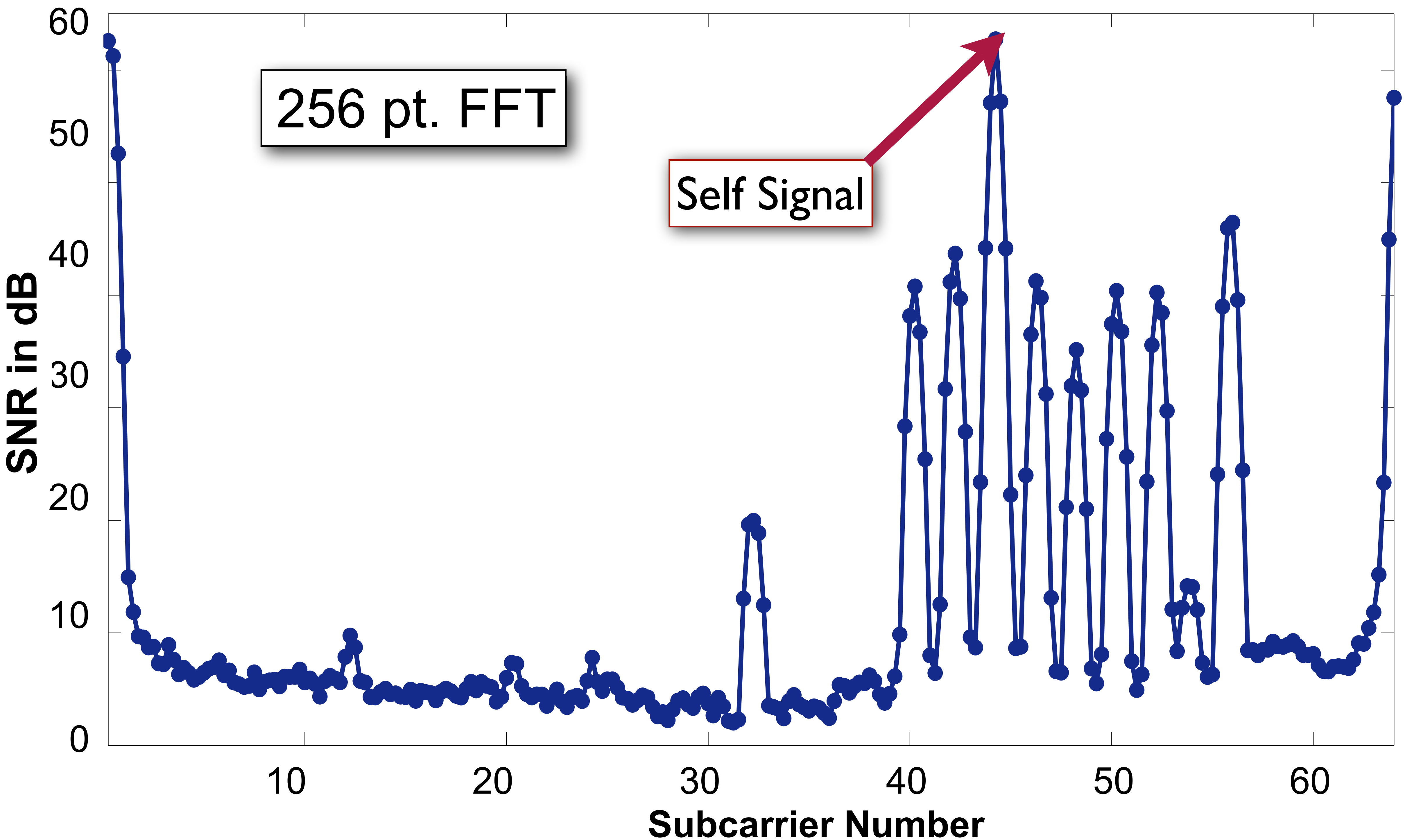
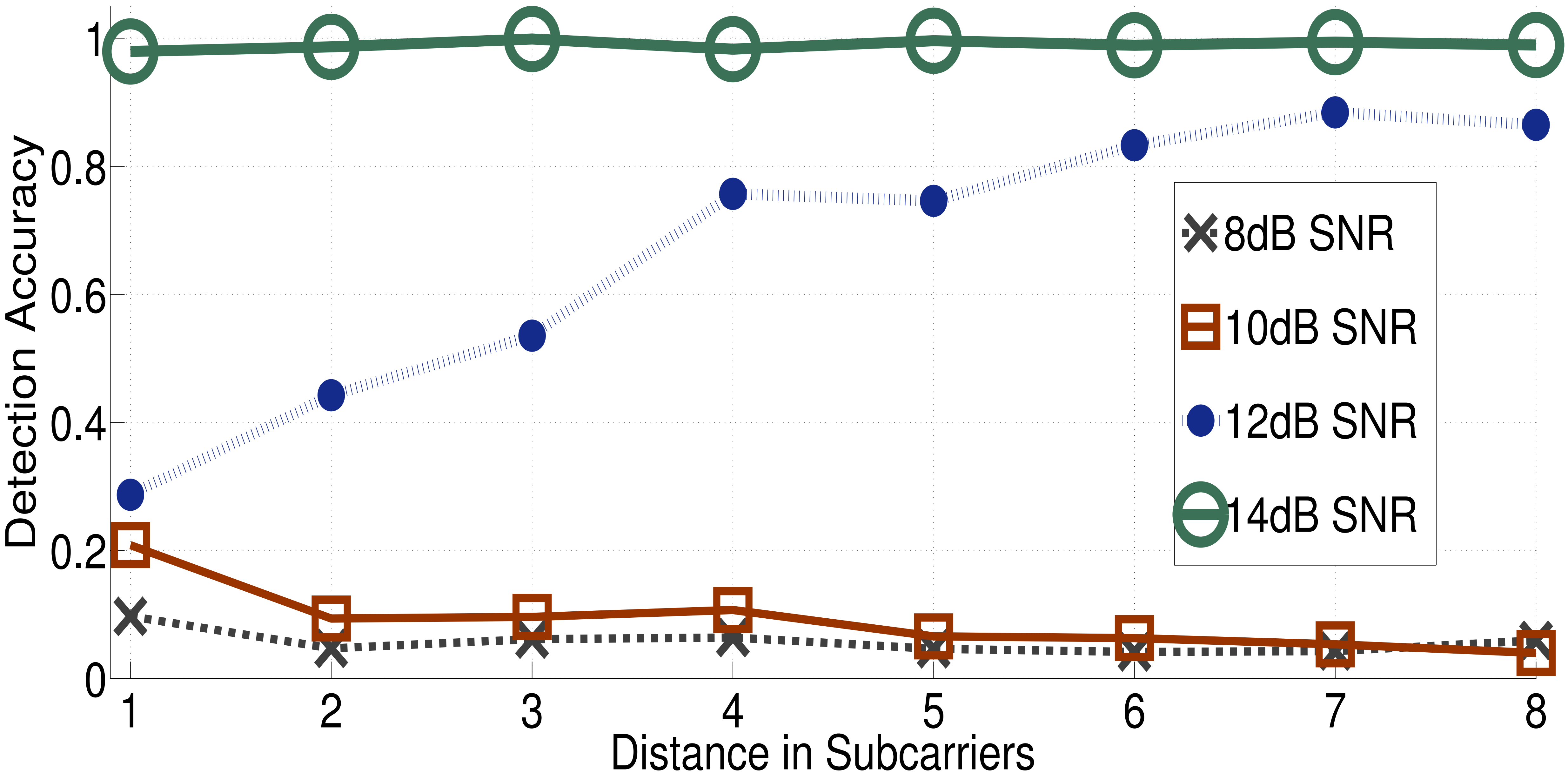


Subcarrier Detection Performance



Robust subcarrier detection at 14dB

Back2F: Performance Evaluation

- Collect traces to answer:
  - What is Back2F's collision probability?
  - How much throughput gain over 802.11

20 AP locations
45 client locations

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  - What is Back2F's collision probability?
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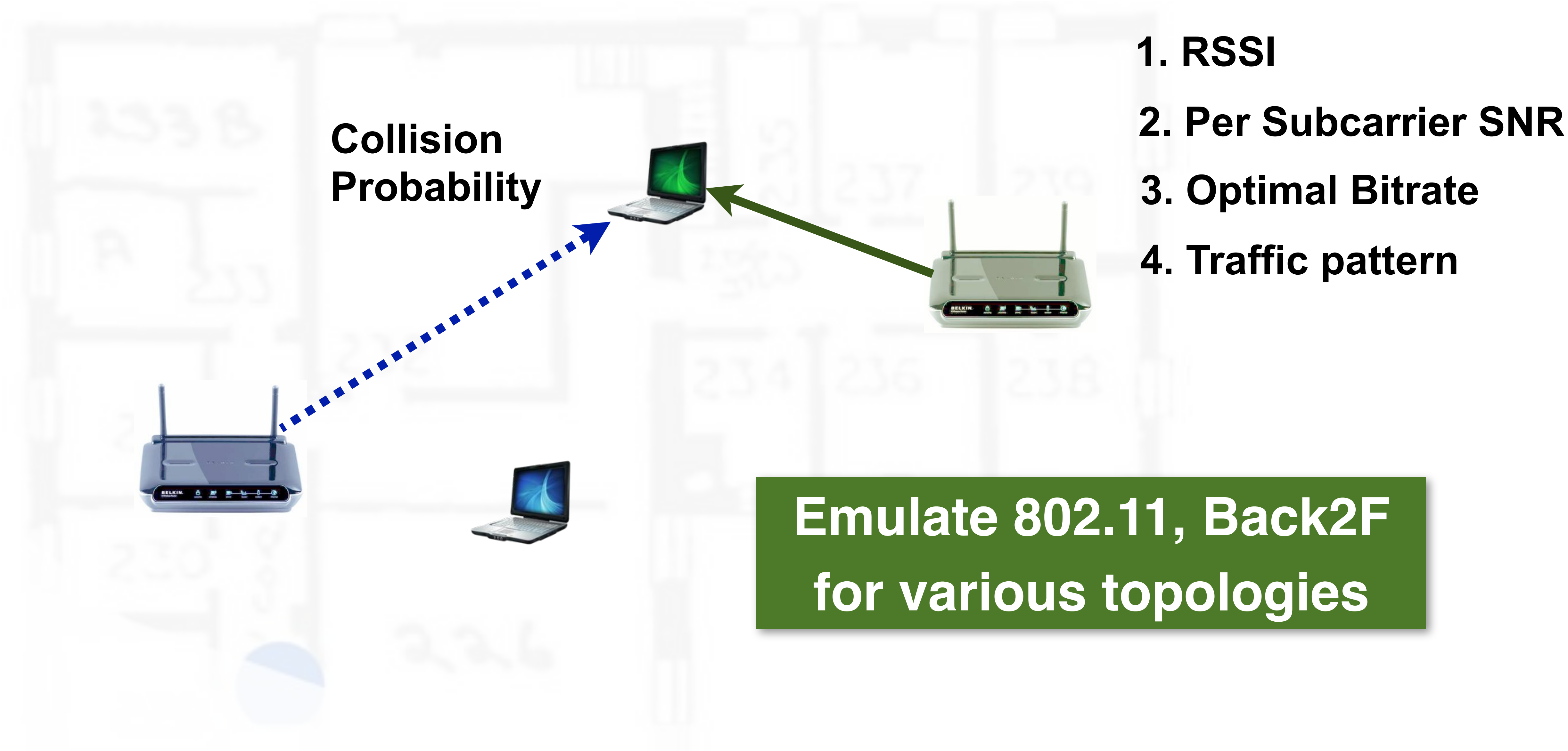
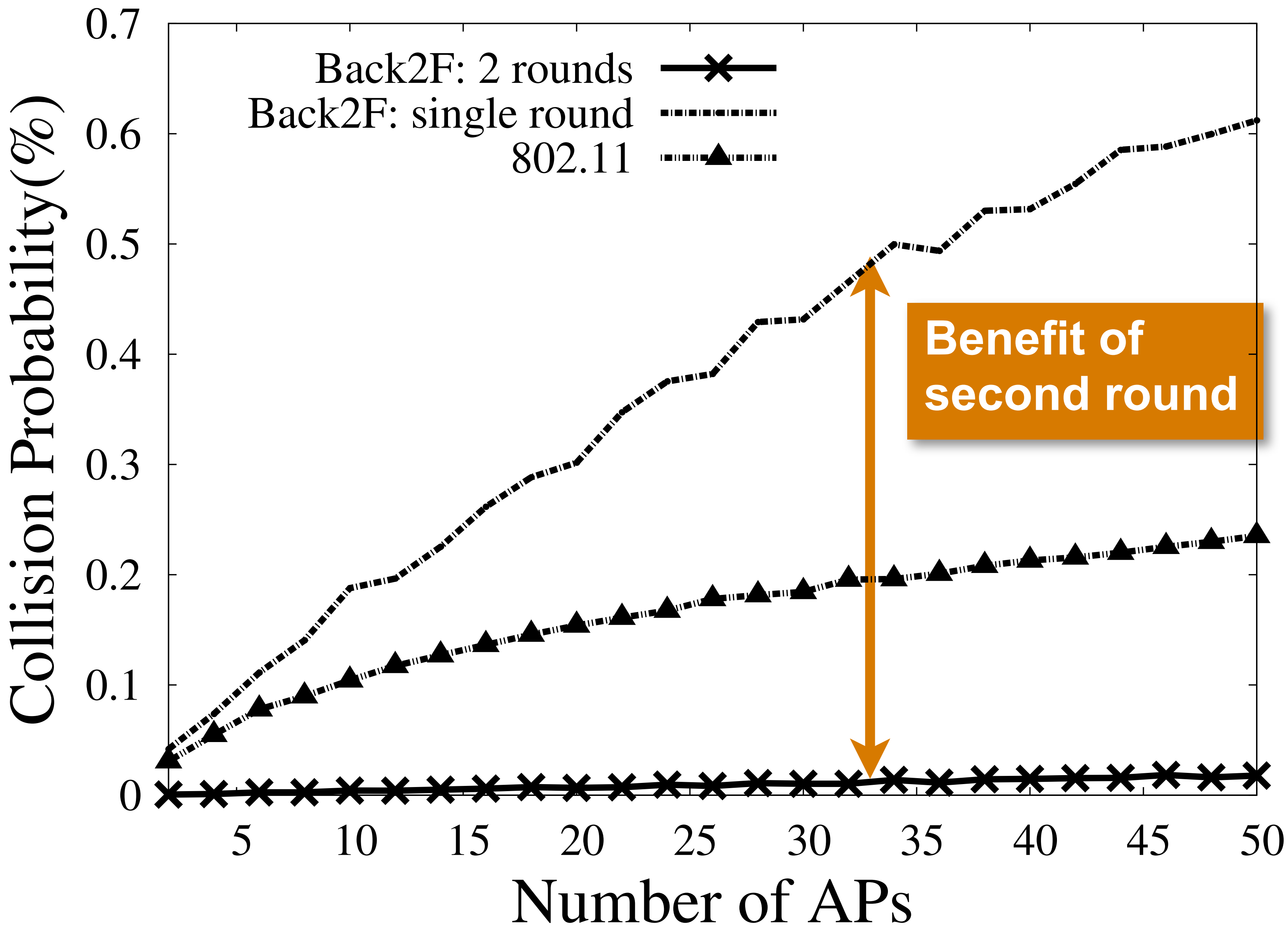


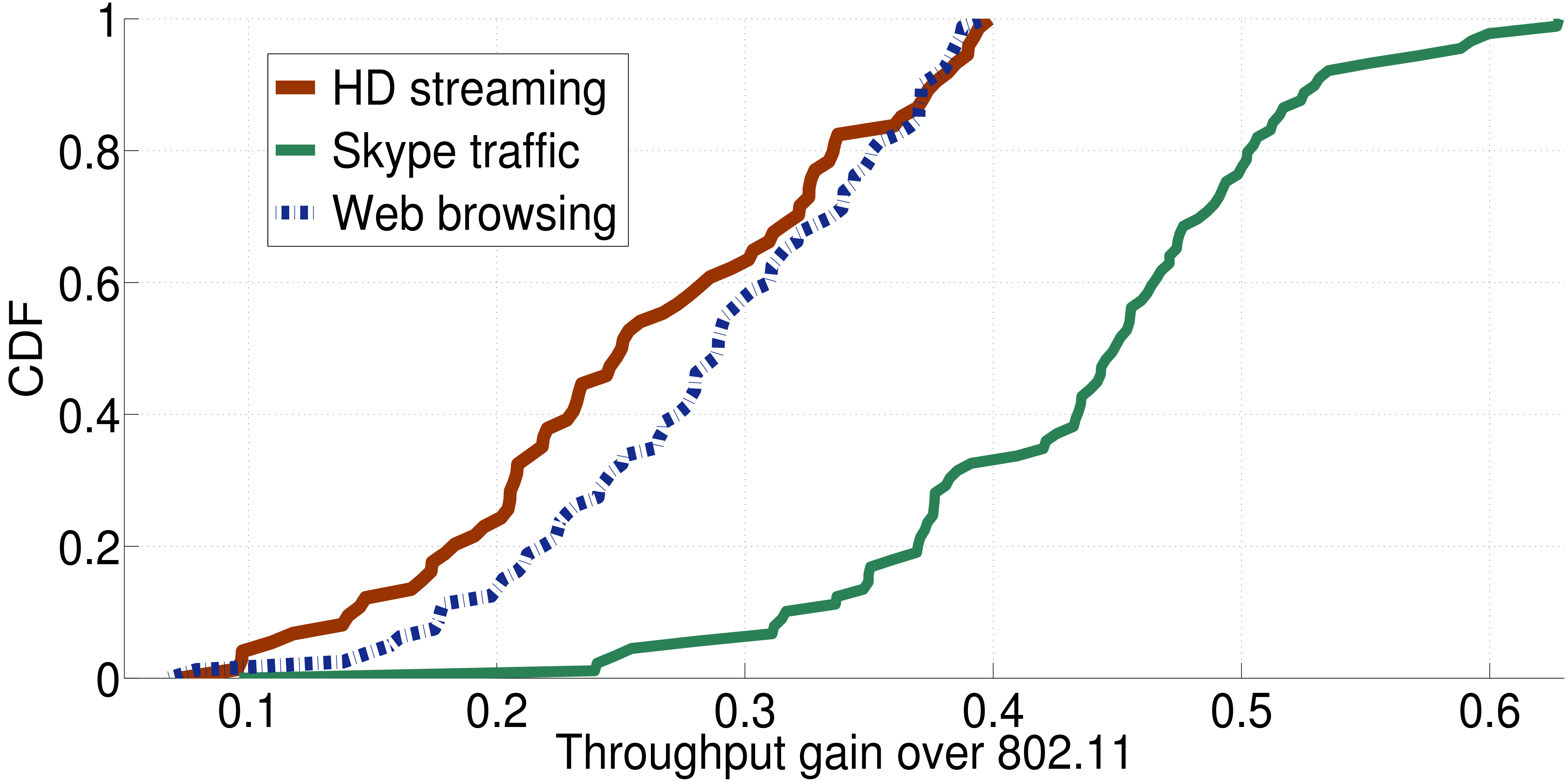
Emulate 802.11, Back2F for various topologies

Back2F: Collision Probability



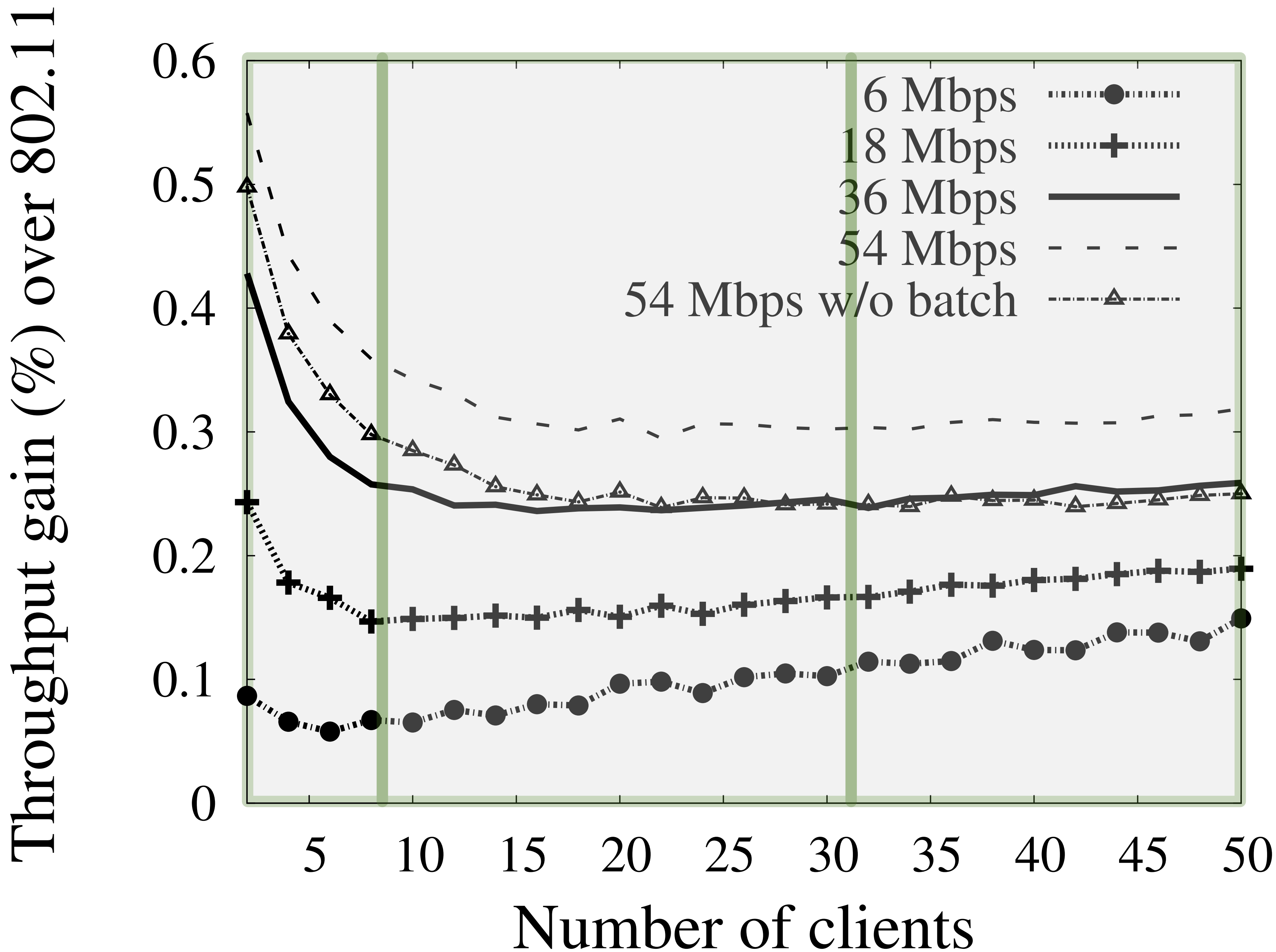
Small collision probability in dense networks

Throughput Evaluation



Higher throughput gain for real time traffic

Throughput Evaluation



Throughput Gain of Upto 50%

Limitation and Discussion

- Robustness of subcarrier based backoff
  - Back2F more sensitive to channel fluctuation
- Need for additional antenna
  - Back2F is complementary to MIMO
- Gain over packet aggregation
  - Aggregation may not be possible for real time traffic
  - Back2F provides gain with aggregation at higher rates
- Interoperability with 802.11
  - May interoperate but will cause unfairness

Summary

- Randomization is an effective method for contention resolution
- 802.11 time domain backoff requires channel to remain idle
- Observation: randomization possible in frequency domain
  - Using OFDM subcarriers
- Back2F: practical system realizing frequency domain contention
- Prevents collisions, provides upto 50% improvement in throughput

Questions, comments?

Thank you

Duke SyNRG Research Group

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