Successive Interference Cancellation: A Back of the Envelope Perspective

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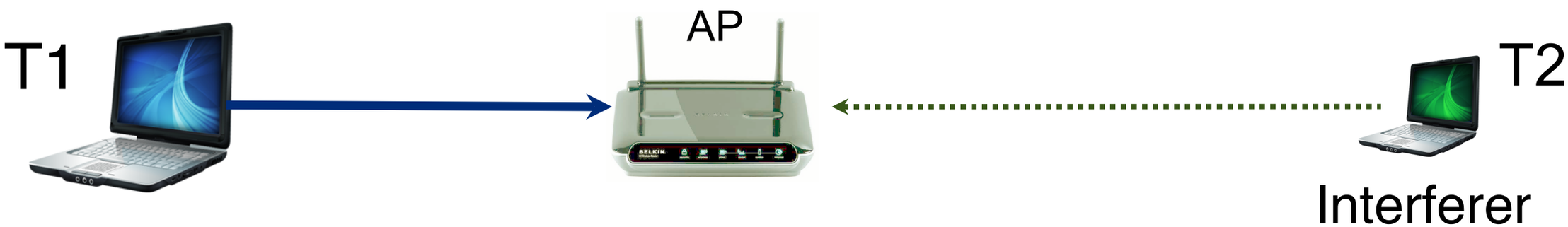
Simple Case of Wireless Transmission

Decoding successful if:

$$\text{SNR} = \frac{\text{Signal}}{\text{Noise}} = \frac{\sim}{\sim} > \text{Threshold}$$

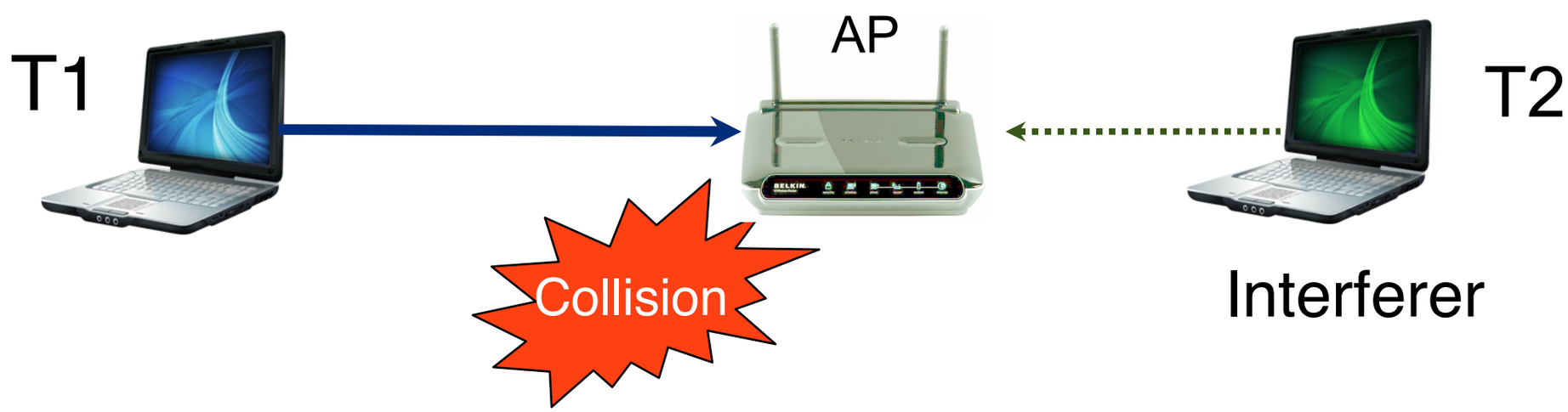
What if parallel transmissions?



Decoding successful only if:

$$\text{SINR} = \frac{\text{Signal}}{\text{Interference} + \text{Noise}} = \frac{\sim}{\sim + \sim} > \text{Threshold}$$

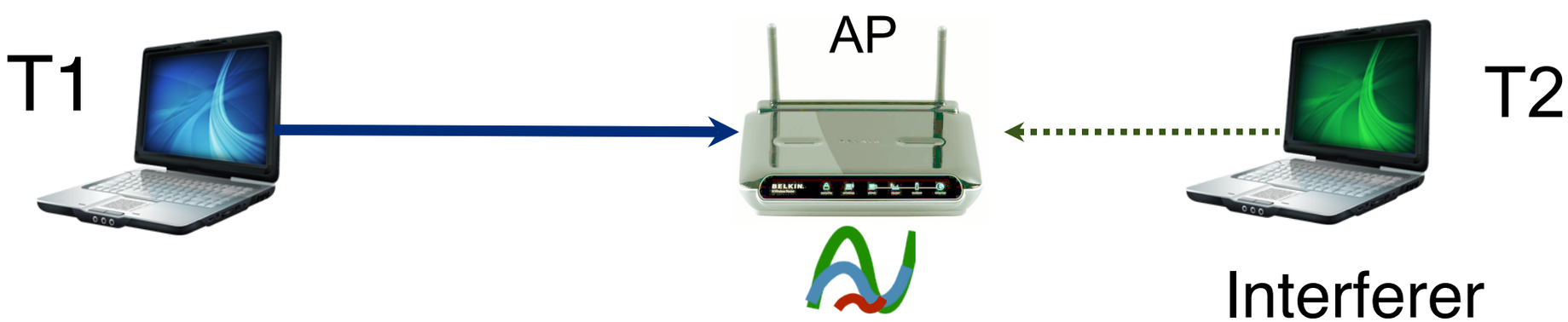
Collision

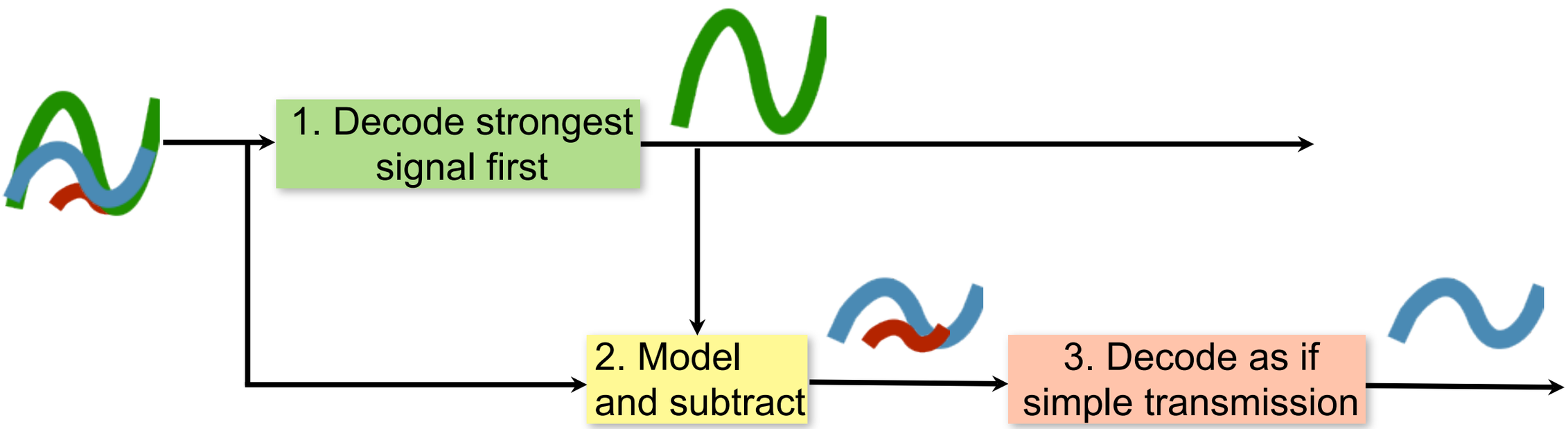


Decoding fails because:

$$\text{SINR} = \frac{\text{Signal}}{\text{Interference + Noise}} = \frac{\sim}{\sim + \sim} < \text{Threshold}$$

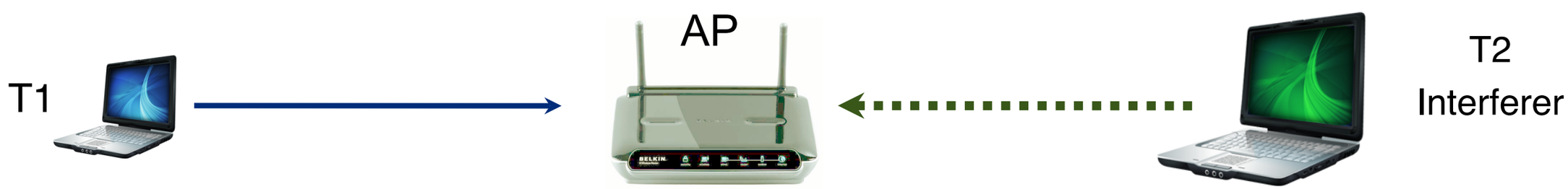
Successive Interference Cancellation



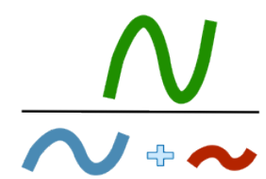


Thus, it is as if SIC can "uncollide" signals, resulting in two successful transmissions

Capacity with SIC



SNR = 

SINR = 

$$R_{blue} = \log\left[1 + \frac{S_{blue}}{noise}\right] \quad + \quad R^*_{green} = \log\left[1 + \frac{S_{green}}{S_{blue} + noise}\right]$$

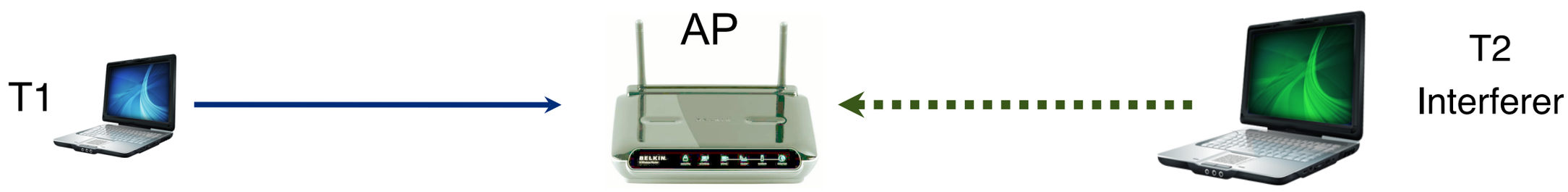
Rate of blue signal remains same

Rate of green signal far less

$$R_{SIC} = \log\left[1 + \frac{S_{blue} + S_{green}}{noise}\right]$$

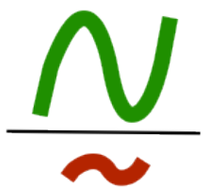
Strong signal penalized, weak signal gets all the benefits

Channel Capacity w/o SIC



SNR = 

$$R_{sic} = \log\left[1 + \frac{S_{blue} + S_{green}}{noise}\right]$$

SNR = 

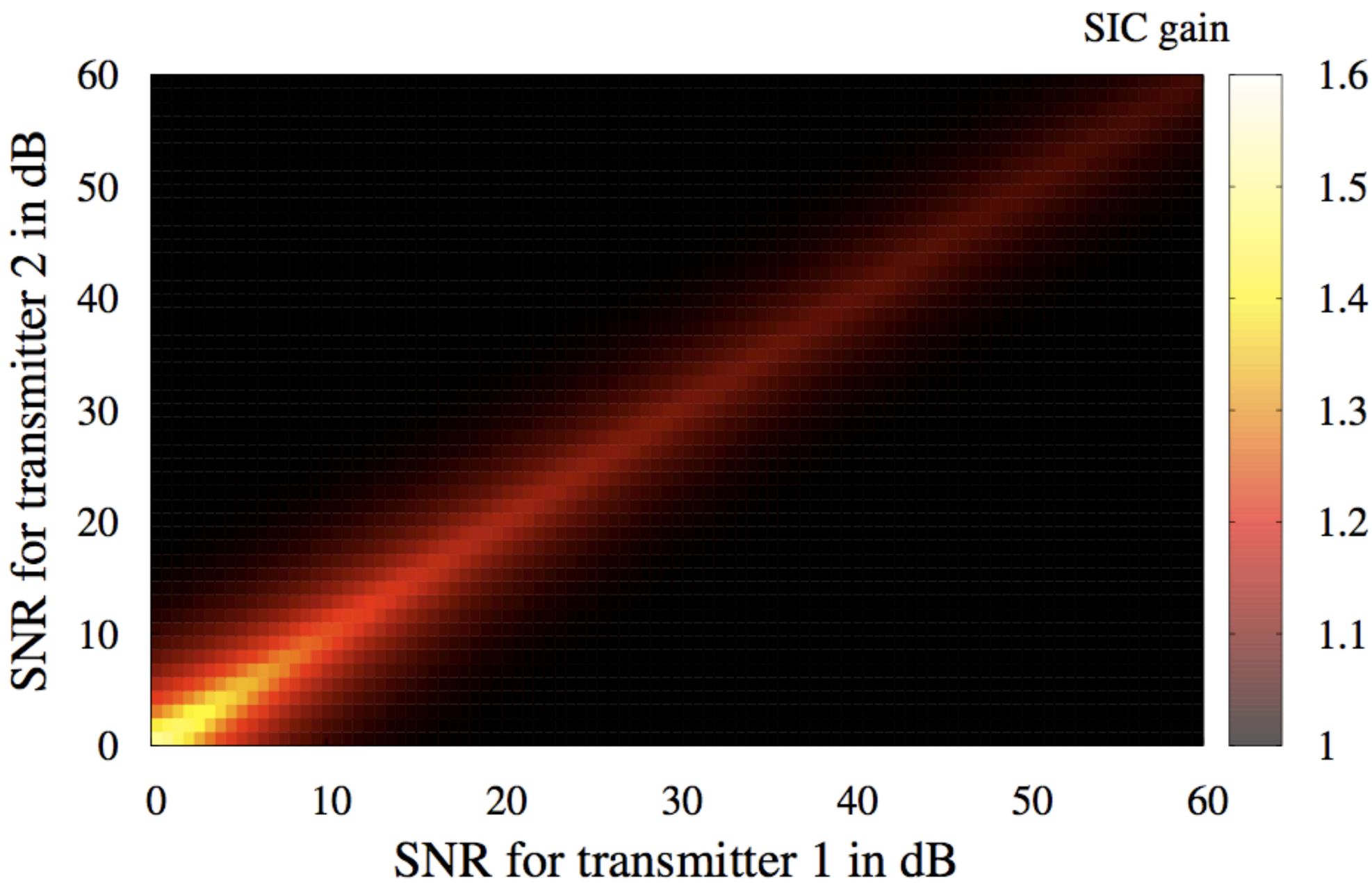
$$R_{blue} = \log\left[1 + \frac{S_{blue}}{noise}\right]$$

$$R_{green} = \log\left[1 + \frac{S_{green}}{noise}\right]$$

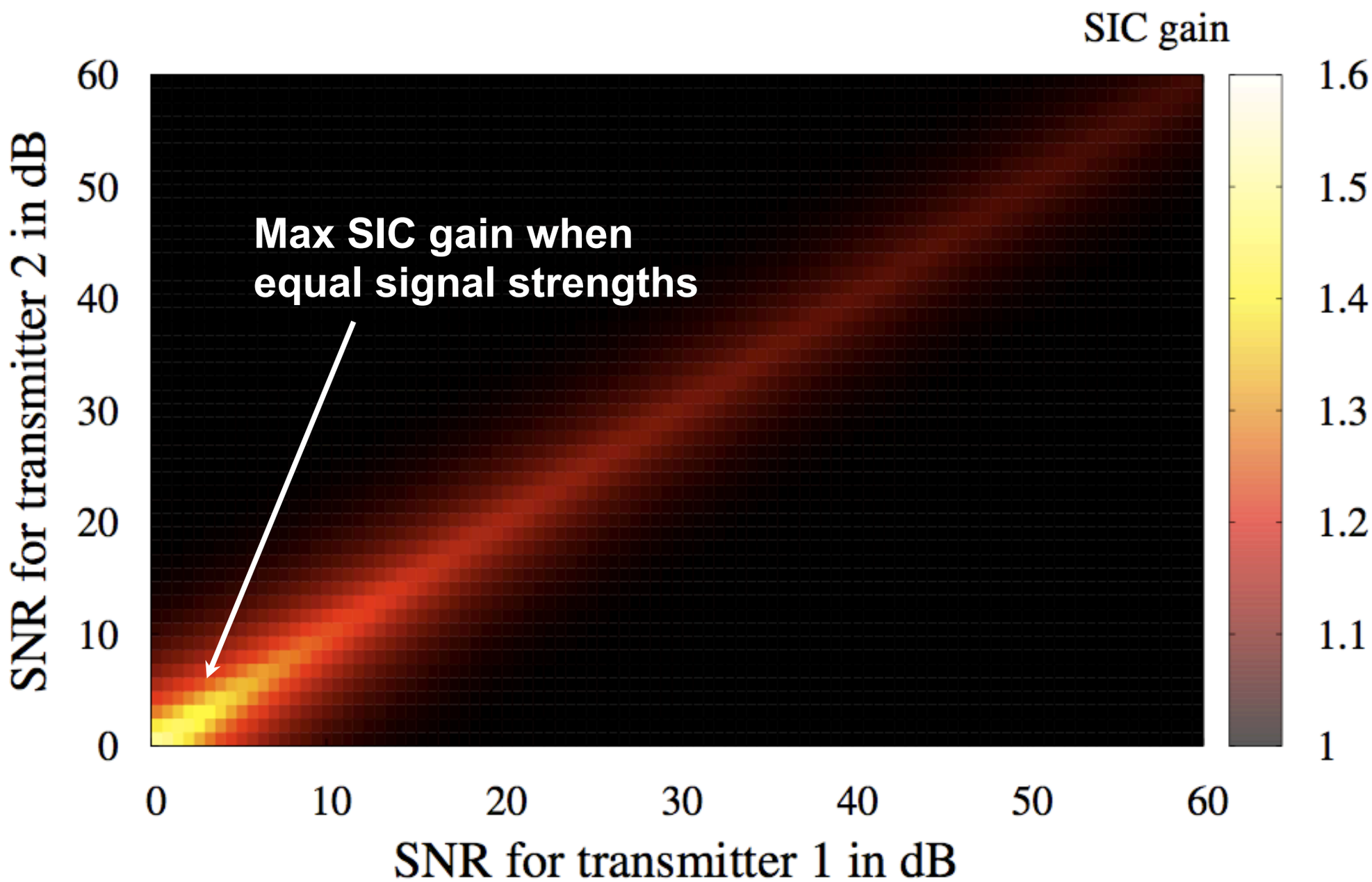
$$R_{woSIC} = \max(R_{blue}, R_{green})$$

$$Gain_{sic} = \frac{\qquad}{\qquad}$$

SIC PHY Capacity Gain



SIC PHY Capacity Gain



As protocol designers ...

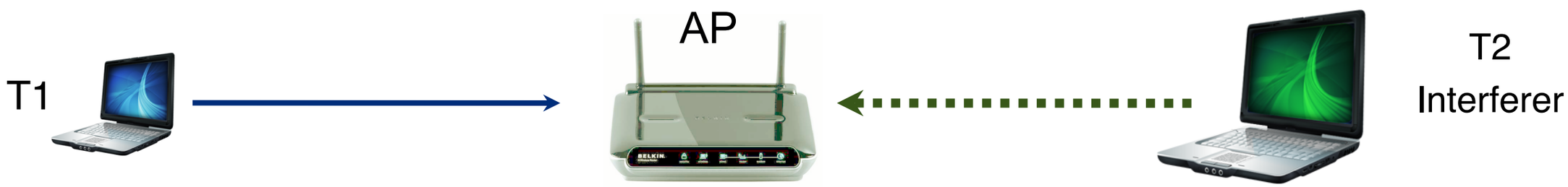
We were tempted to schedule packet transmissions of similar signal strengths ...

Our interpretation was that ...

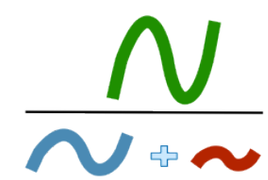
maximizing SIC capacity will maximize throughput

But let’s verify that ...

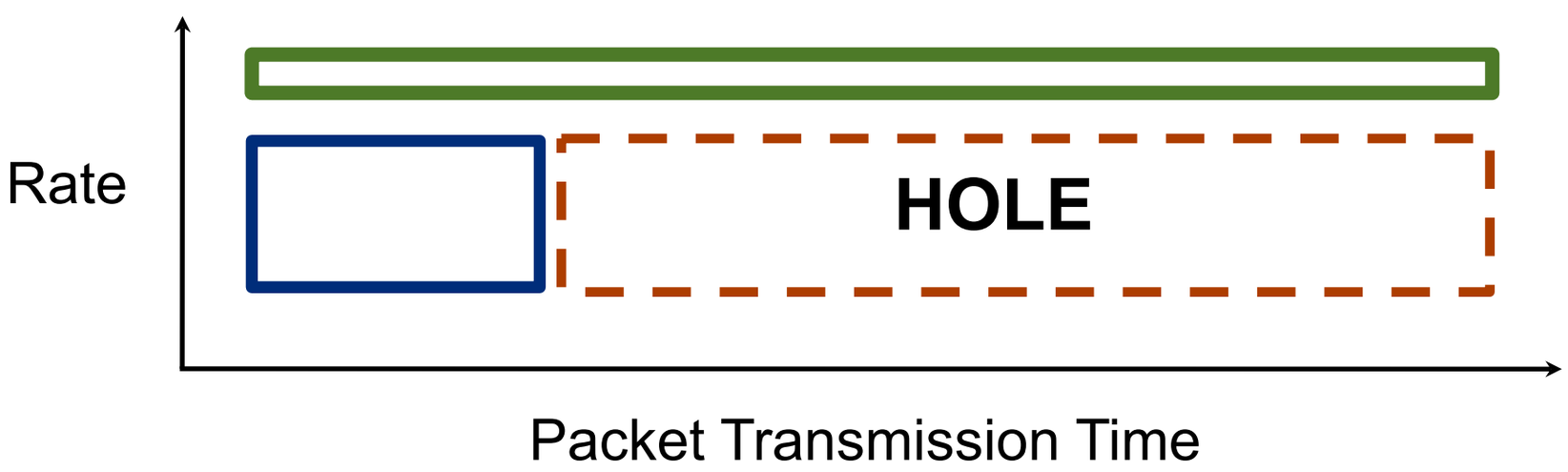
SIC: A Packet Perspective



- Stronger green packet has to be at low rate

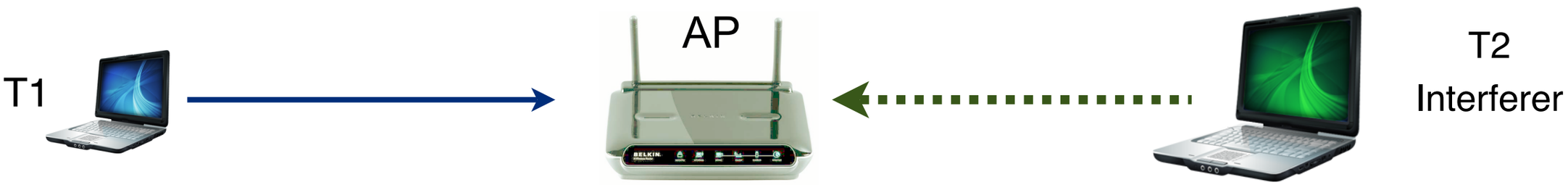


- Weaker blue packet can be at a high rate



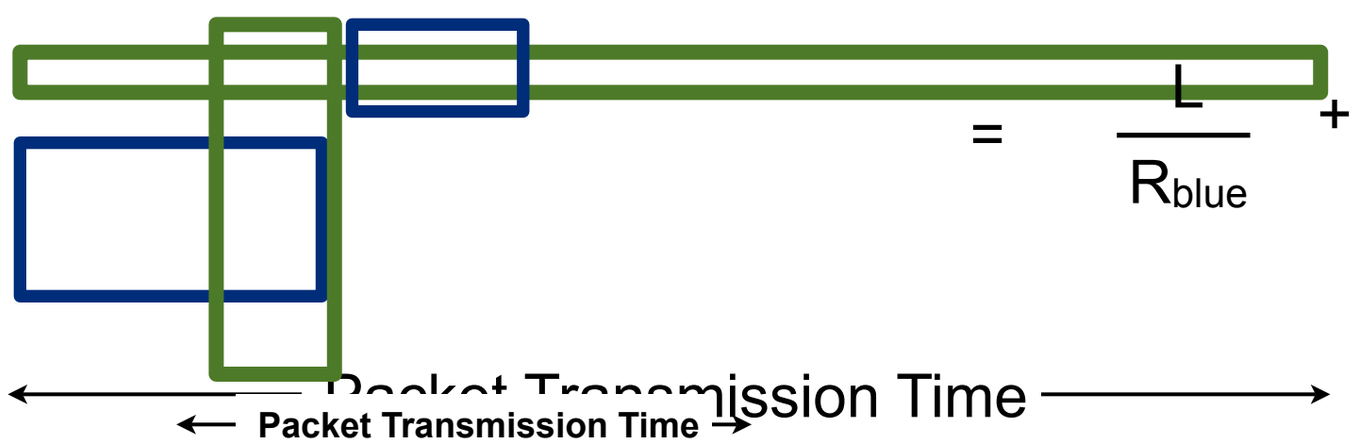
MAC Layer throughput can actually suffer

Mathematically ...



$$\text{Time}_{SIC} = \qquad = \max\left[\frac{L}{R_{blue}}, \frac{L}{R^*_{green}}\right]$$

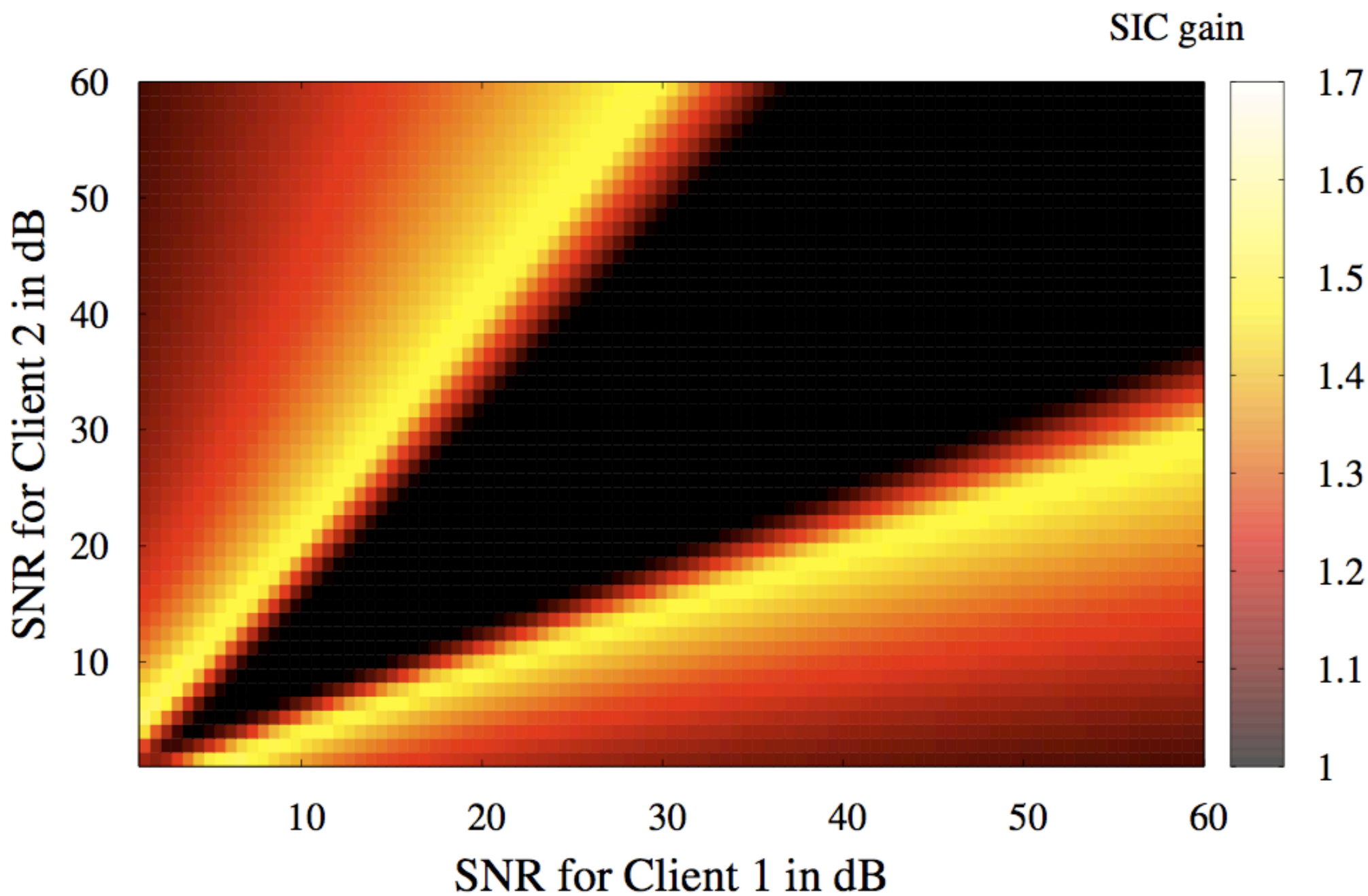
$$\text{Time}_{woSIC} =$$



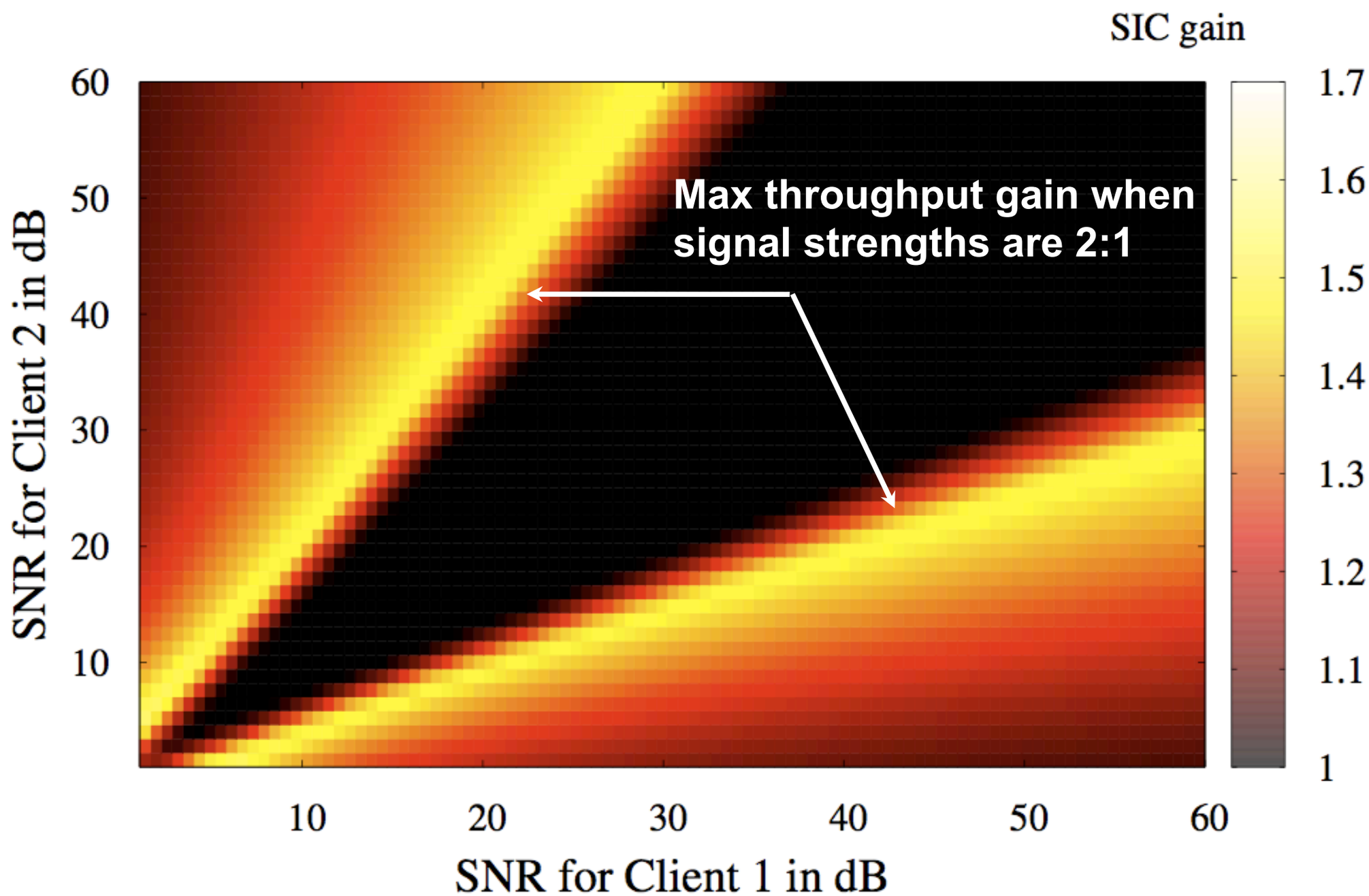
$$= \frac{L}{R_{blue}} + \frac{L}{R_{green}}$$

SIC Gain = _____

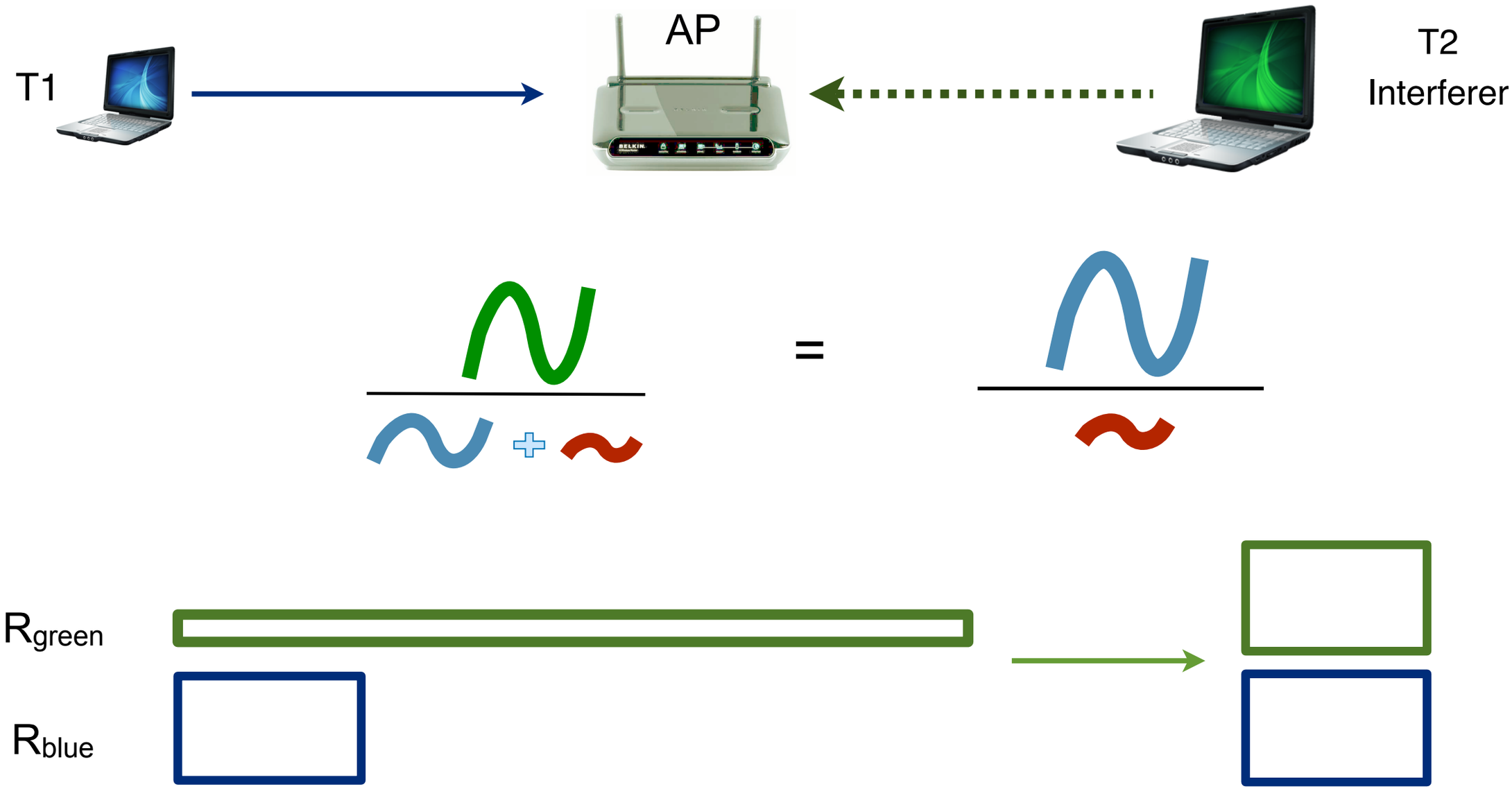
SIC Throughput Gain



SIC Throughput Gain



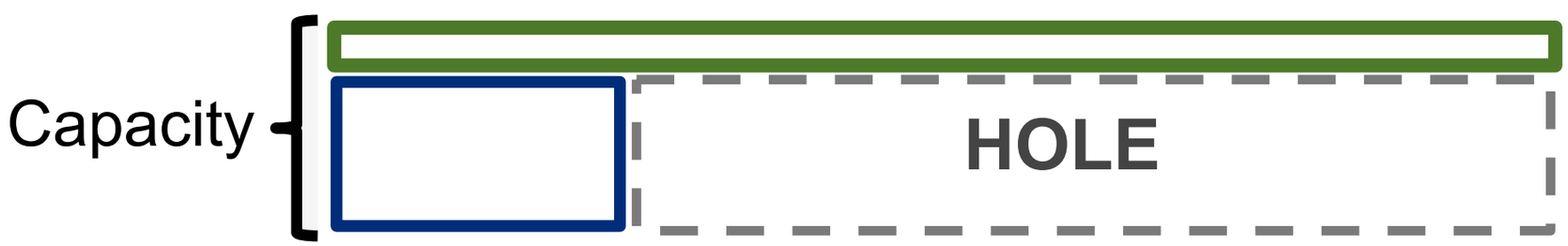
Why is This Happening?



Capacity Vs. Throughput

- We expected:
  - Maximizing SIC capacity will maximize throughput

- Reality:
  - Equal signal strengths maximize capacity but not throughput



Can’t we improve MAC layer throughput with SIC

by reducing size of the hole ...

We study SIC enabled throughput in two scenarios

1. Two transmitters transmitting to a common receiver

2. Two transmitters transmitting to distinct receivers

We begin with

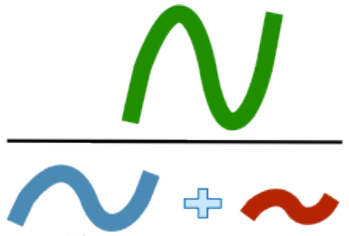
1. Common receiver

We consider:

1. Power control
2. Scheduling
3. Multirate packetization
4. Packet packing

(1) Power Control

- Reduce power of blue Tx such that  = 2 * 

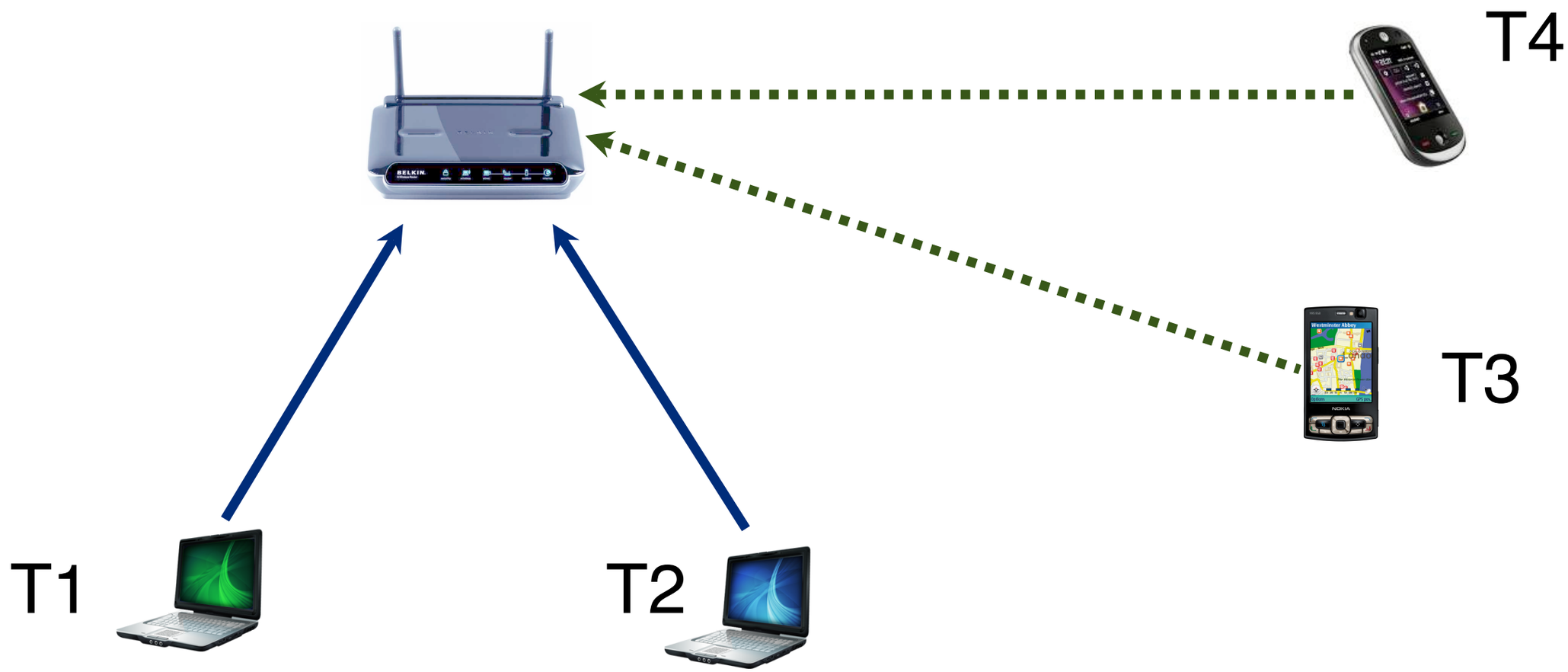
$SINR^*_{green}$ = 

Reduce

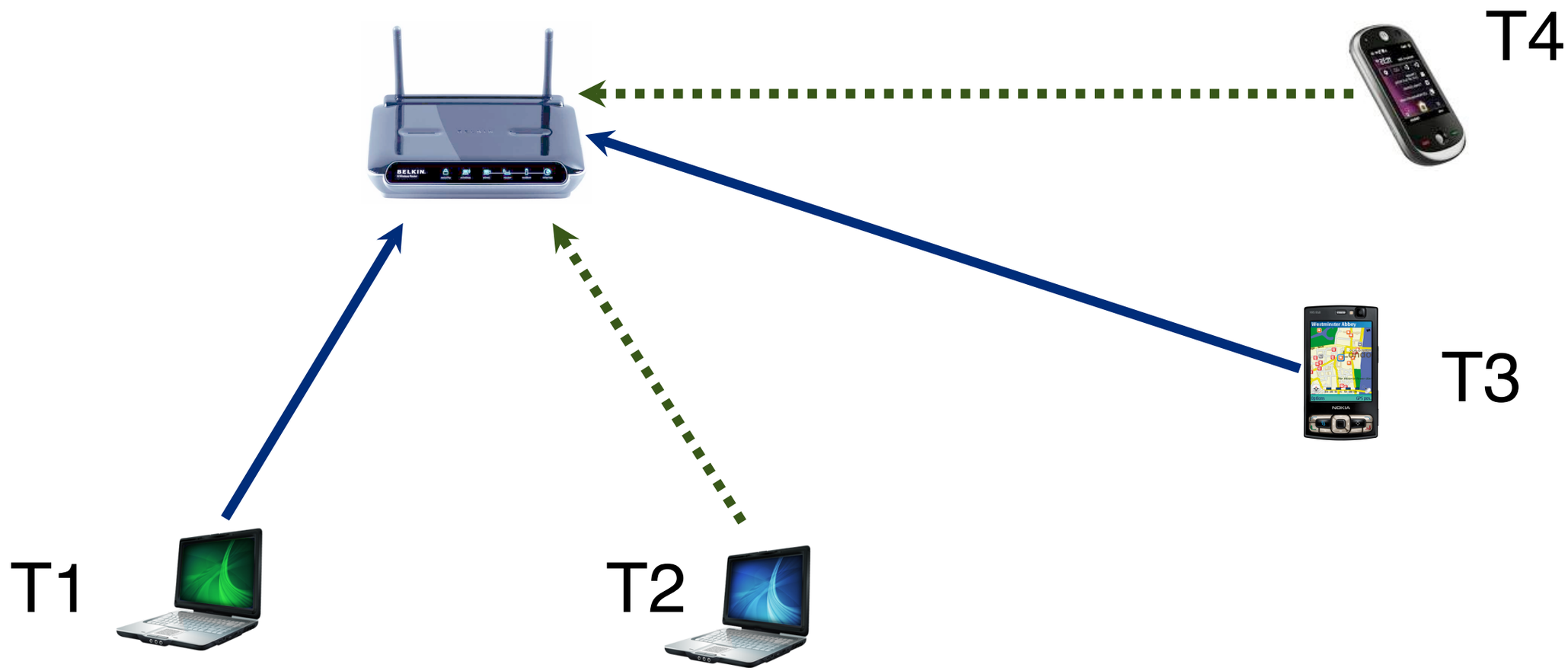
R_{green} 

R_{blue} 

(2) Client Pairing



(2) Client Pairing



T1, T3

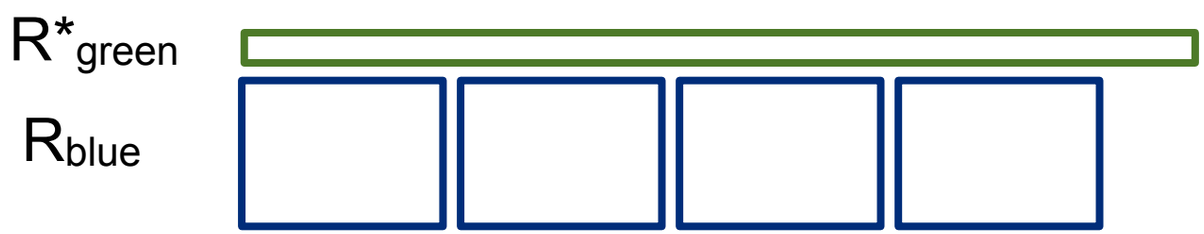
T2, T4

(3) MultiRate Packetization

- Multirate Packetization
  - Send the strong packet at high rate after weak packet has finished

(4) Packet Packing

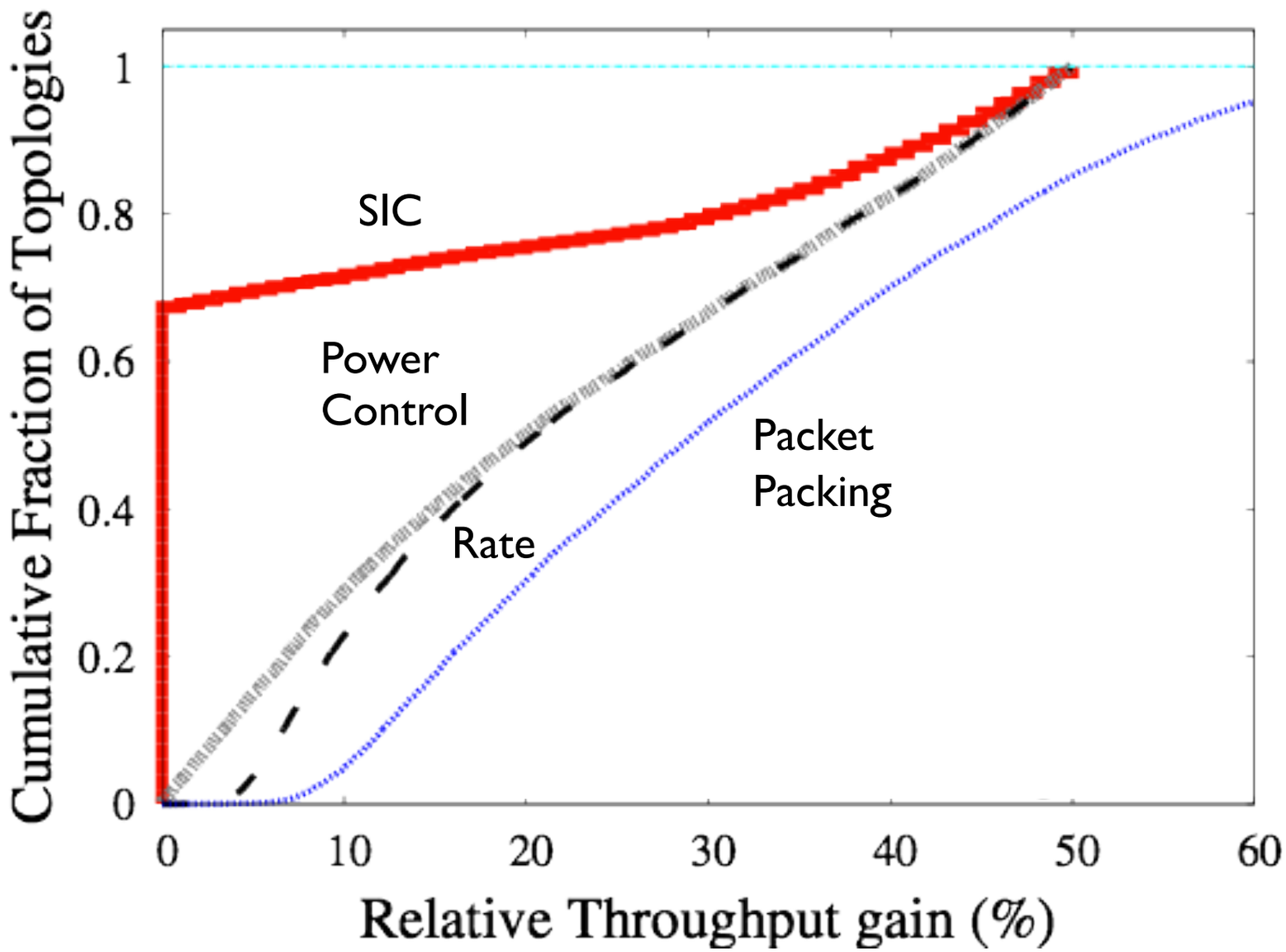
- Packet Packing
  - Send multiple packets to fill up the hole
  - Hard because stronger signal modeling becomes difficult



How Does Adaptation Help?

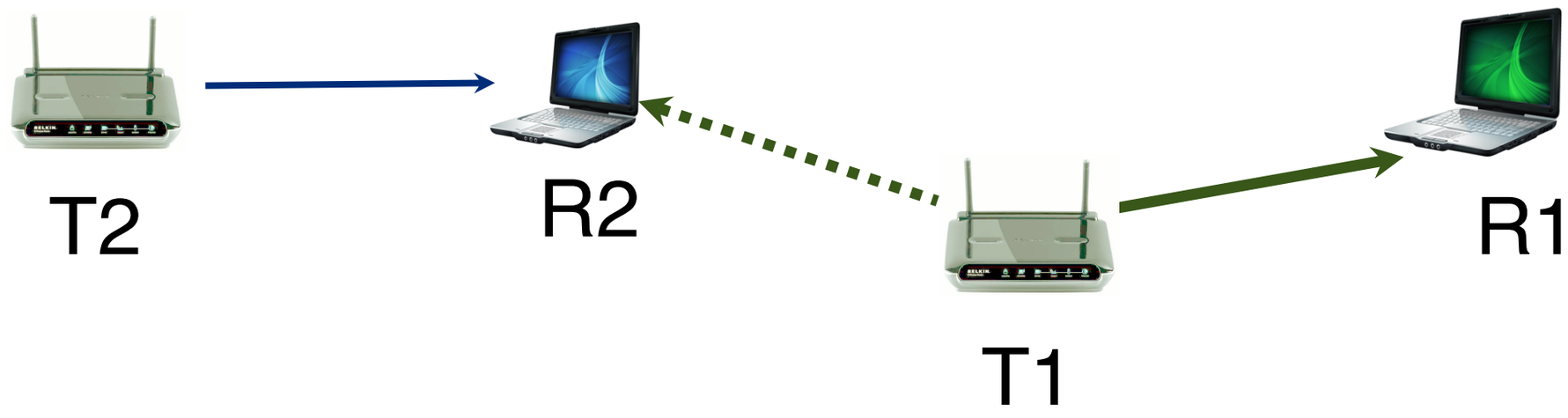
- Perform Monte Carlo Simulations

Upload Performance with MAC Modifications



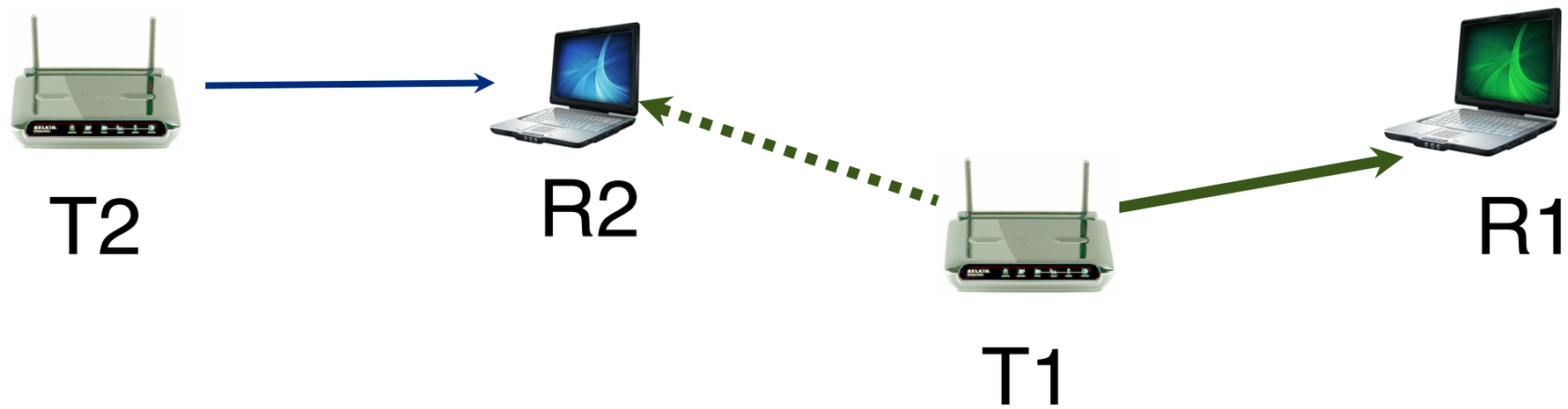
Considerable Improvement with Adaptation

2. Distinct Recievers



Situations much less favorable to SIC

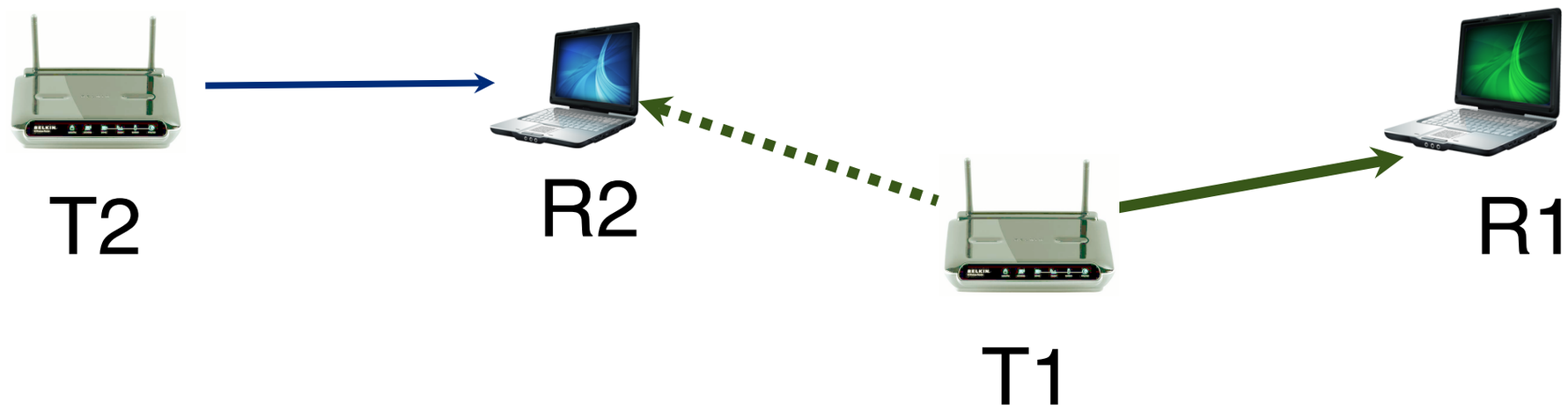
2. Distinct Recievers



Main Concern:

- T1 will transmit at **best possible bit-rate** to R1
- R2 has to decode T1's signal **at this bit rate...**
  - Despite the presence of T2's signal

2. Distinct Recievers



Thus, necessary (but not sufficient) condition:

- R2's interferer(T1) must be closer than its own transmitter(T2)
- T1's own receiver(R1) must be further than interfered receiver(R2)

Gains available when all conditions hold

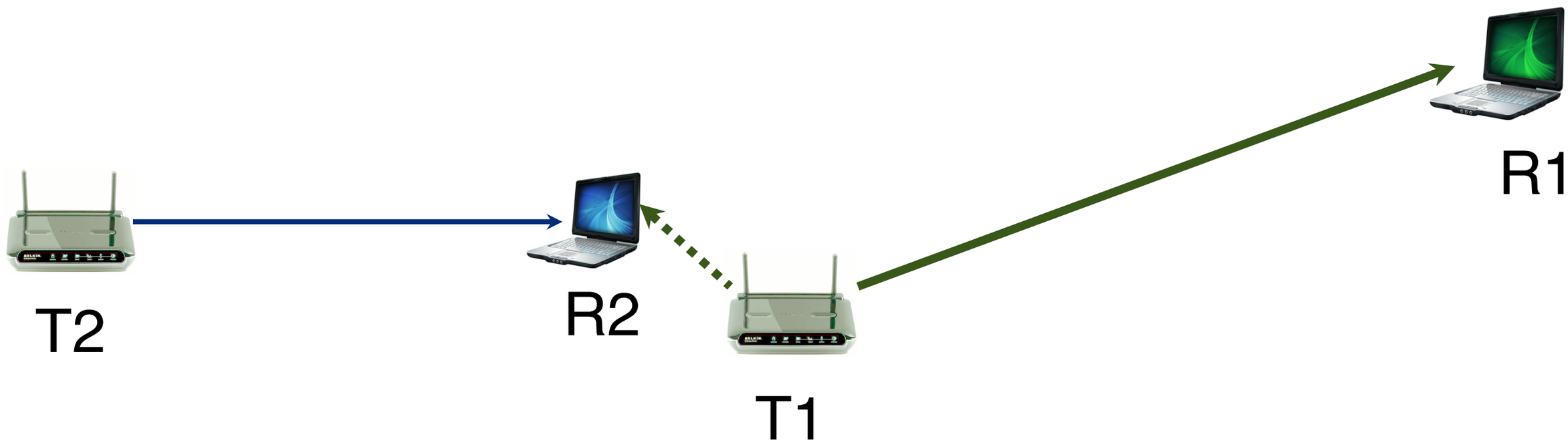
T2

R2

T1

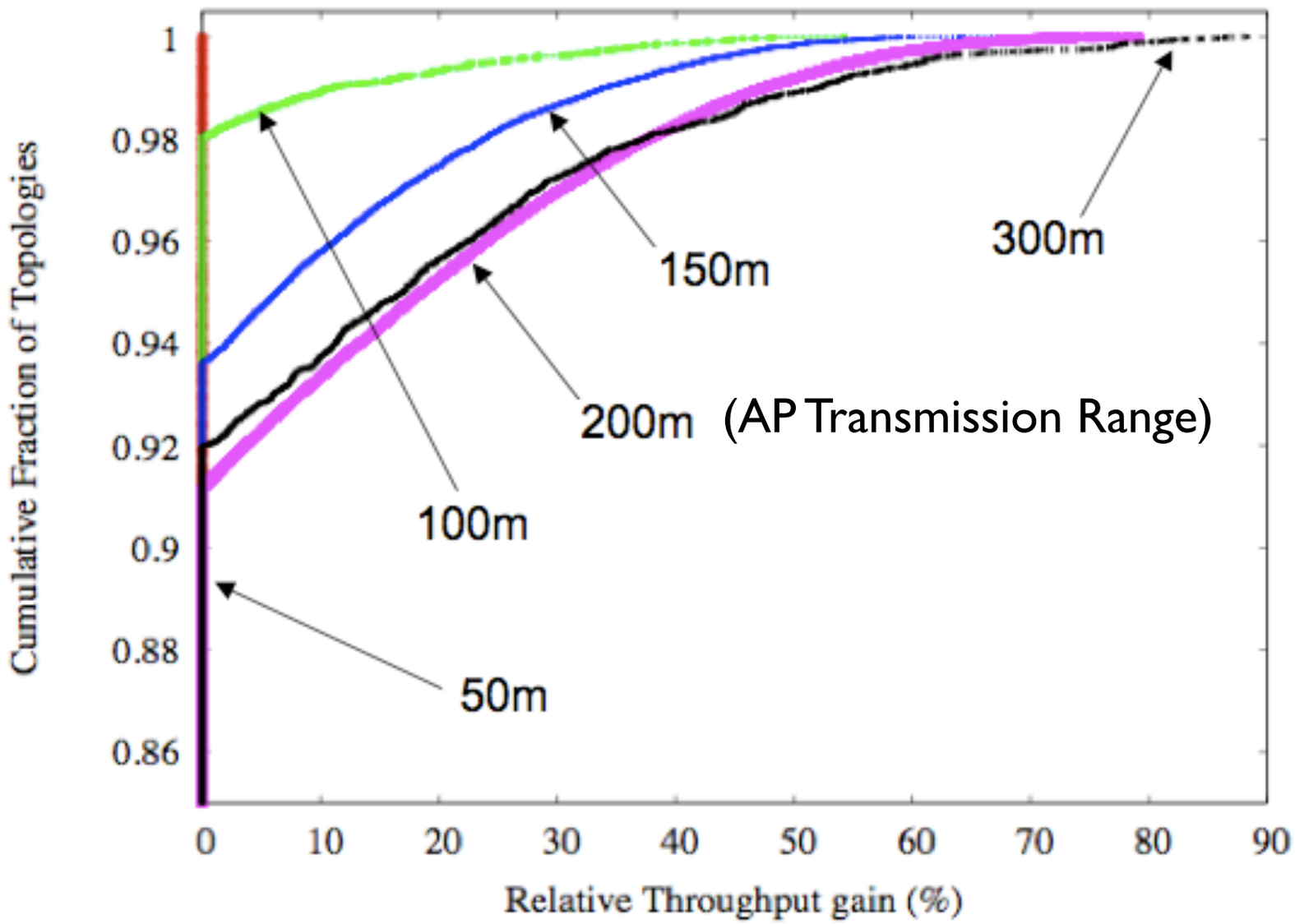
R1

Gains available when all conditions hold



How often do these SIC permissible topologies occur?

Monte Carlo Simulation

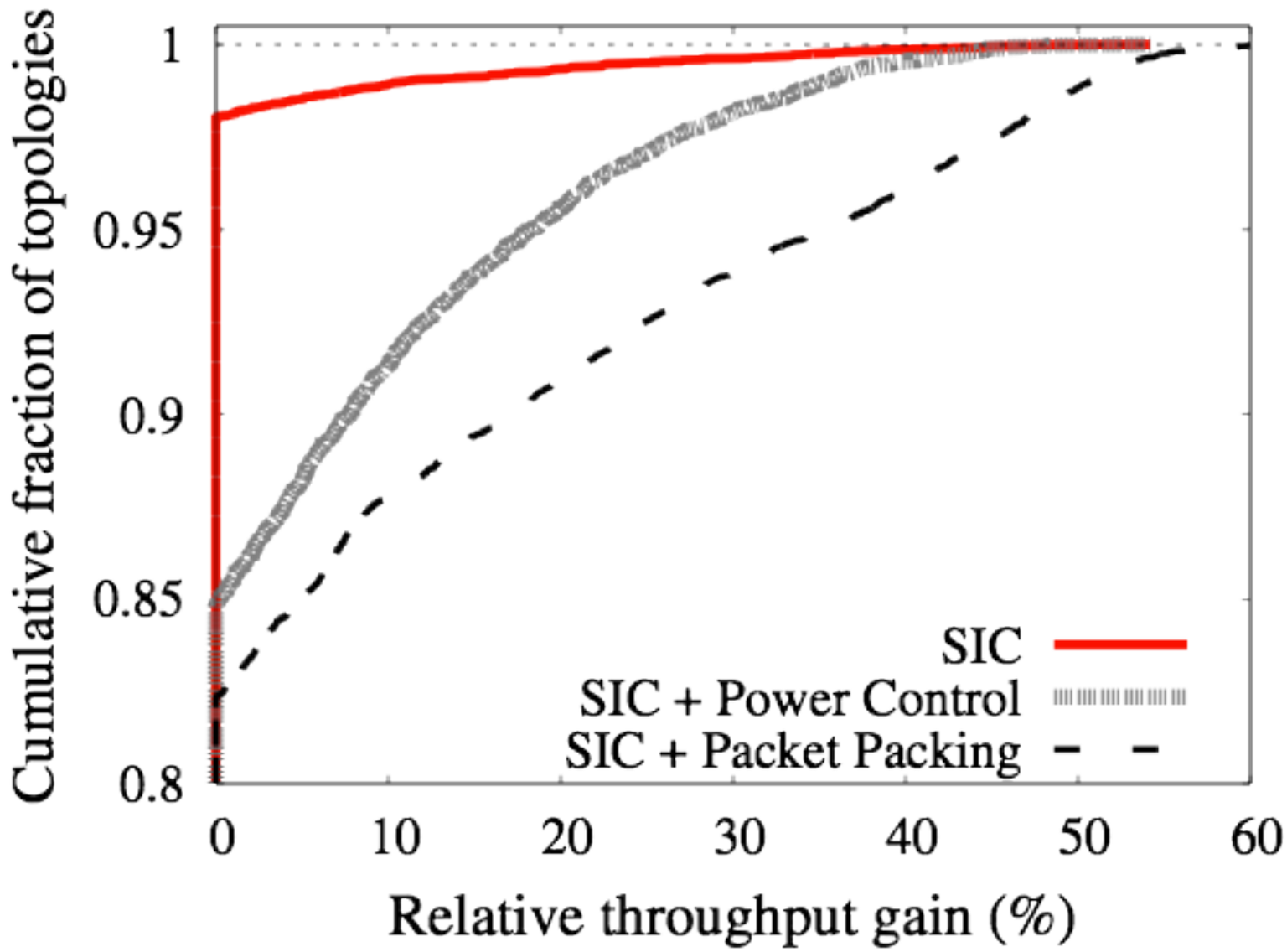


Gain with SIC in less than 10% of the cases

Can protocol adaptation help?

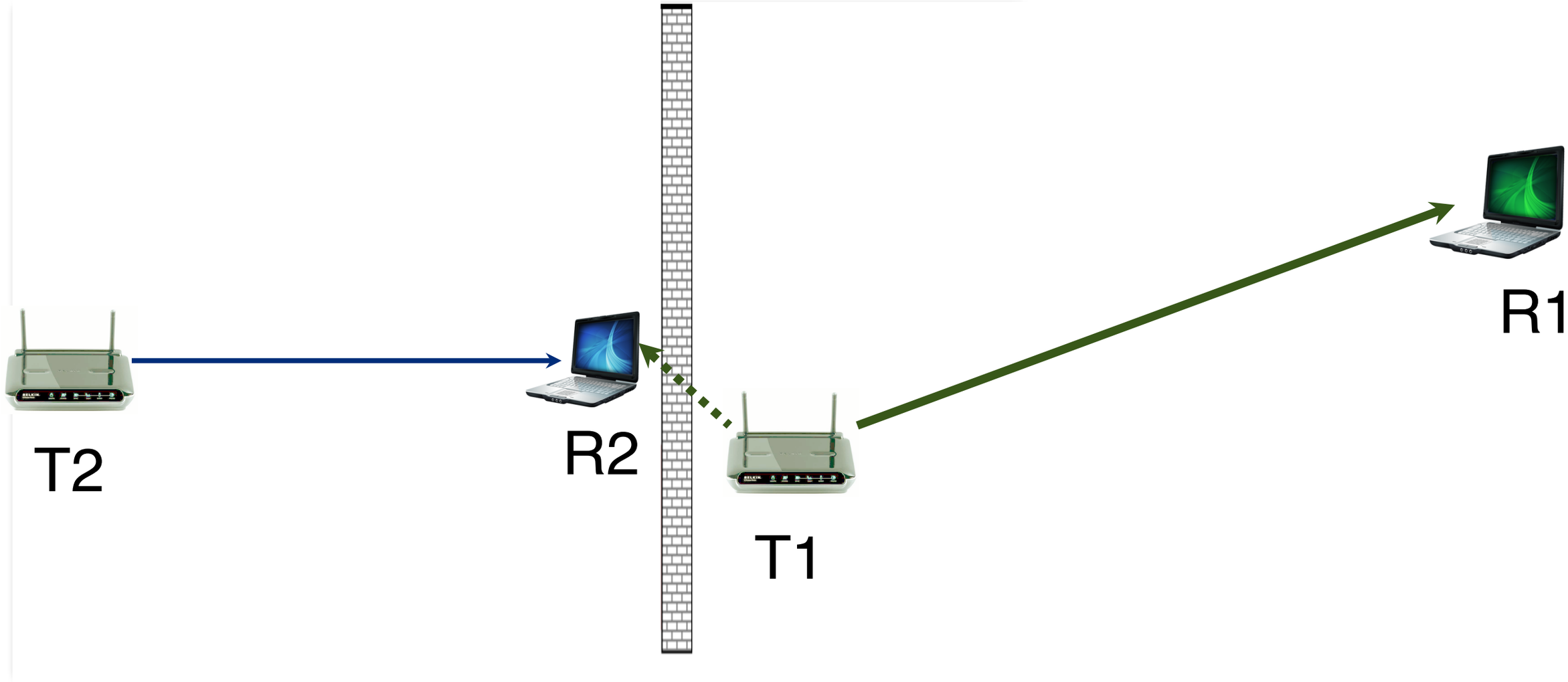
1. Power control
2. Scheduling
3. Multirate packetization
4. Packet packing

Does MAC Adaptation Help?



Not many topologies support SIC … thus limited scope for protocols

Implication on Network Architecture?

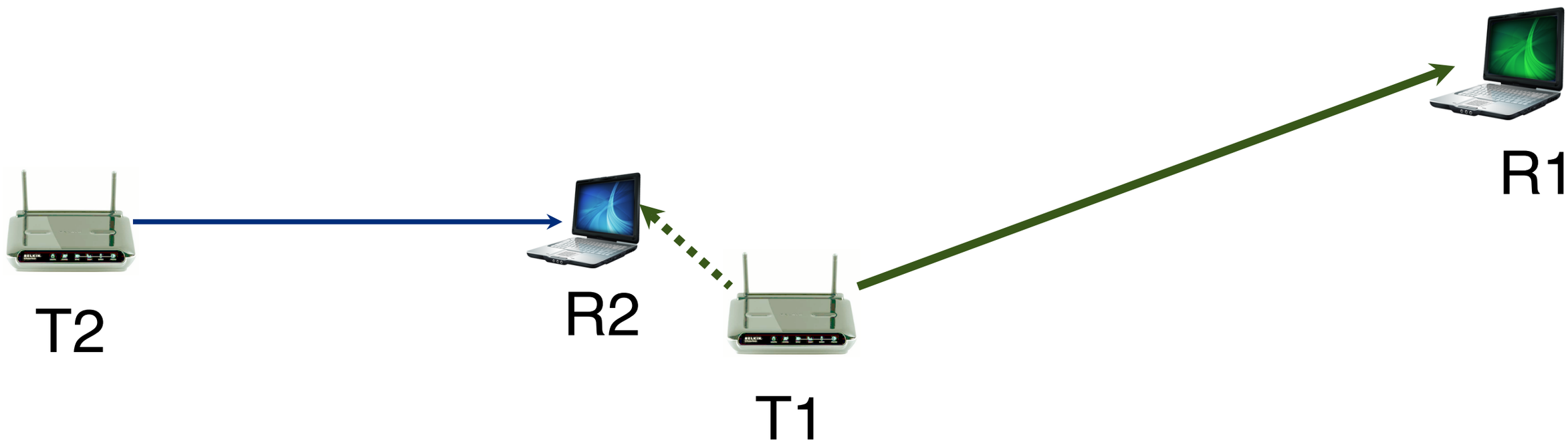


Enterprise WLANs:

- Clients likely to associate with stronger AP
- Such scenarios unlikely

Residential WLANs:

- Neighbors AP may be stronger
- Some SIC scenarios possible



Of course:

SIC throughput gains will increase if bit rate T1->R1 is sub optimal

However, rate adaptation schemes such as SoftRate and AccuRate approaching optimality ... little room for SIC

Mismatch with Literature?

Interference cancellation has been shown to be beneficial ...
Our observations are not in conflict

In existing schemes, interfering bits are known
ZigZag, ANC, CSMA/CN, Full Duplex ...

This paper investigates the case of
Unknown Interference Cancellation

Conclusion

- Successive Interference Cancellation
  - A PHY layer capability to “uncollide” transmissions
- Throughput gain is not immediate from SIC
  - Permissible bit rates impact the length of packet transmission times
  - Creates under-utilization of the channel
- Protocol adaptations possible to cope with problem
  - Some gains available for common receiver scenario
  - However, limited gains for networks with distinct receivers

Takeaway Message

SIC aware protocol design fraught
with pitfalls …

Consider doing a back-of-the-envelope calculation
before plunging into system design

Questions, comments?

Thank you

Duke SyNRG Research Group

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