THE UNIVERSITY of WISCONSIN MADISON

WiNGS Labs

PIE in the Sky : Online Passive Interference Estimation for Enterprise WLANs

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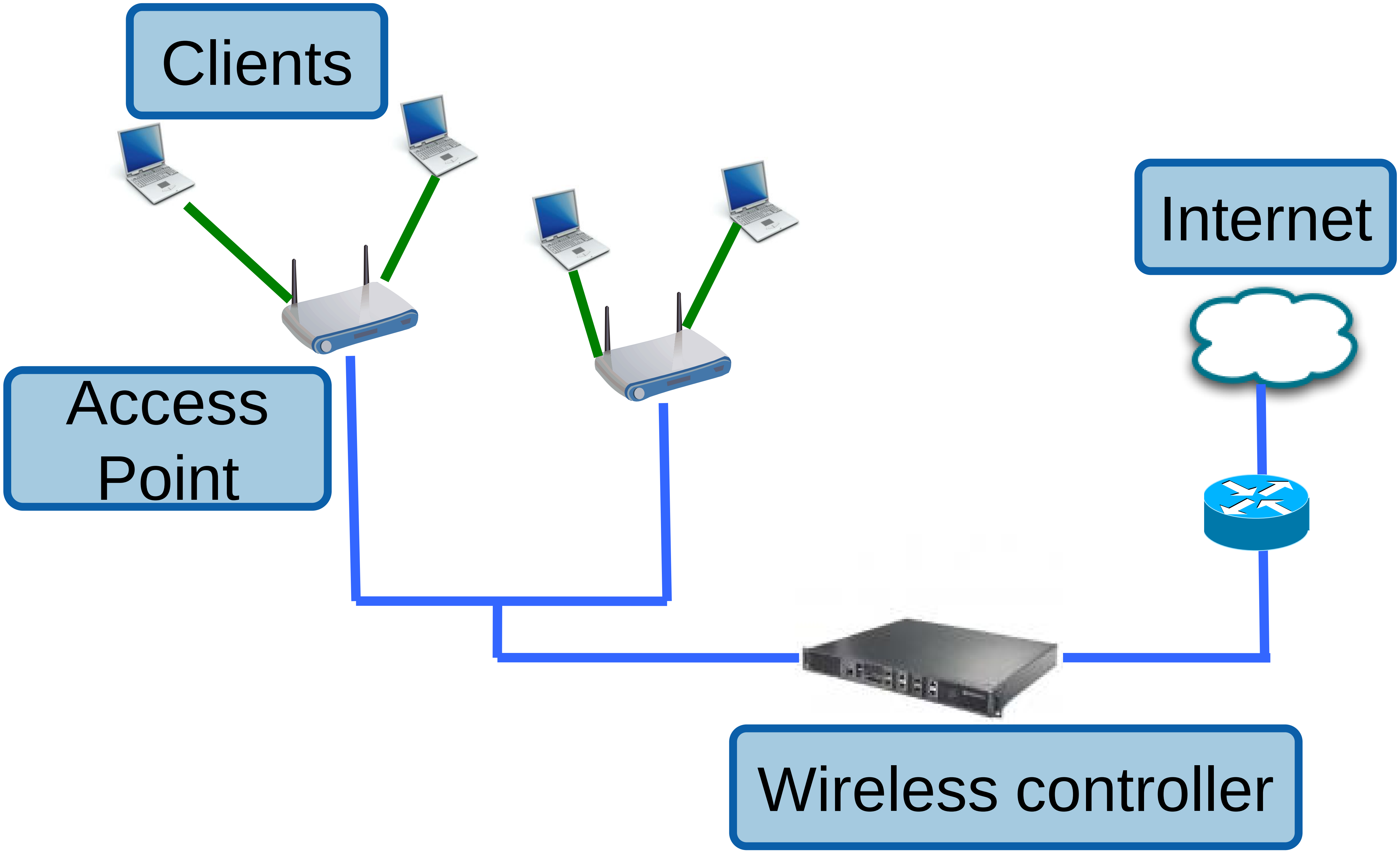
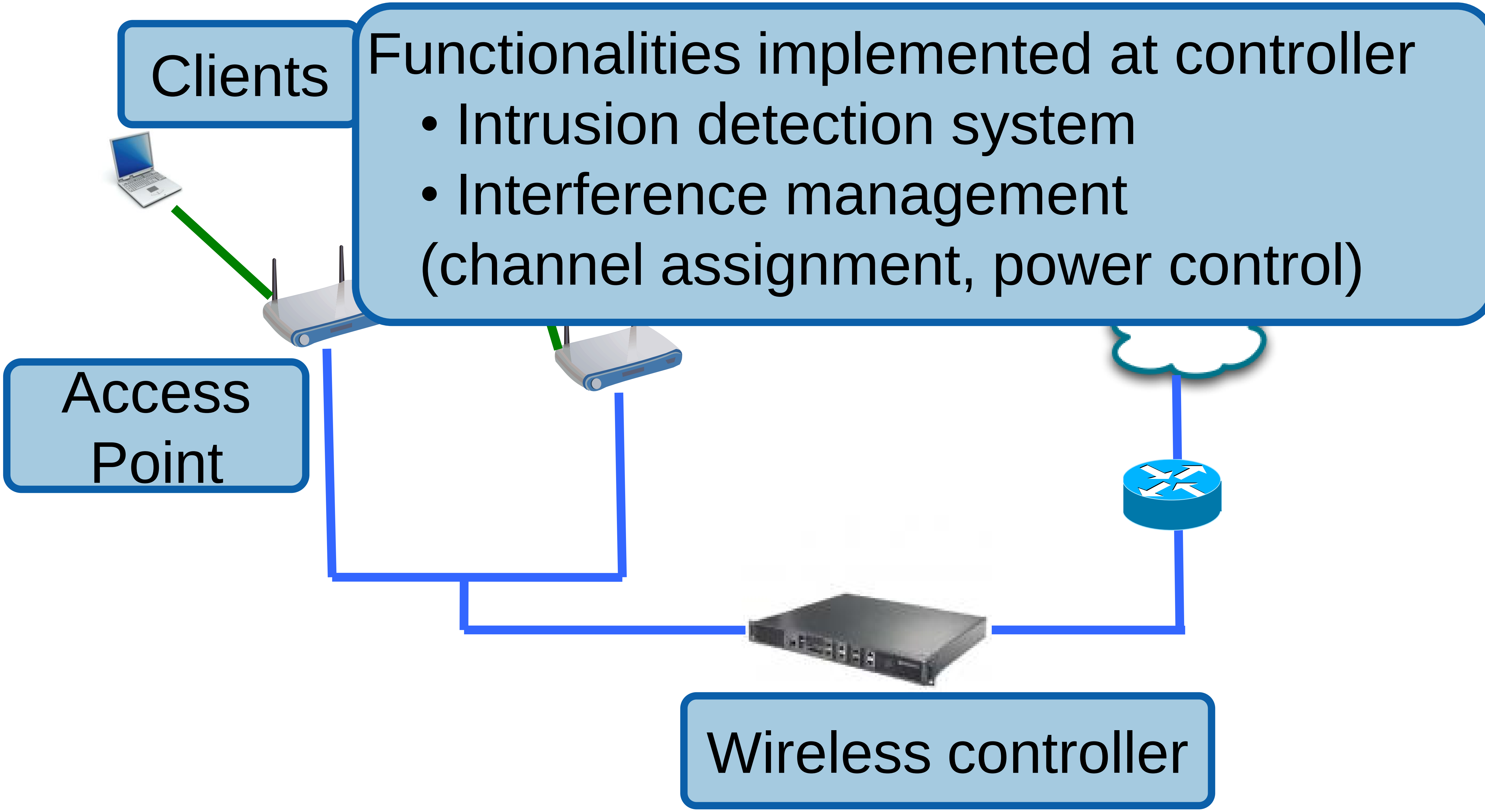
Enterprise WLAN setting



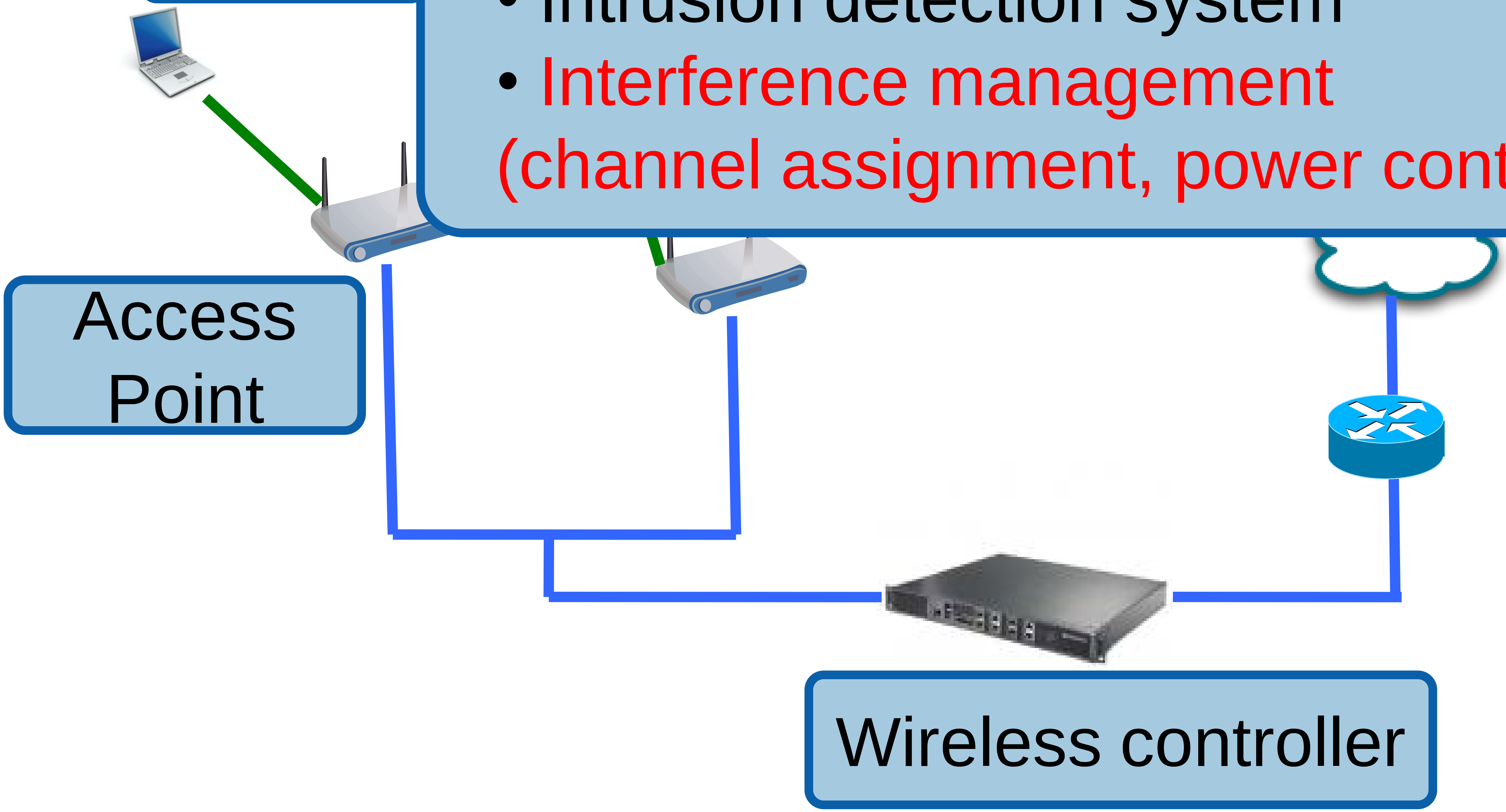
Enterprise WLAN setting



Enterprise WLAN setting

Functionalities implemented at controller

- Intrusion detection system
- Interference management (channel assignment, power control)



Problems with wireless*

“The wireless is being flaky.”

“Flaky how ?”

“Well my connection dropped earlier and now it seems to be slow”

User

“We will take a look.”

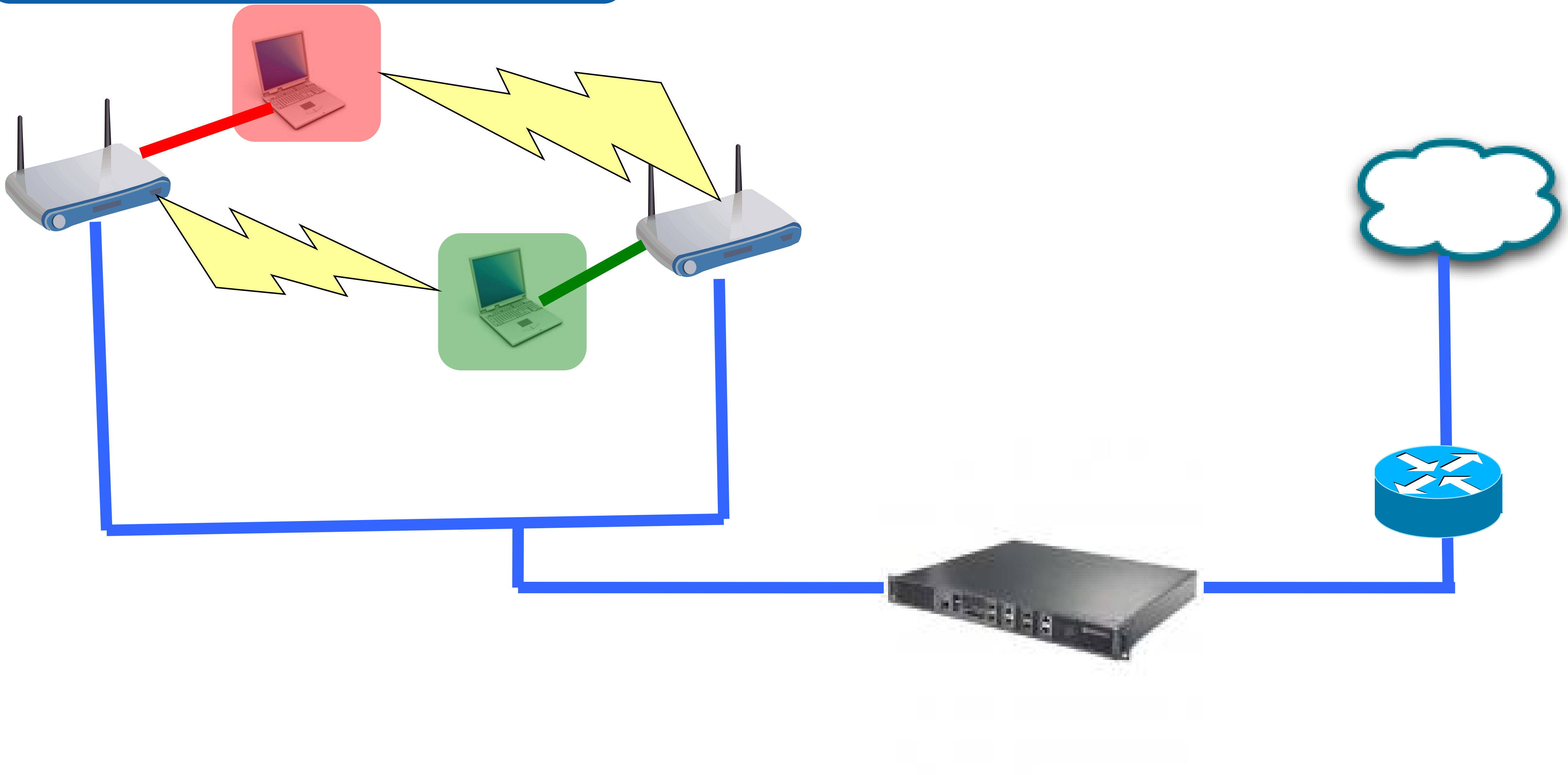
“Wait, now it seems fine.”

Support

*Slide borrowed from Cheng et. al (Jigsaw, Sigcomm ’06)

Problems with wireless

Hidden terminals



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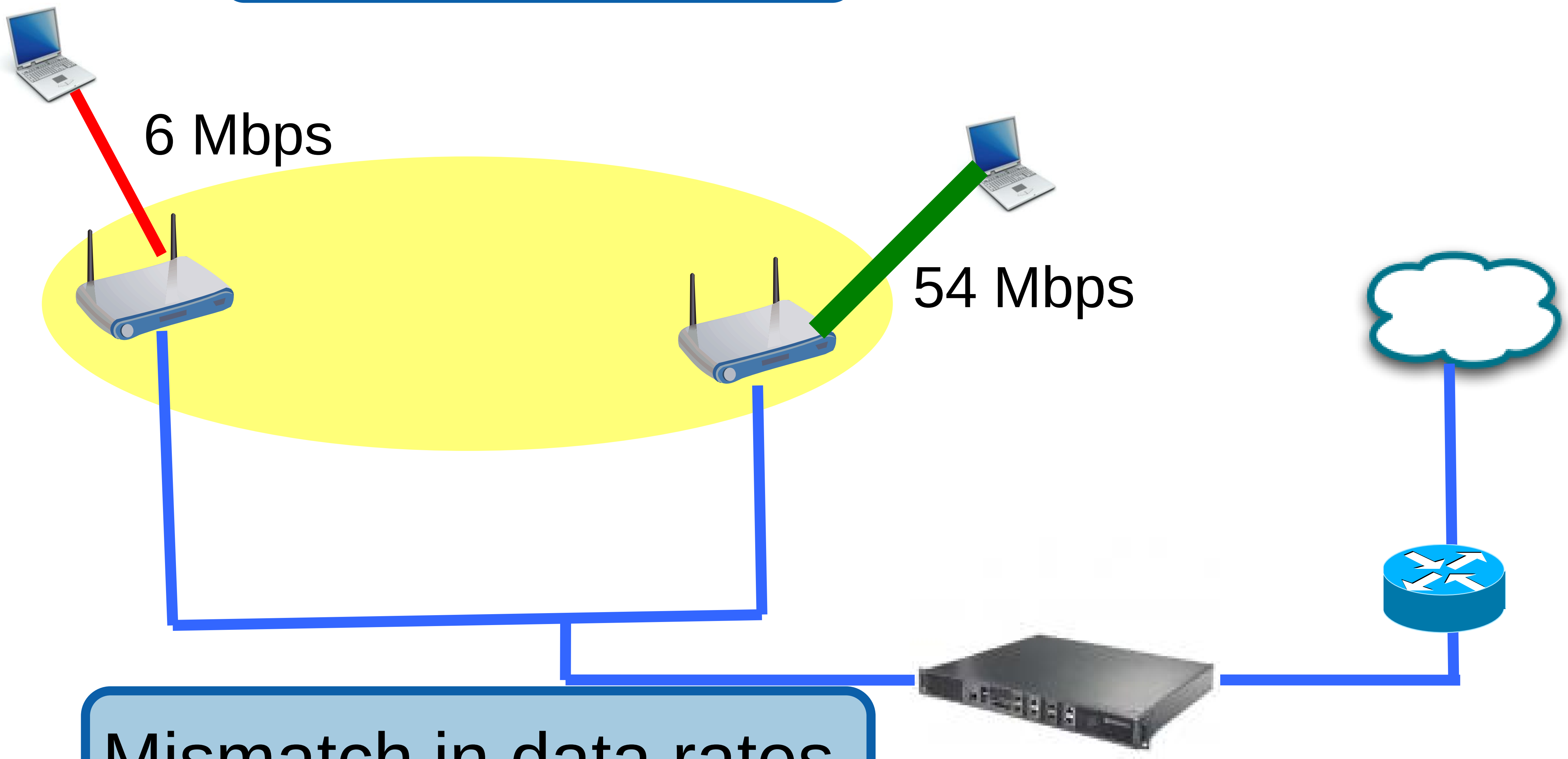
Problems with wireless

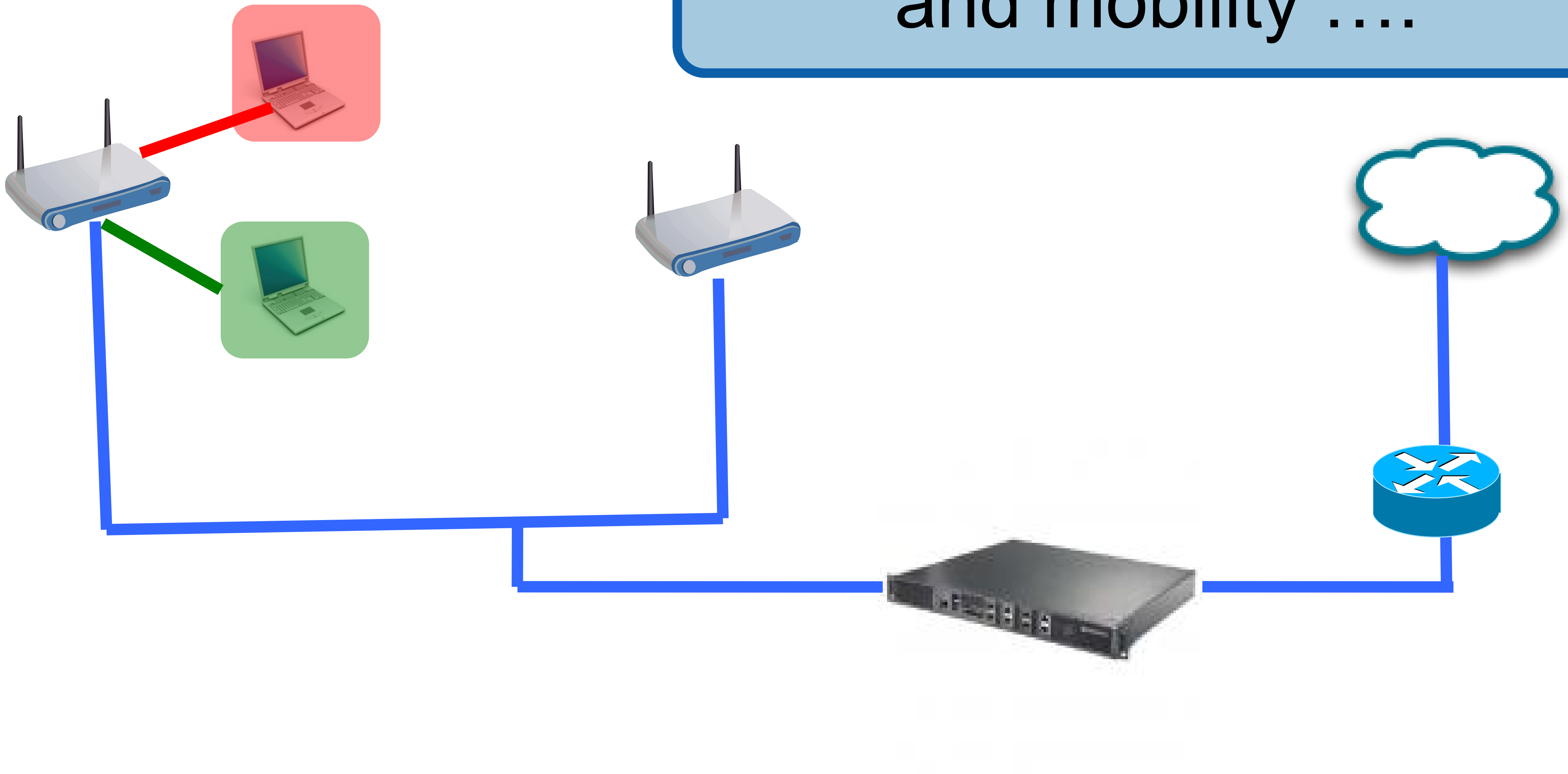
Rate anomaly



Mismatch in data rates, slows down fast links

Problems with wireless

Increasing client density and mobility ….



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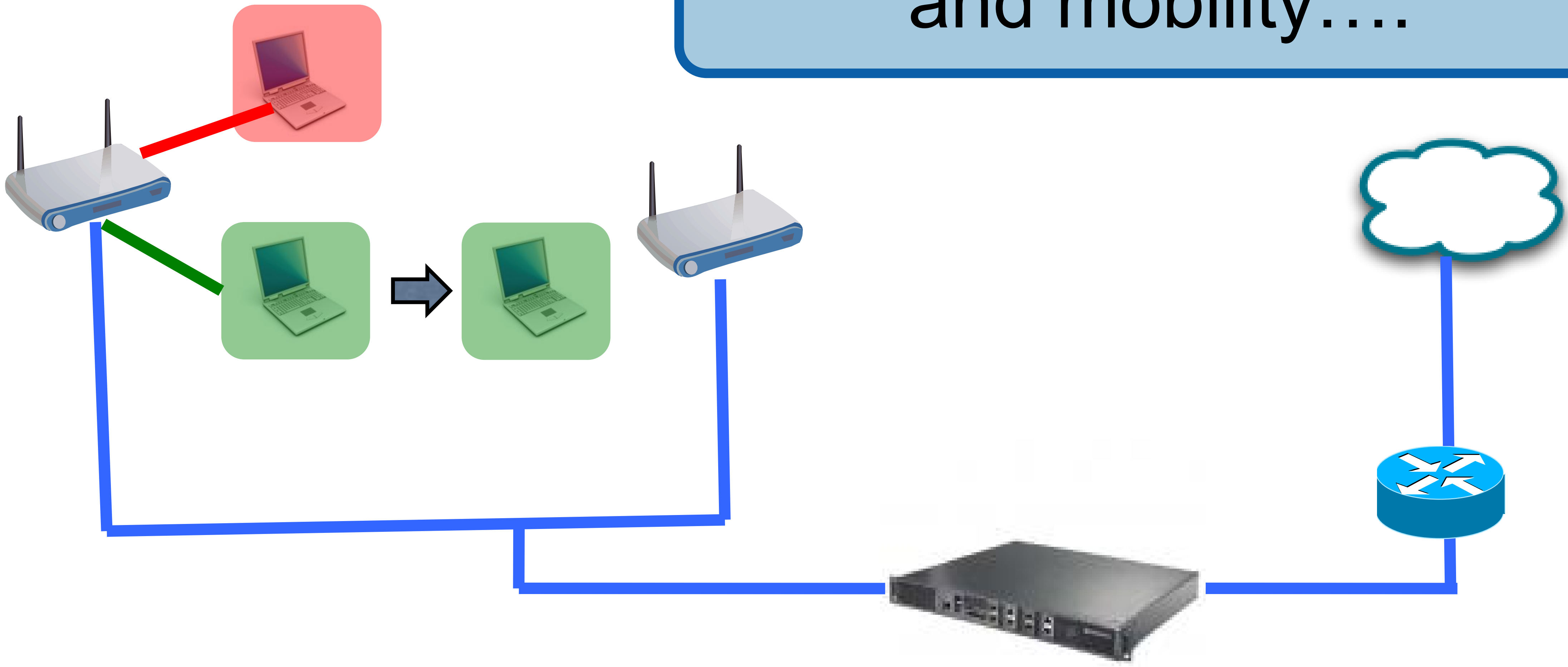
Problems with wireless

Increasing client density and mobility….



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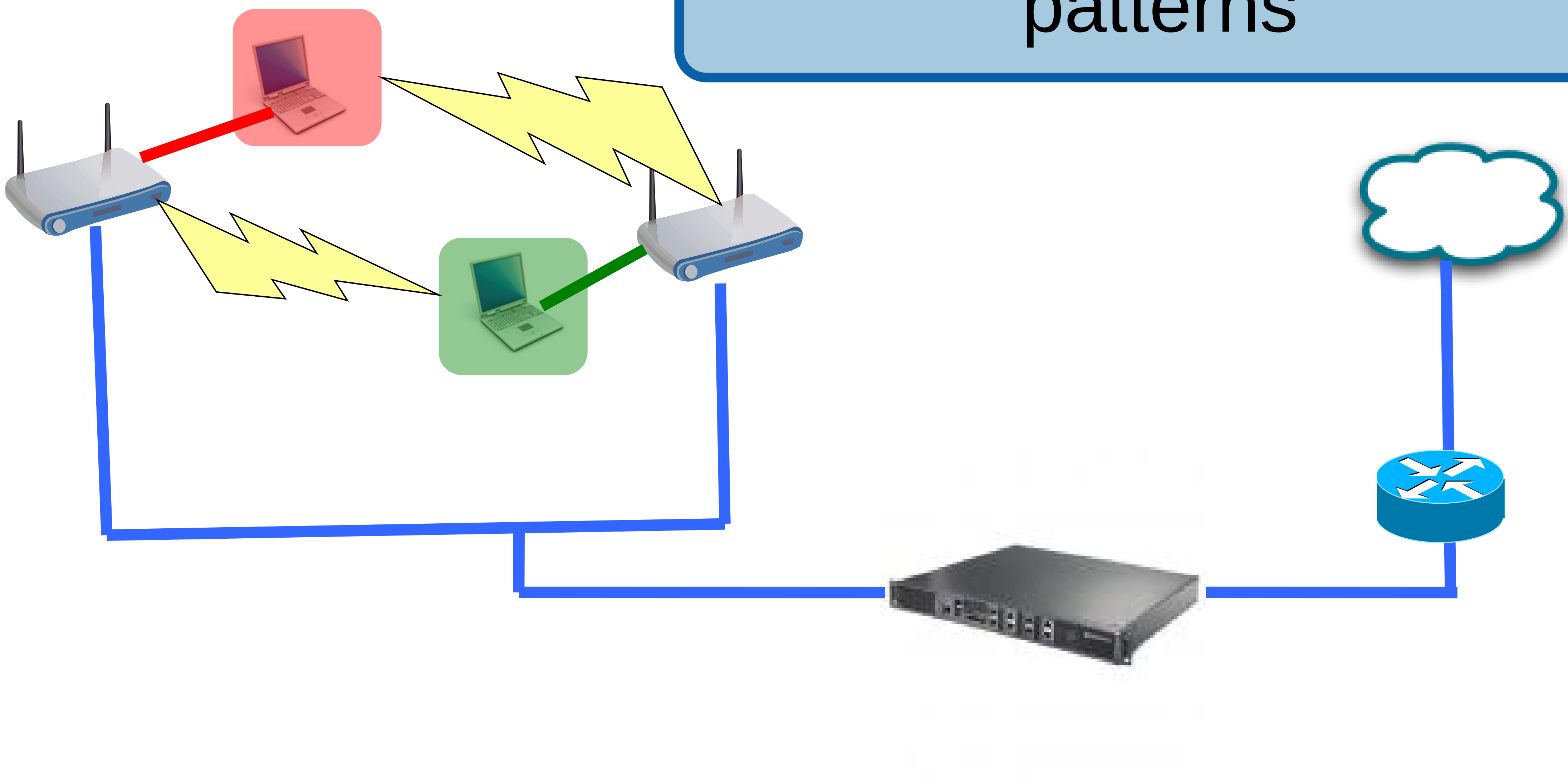
Problems with wireless

…. changing interference patterns



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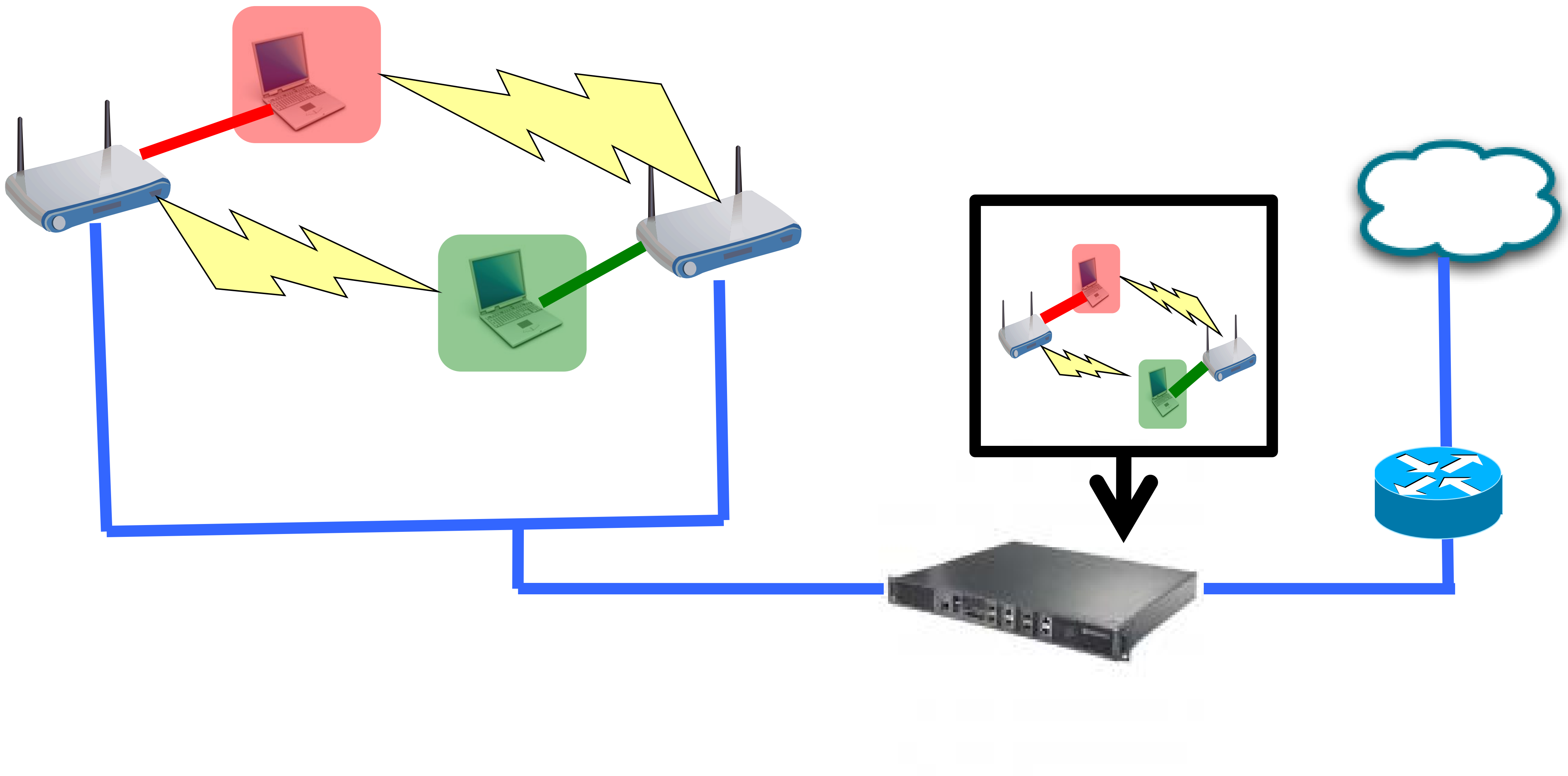
Interference management in WLANs



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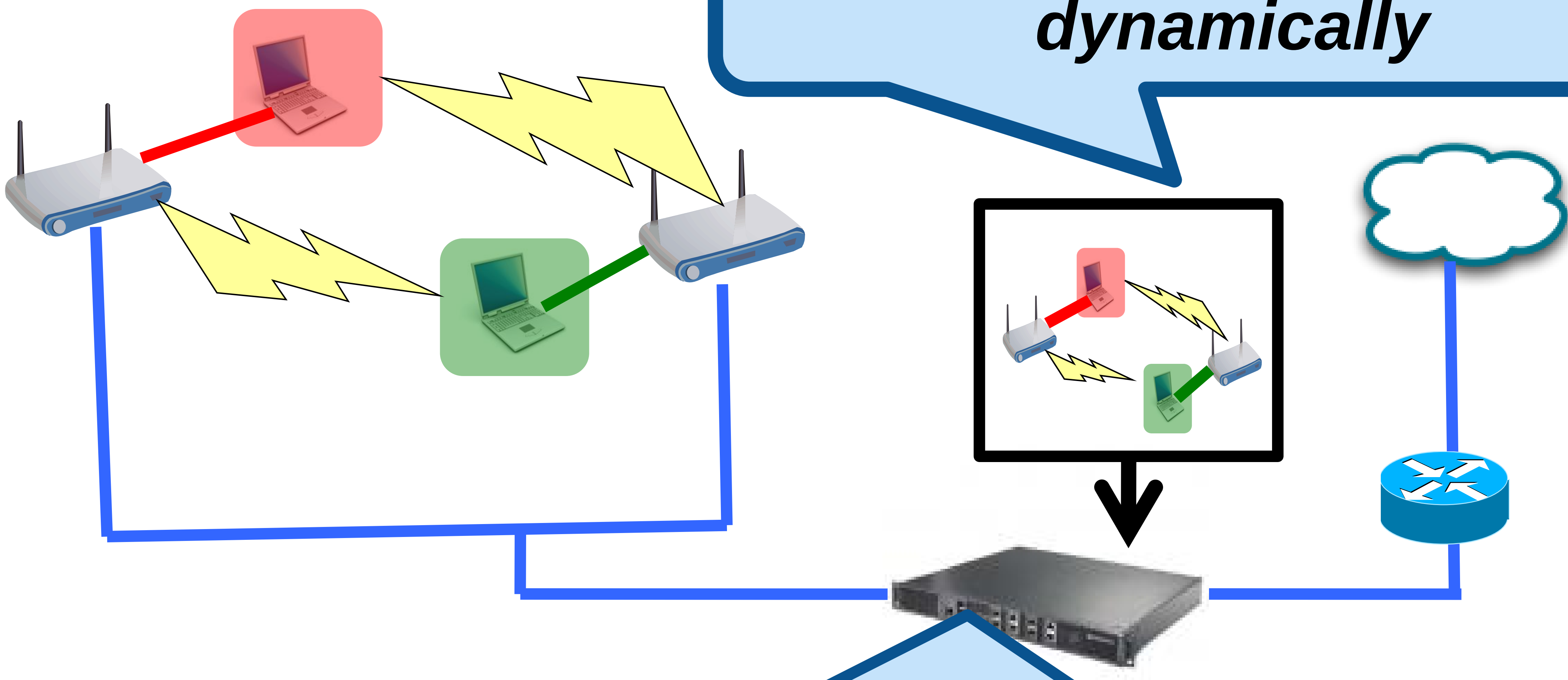
Interference management in WLANs

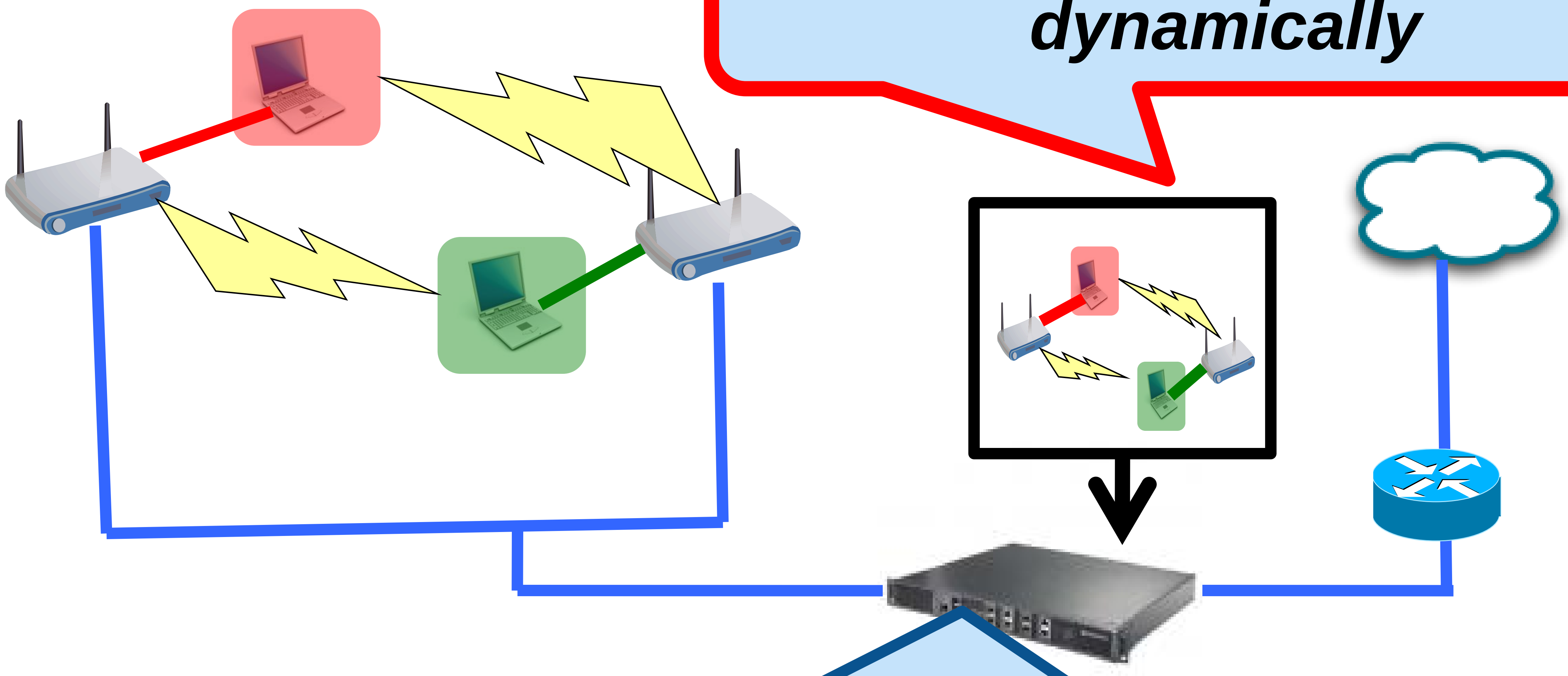


Estimate Interference *dynamically*

Manage Interference (data scheduling, transmit power control, channel assignment)

Interference management in WLANs

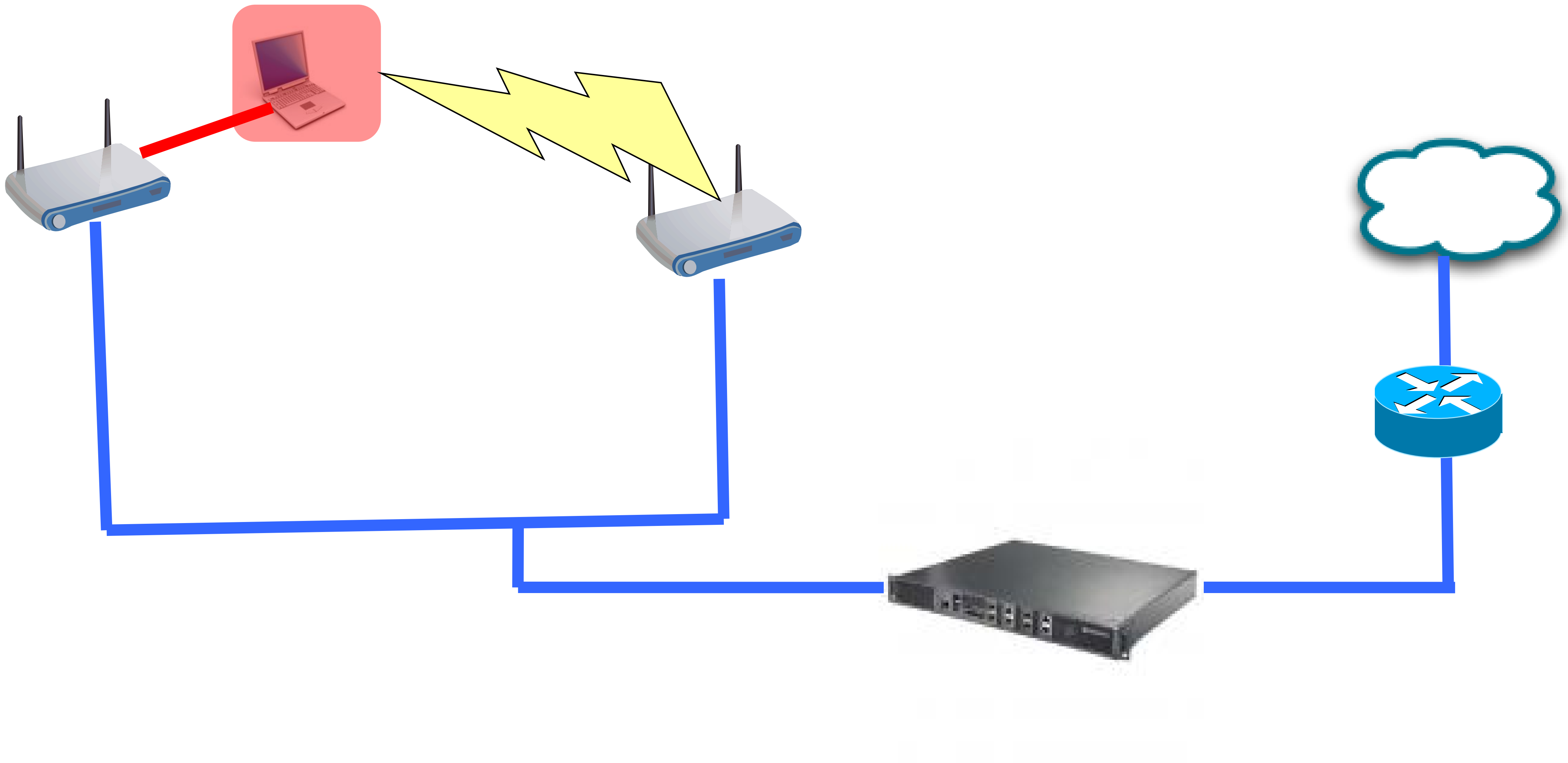
Estimate Interference *dynamically*



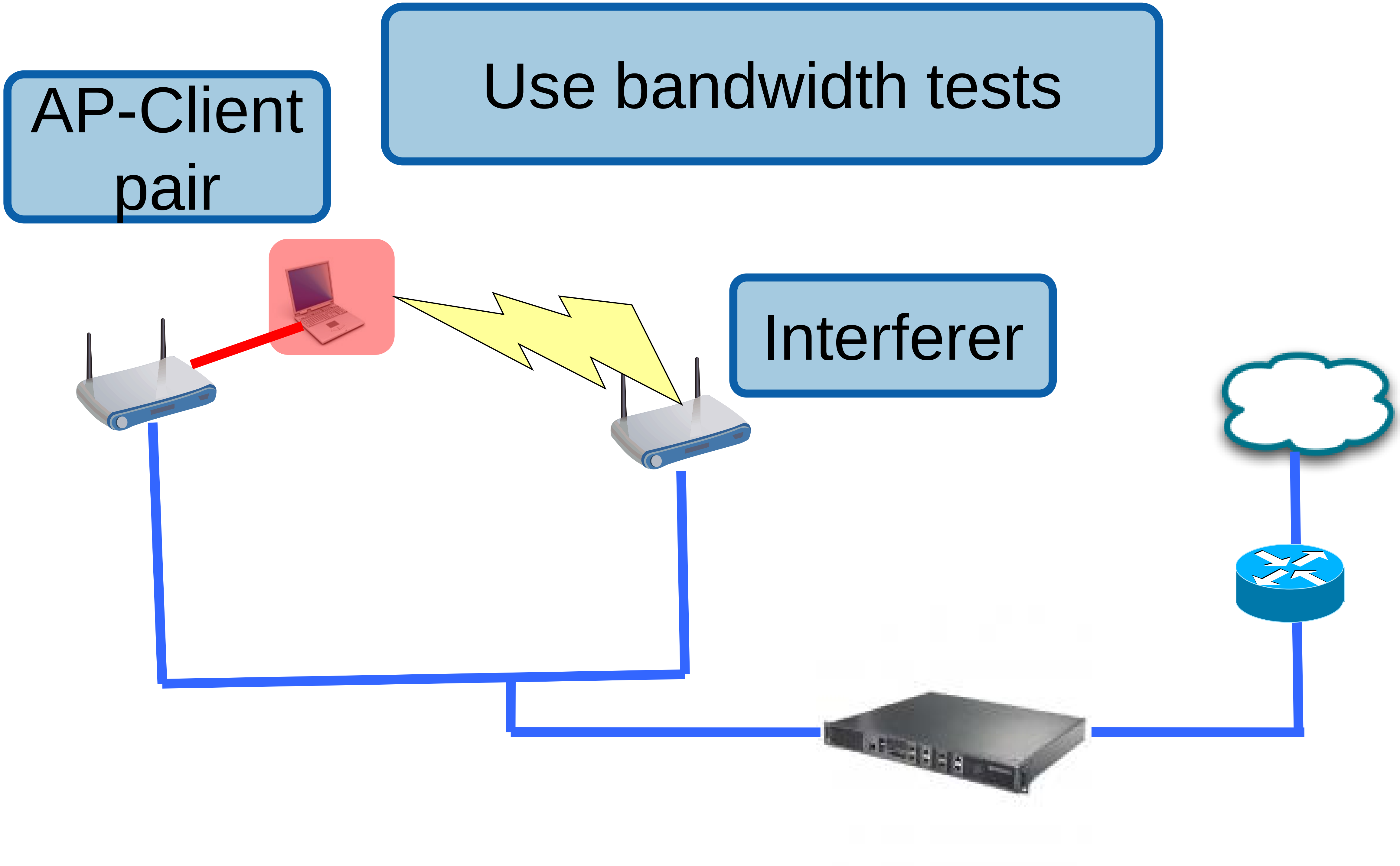
Manage Interference (data scheduling, transmit power control, channel assignment)

How to estimate interference ?

Use bandwidth tests

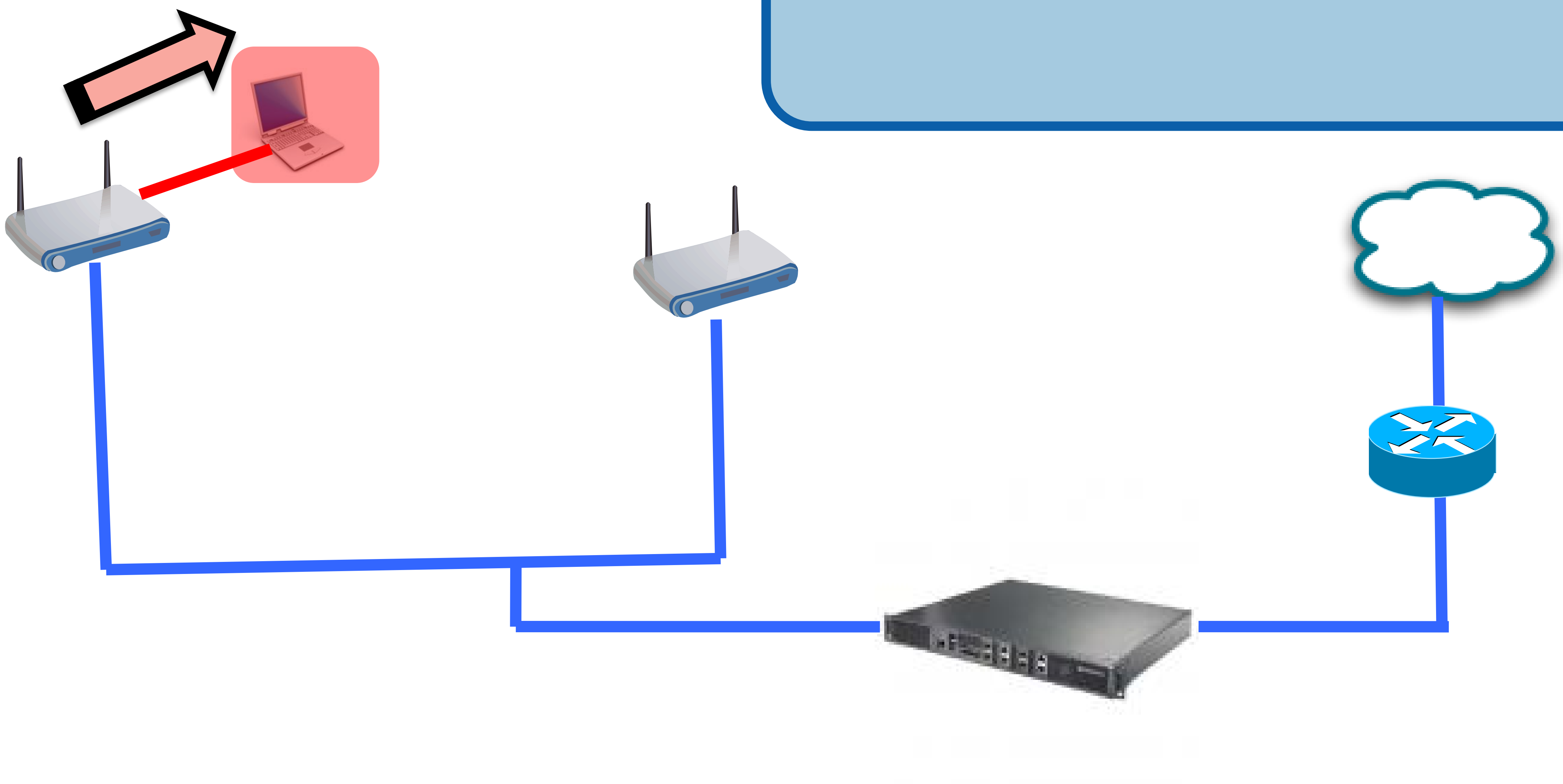


How to estimate interference ?



How to estimate interference ?

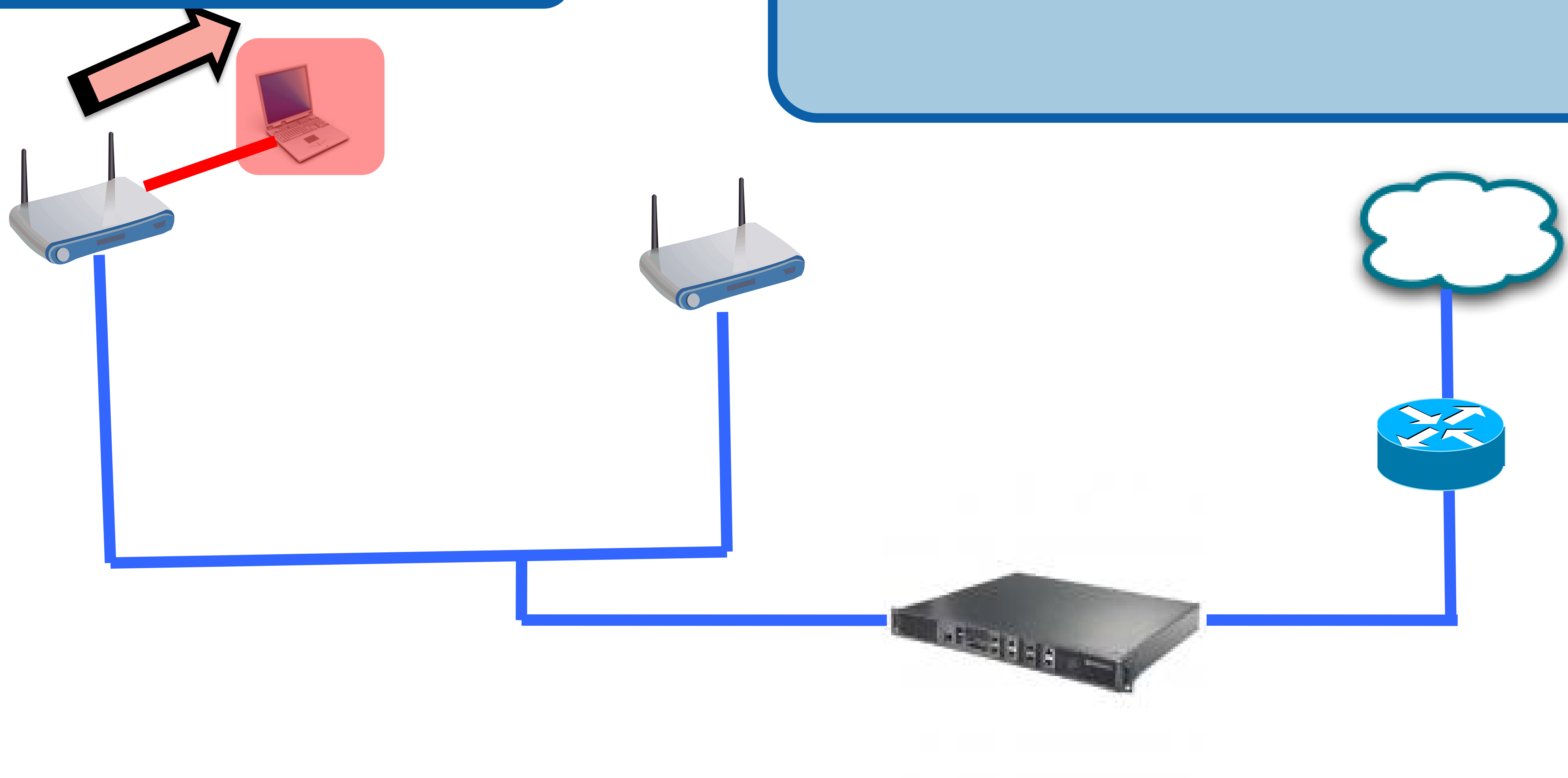
1) Measure AP-Client delivery in isolation



How to estimate interference ?

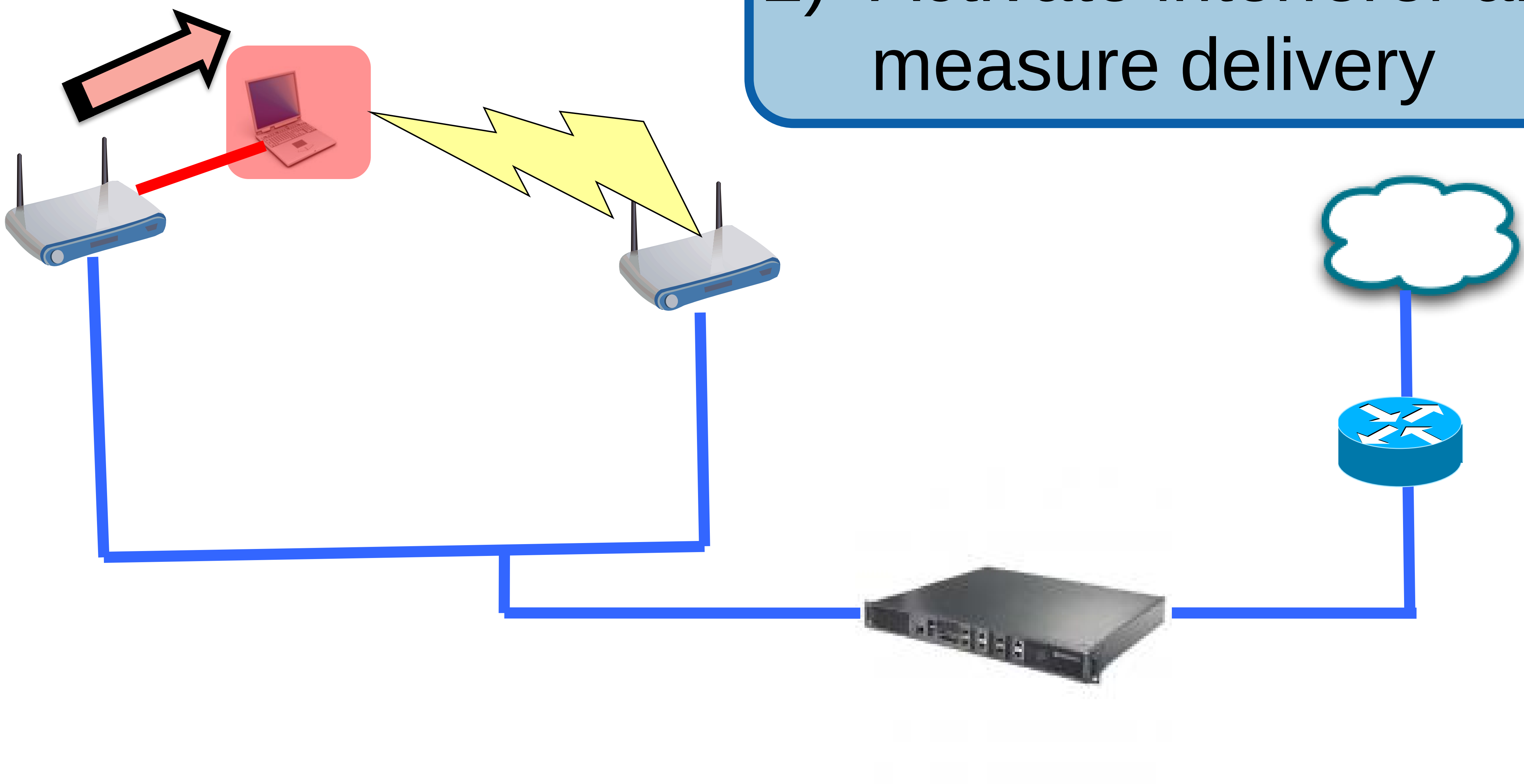
Isolation
delivery= 0.95

1) Measure AP-Client delivery in isolation



How to estimate interference ?

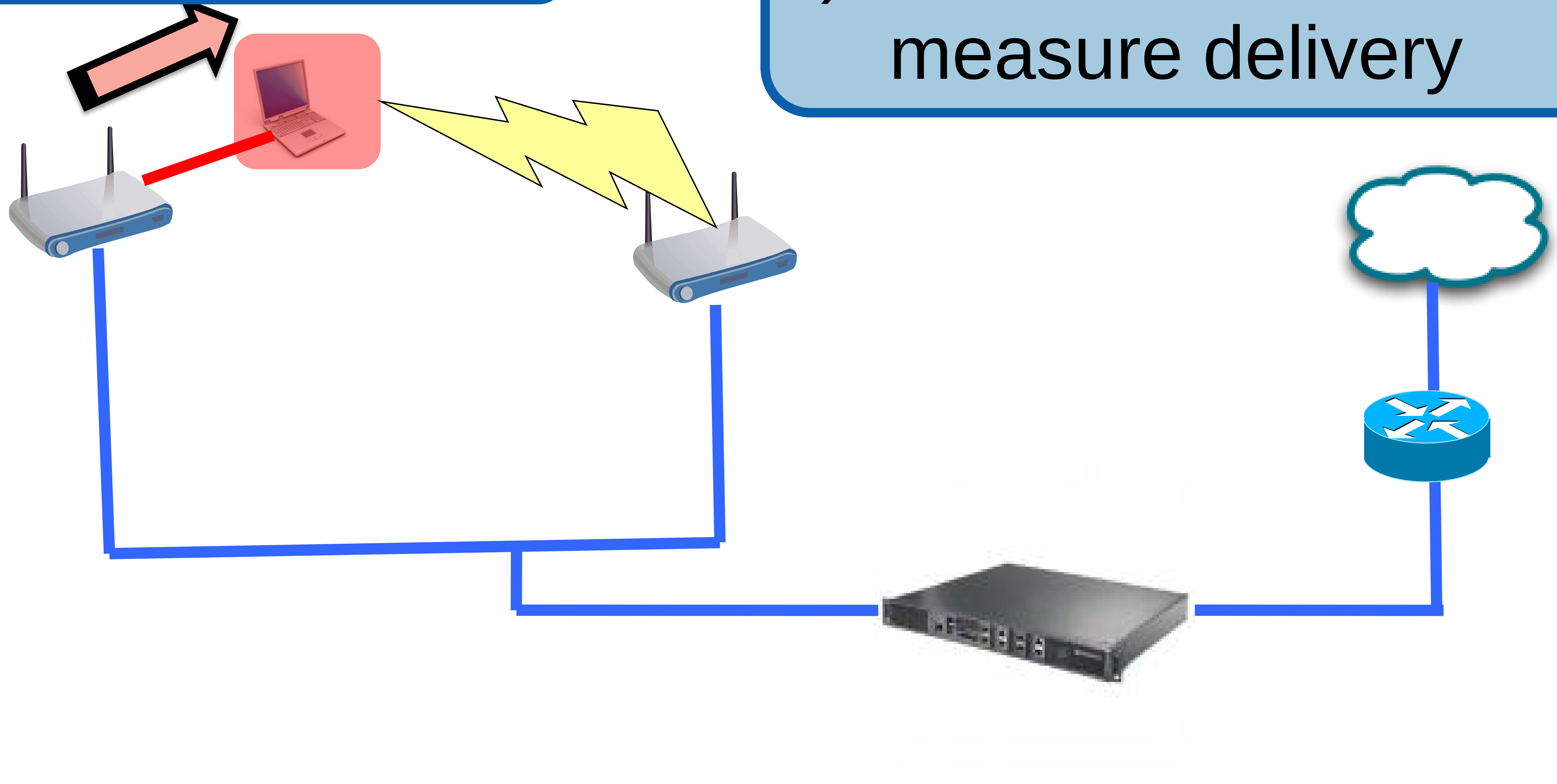
1) Measure AP-Client delivery in isolation
2) Activate interferer and measure delivery



How to estimate interference ?

Interference delivery= 0.66

1) Measure AP-Client delivery in isolation
2) Activate interferer and measure delivery



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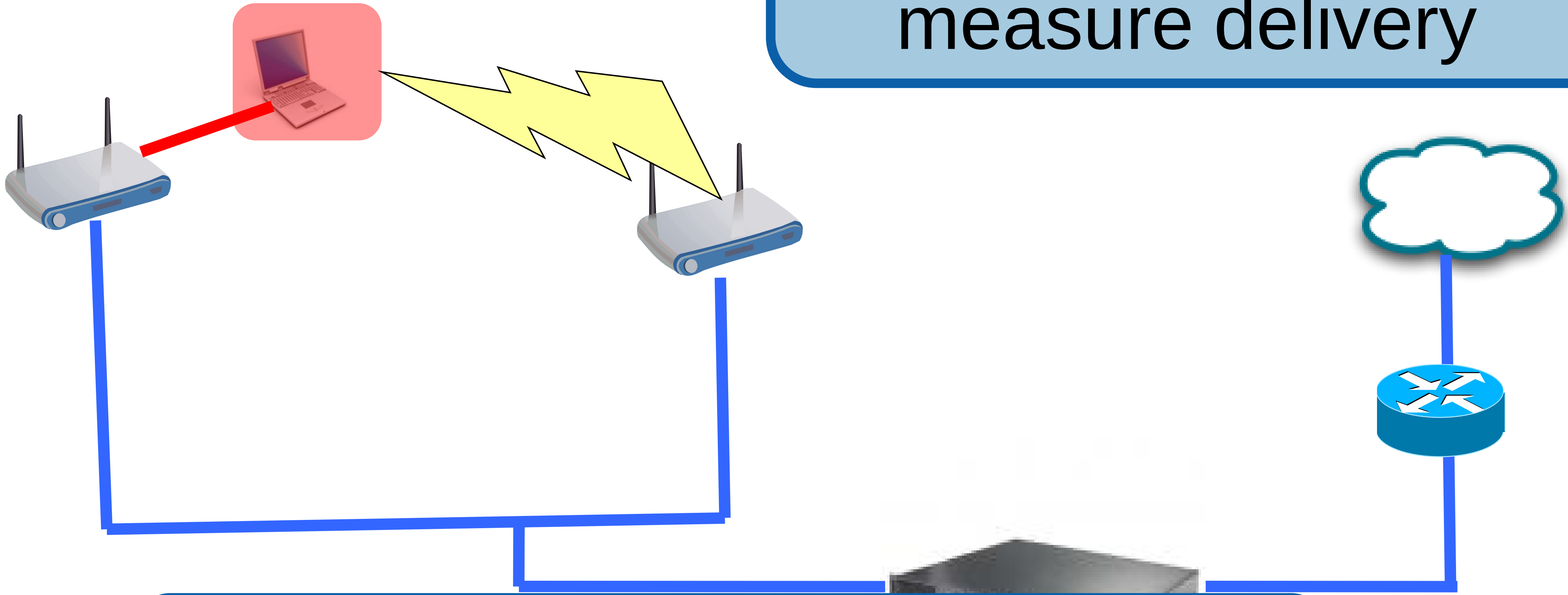

Link Interference Ratio (LIR) = del Interference / del isolation

How to estimate interference ?

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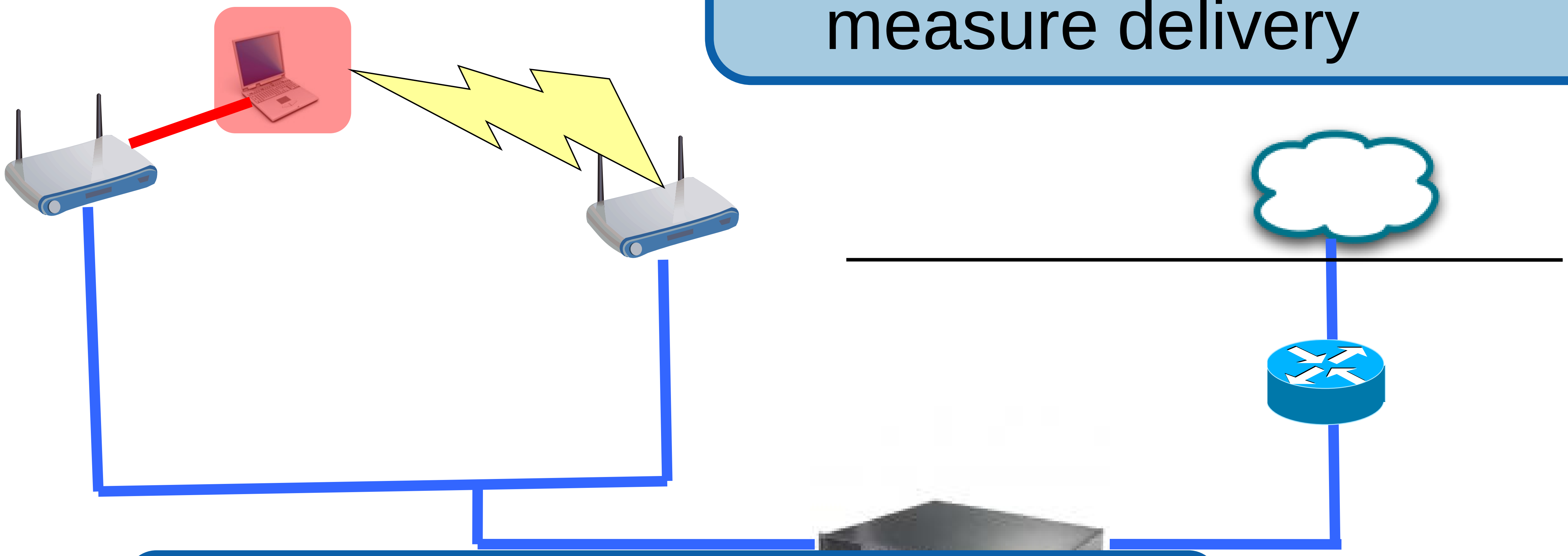

Link Interference Ratio (LIR) = 0.66 / 0.95 = 0.69

How to estimate interference ?

1) Measure AP-Client delivery in isolation
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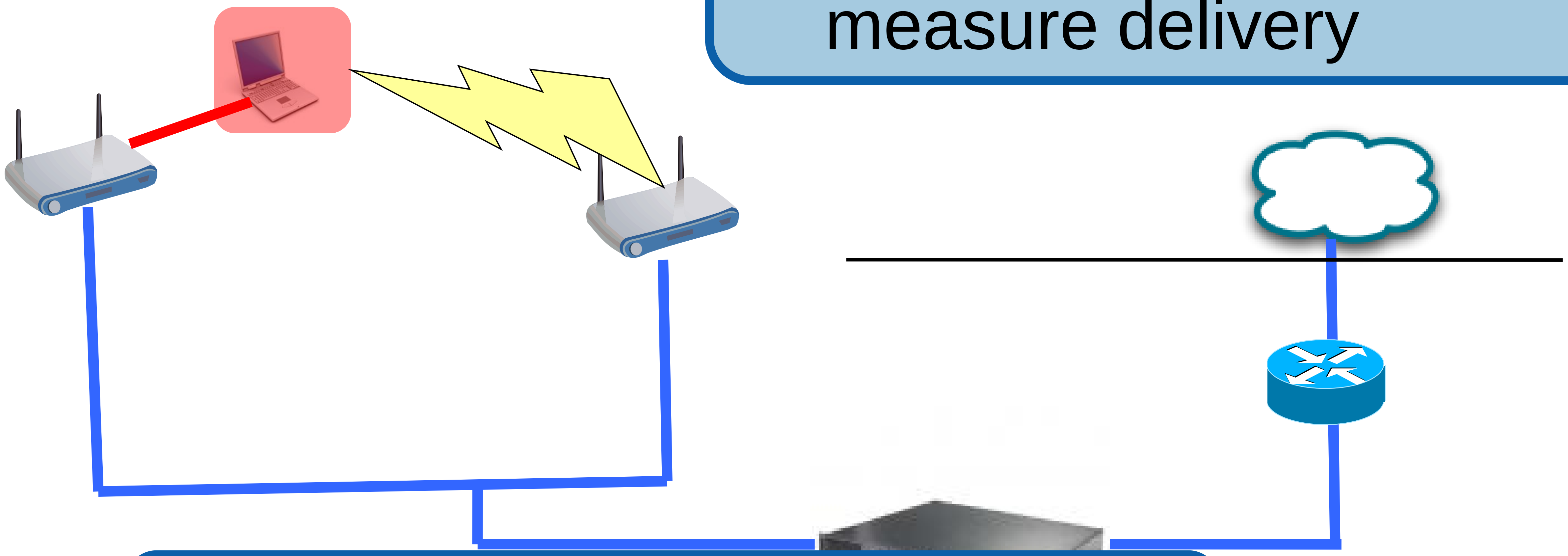

But are bandwidth tests practical ?

- Can we use bandwidth tests in live settings
  - Good accuracy – ✓
  - Network downtime required - **X**
  - Not scalable (~ 1 hr for 20 AP-Client pair network) - **X**
  - Not based on realistic rates and packet sizes – **X**
  - Inefficient in dynamic scenario (client mobility) – **X**

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  - Not based on realistic rates and packet sizes – **X**
  - Inefficient in dynamic scenario (client mobility) – **X**

Can we estimate interference in a passive, real-time way ?

PIE Outline

- Motivation
  - Conventional bandwidth tests not sufficient
- Passive Interference Estimation (PIE)
  - Polling period of PIE
  - Accuracy of PIE
  - Realistic trace replay with PIE
- Applications of PIE
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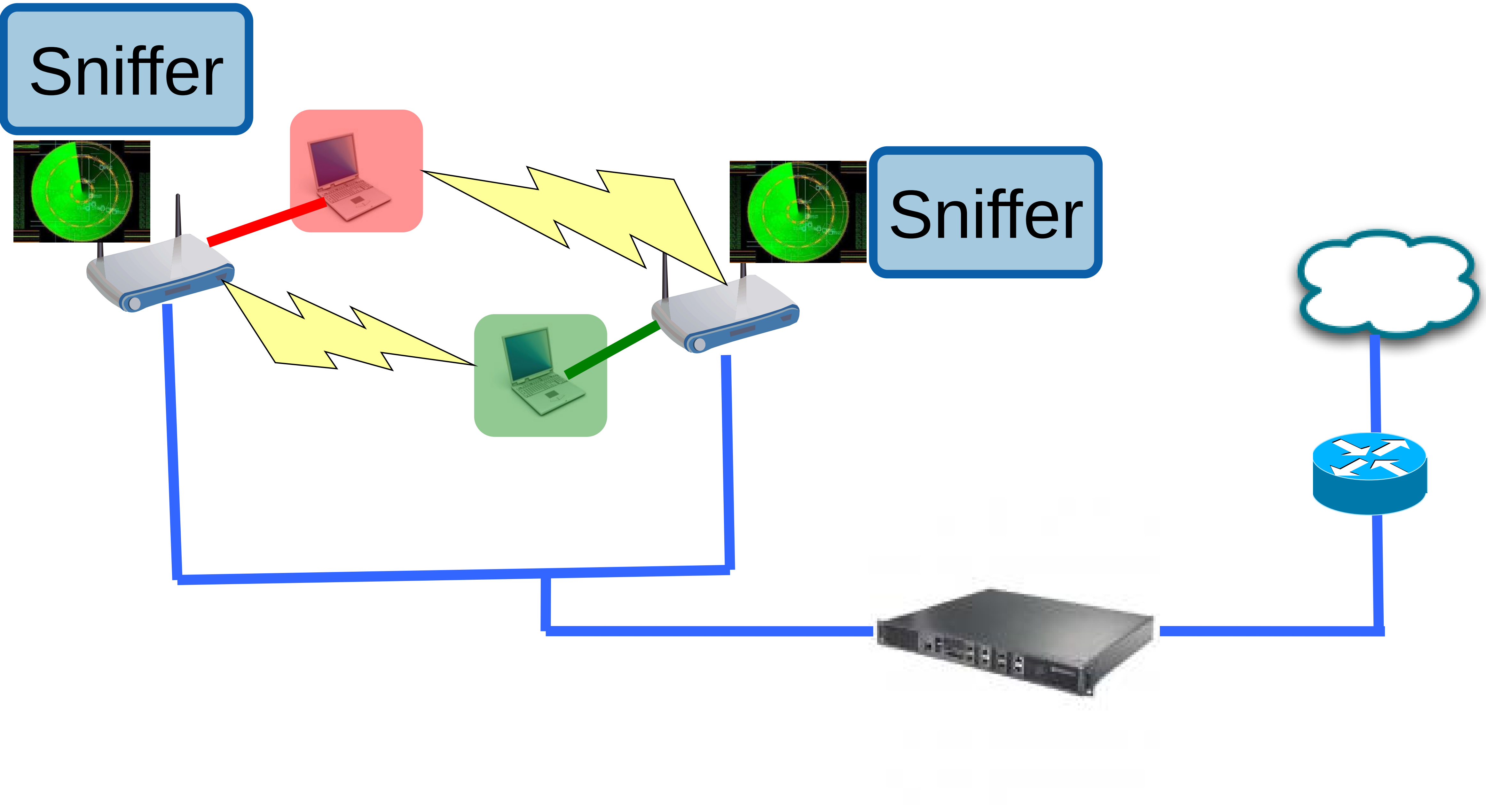
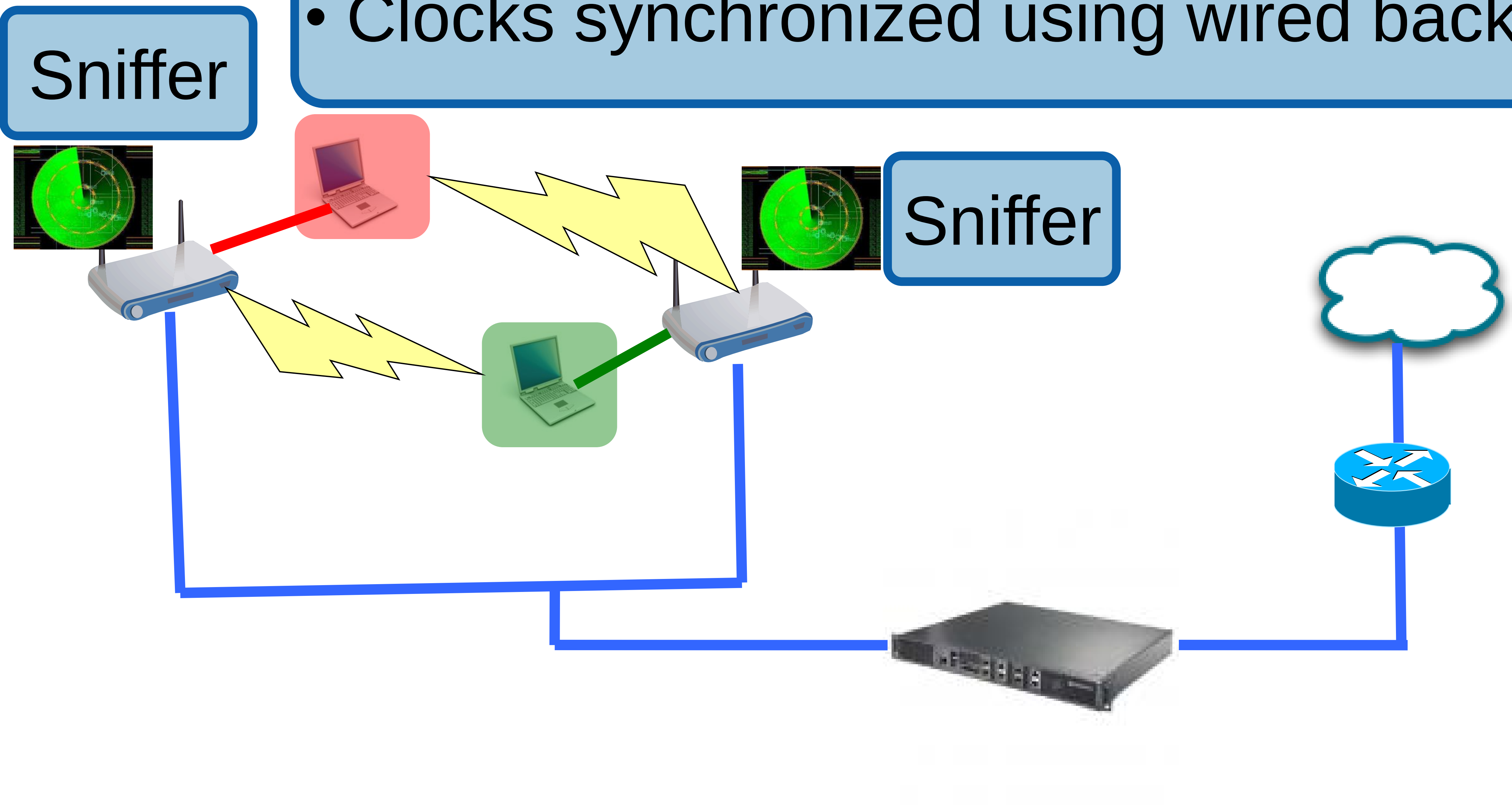
Estimating interference passively



Estimating interference passively

- Sniffer could be a dedicated wireless radio
- Clocks synchronized using wired backplane



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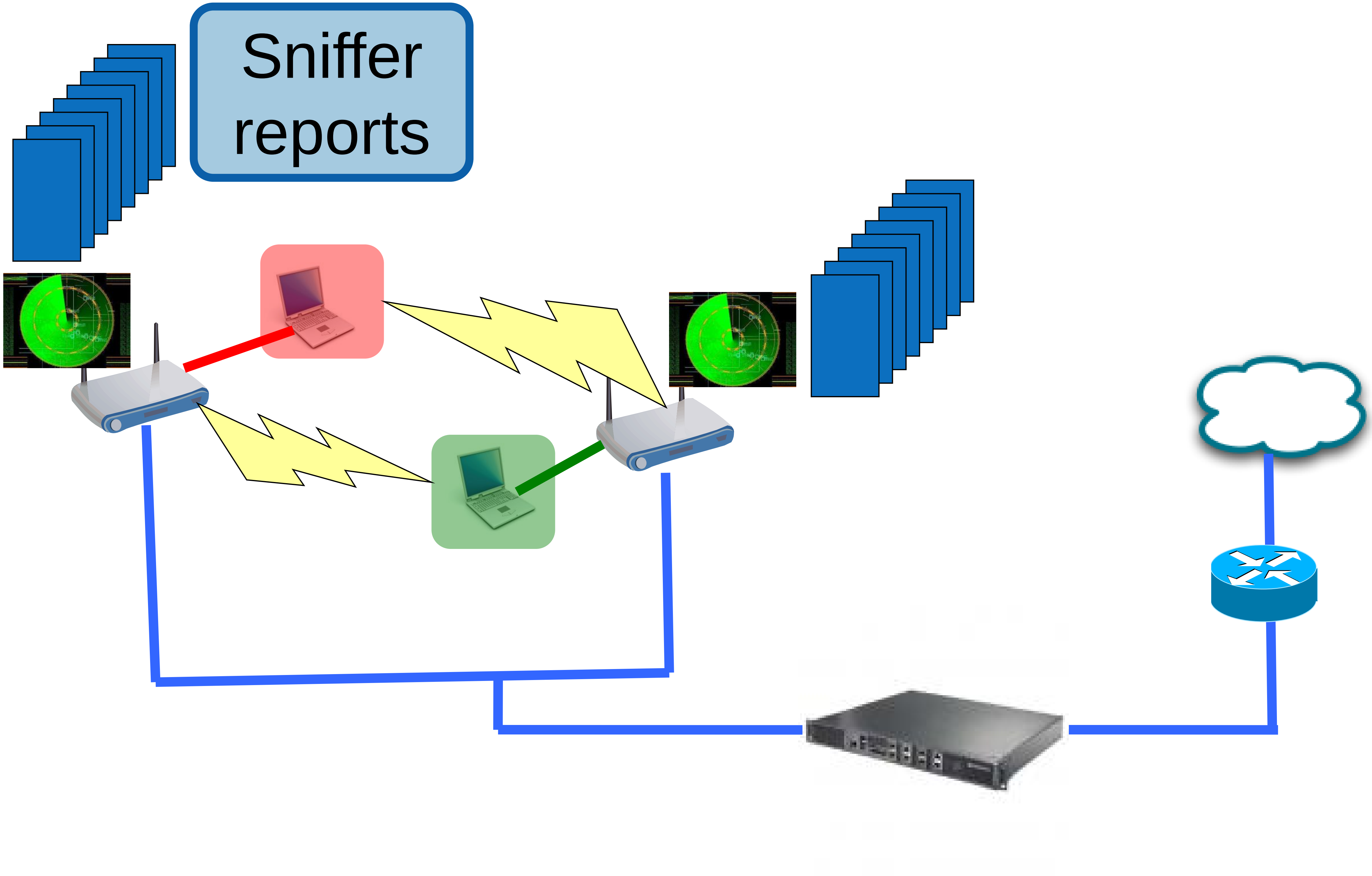

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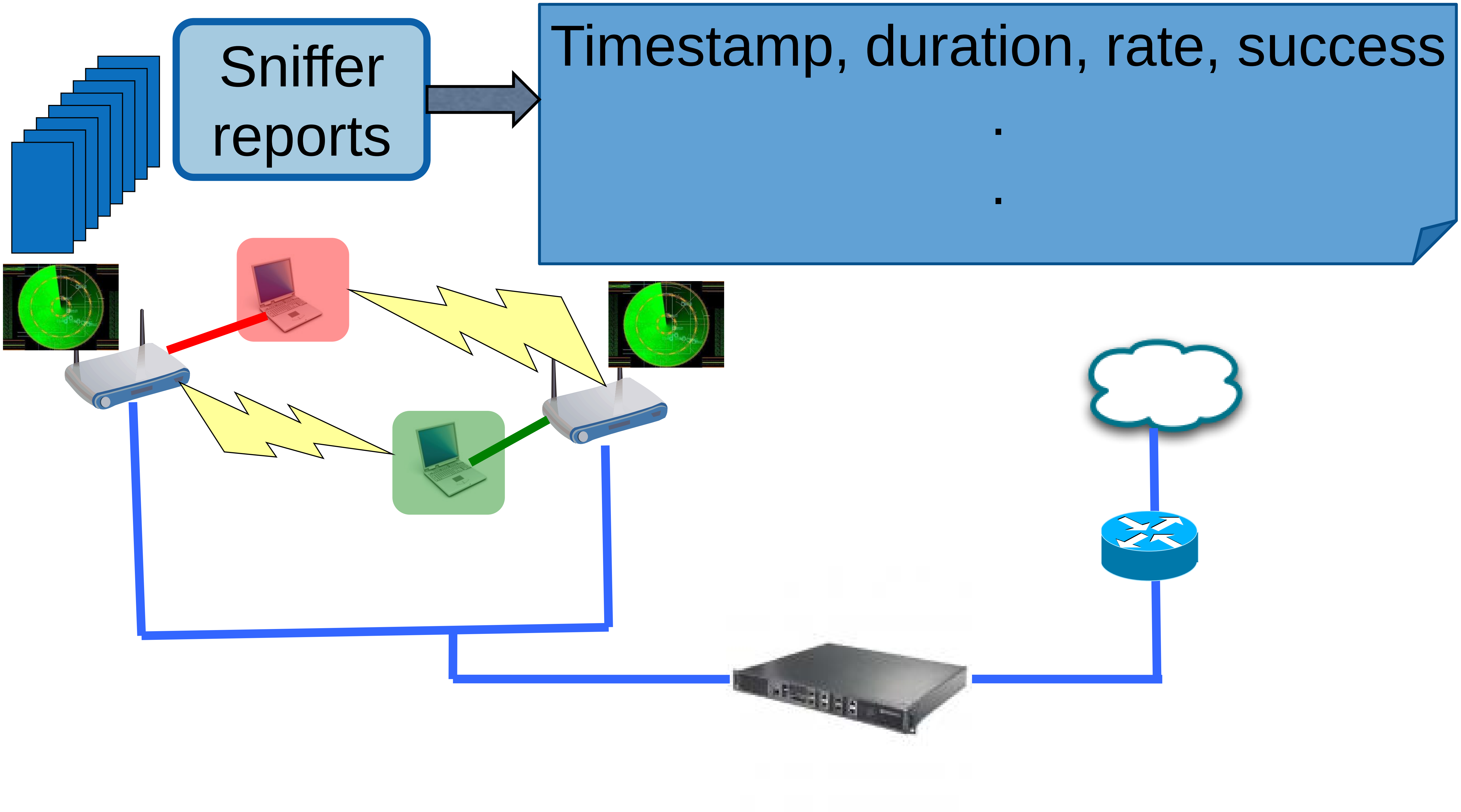

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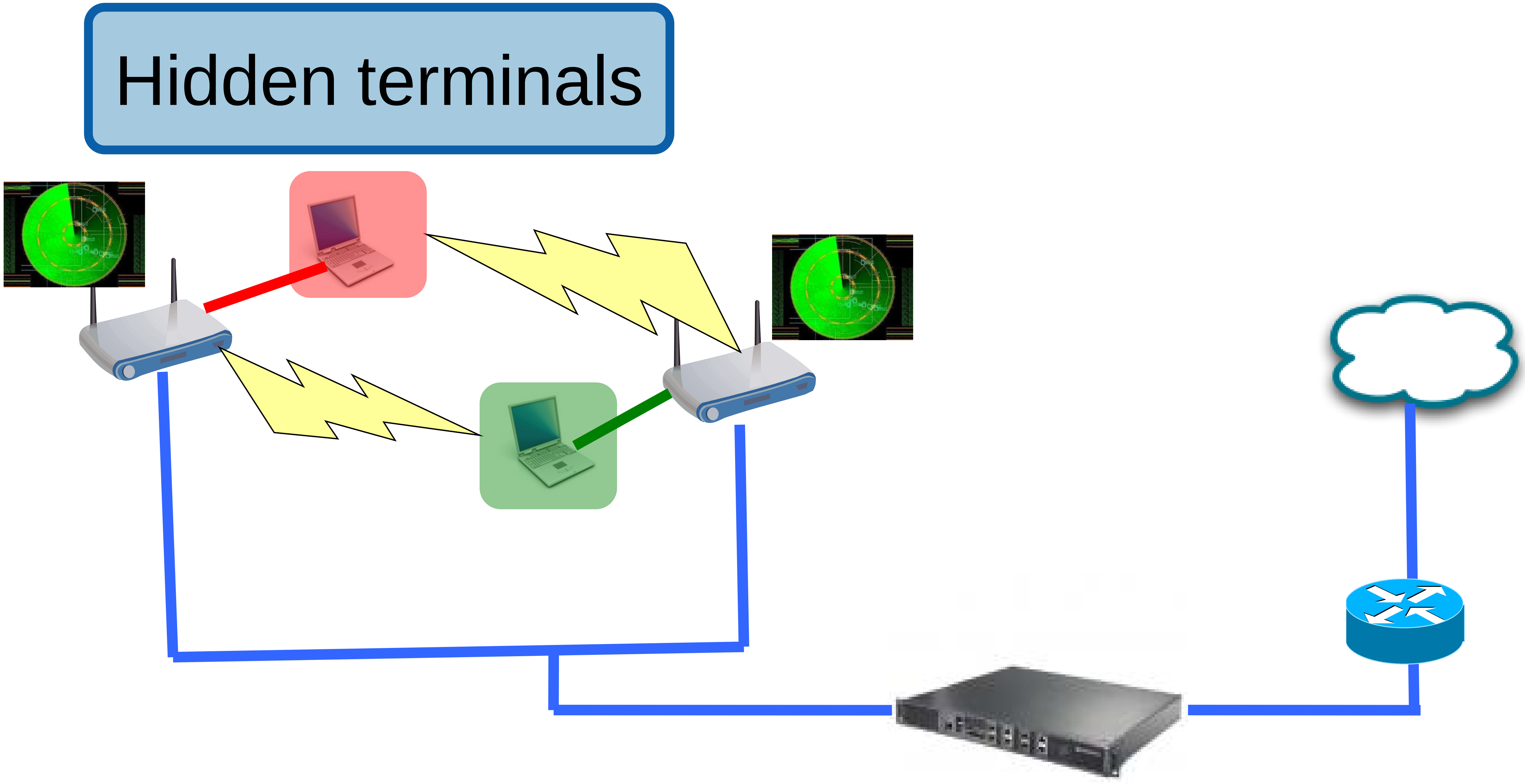
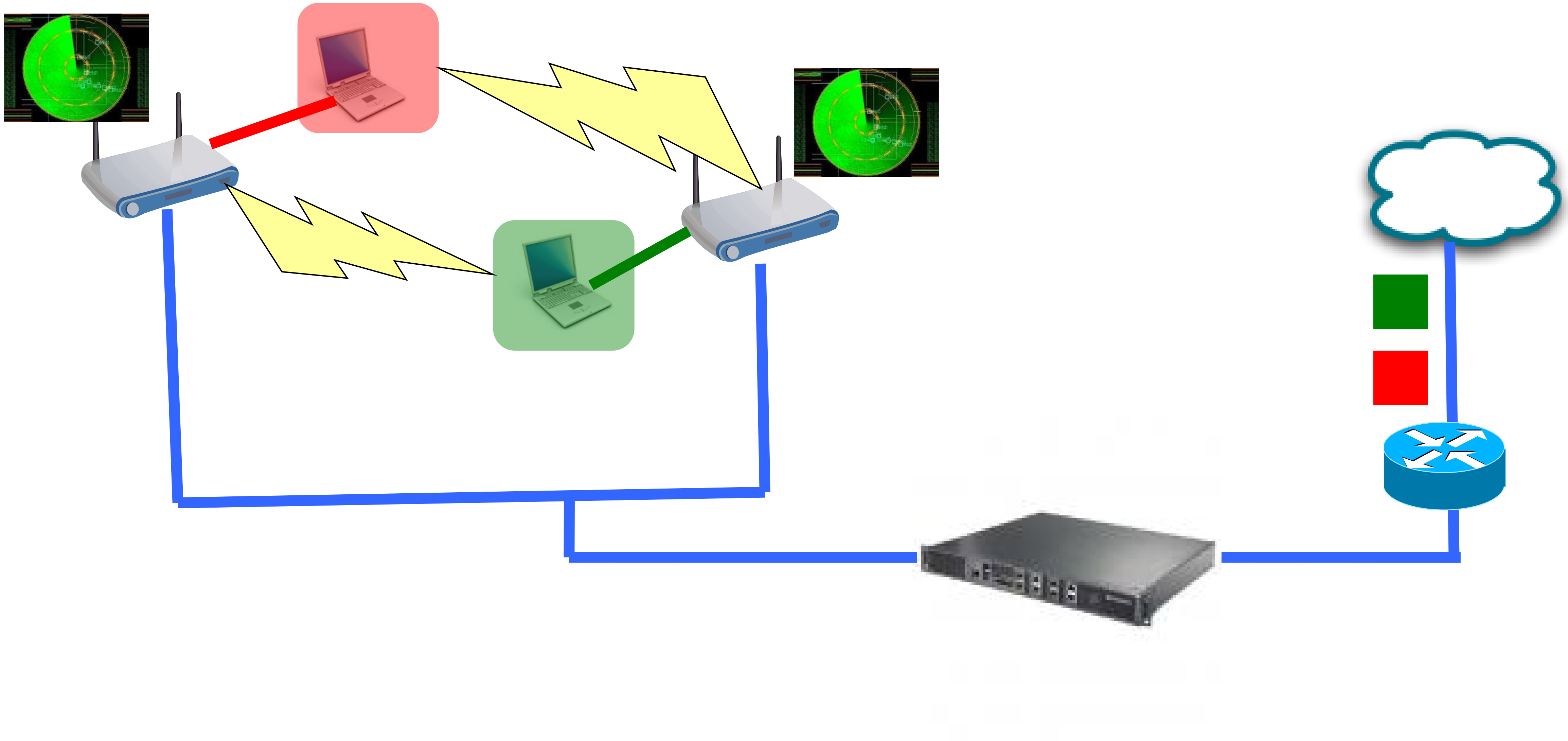


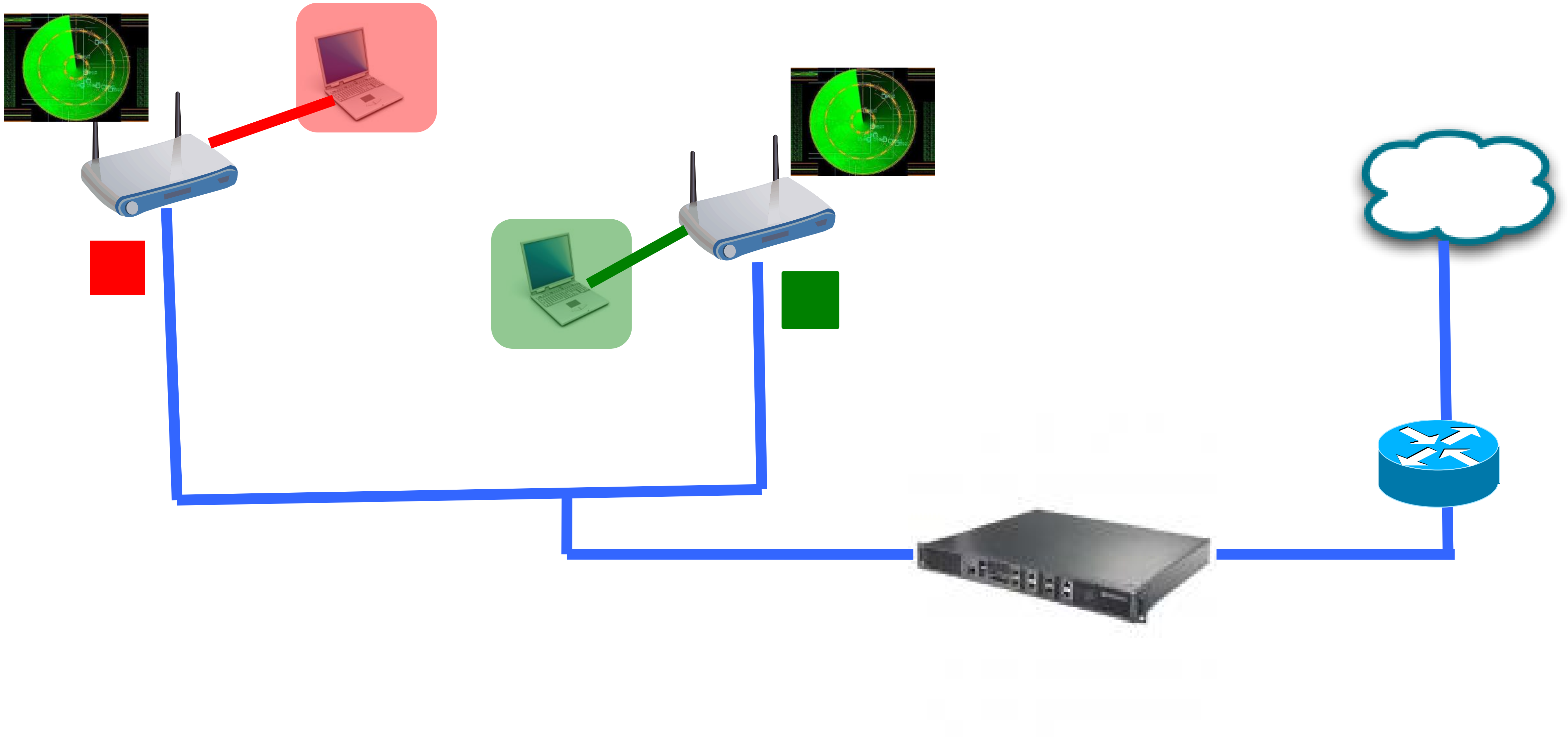
Estimating interference passively

Hidden terminals



Estimating interference passively

Hidden terminals



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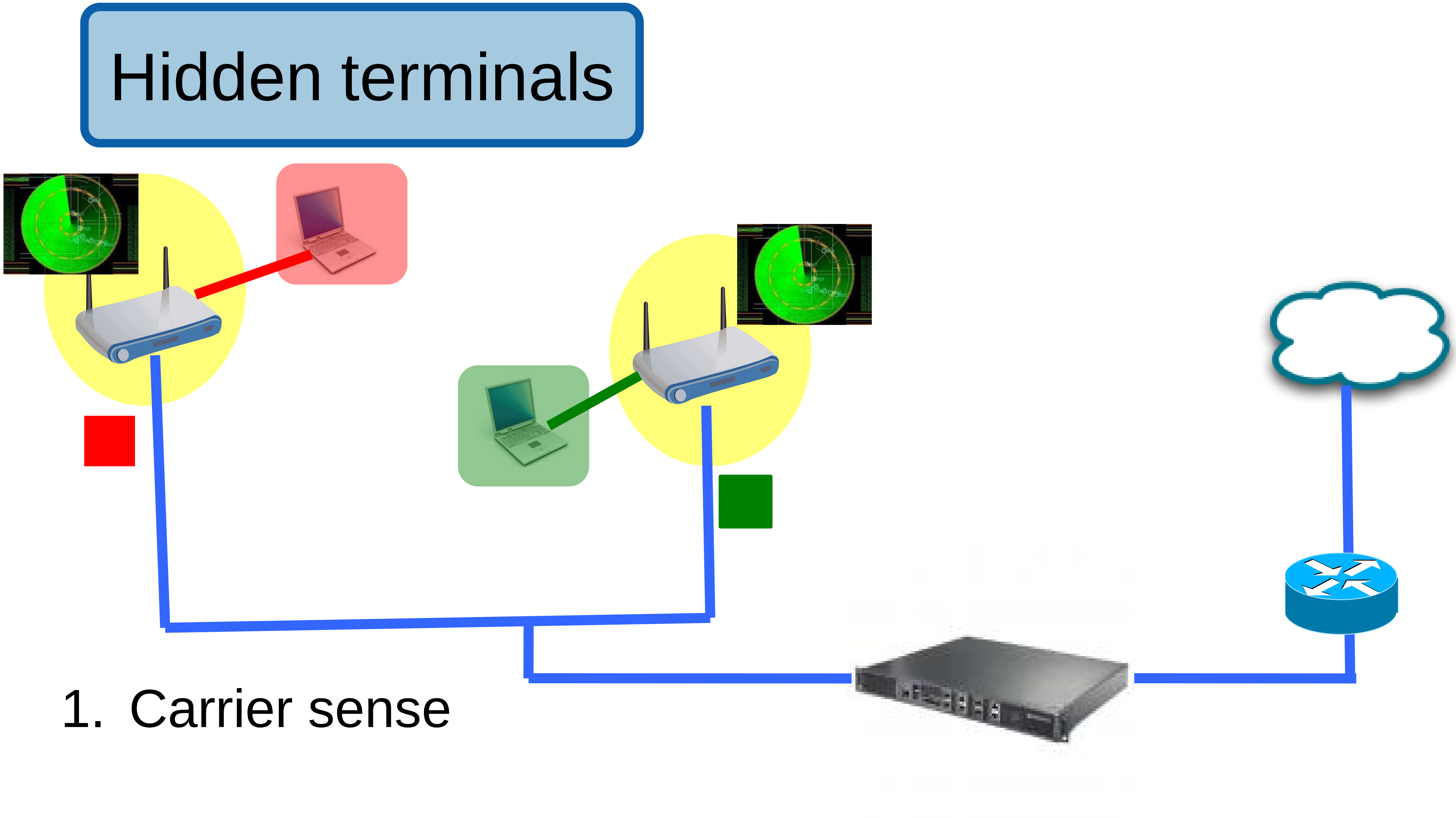
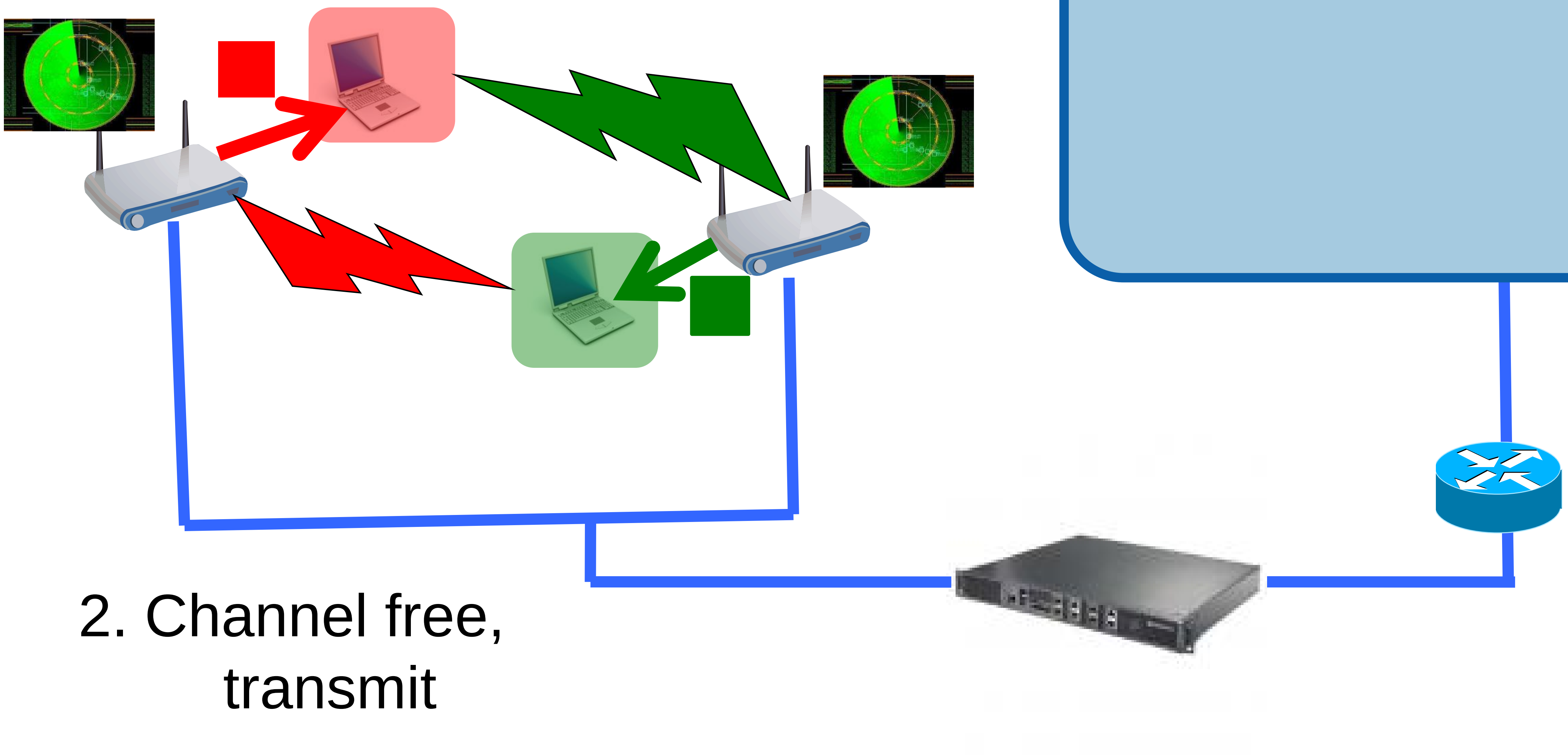


1. Carrier sense

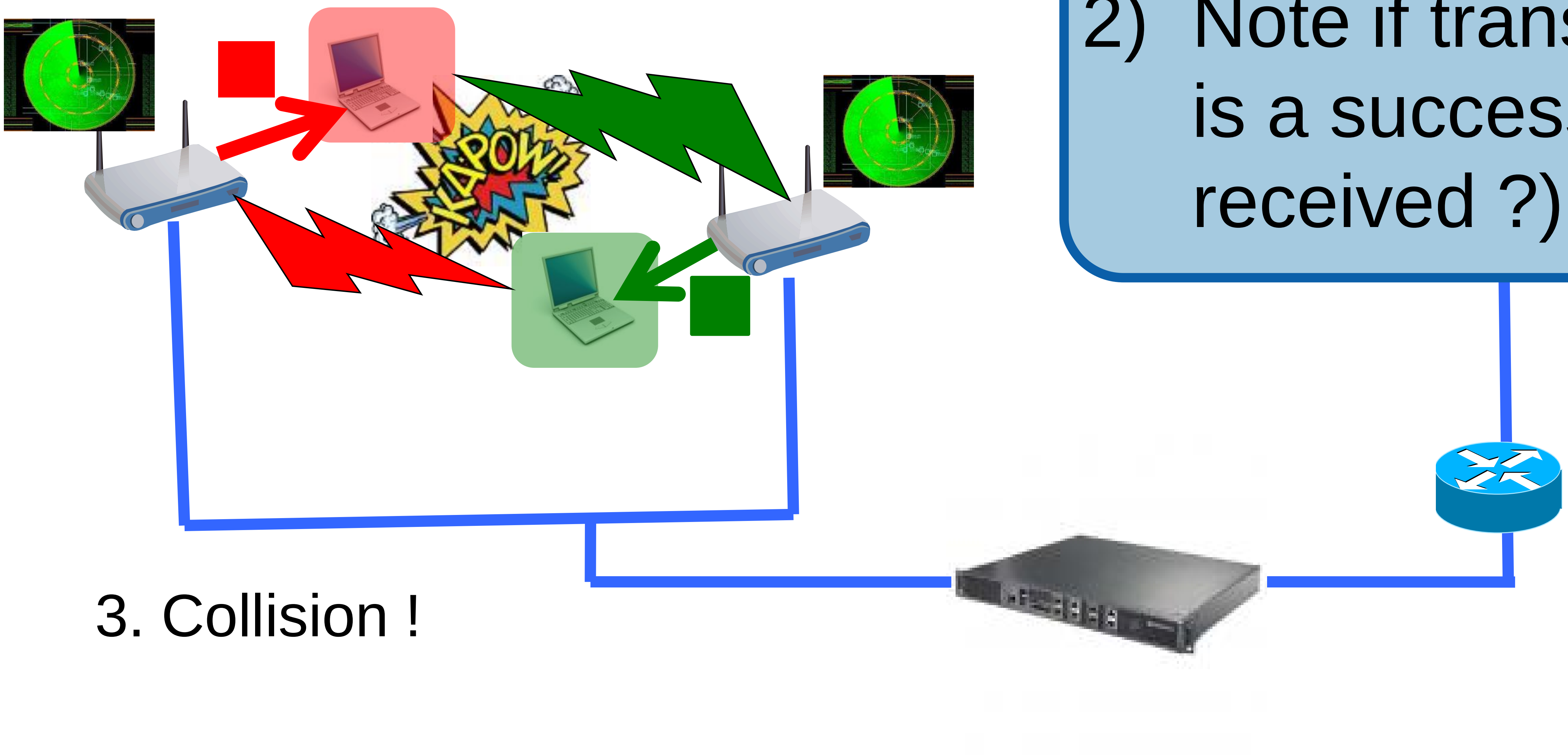
Estimating interference passively

Hidden terminals

1) Note timestamp, rate, duration



Estimating interference passively



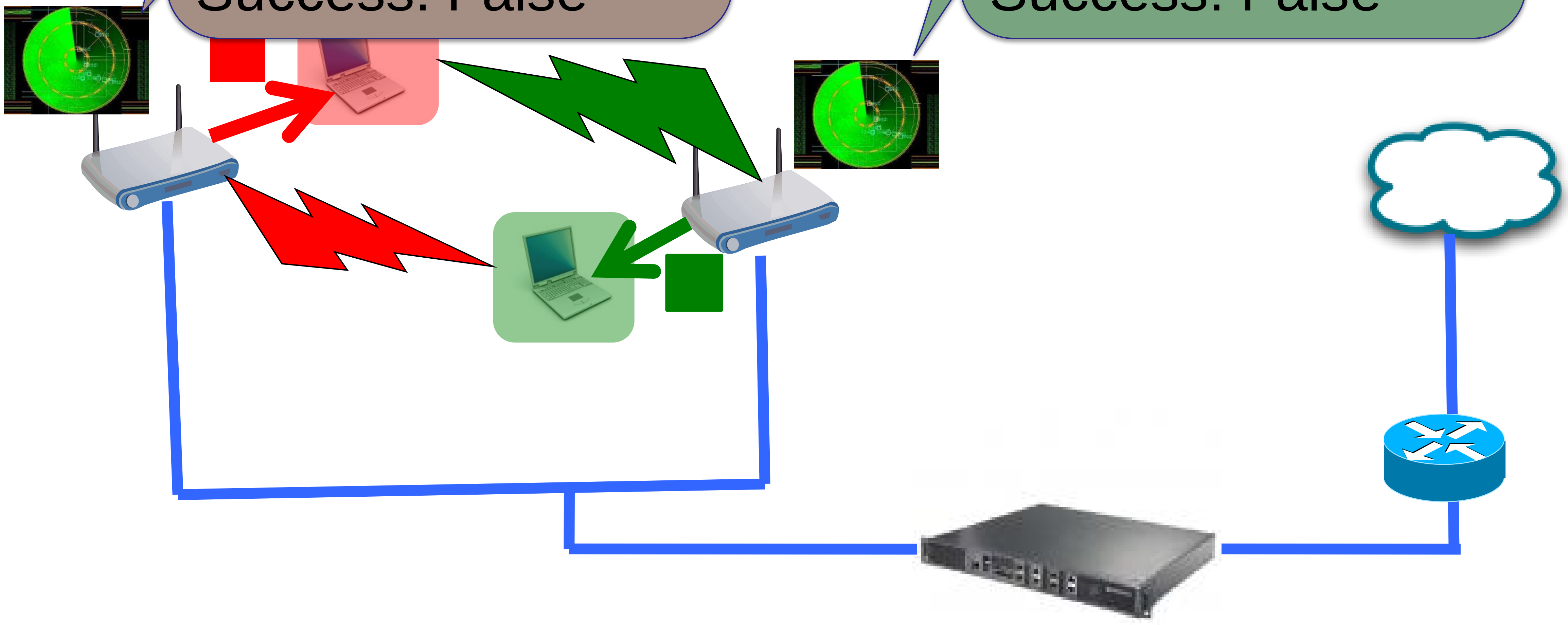
1) Note timestamp, rate, duration
2) Note if transmission is a success (ack received ?)

3. Collision !

Estimating interference passively

Timestamp: T0
Rate: 6Mbps
Length: 1400 bytes
Success: False

Timestamp: T0 + δ
Rate: 12Mbps
Length: 600 bytes
Success: False



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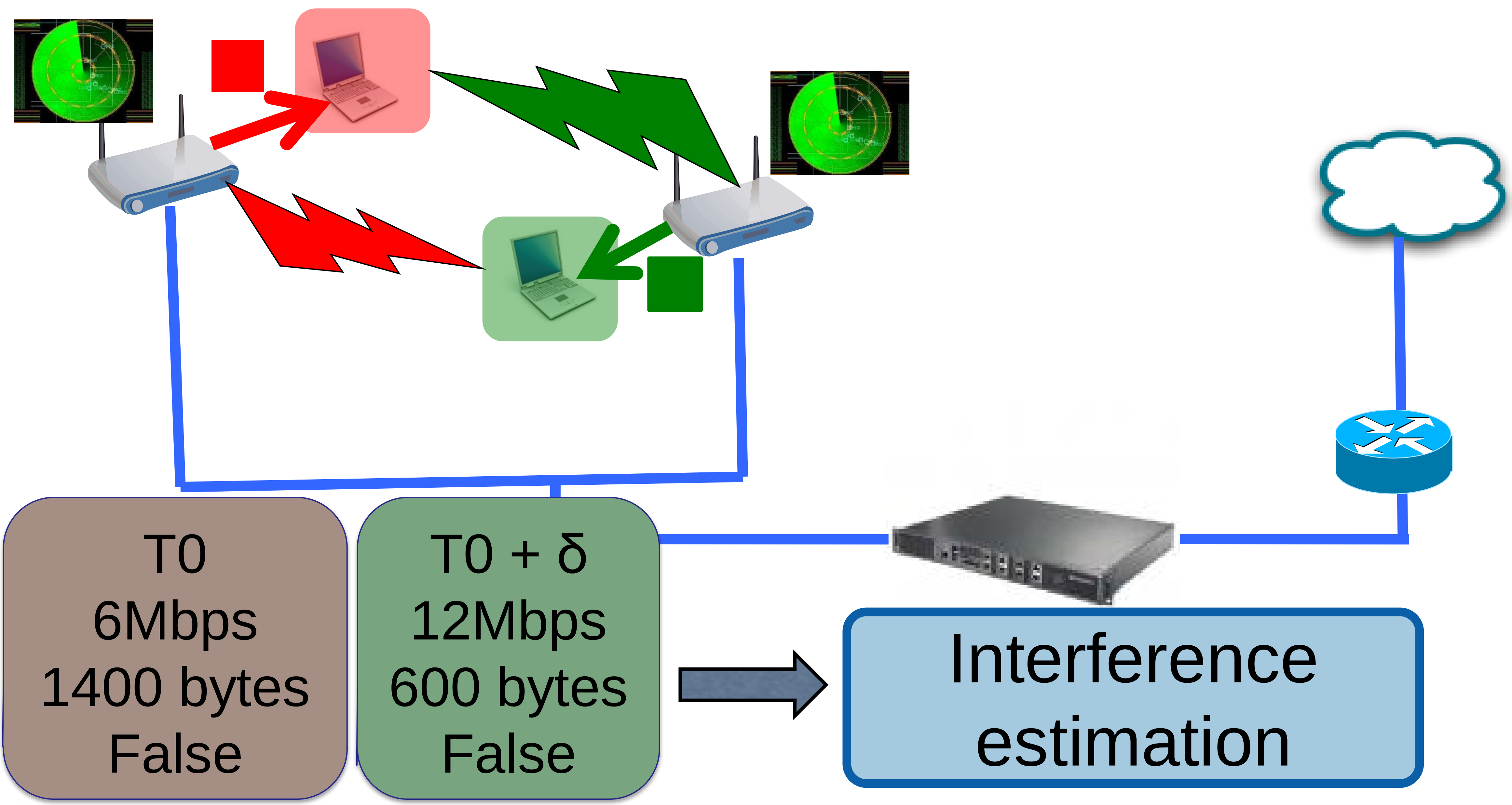

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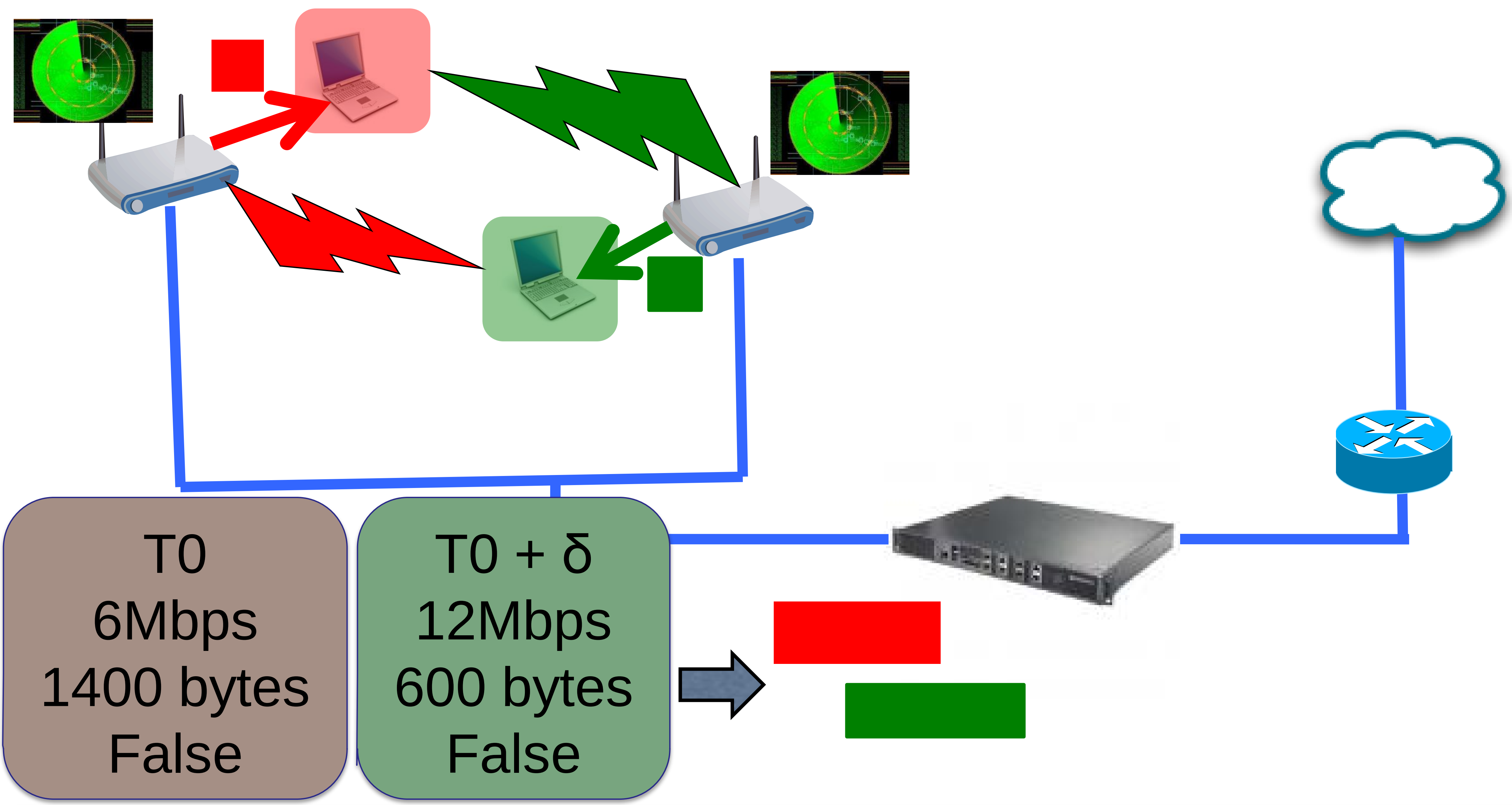

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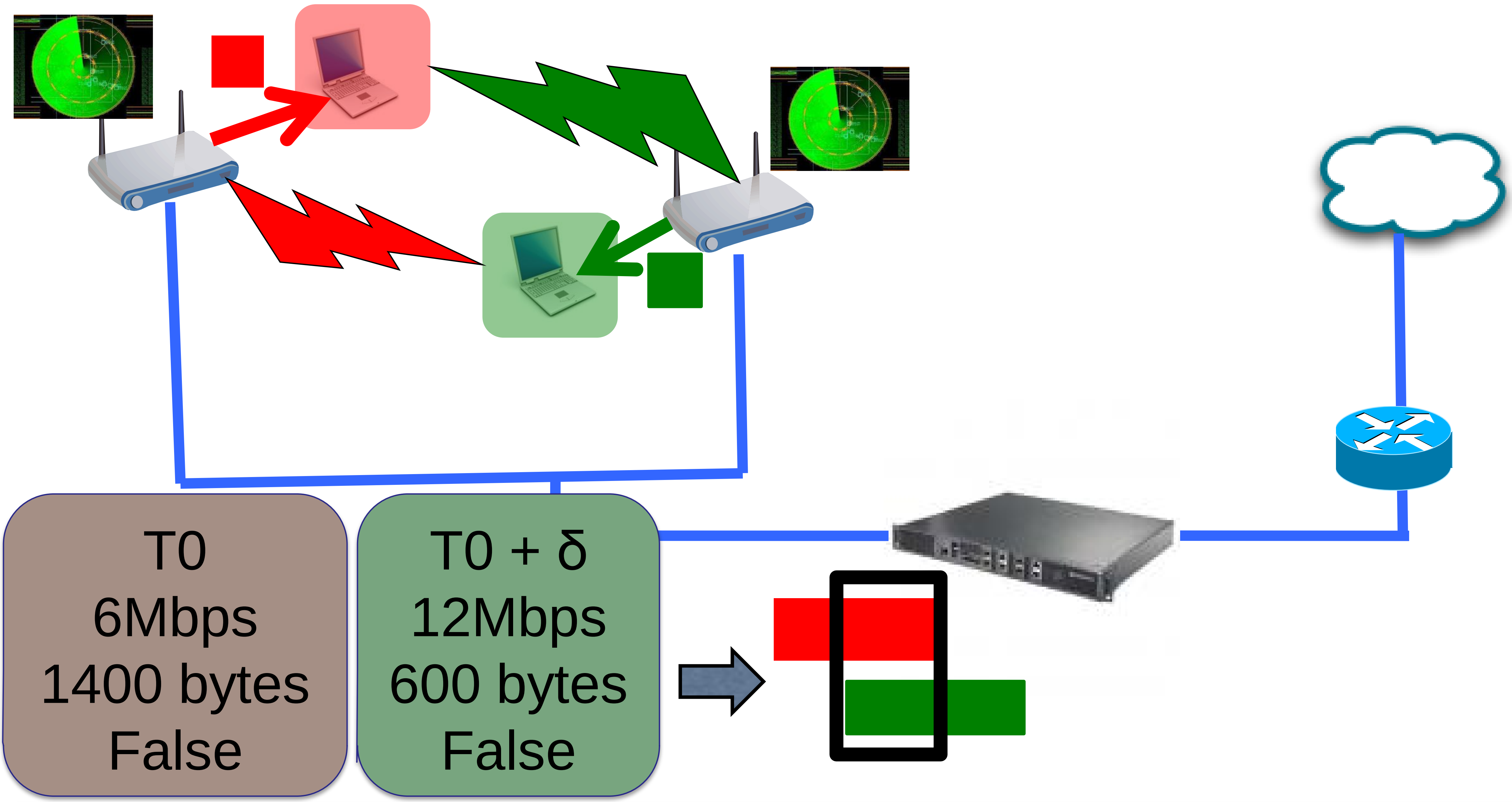

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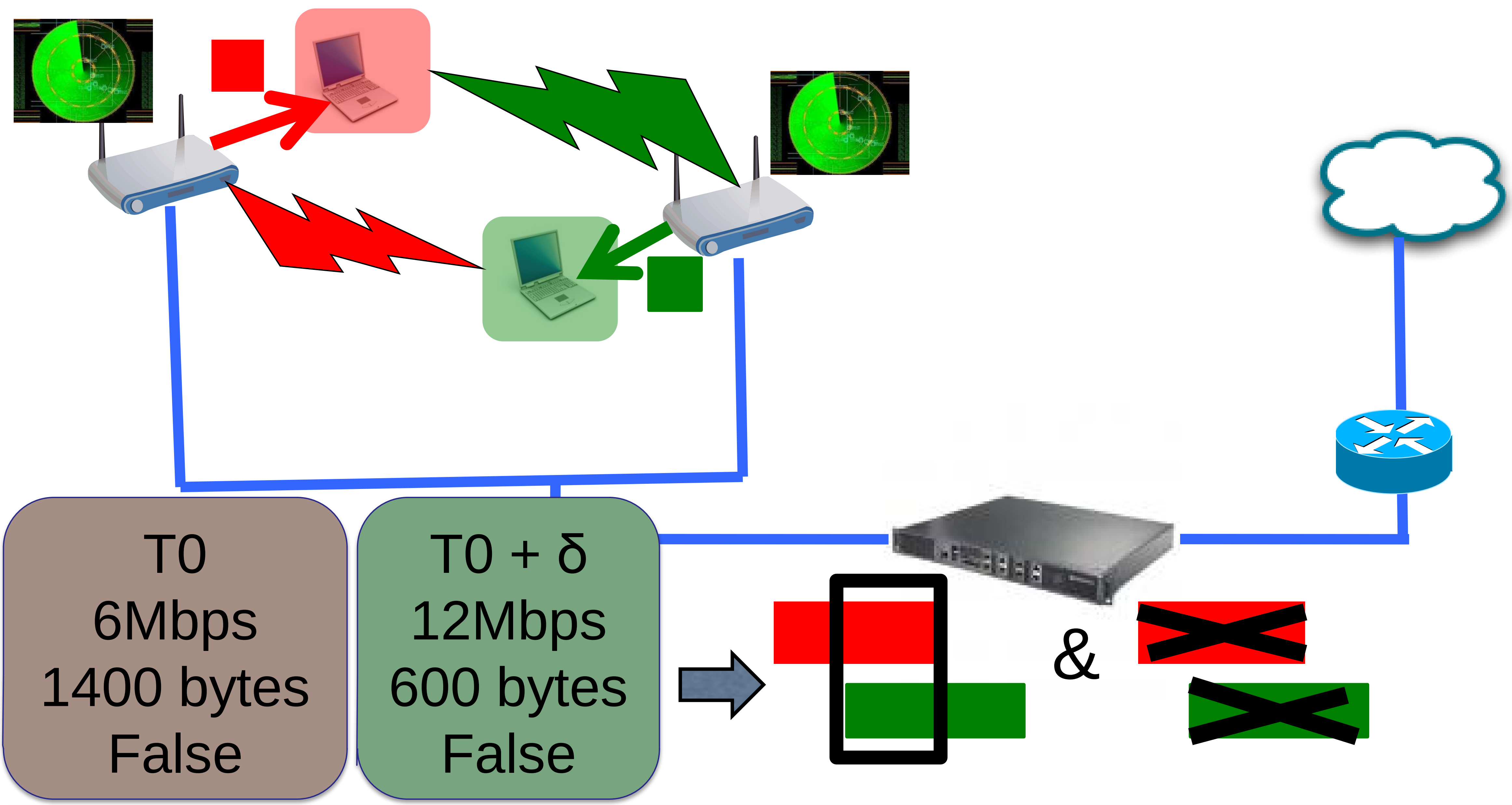

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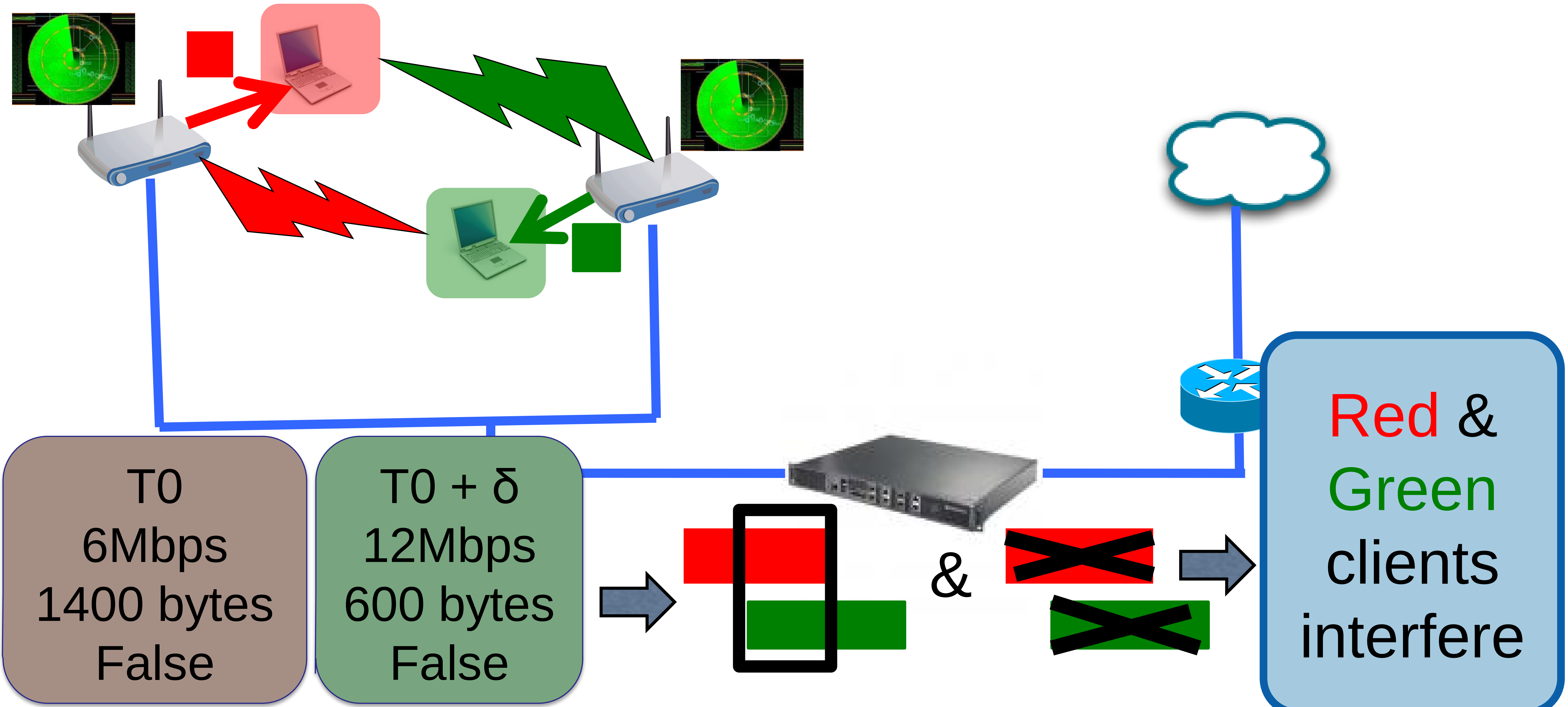

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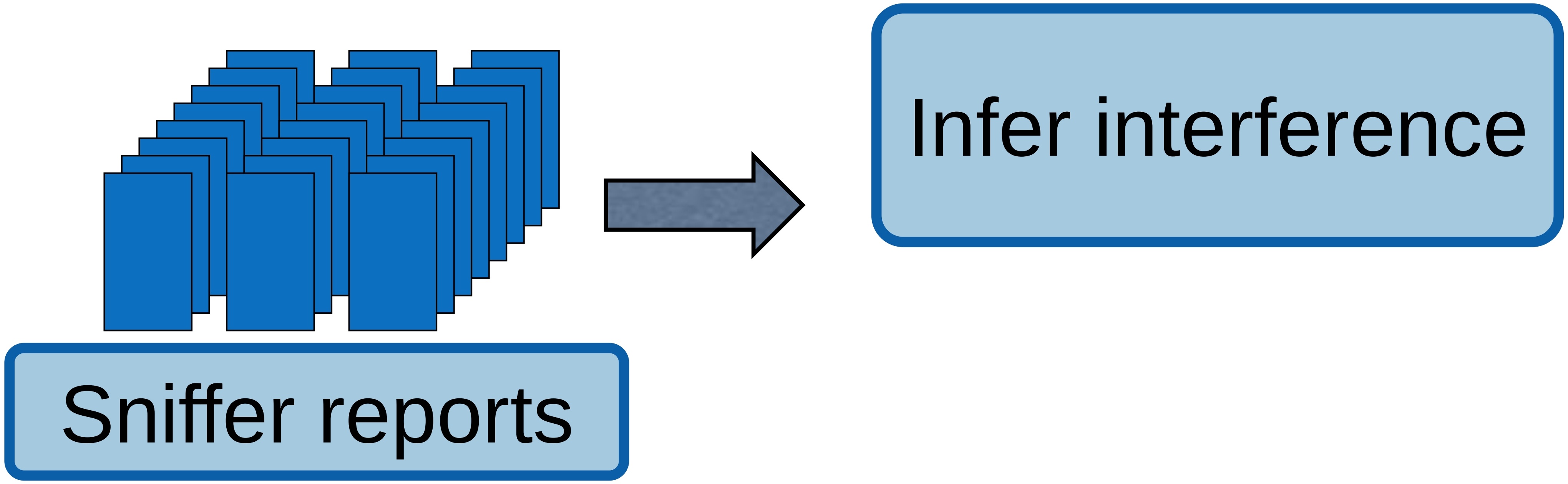

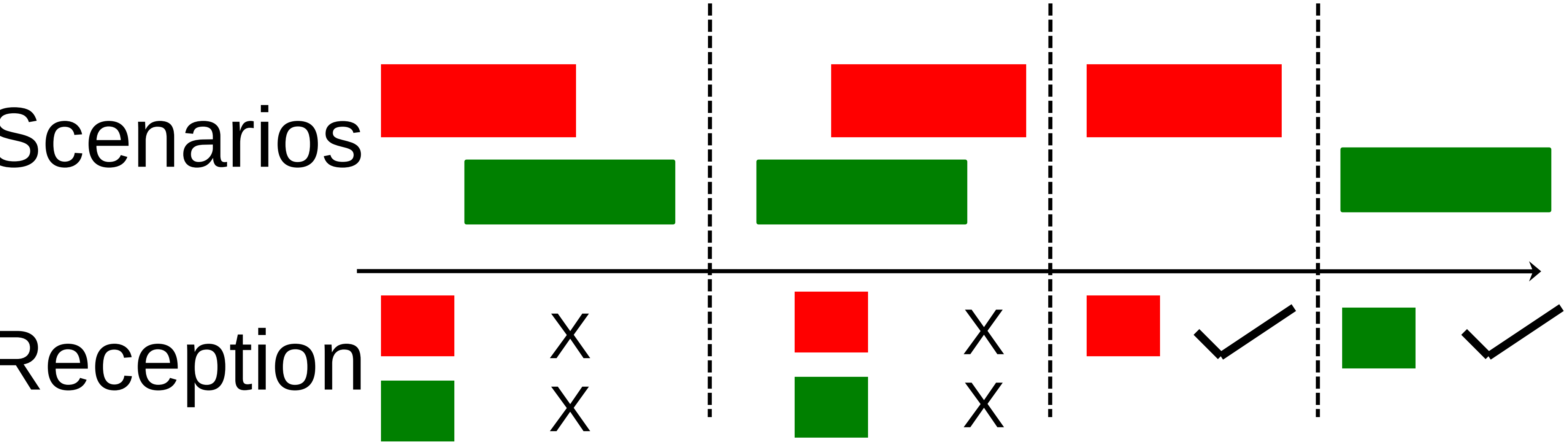

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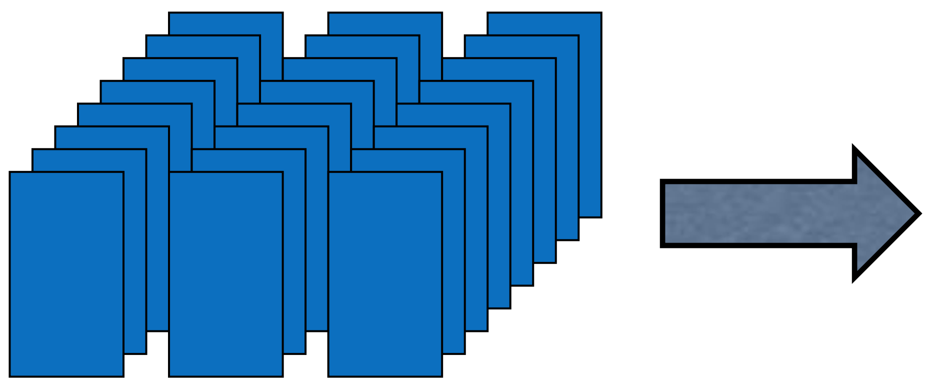
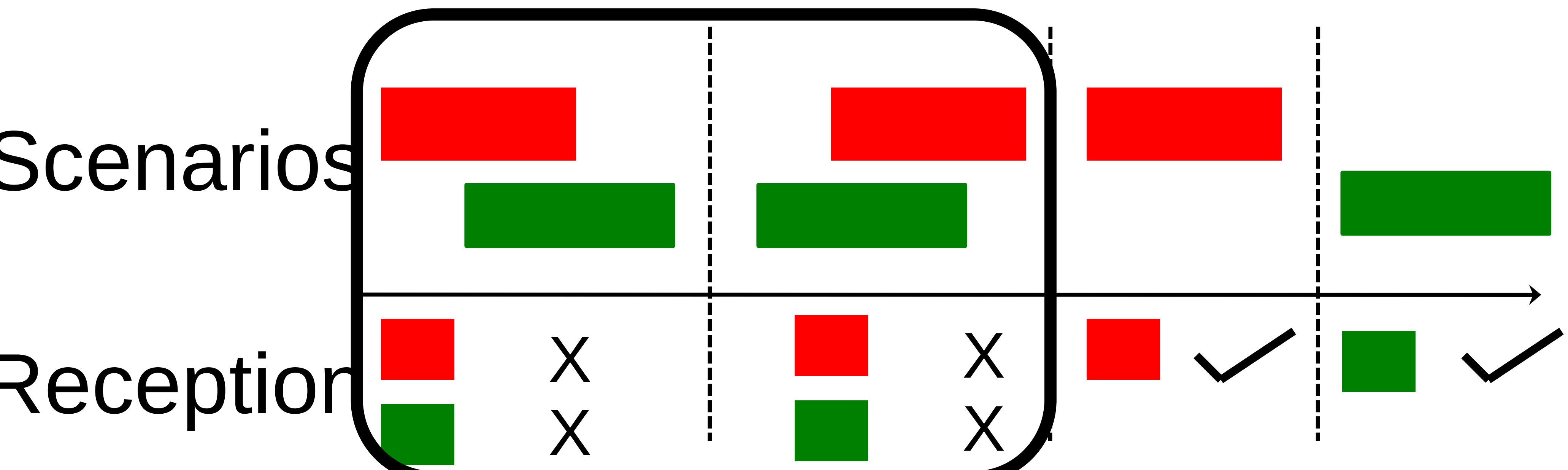


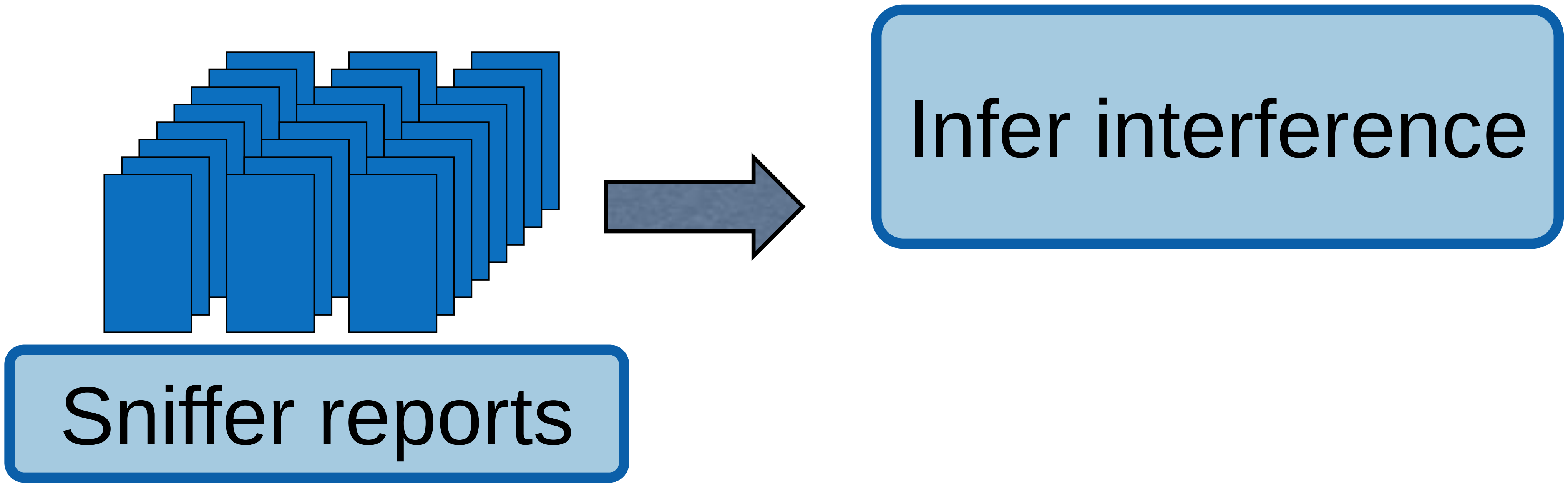
Sniffer reports

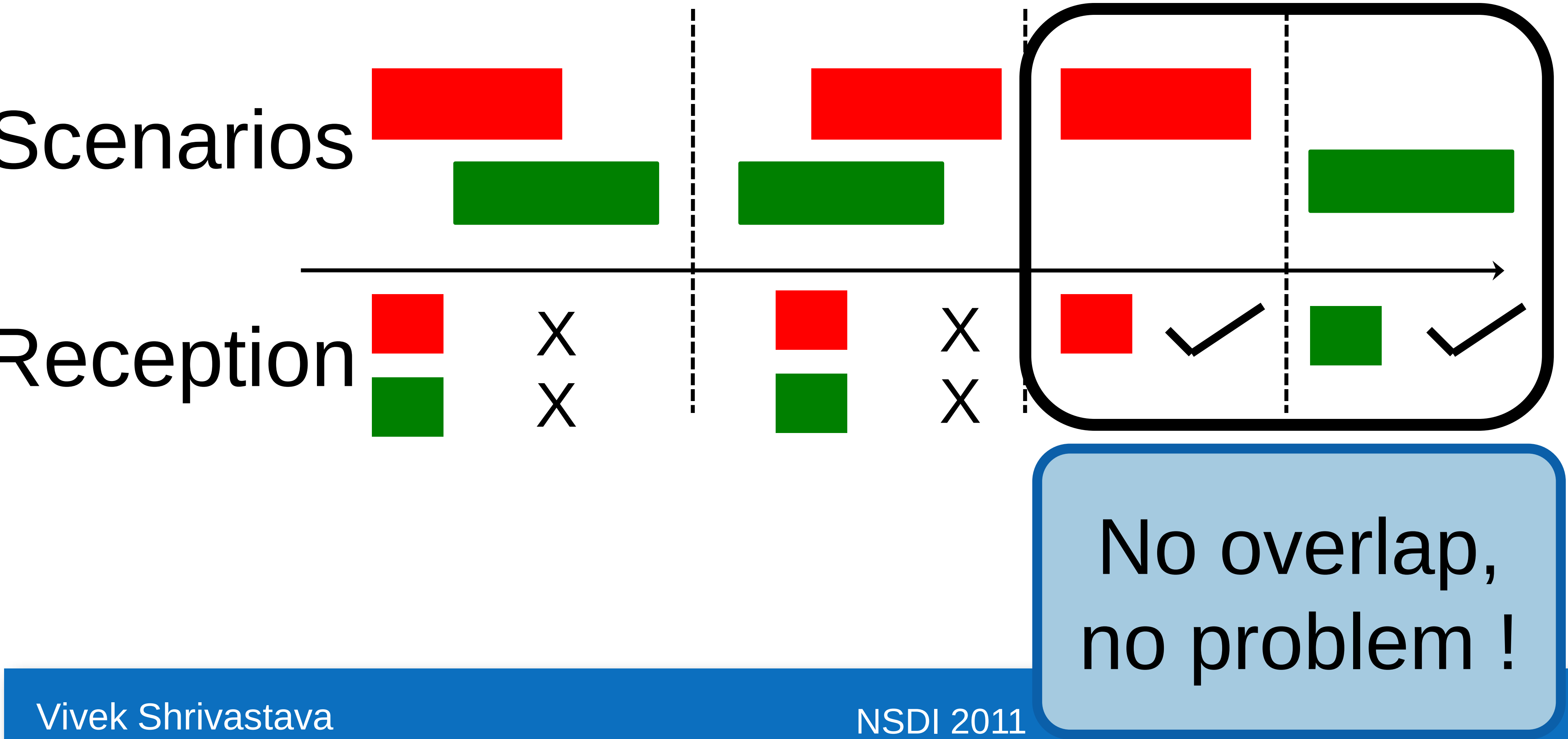
Infer interference



Red and Green packets overlaps => both lost

Estimating interference passively





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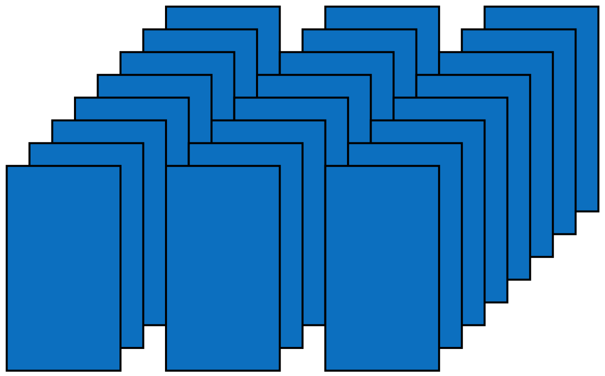
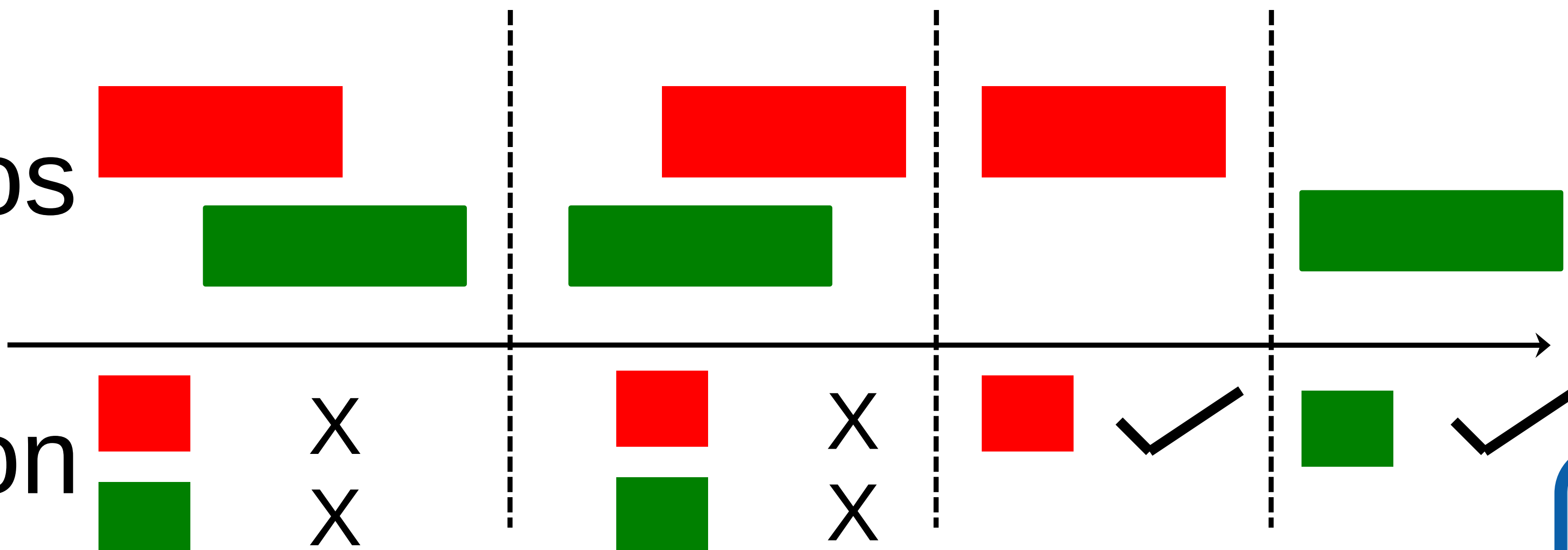


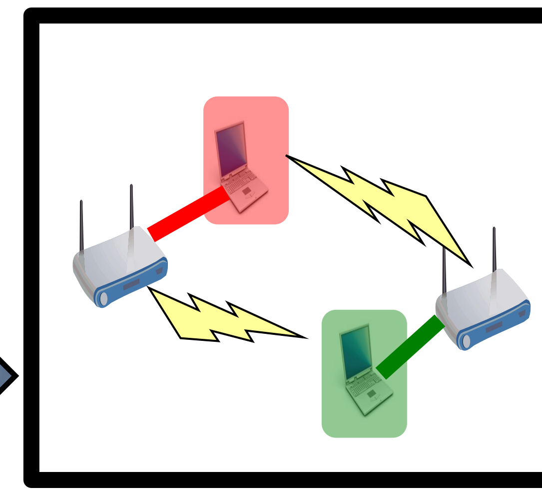
Sniffer reports

Infer interference

Scenarios

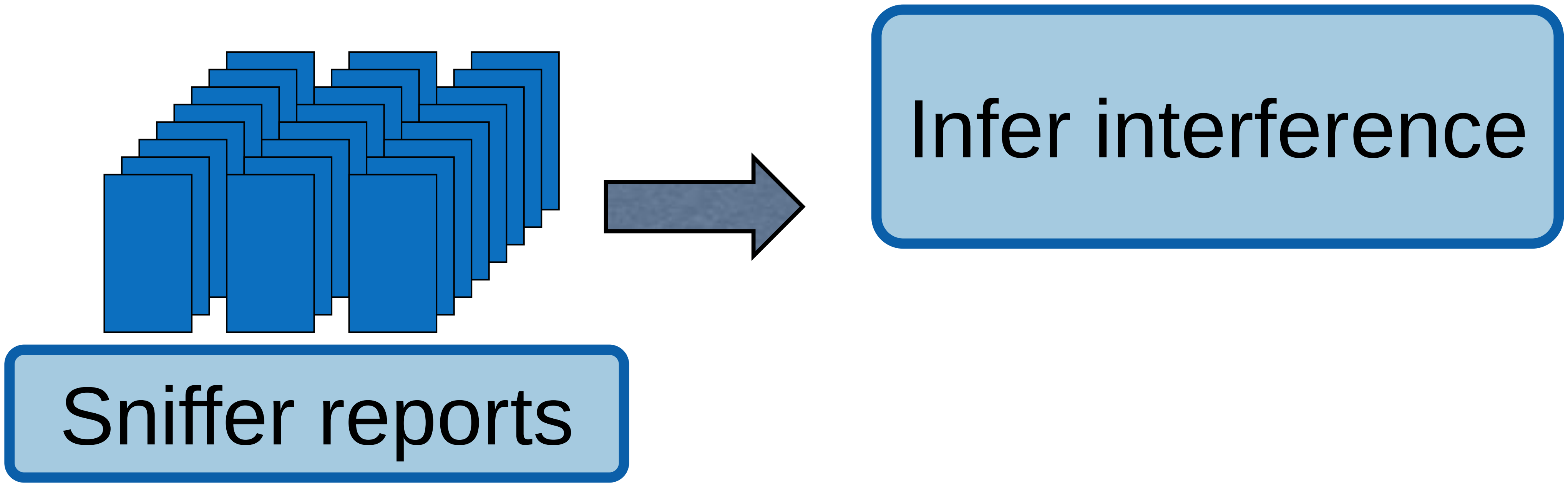
Reception

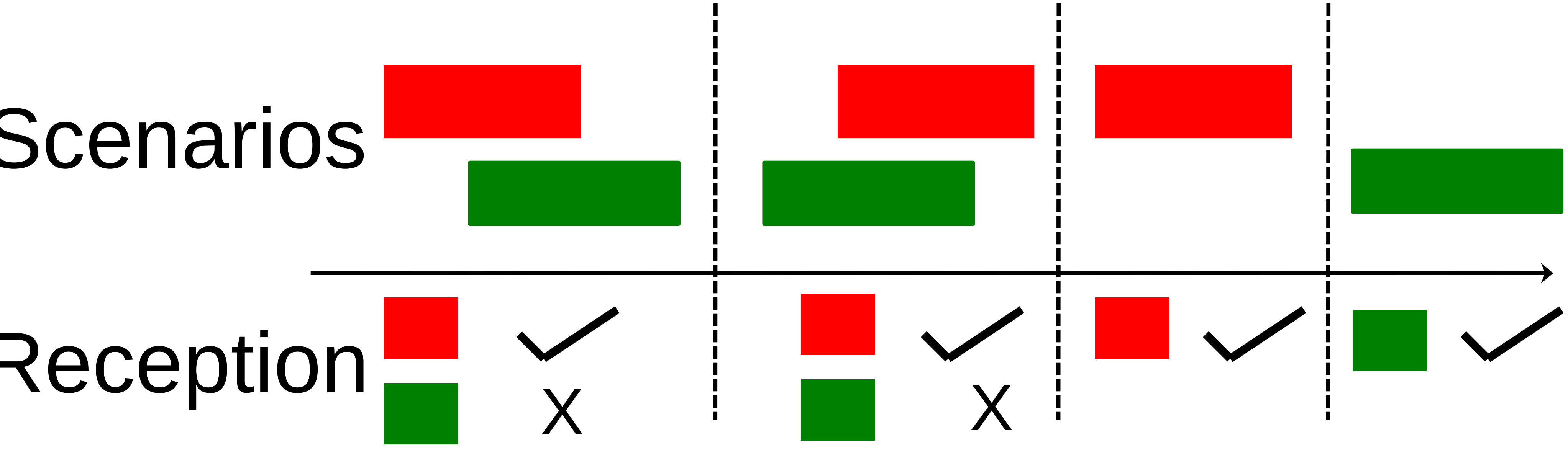




Both way hidden terminals

Estimating interference passively





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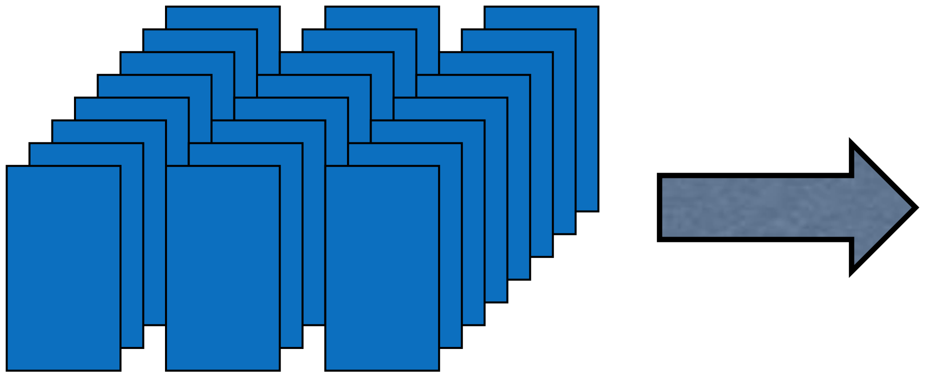
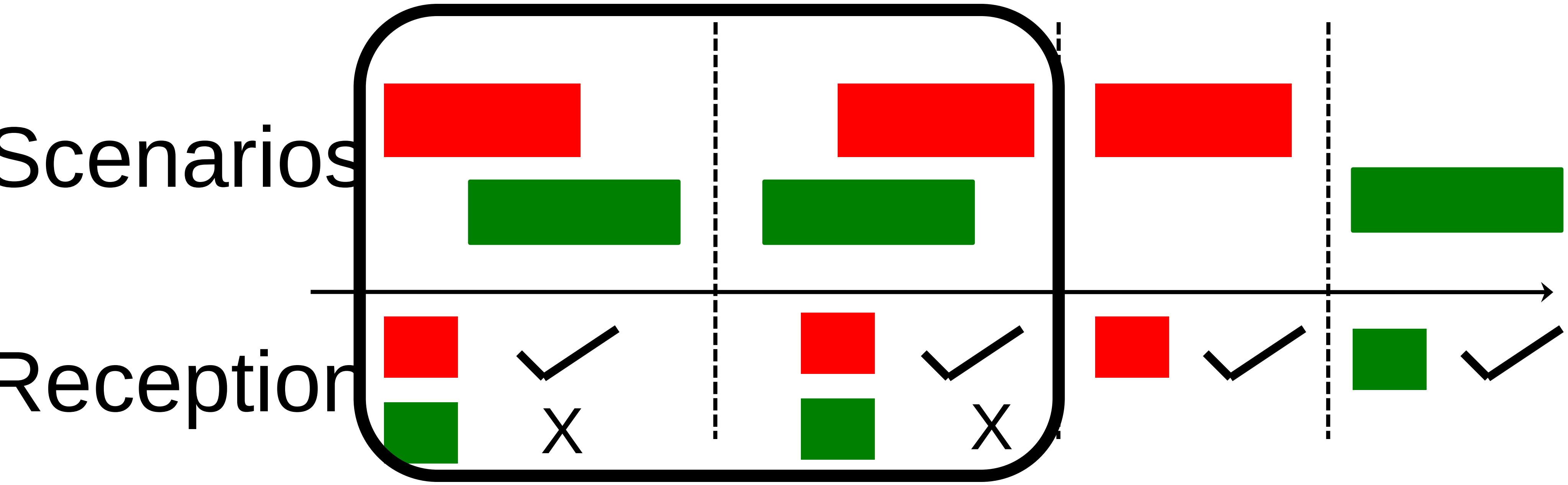


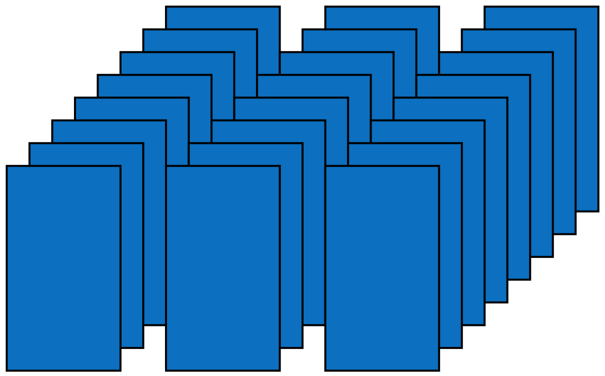
Sniffer reports

Infer interference



Red and Green packets overlaps => Green is lost

Estimating interference passively



Sniffer reports

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Scenarios

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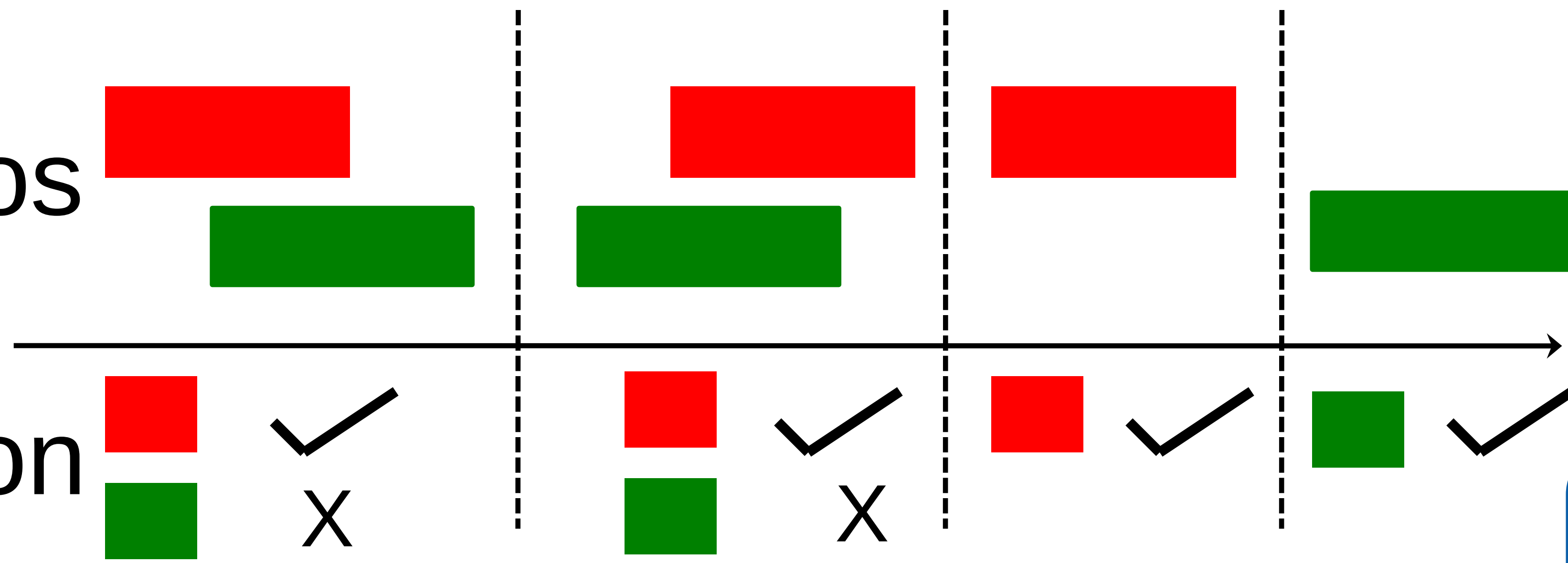
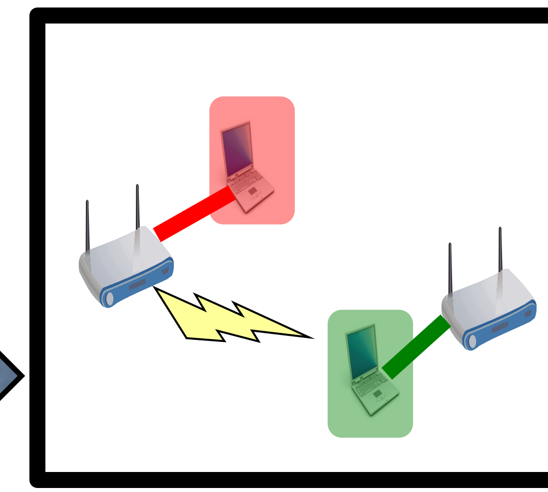




One way hidden terminals

Computing interference measure in PIE

- Compute Isolation loss rate
  - Fraction of non-overlapping packets lost
- Compute Interference loss rate
  - Fraction of overlapping packets lost
- Interference measure (LIR):

(1 – Interference loss) / (1 – Isolation loss)

How quickly can PIE converge ?

- Time taken by PIE to converge depends on two key properties
  - Periodicity with which sniffer reports are collected by the controller
  - Traffic patterns for the links which dictate the number of interference events captured in a time interval

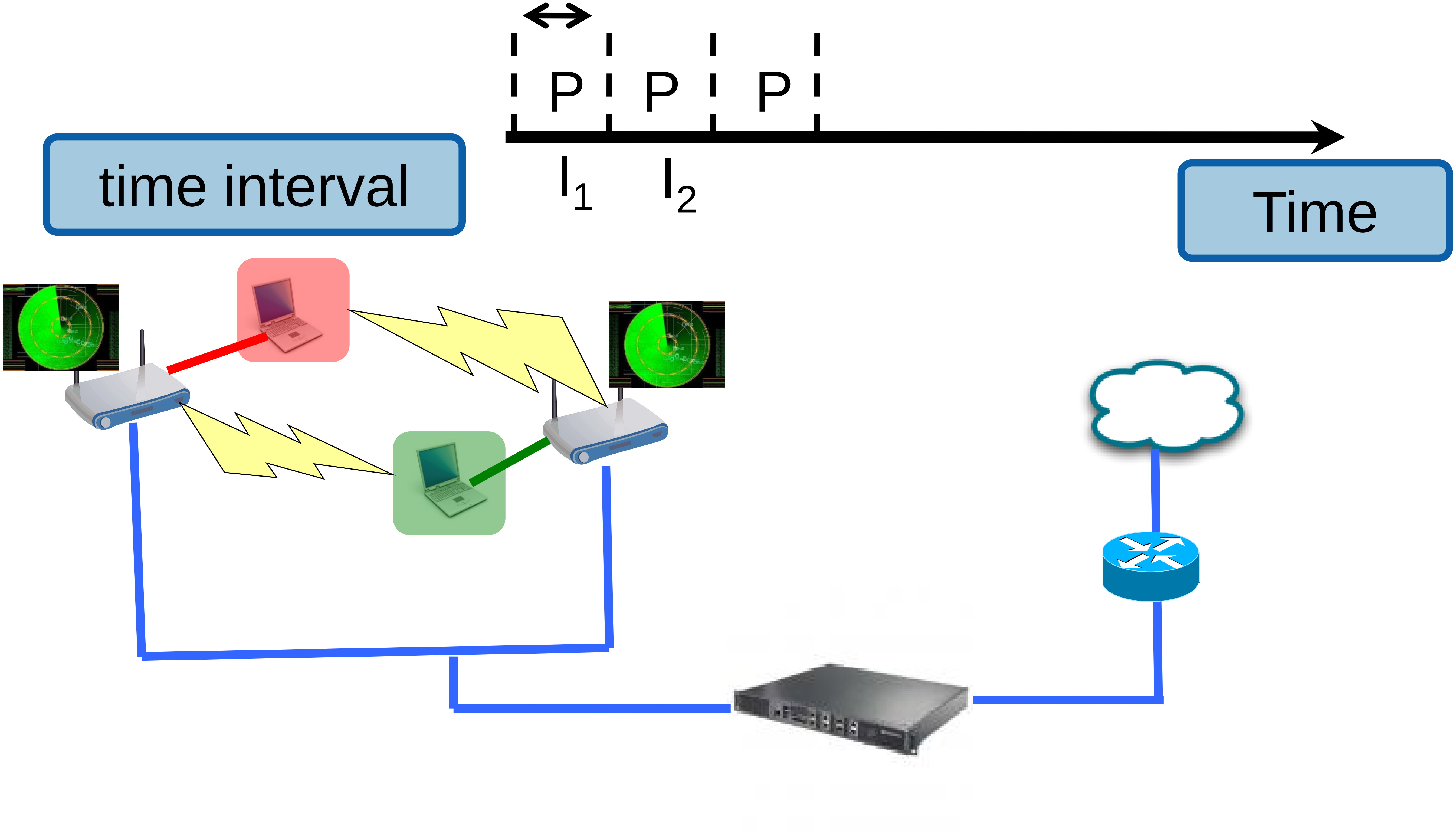
How quickly can PIE converge ?

- Time taken by PIE to converge depends on two key properties
  - Periodicity with which sniffer reports are collected by the controller
    - What is the minimum polling period ?
  - Traffic patterns for the links which dictate the number of interference events captured in a time interval
    - How much time does PIE take under realistic access patterns ?

PIE Outline

- Motivation
  - Conventional bandwidth tests not sufficient
- Passive Interference Estimation (PIE)
  - Polling period of PIE
  - Accuracy of PIE
  - Realistic trace replay with PIE
- Applications of PIE
- Summary

What is the minimum polling period ?



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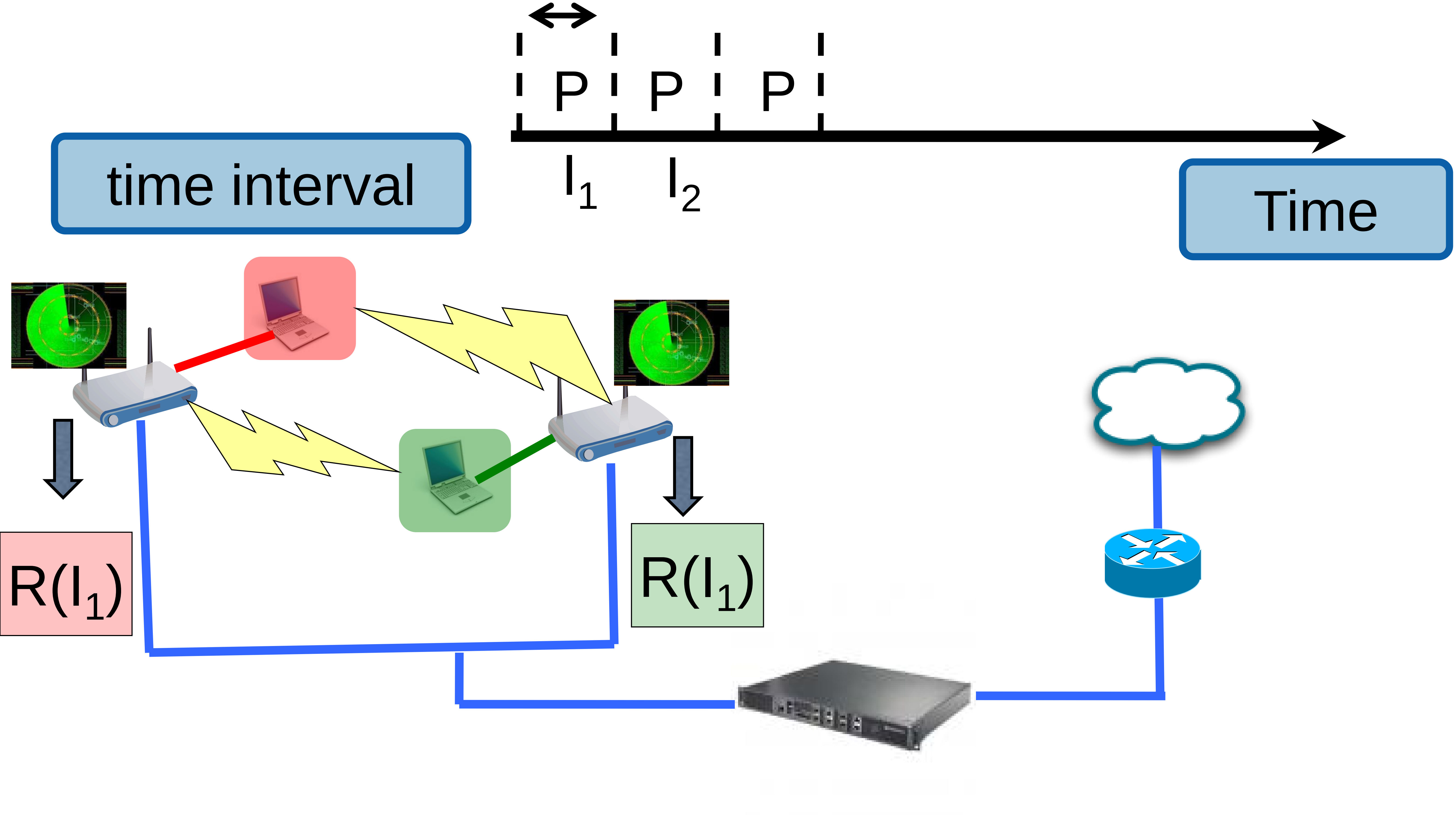

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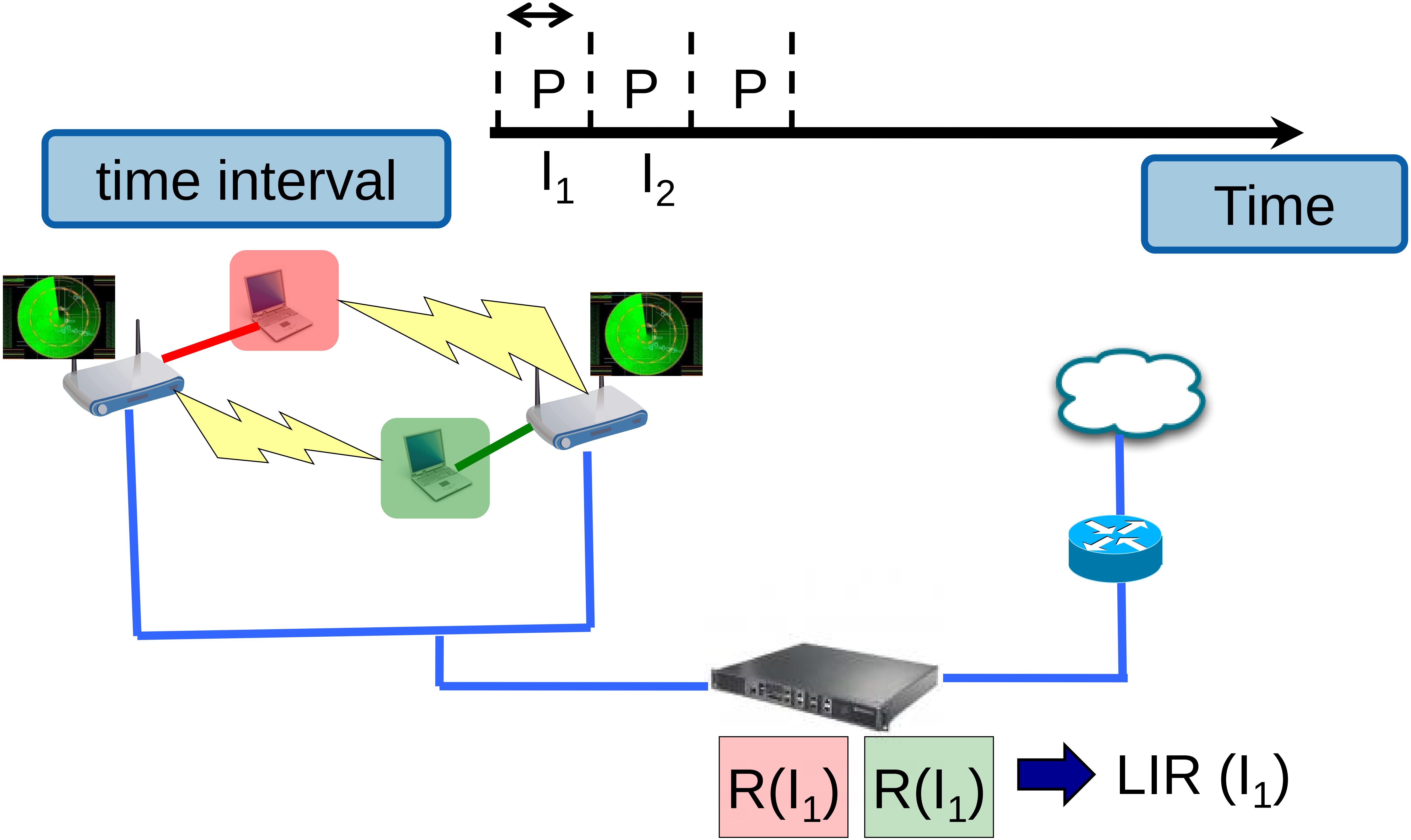

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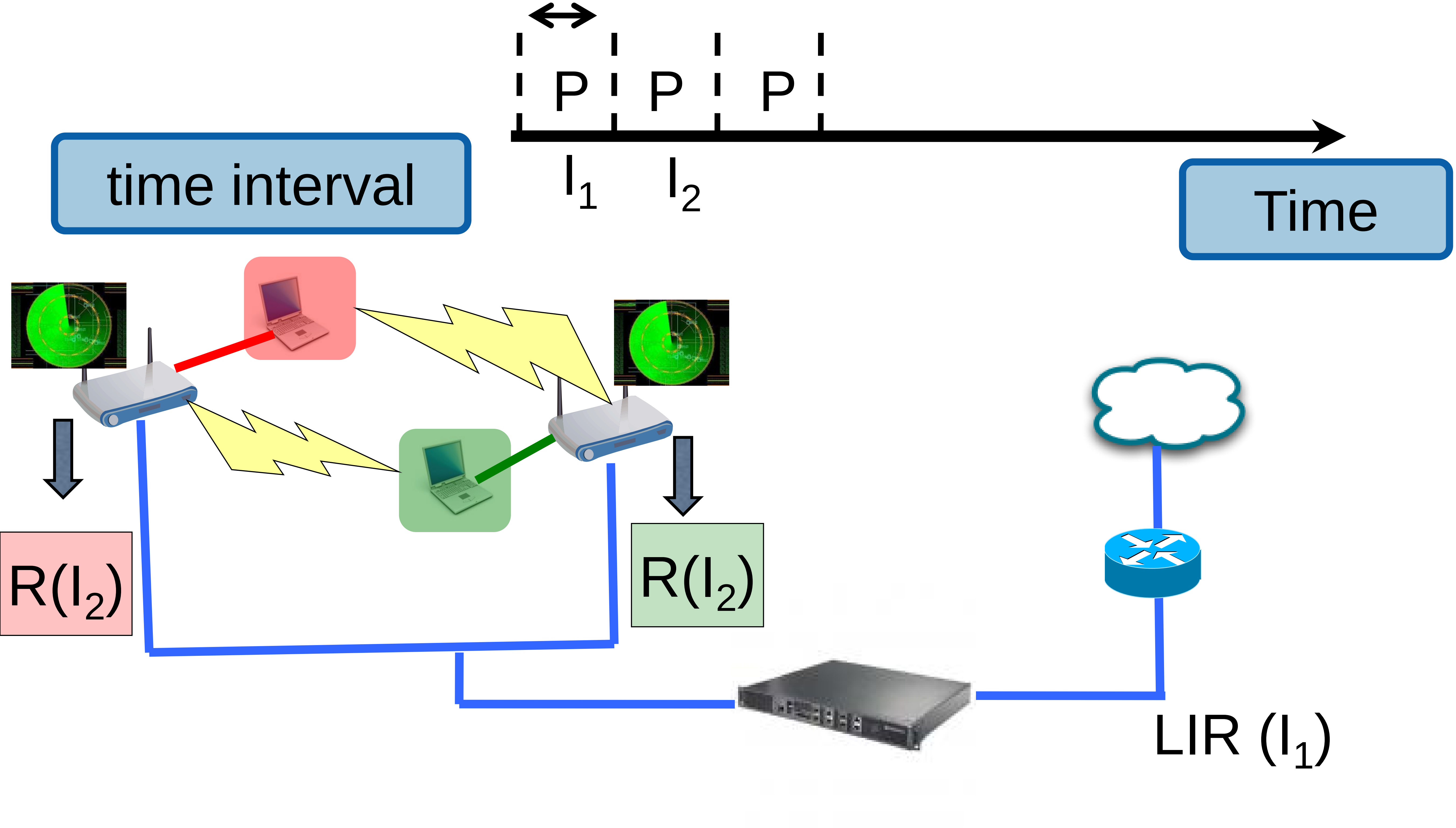

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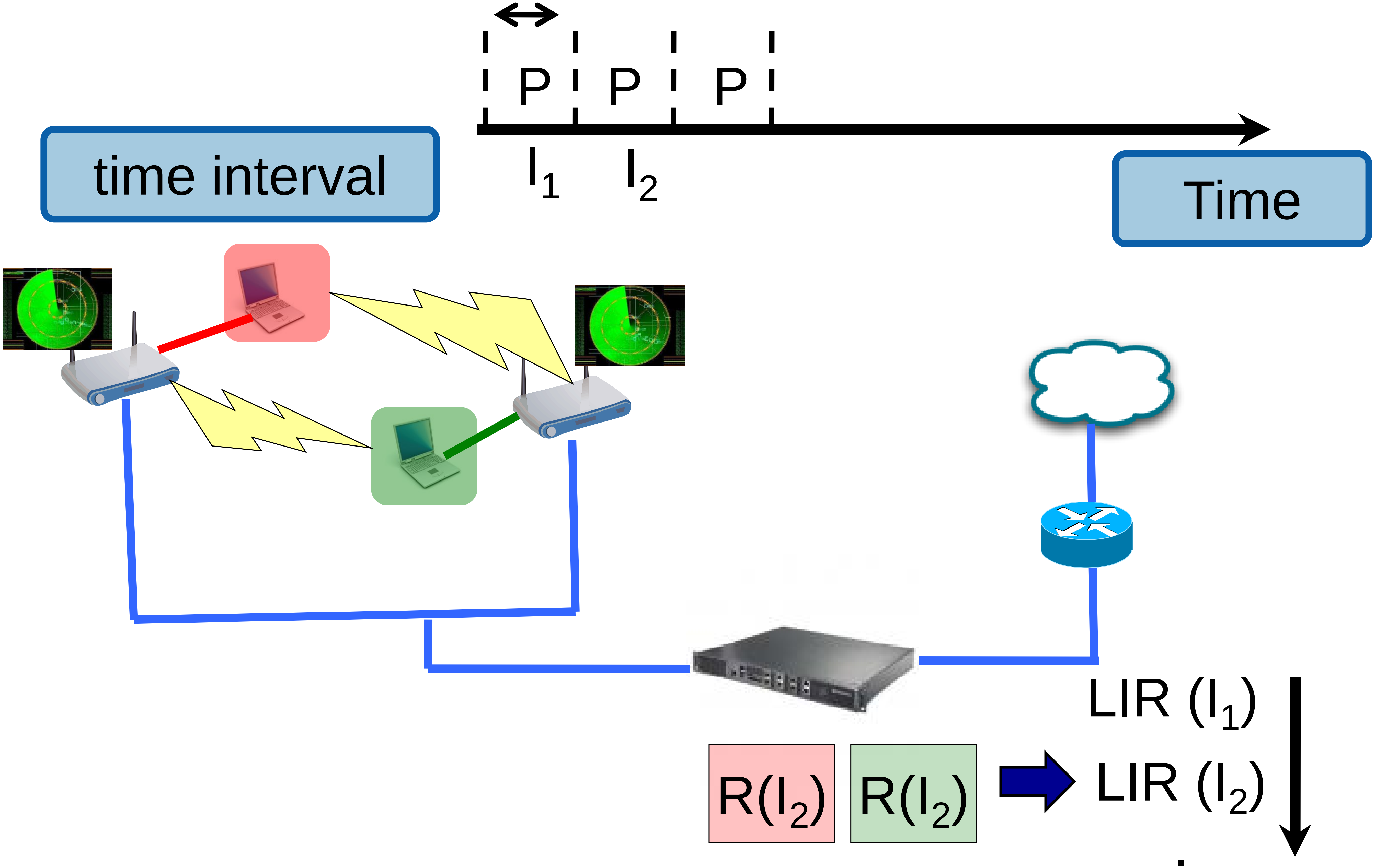

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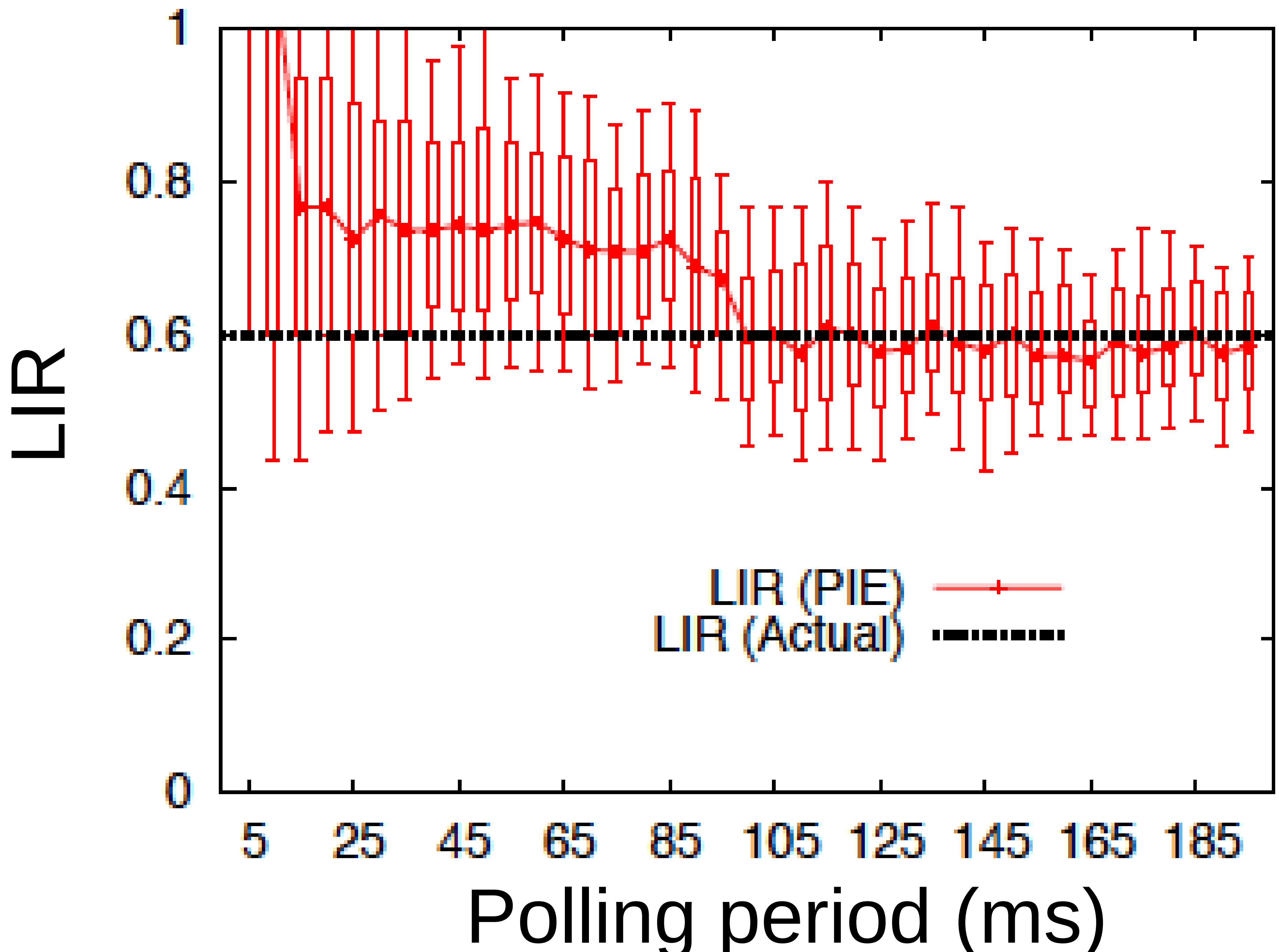
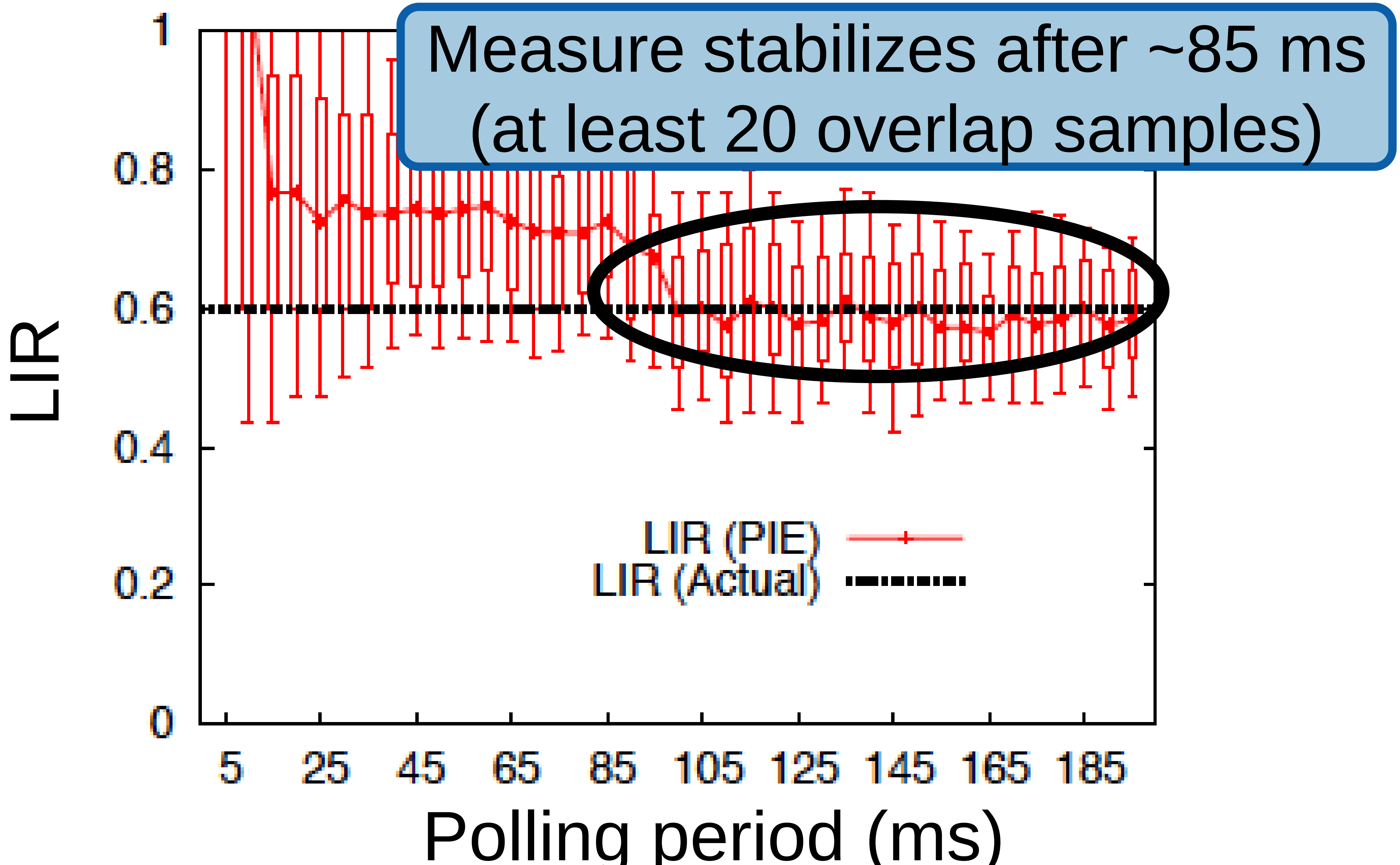


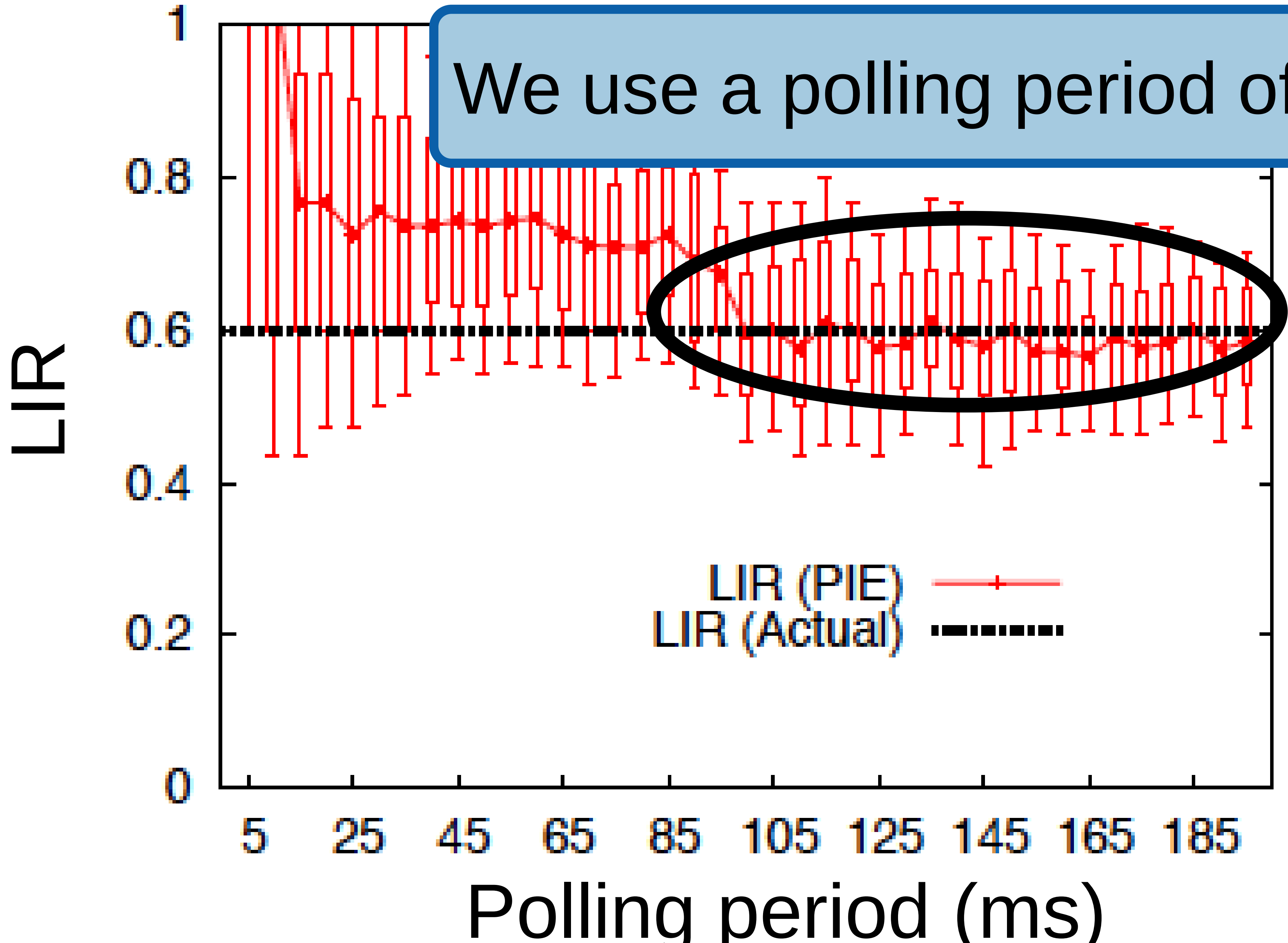
Stability of interference measure for saturated traffic

What is the minimum polling period ?



Stability of interference measure per polling period

What is the minimum polling period ?



We use a polling period of 100ms

Stability of interference measure per polling period

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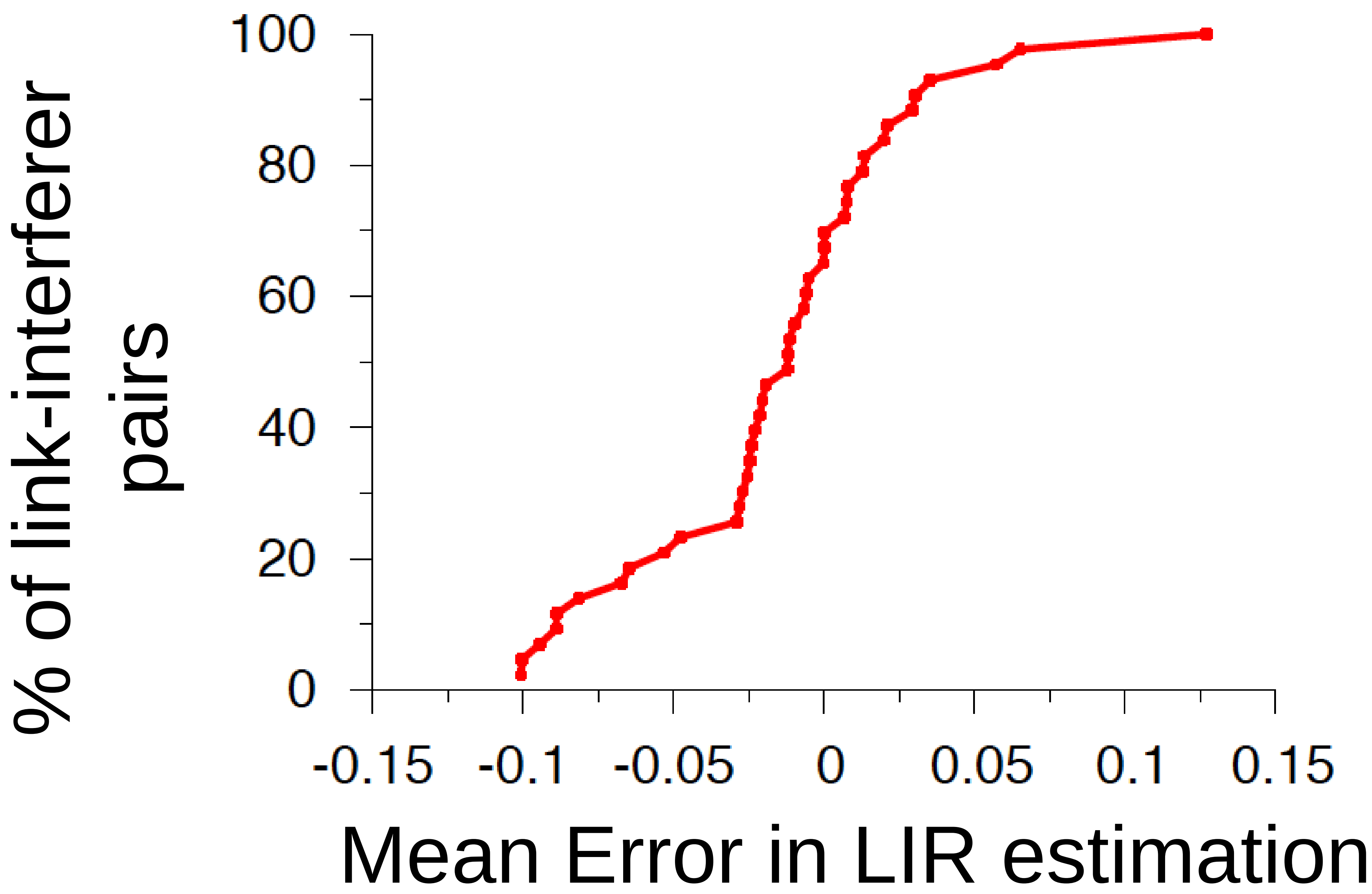
How accurate is PIE ?



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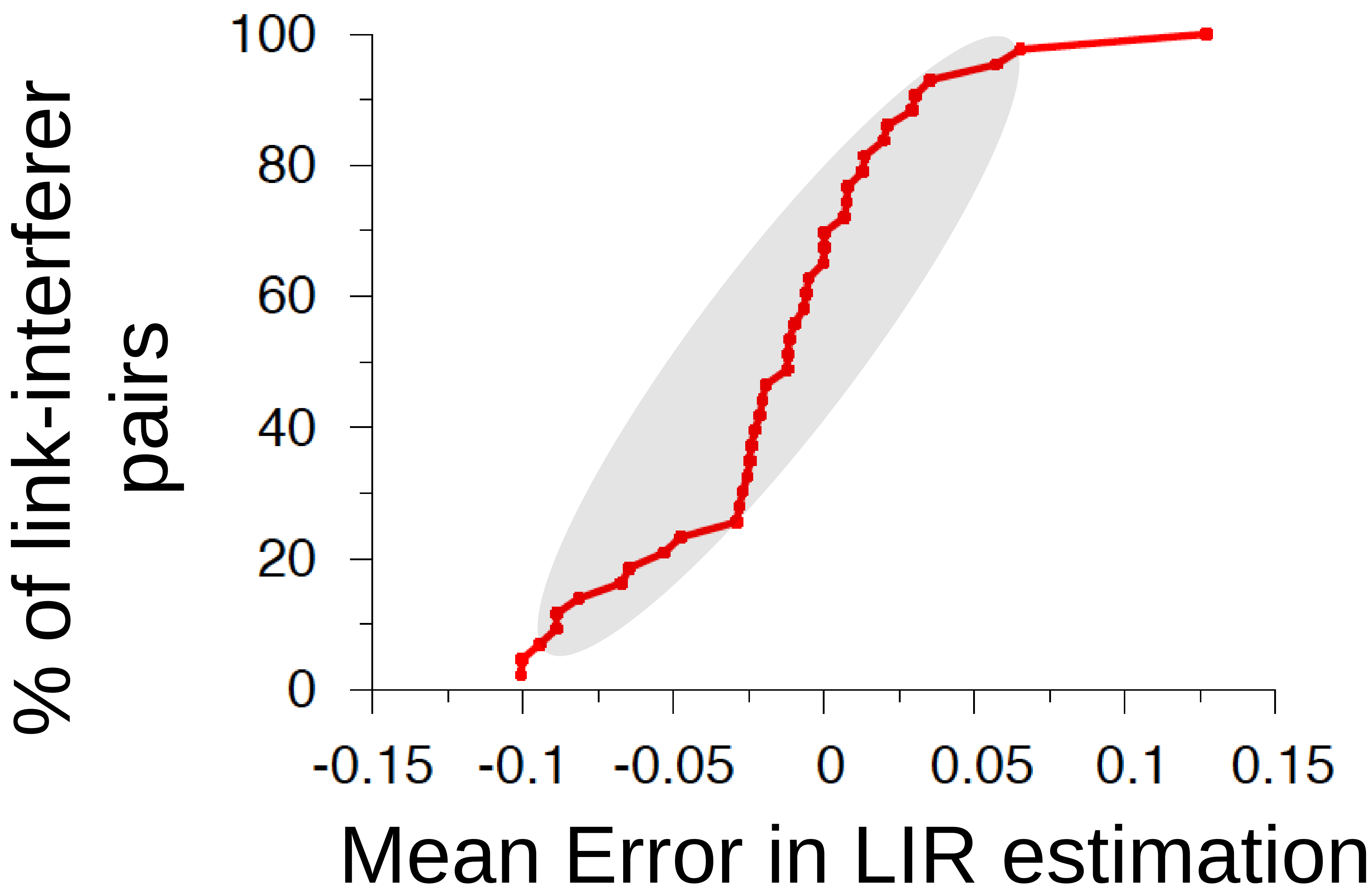

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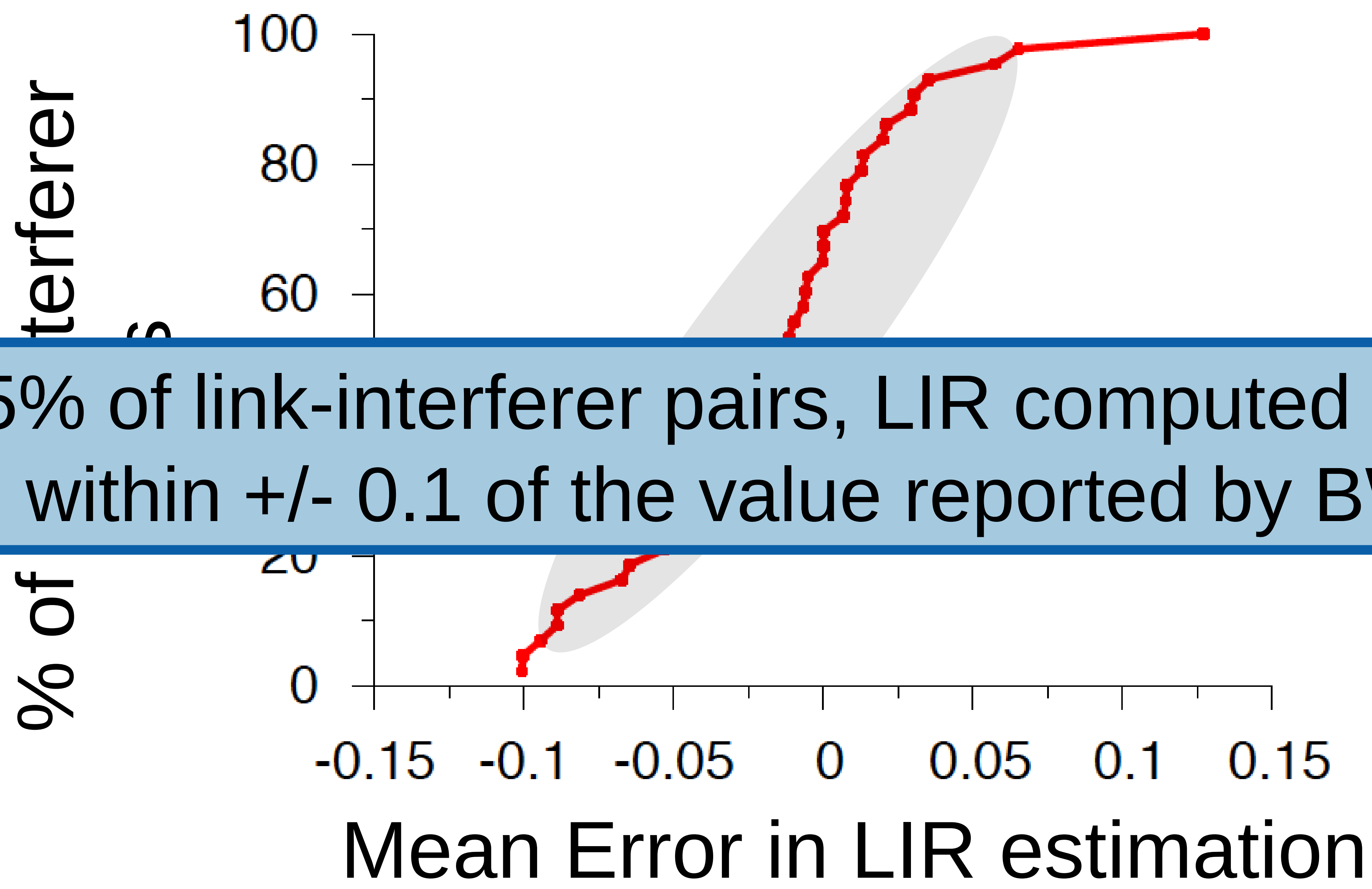
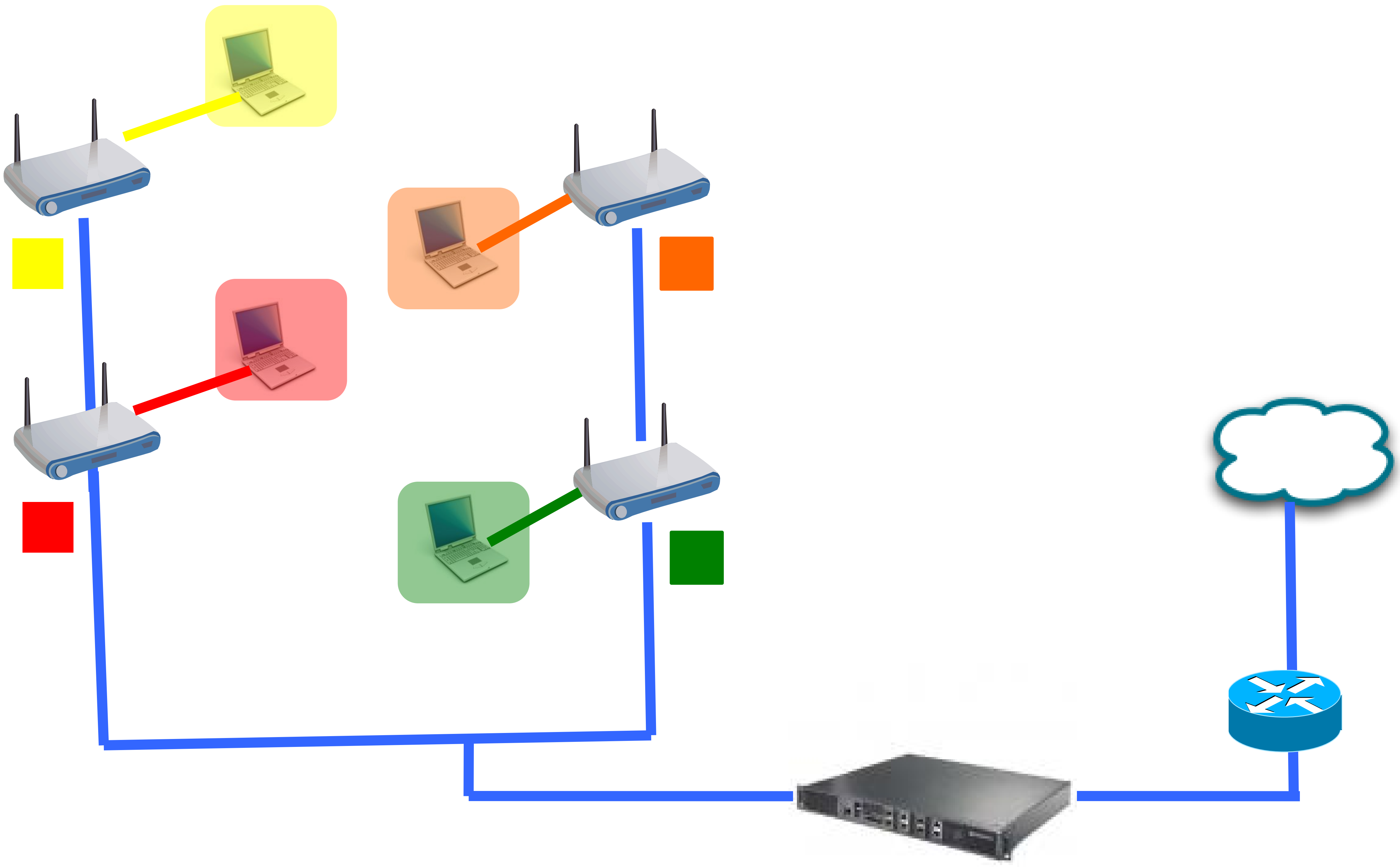


95% of link-interferer pairs, LIR computed by PIE is within +/- 0.1 of the value reported by BW test

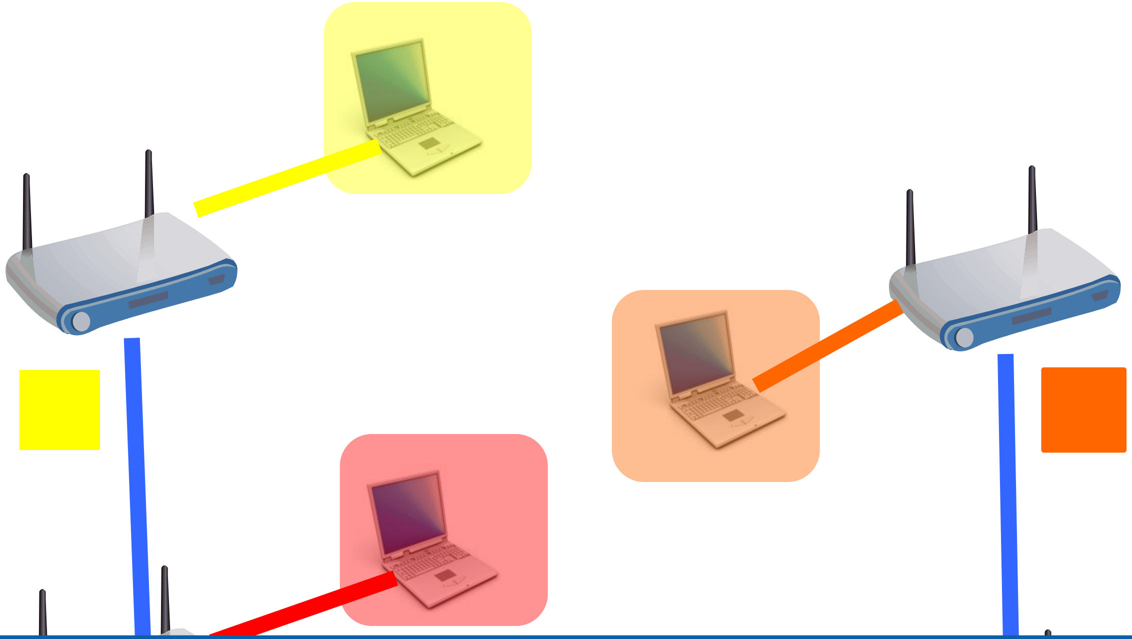
PIE Outline

- Motivation
  - Conventional bandwidth tests not sufficient
- Passive Interference Estimation (PIE)
  - Polling period of PIE
  - Accuracy of PIE
  - Realistic trace replay with PIE
- Applications of PIE
- Summary

PIE with realistic access patterns

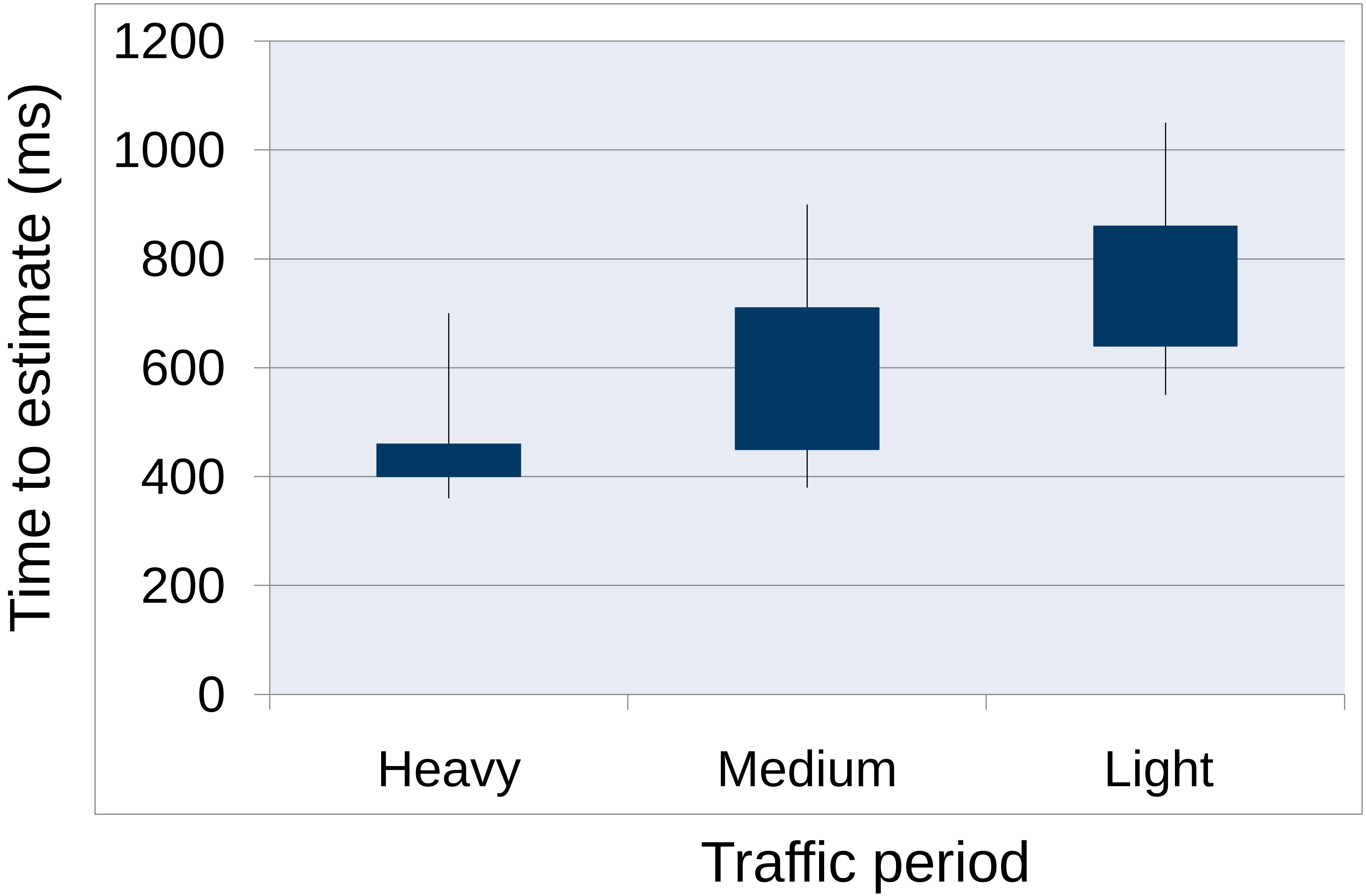


PIE with realistic access patterns

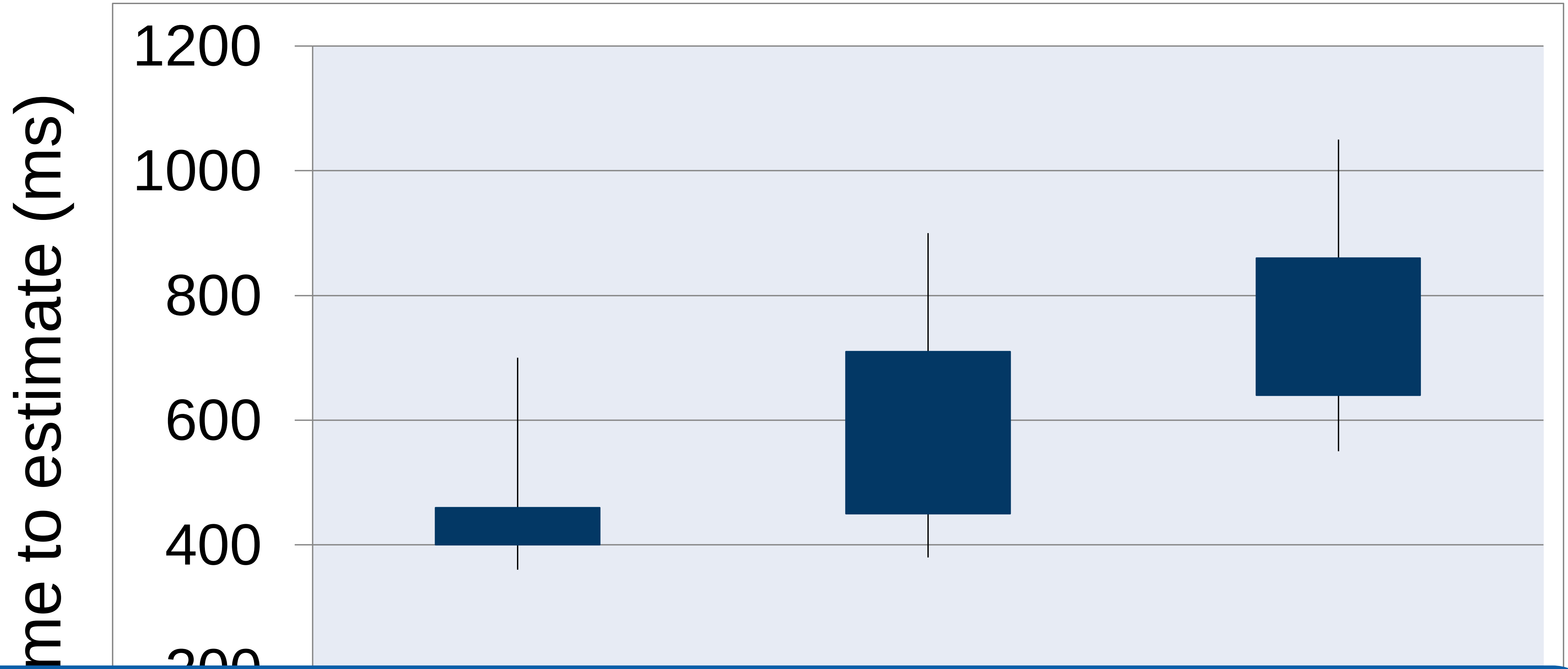


- Evaluate PIE using realist traffic patterns on a 15 node topology (7 AP – 8 laptops)
- Each client laptop replays the traffic patterns of an actual client from a real wireless trace
- Three activity periods: heavy (> 40 % medium busy), medium (40 – 20% busy), light (< 20% busy)

PIE with realistic access patterns



PIE with realistic access patterns



• Convergence is faster for higher client activity

• Even for light activity, median time of estimate LIR is less than 650 ms

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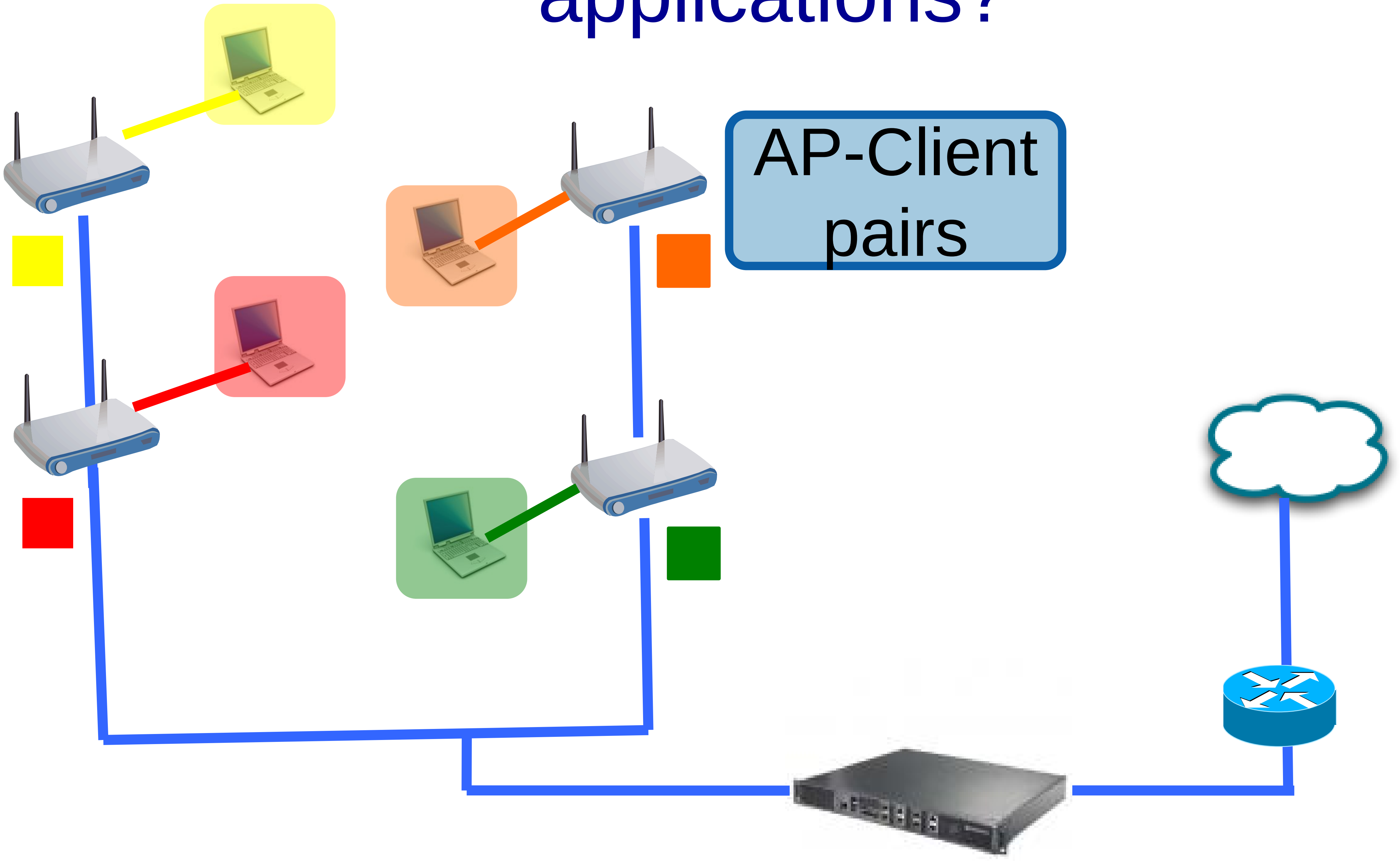
What is the impact on WLAN applications?



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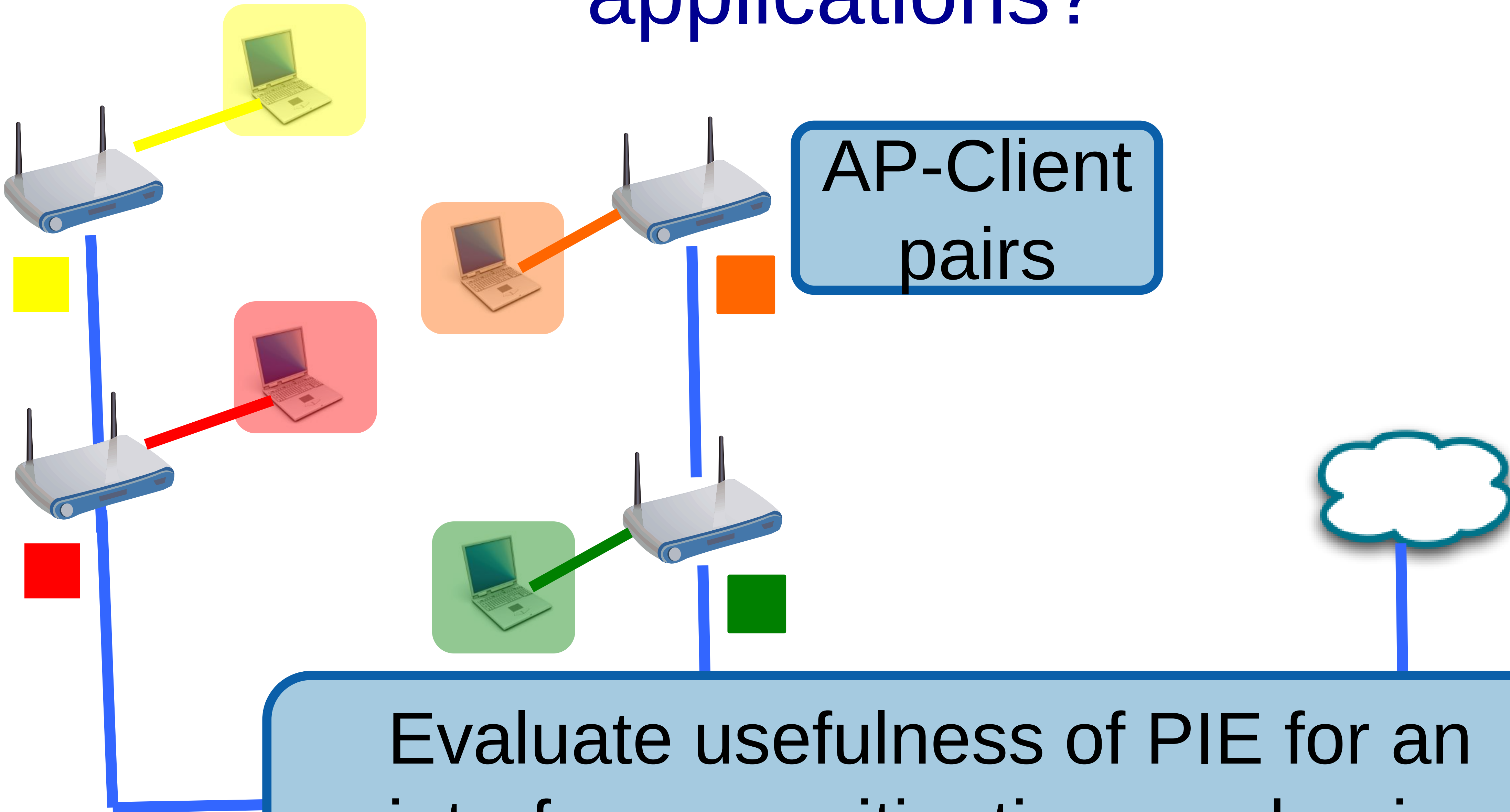
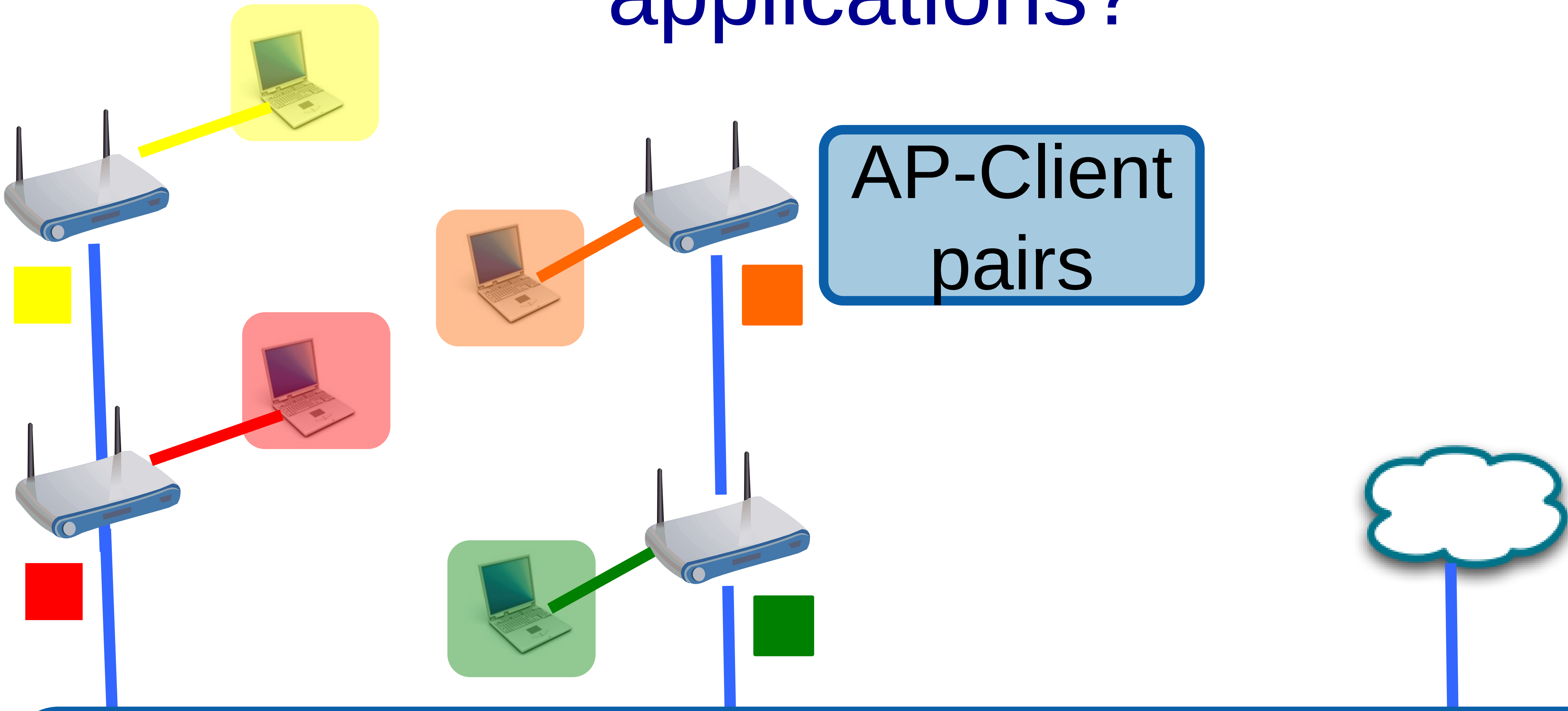


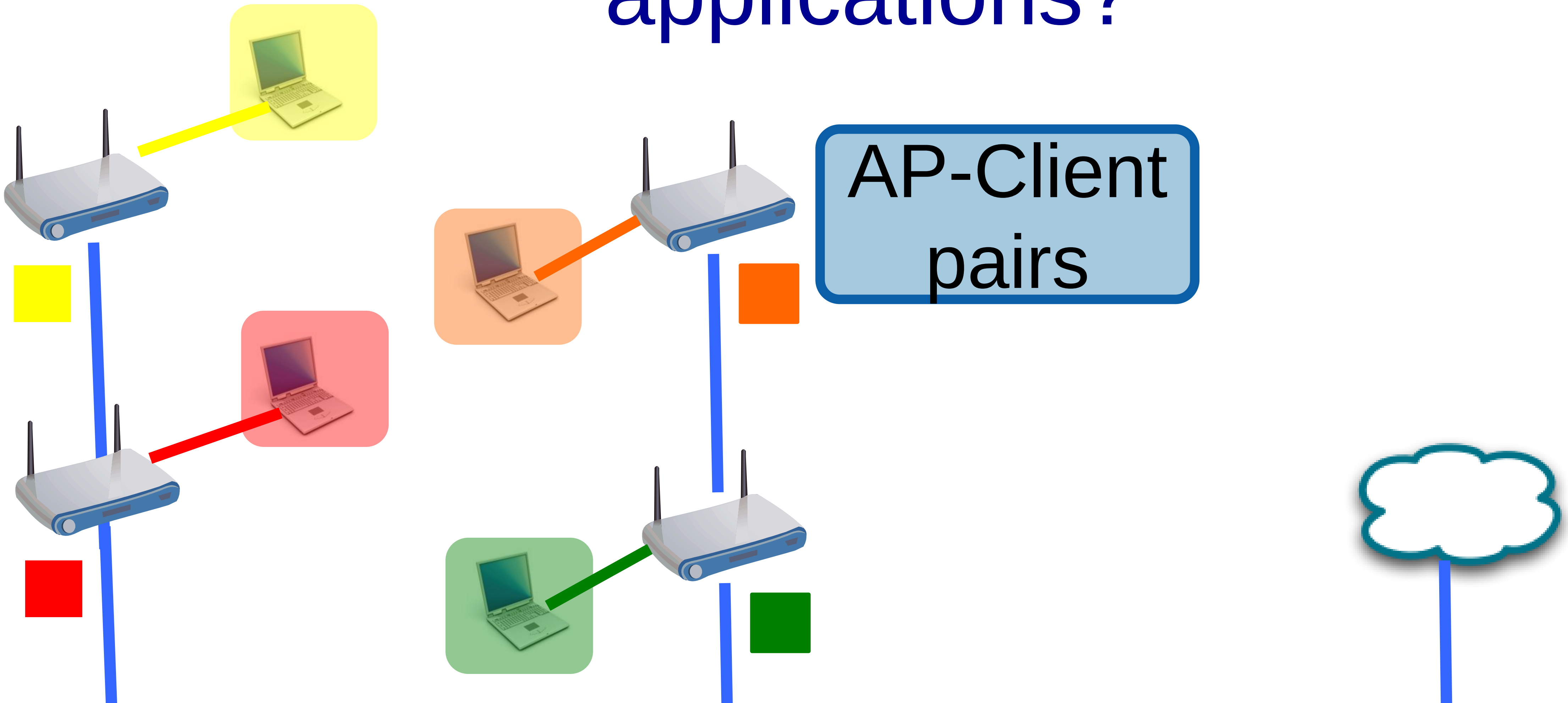
Evaluate usefulness of PIE for an interference mitigation mechanism (data scheduling using CENTAUR – Mobicom '09)

What is the impact on WLAN applications?



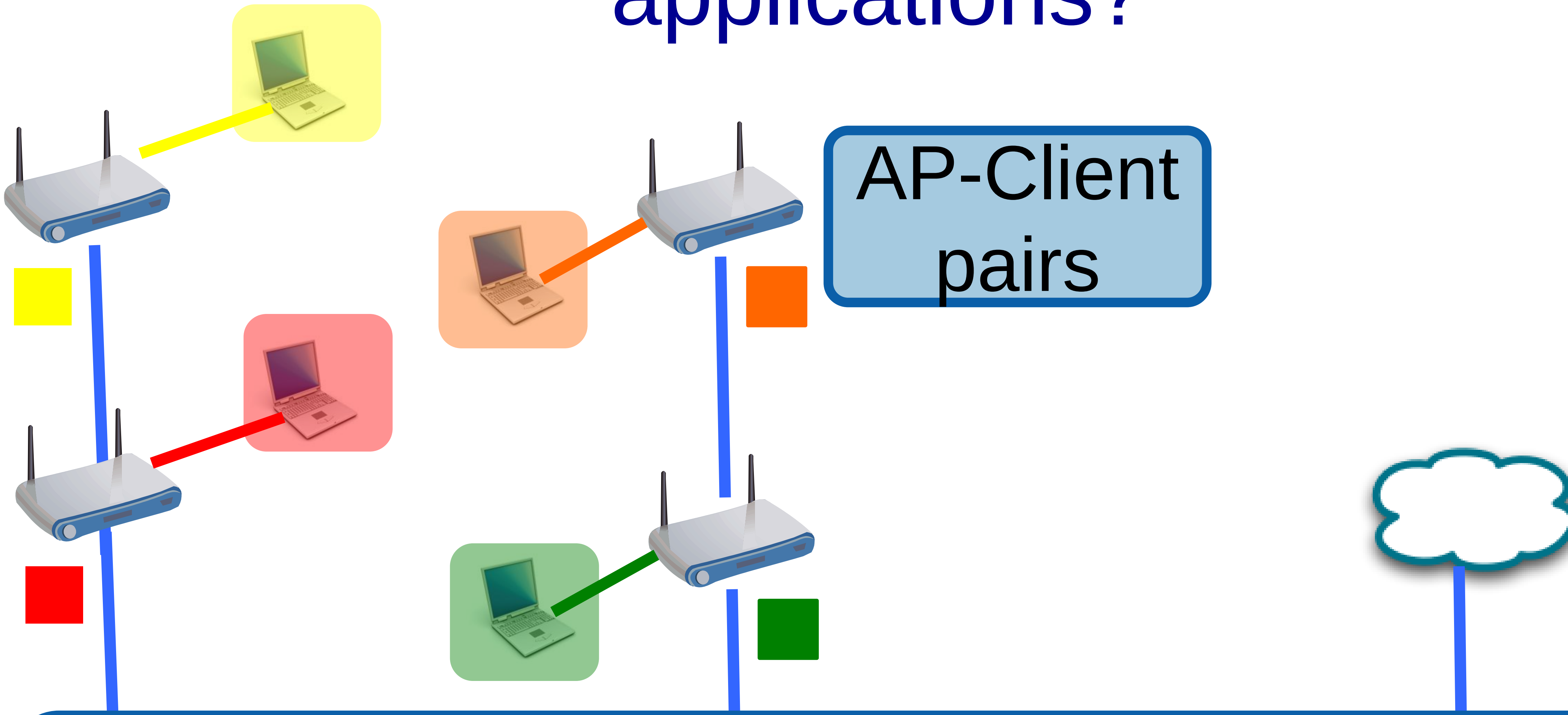
1. Estimate interference using PIE

What is the impact on WLAN applications?



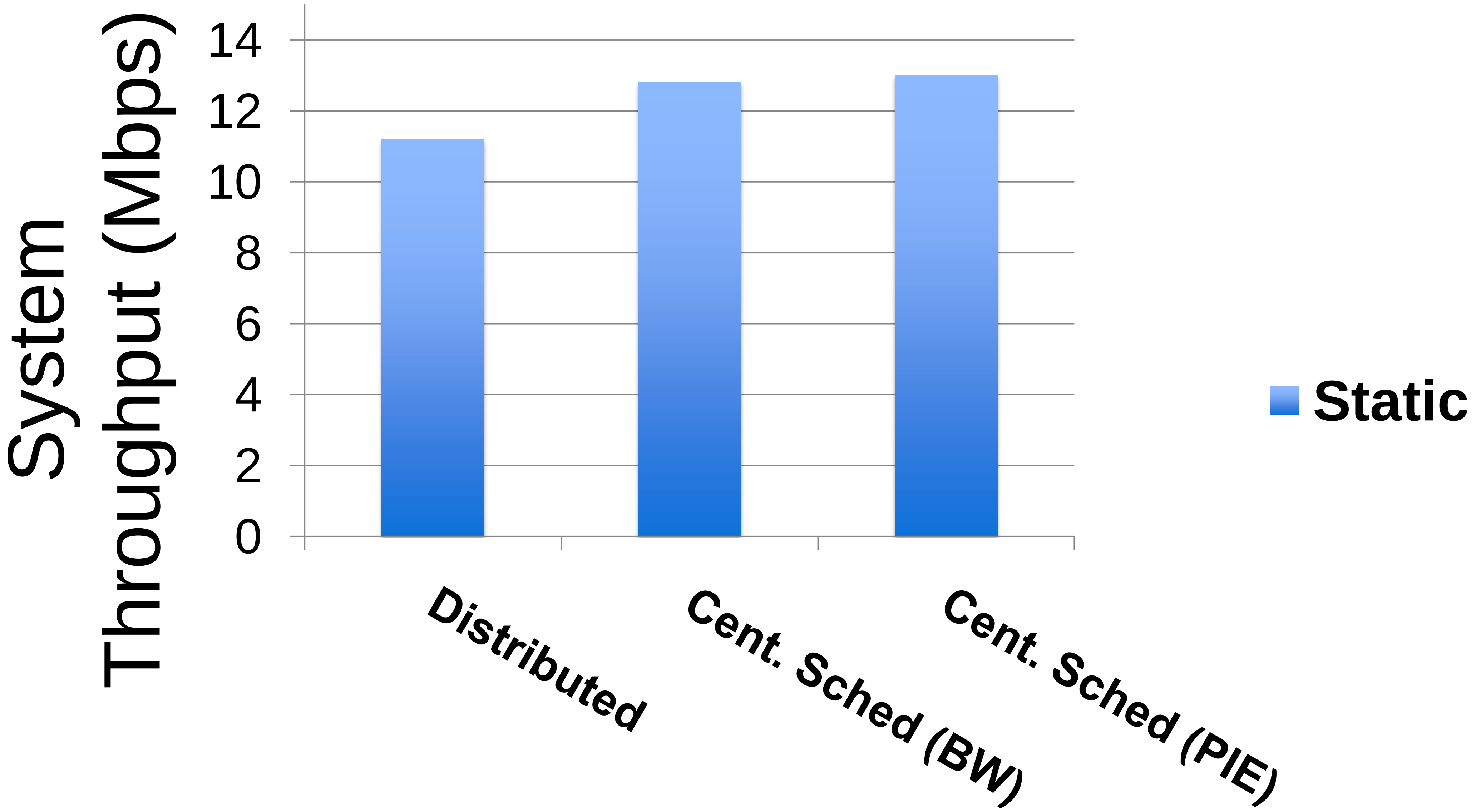
1. Estimate interference using PIE
2. Input estimate to a centralized data scheduler

What is the impact on WLAN applications?



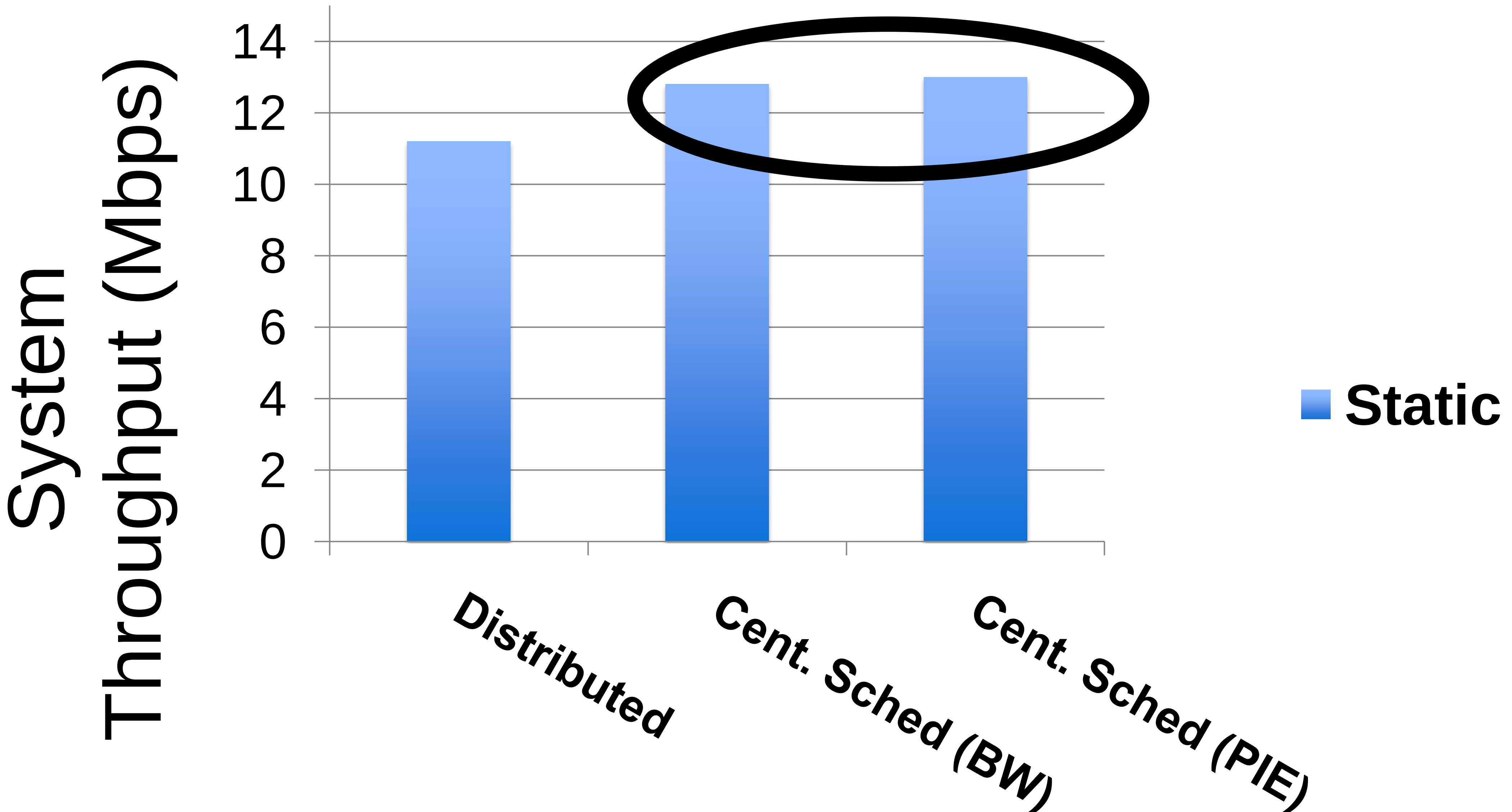
1. Estimate interference using PIE
2. Input estimate to a centralized data scheduler
3. Evaluate performance under dynamic scenarios

What is the impact on end users ?



Static scenario

What is the impact on end users ?



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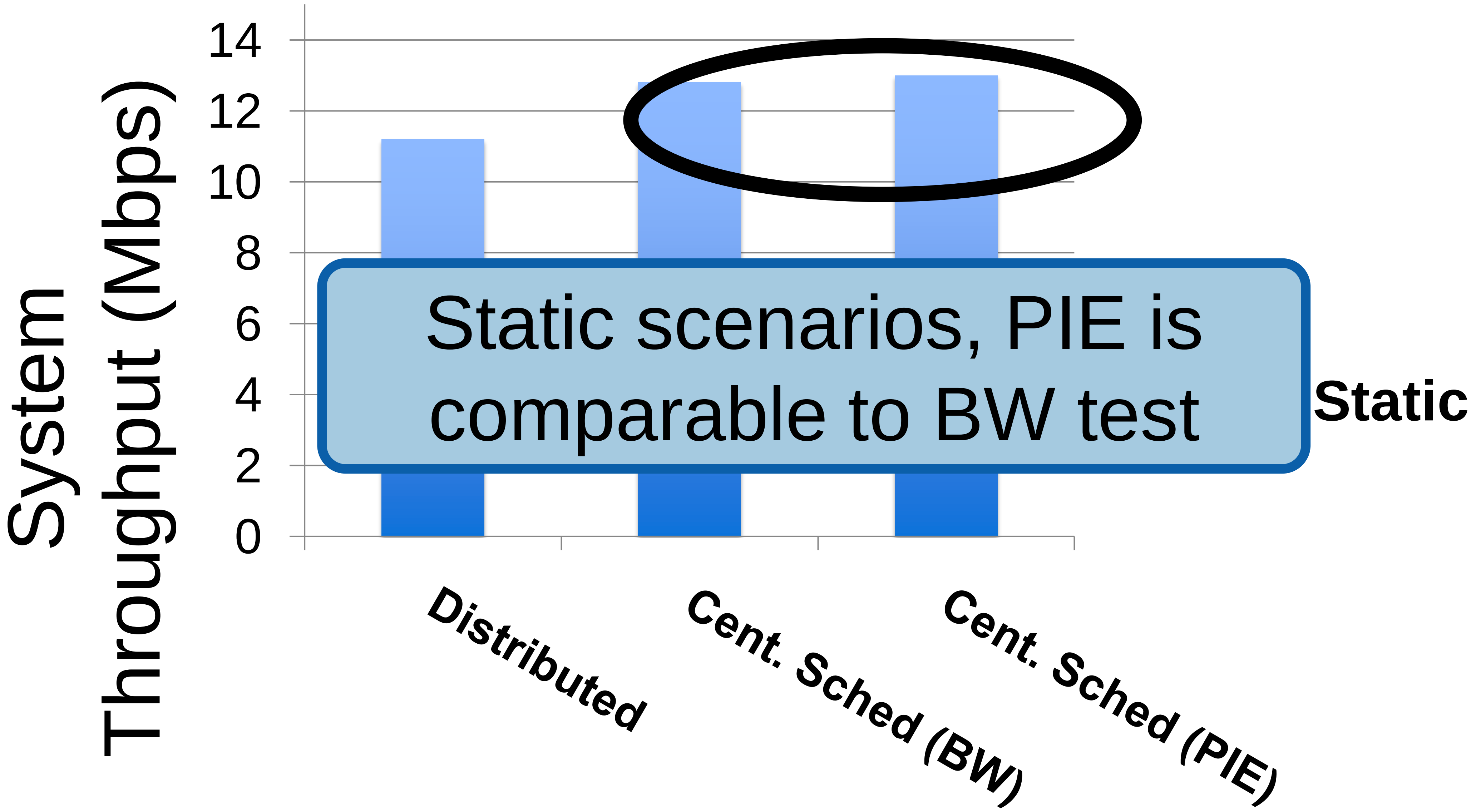

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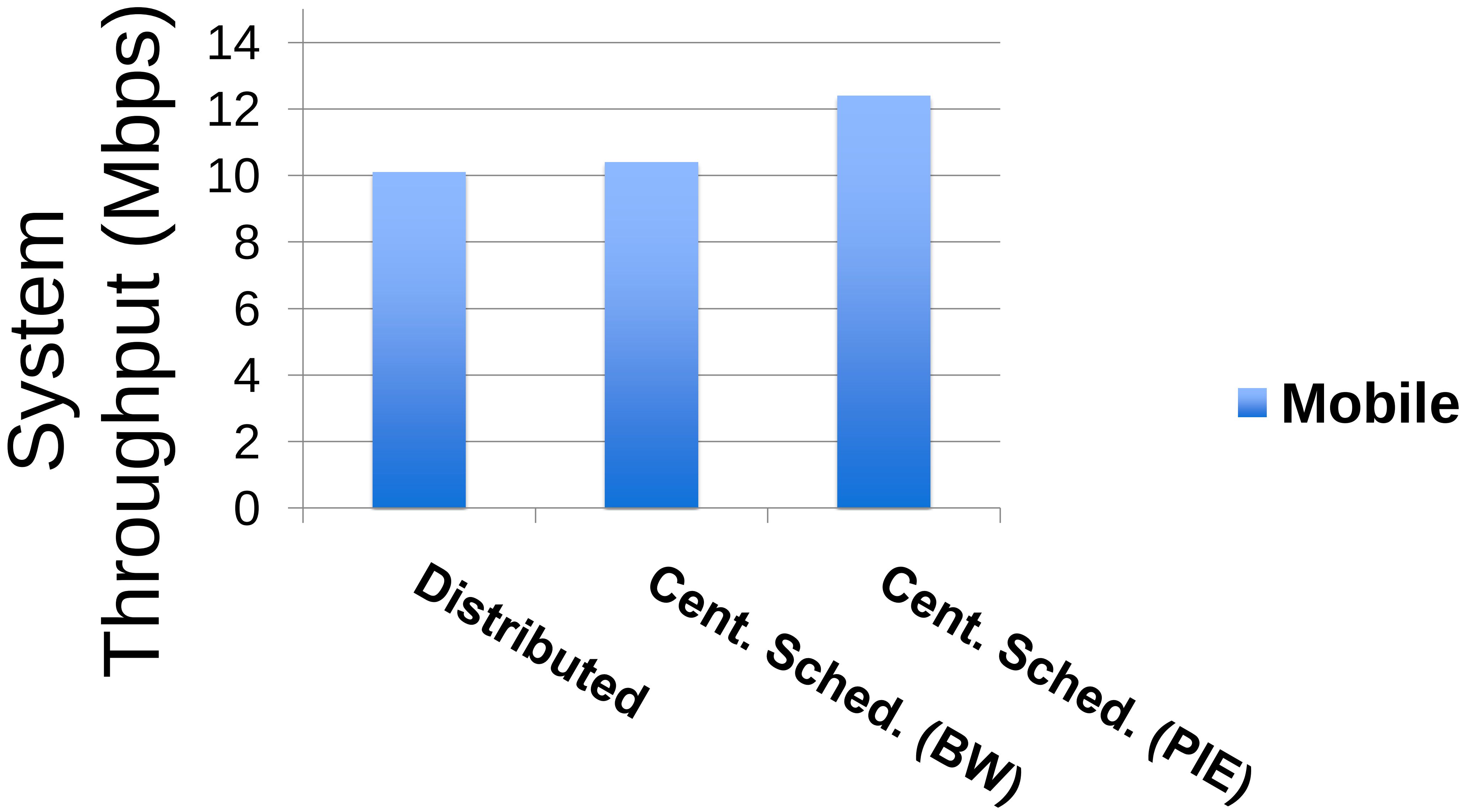
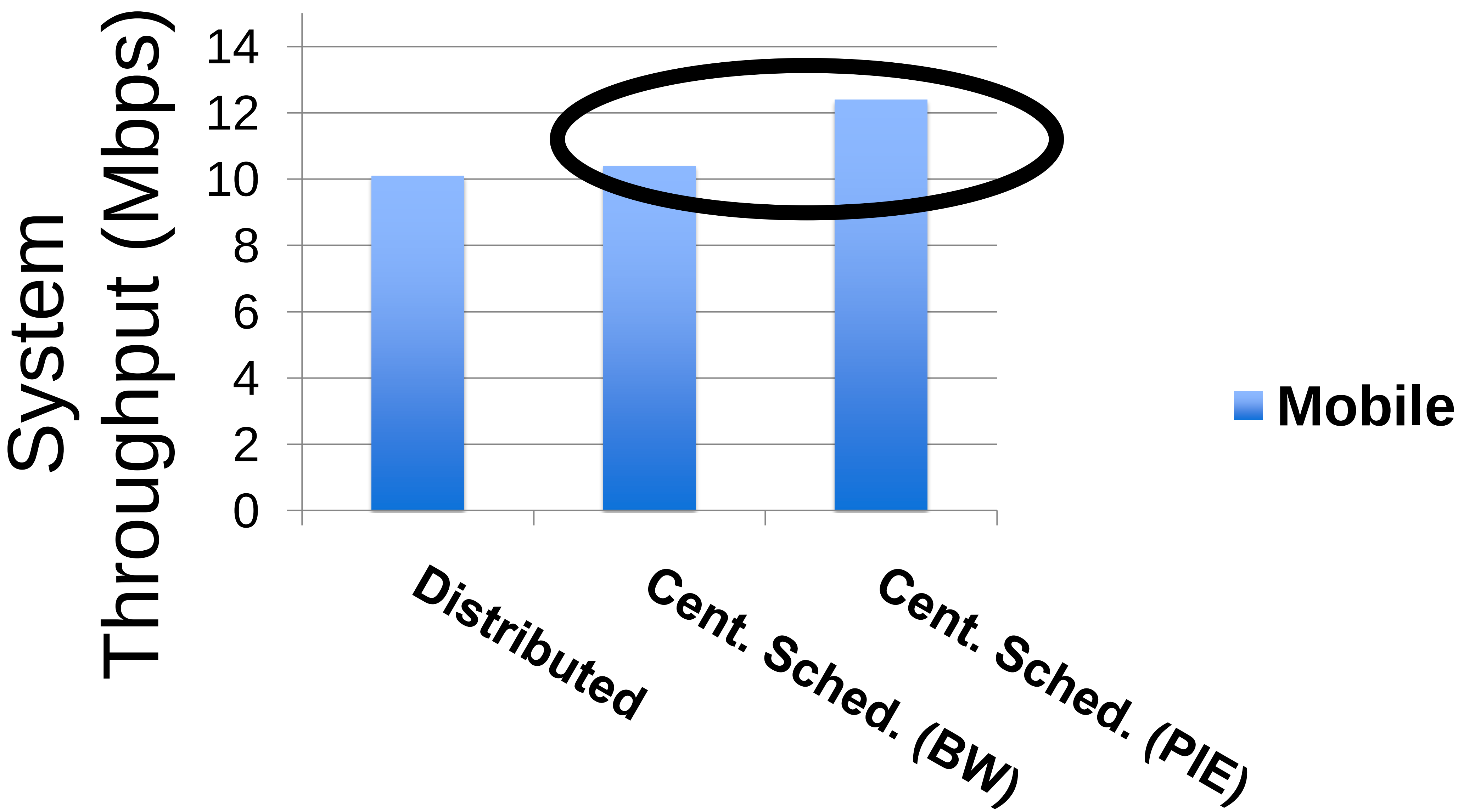


Mobile scenario

What is the impact on end users ?



Mobile scenario

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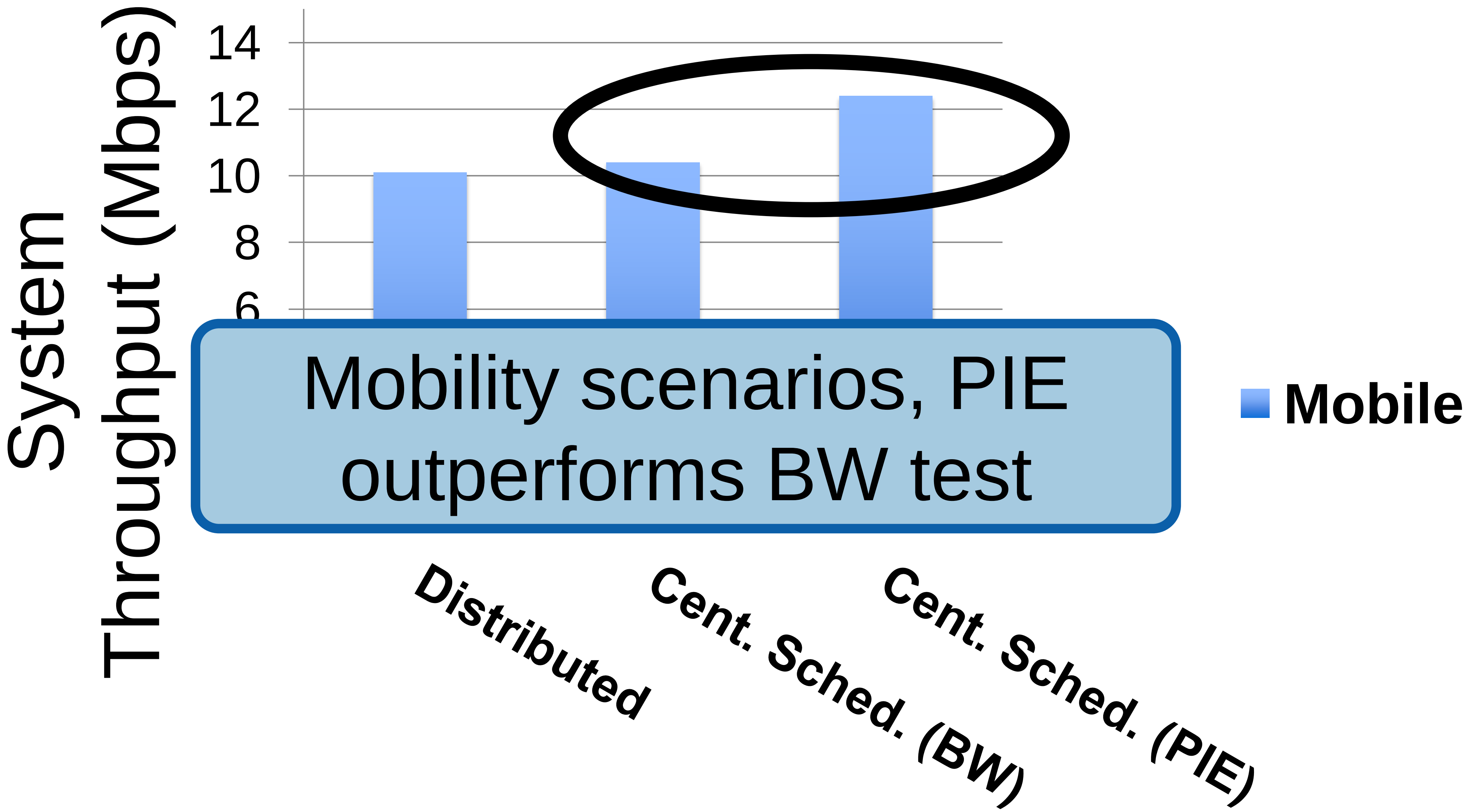

Mobility scenarios, PIE outperforms BW test

Mobile scenario

What is the impact on end users ?

- PIE can also be used to monitor production systems (like Jigsaw)
- We monitored two production WLANs
- Use testbed nodes in proximity of production APs as sniffers
- Identify hidden terminals and rate anomaly problems

What is the impact on end users ?

WLANs	Hidden terminal cases (LIR < 0.7)	Rate anomaly cases (Ratio of rates < 0.2)
WLAN1	8%	21%
WLAN2	11%	22%

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WLAN2	11%	22%

- Hidden terminals are rare, but can become pain points for clients
- Rate anomaly is more frequent, but do not cause drastic performance issues

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Related Work

- PIE leverages techniques from Jigsaw, WIT (Sigcomm 2006) and builds on their ideas
- Focus of Jigsaw, WIT was to understand interference, ours is to compute it in real-time
- CMAP also infers interference to harness exposed terminals, but requires physical layer change
- Active techniques like Microprobing (CoNext 2008) still require downtime and do not use realistic traffic

PIE Limitations

- Does not handle non-WiFi interferer like microwaves.
- Can miss external interferers if none of the enterprise APs can listen to the interferer
- May miss client conflicts, can use client participation in PIE to enhance the system
- Interference detection techniques at the physical layer may be more accurate in some scenarios where diversity is too low for PIE to function

PIE Summary

- Online interference estimation important for interference mitigation
  - BW test incurs high overhead, requires downtime
- PIE is a passive mechanism, generates interference estimates in real time
  - Leverages centralized infrastructure to collect real time reports from APs
  - Non-intrusive with good accuracy

Thank you !

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