The β-Factor: Measuring Wireless Link Burstiness

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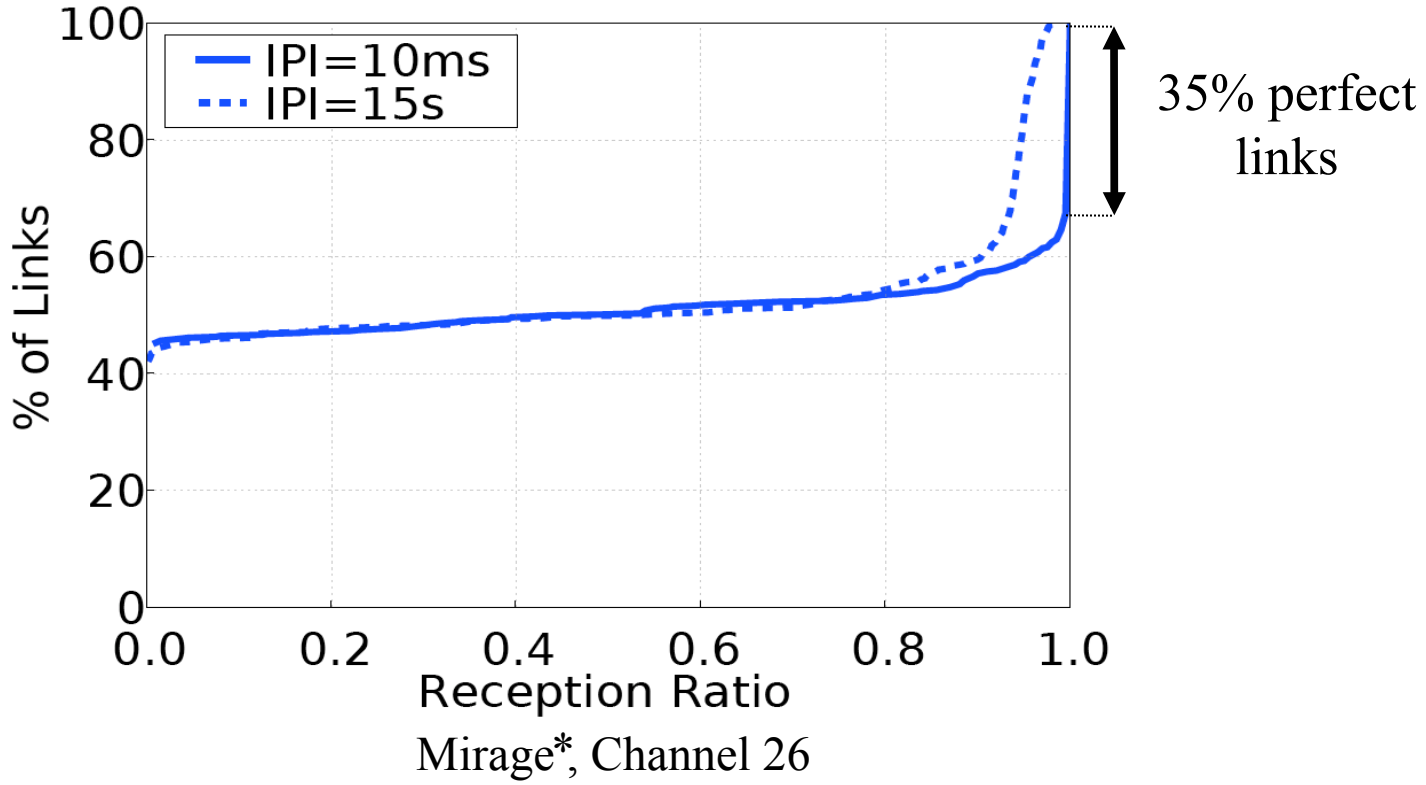
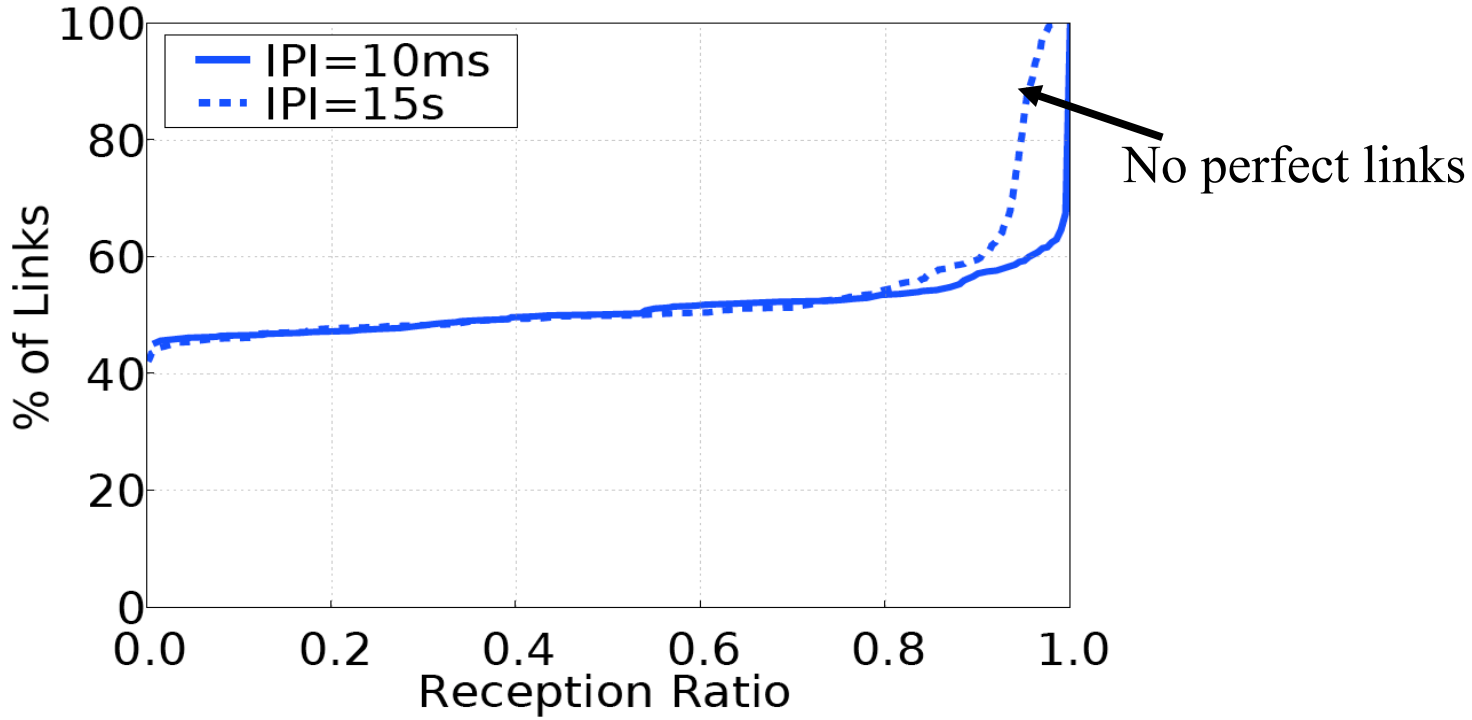
Link Dynamics



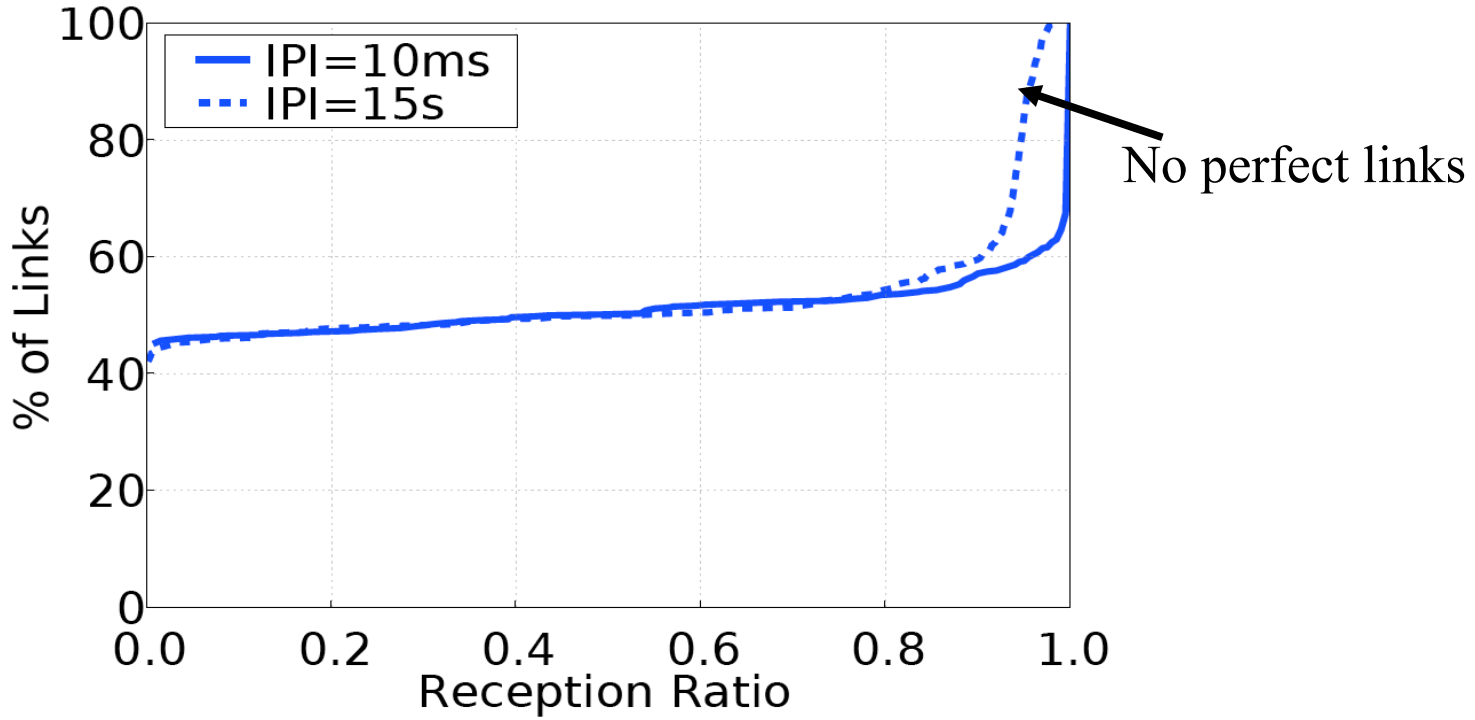
* Intel Berkeley Mirage Testbed

Link Dynamics



Mirage, Channel 26

Link Dynamics



Mirage, Channel 26

- Links are bursty

Problem Statement

- Links are bursty
- Burstiness affects protocol performance
- Need a way to measure it
  - Towards better understanding of wireless network protocol behavior

In this talk

- Introduce burstiness metric: β
- How useful is β?
- Causes of burstiness

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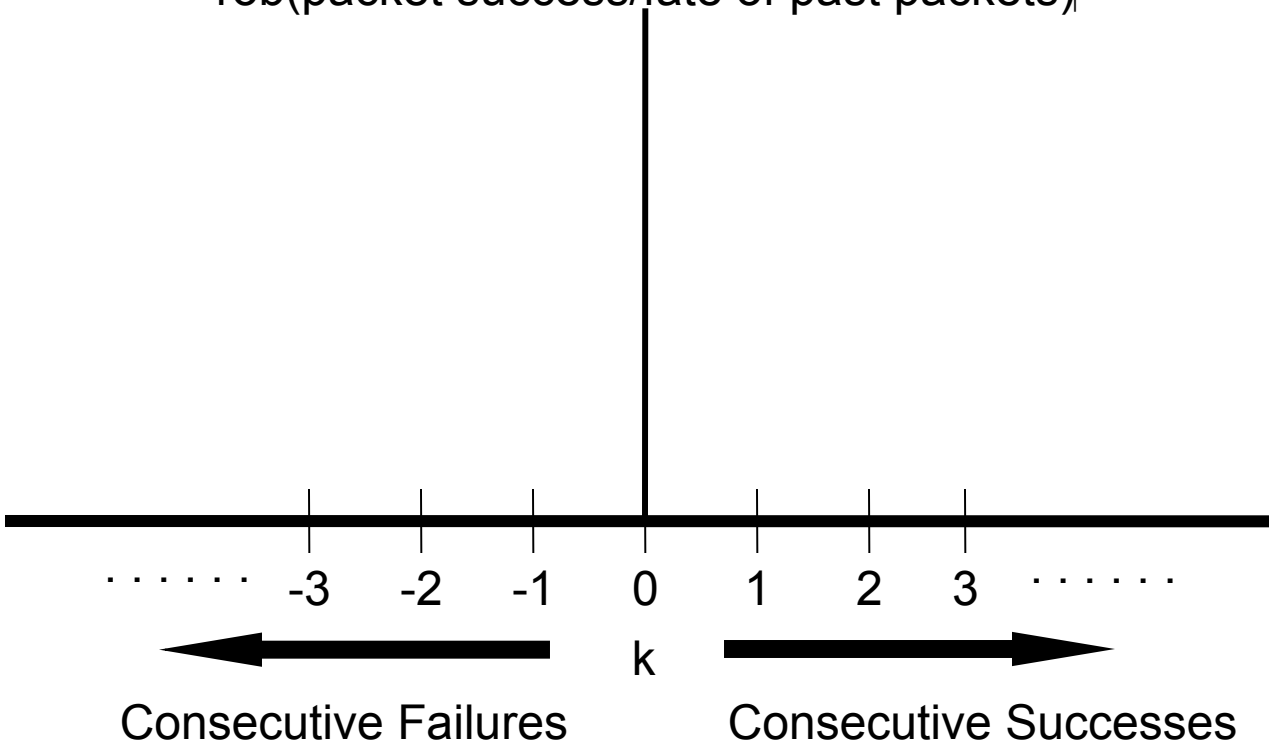
Links and Burstiness Metric

- Need a scalar metric
- Perfectly bursty link
  - Link with a long string of consecutive successes or a long string of failures
  - $\beta = 1.0$
- Independent link
  - Link with independent packet events
  - $\beta = 0.0$

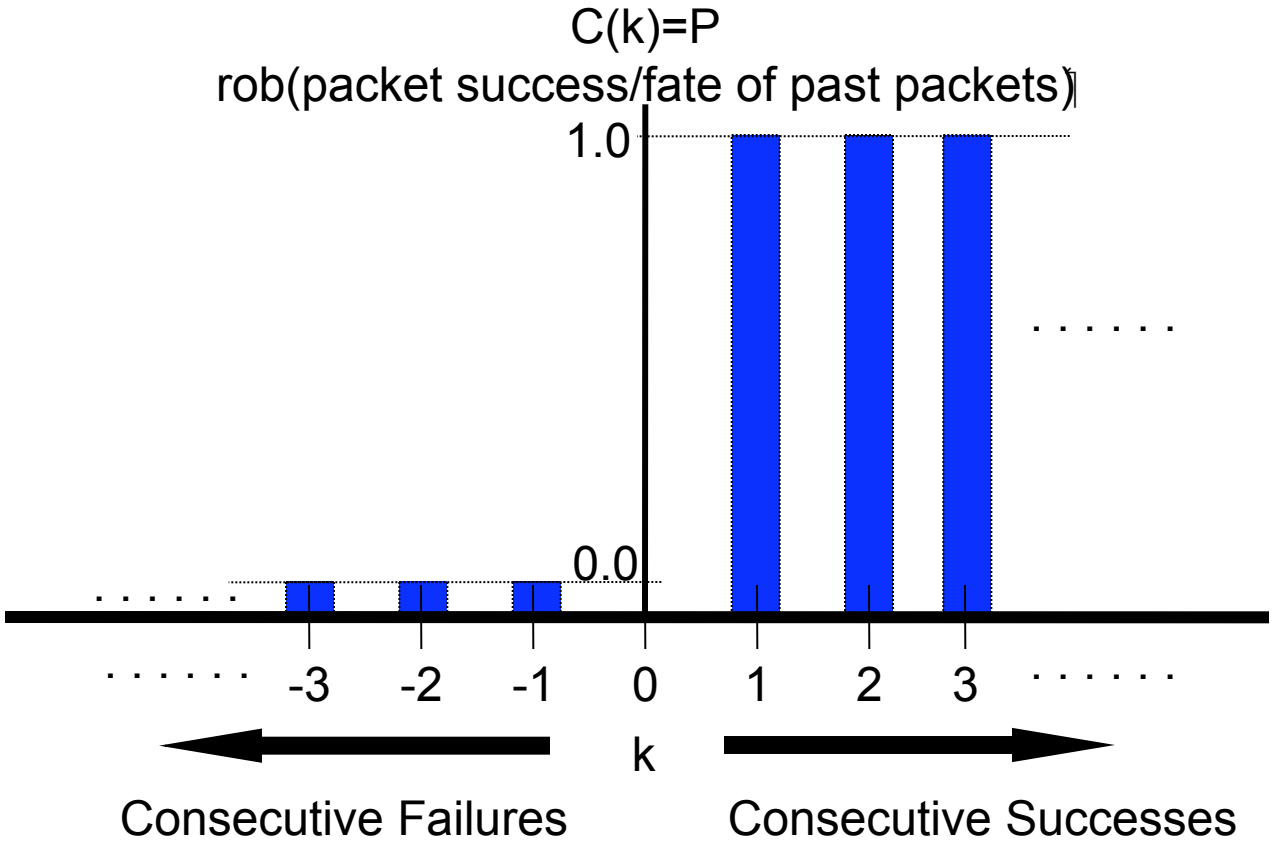
Conditi
o
nal Packet Delivery Function (CPDF)

C(k)=P
rob(packet success/fate of past packets)



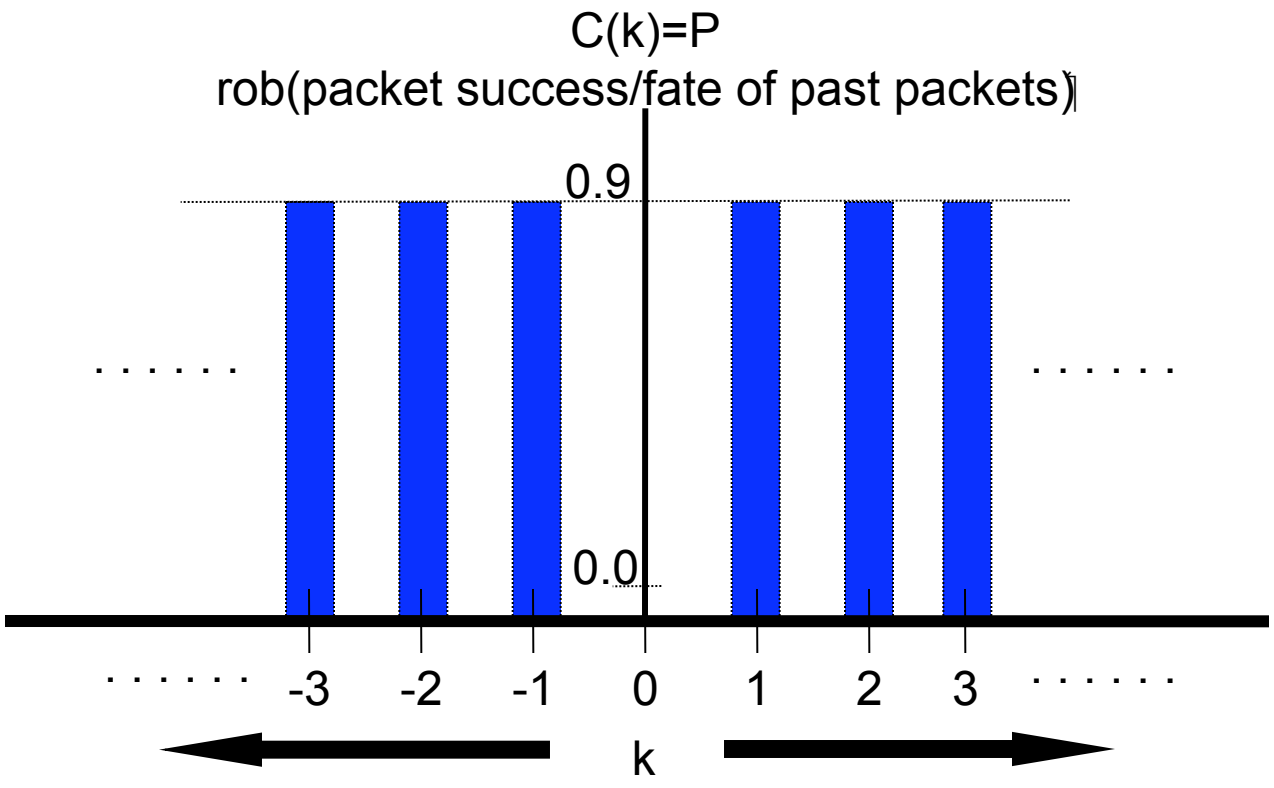
CPDF: Perfectly Bursty Link

- A link with a single burst of success or failure



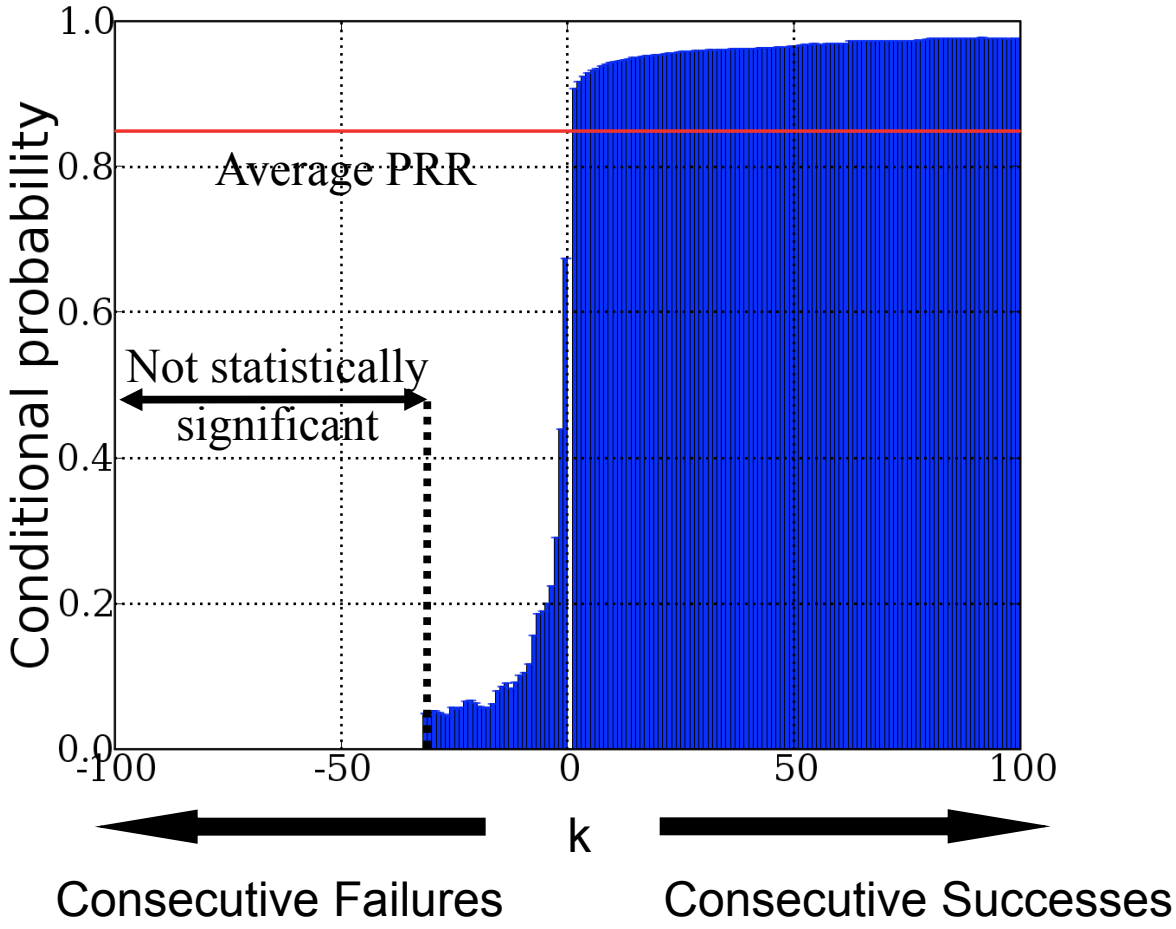
CPDF: Independent Link

- A link with independent packet events



A synthetic independent link with PRR=90%

CPDF of an Empirical Link



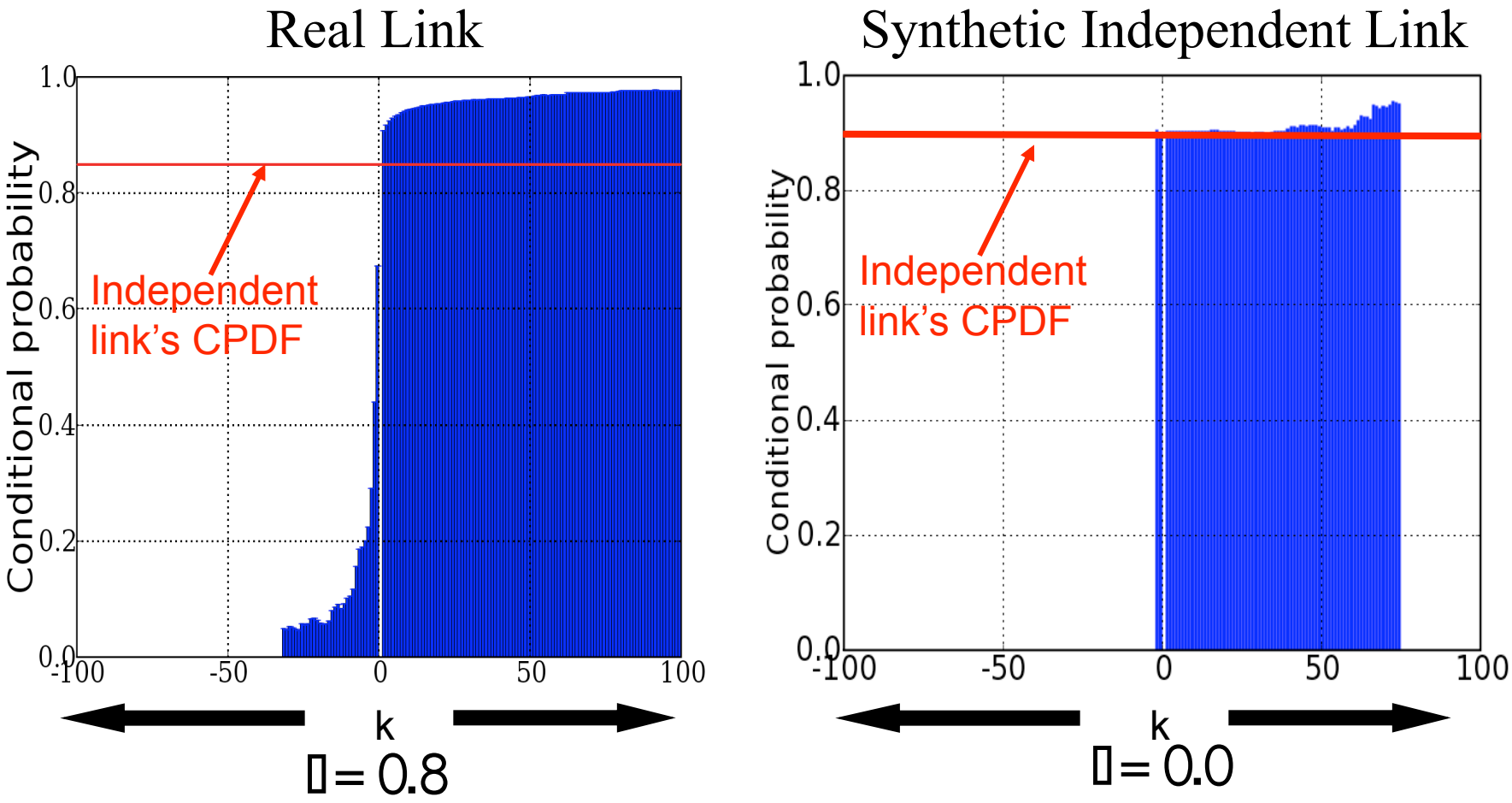
Burstiness: The β-Factor

- Use KW distance
  - distance from perfectly bursty CPDF
  - independent links can have low distance
- For β:
  - compare distance of a link to the distance of an independent link with same PRR
- β code available at http://sing.stanford.edu/srikank/betacalc.py

Burstiness: The β-Factor

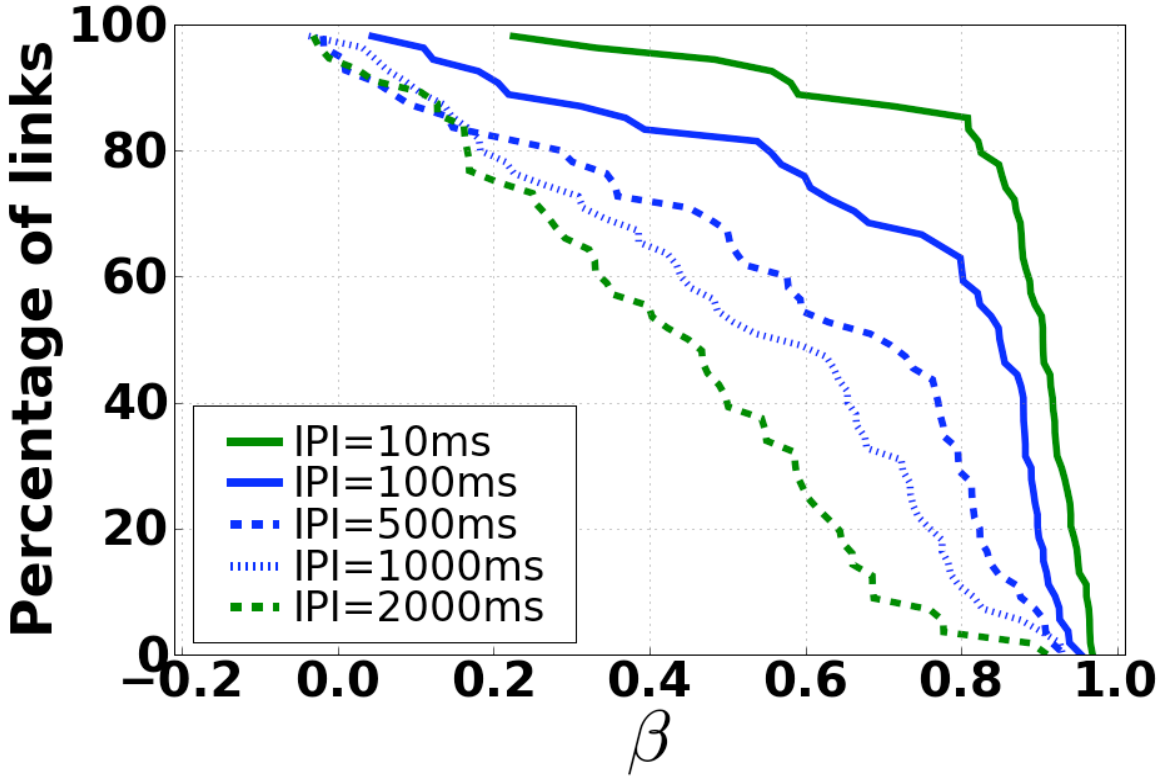
- β>0: Bursty link
- β=0: Independent link
- β<0: Oscillatory link

The β-Factor: Examples

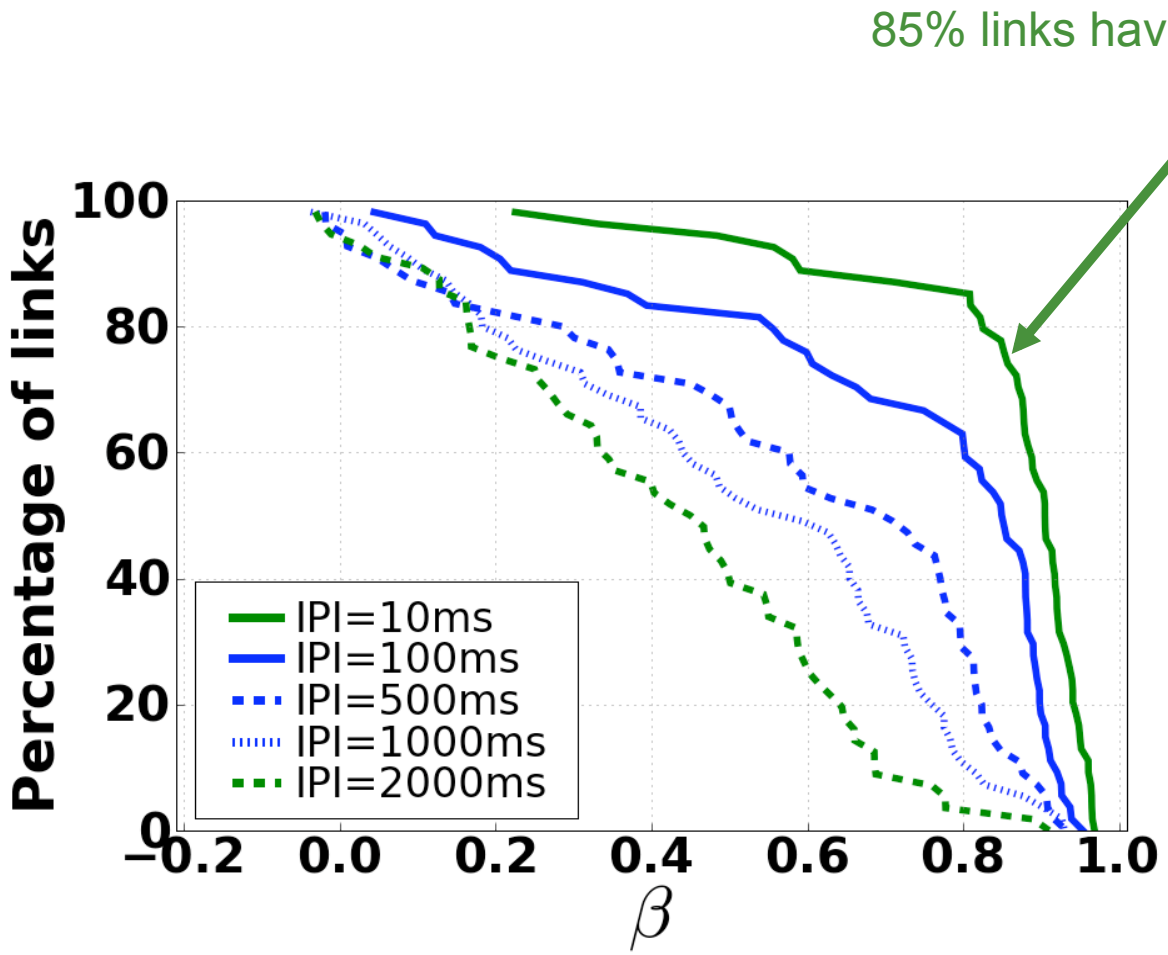


The β Distribution on Mirage

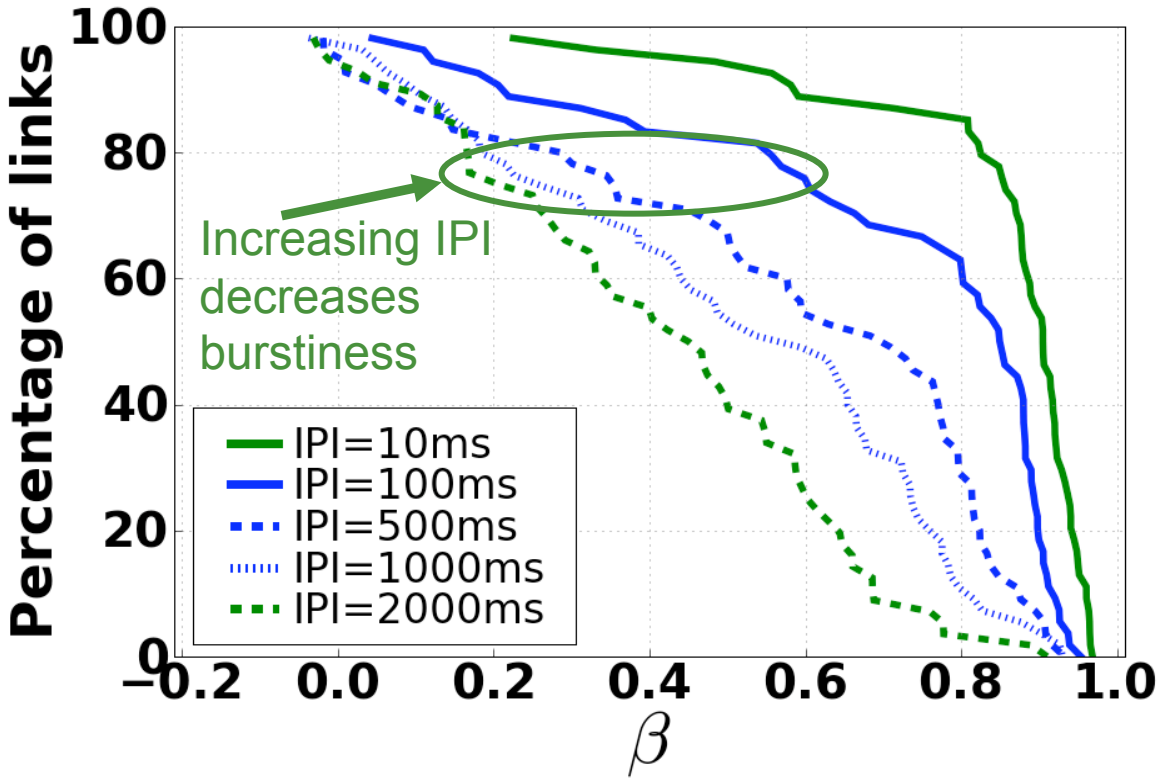
- β is plotted only for intermediate links



The β Distribution on Mirage



The β Distribution on Mirage



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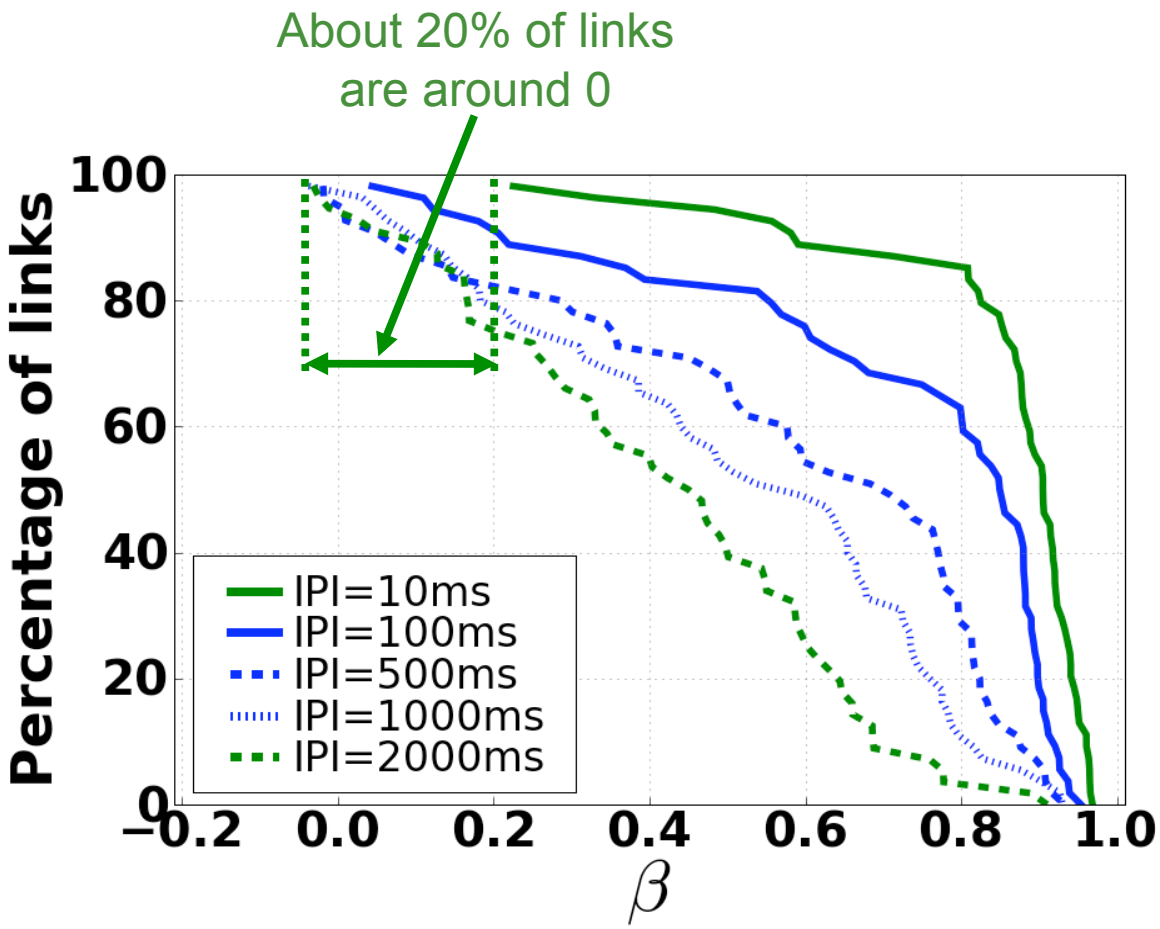

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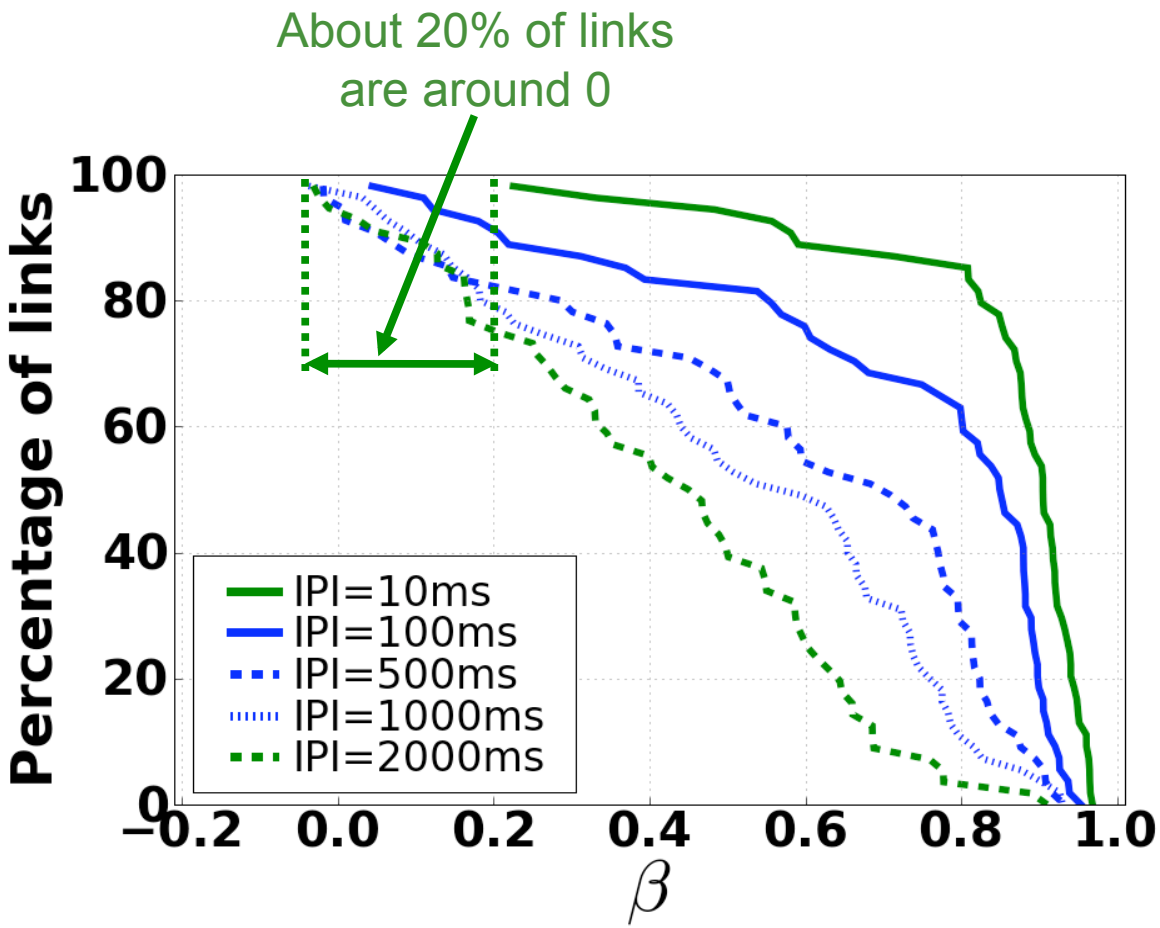


- 500ms: a good choice for independent reception

In this talk

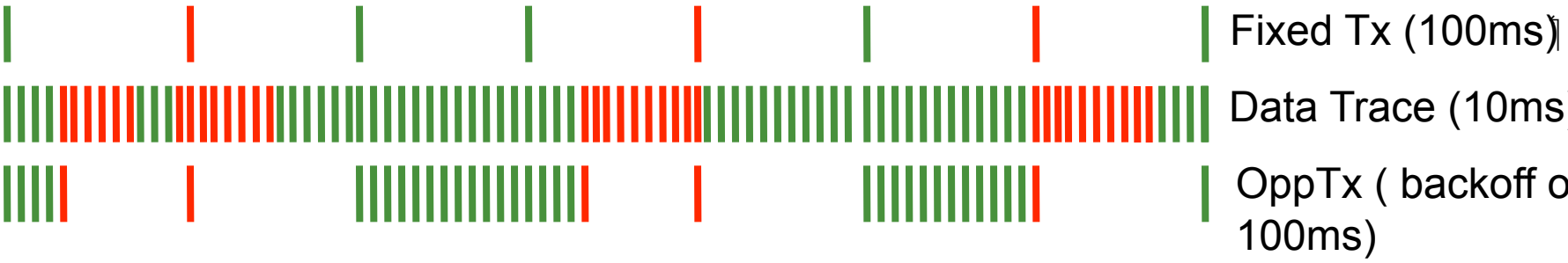
- Introduce burstiness metric: β
- How useful is β?
- Causes of burstiness

How useful is β?

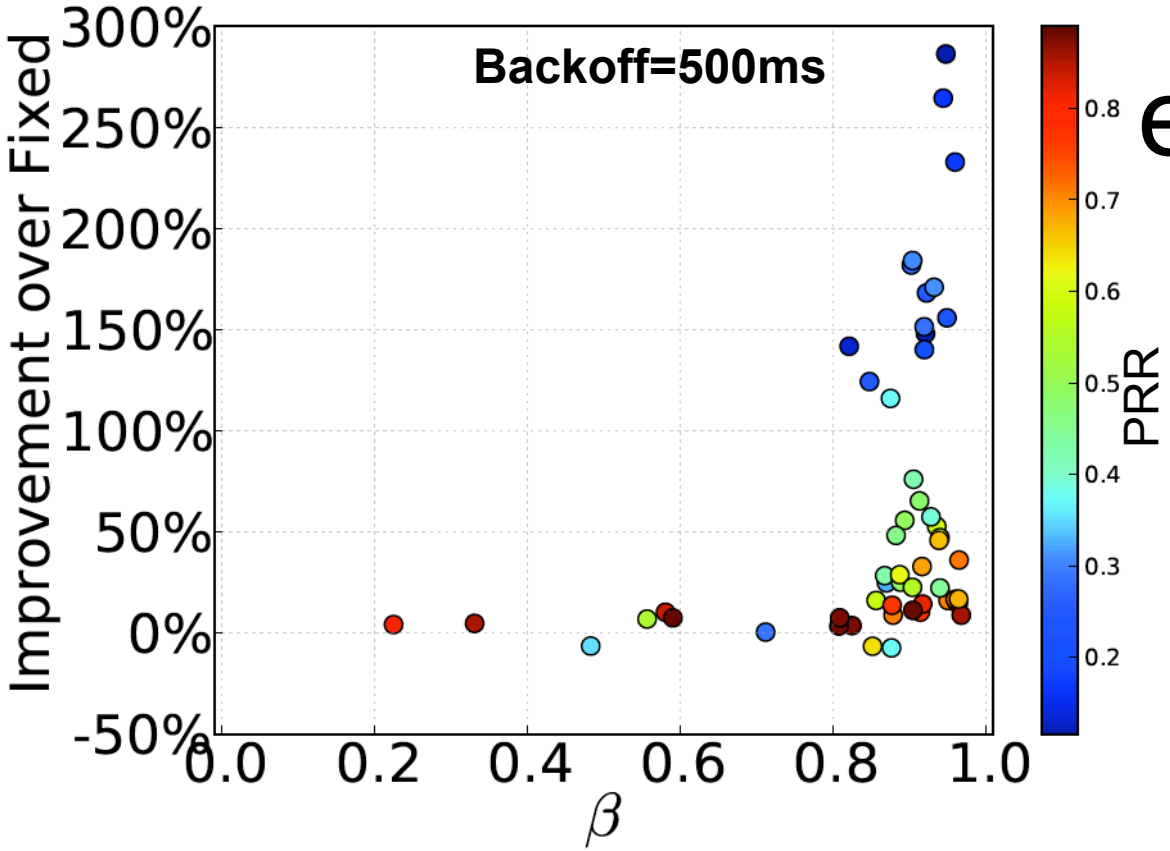
- Opportune Transmissions
  - Naïve algorithm
    - On success, send next packet soon
    - On failure, wait
  - Similar in principle to:
    - Many MAC protocols do this
  - How long to wait?
    - too long: underutilize link
    - too short: wasteful use of channel
    - **β gives us this value: 500ms**

Opportune Transmissions (OppTx)

- Replay data trace
- Compare PRR of OppTx with Fixed Rate transmissions



Opportune Transmis s ions ((



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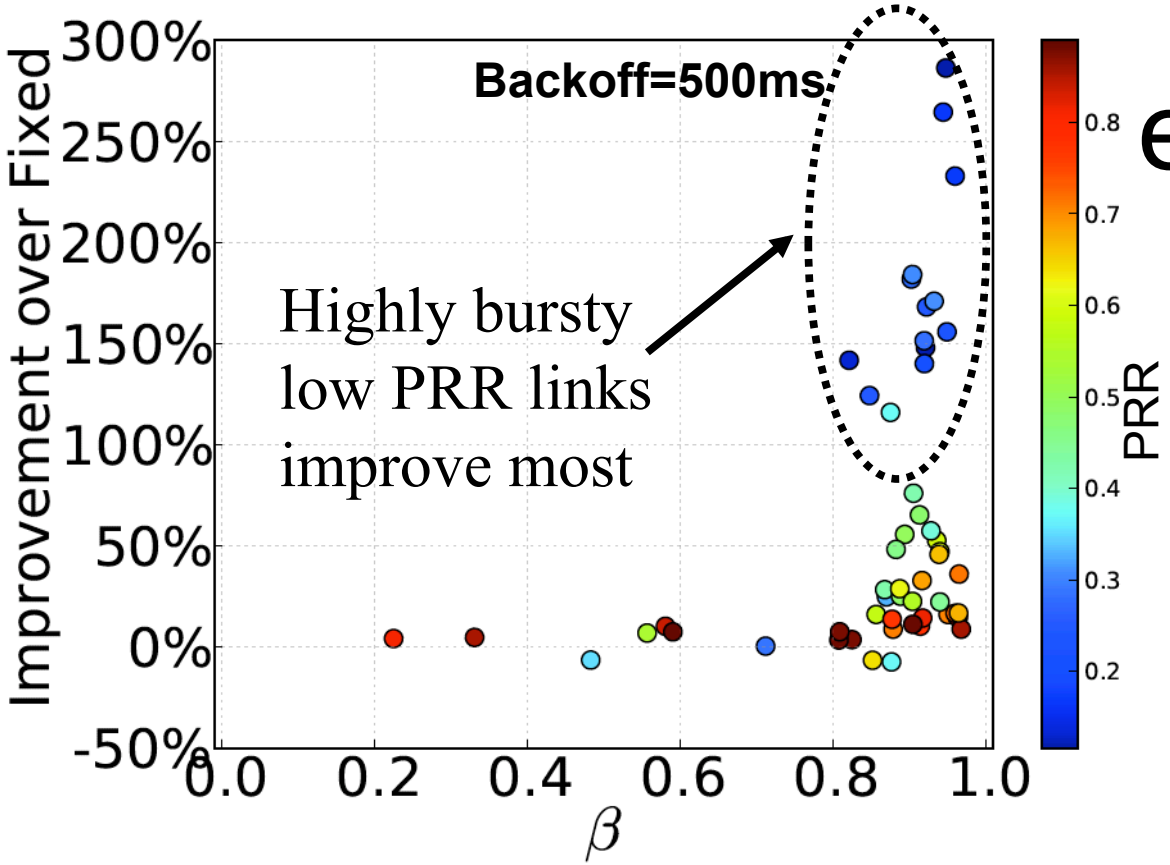
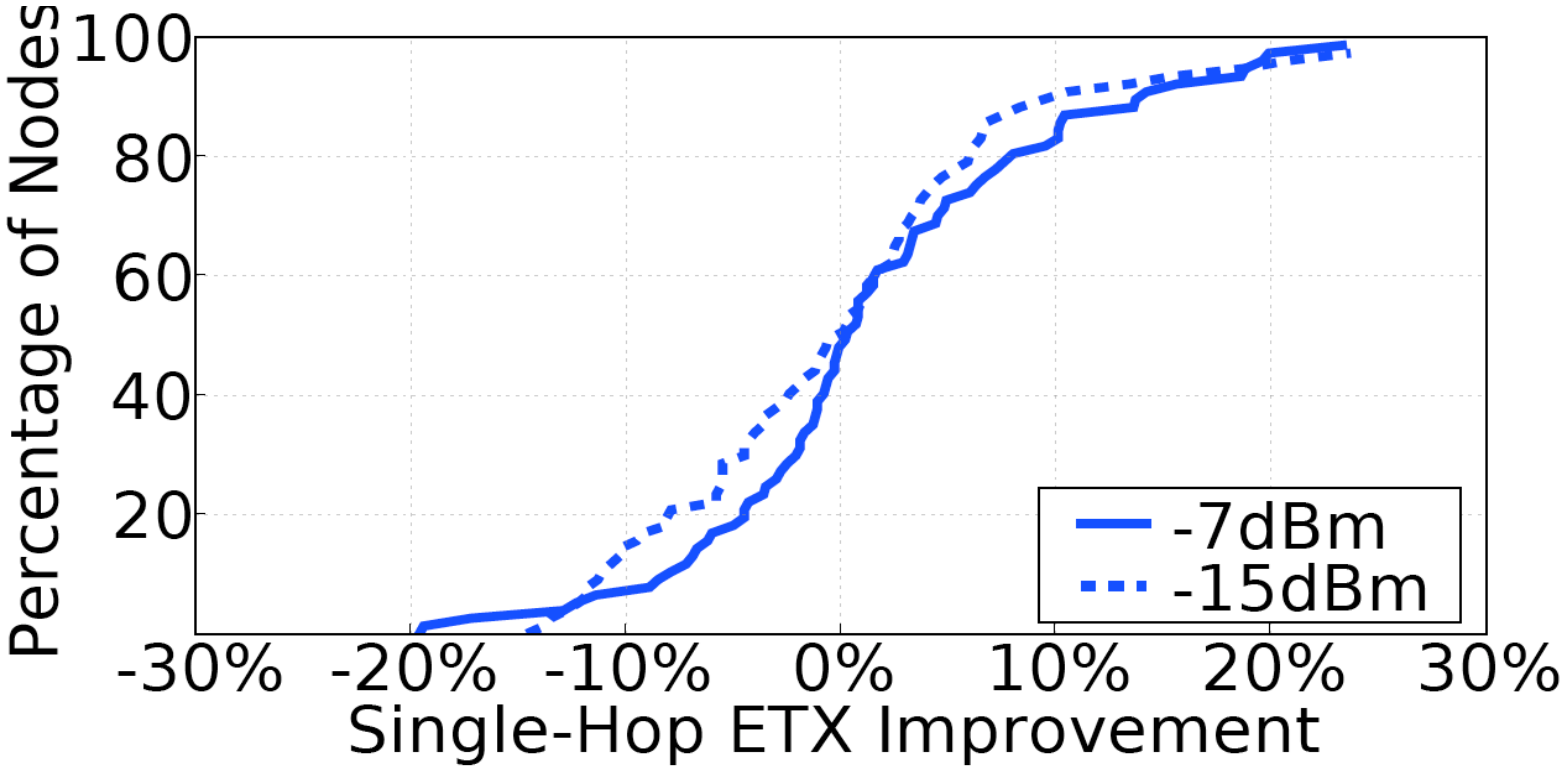
Opportune Transmis s ions ((ents



CTP and β

- Modified No-Ack Time to 500ms
- Compare transmission costs of modified CTP with
  C
  TP with default No-Ack Time (Immediate~16-31ms)
- Ran an experiment on 80 Mirage nodes
  - Packet every 10s from every node
  - Count
    reception
    s upon first packet at the root (allow for topology discovery)

CTP and β: Single-Hop Performance



- 50% of the links don't improve
- Only 10% of links improve above 15%

CTP and β: End-to-End Performance

- Compute transmission cost
  - (total # txs)/(# uniquely rcvd pkts at sink)

	-7dBm	-15dBm
Immediate	4.73	6.71
Opportune	4.02	5.65
Reduction	15%	15%

- More end-to-end improvement (~15%) than anticipated
  - CTP uses links that improve

CTP and β: Take Away

- Improving a few links can improve end-to-end performance
- Trading-off Latency (No free lunch!)
  - CTP-OppTx: 4s at -7dBm and 25s at -15dBm
  - CTP-Immediate: 1s

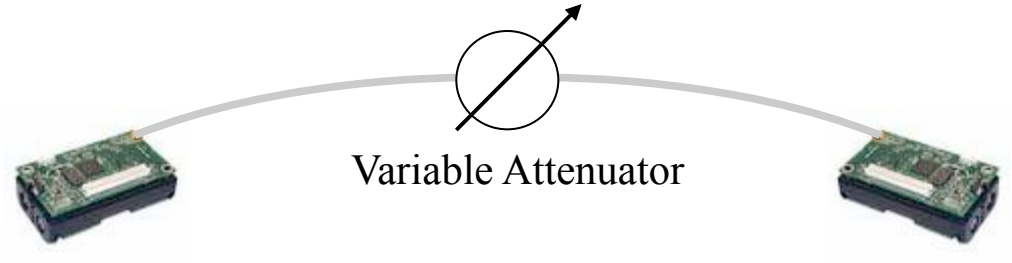
In this talk

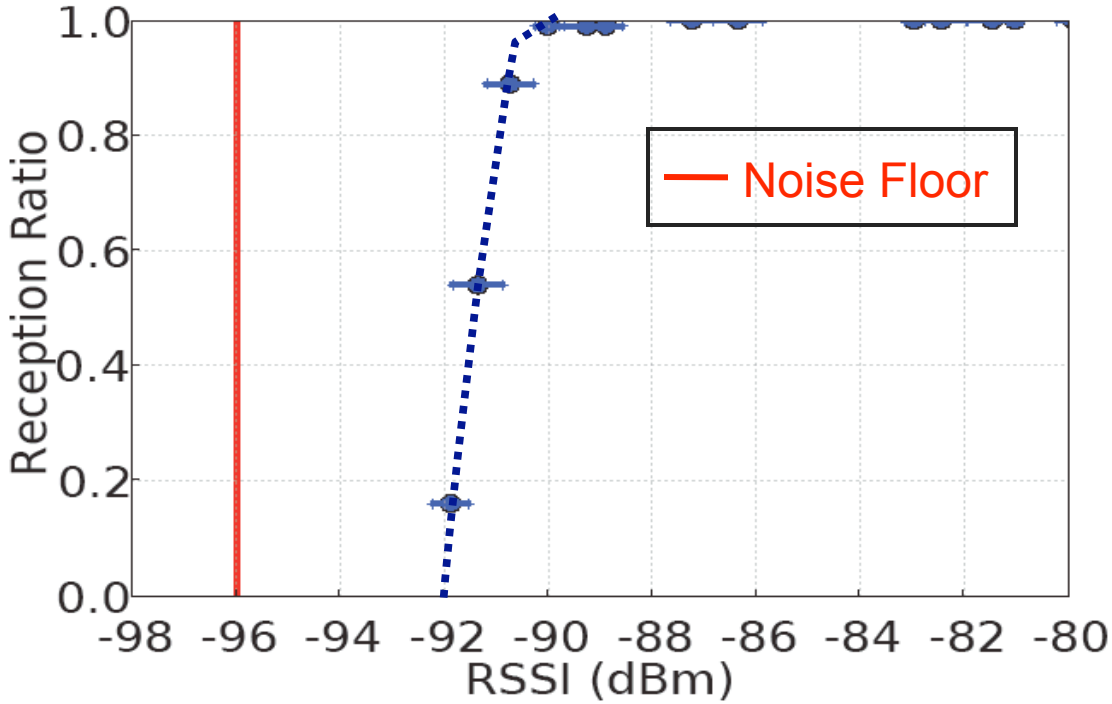
- Introduce burstiness metric: β
- How useful is β?
- Causes of burstiness

Why look for causes?

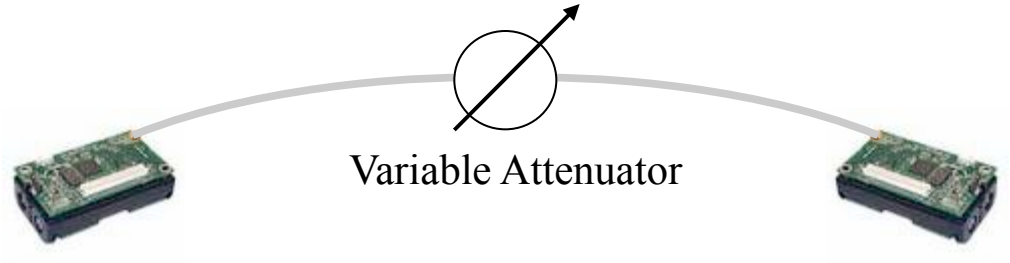
- Can we generalize the results?
  - Results could be due to Mirage
- A common cause allows generalization
- Could it be the channel variations?

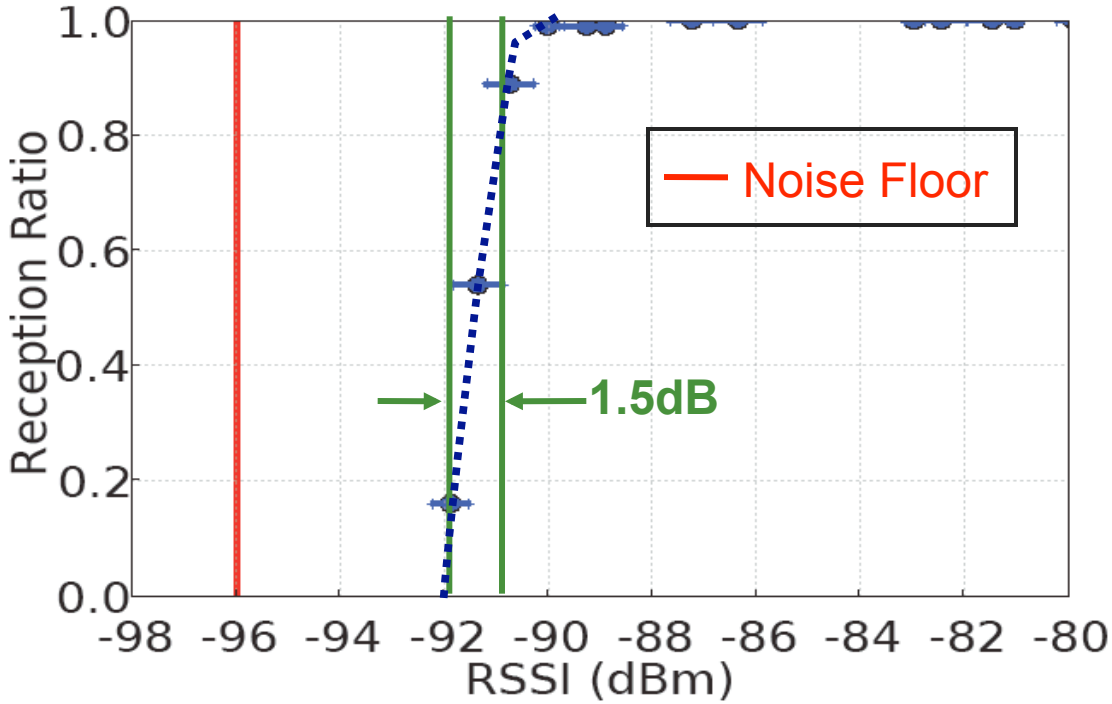
Causes of Burstiness: RSSI





Causes of Burstiness: RSSI





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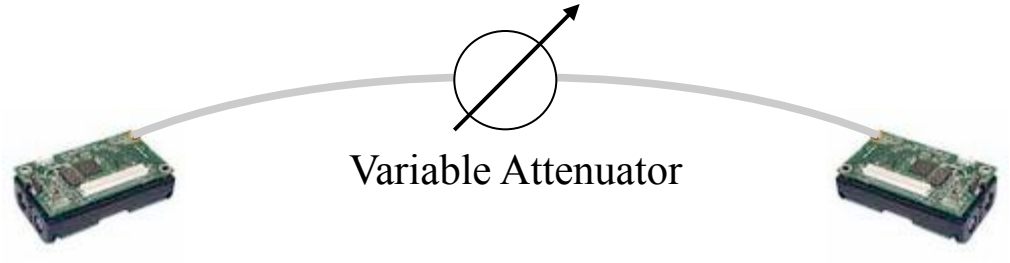
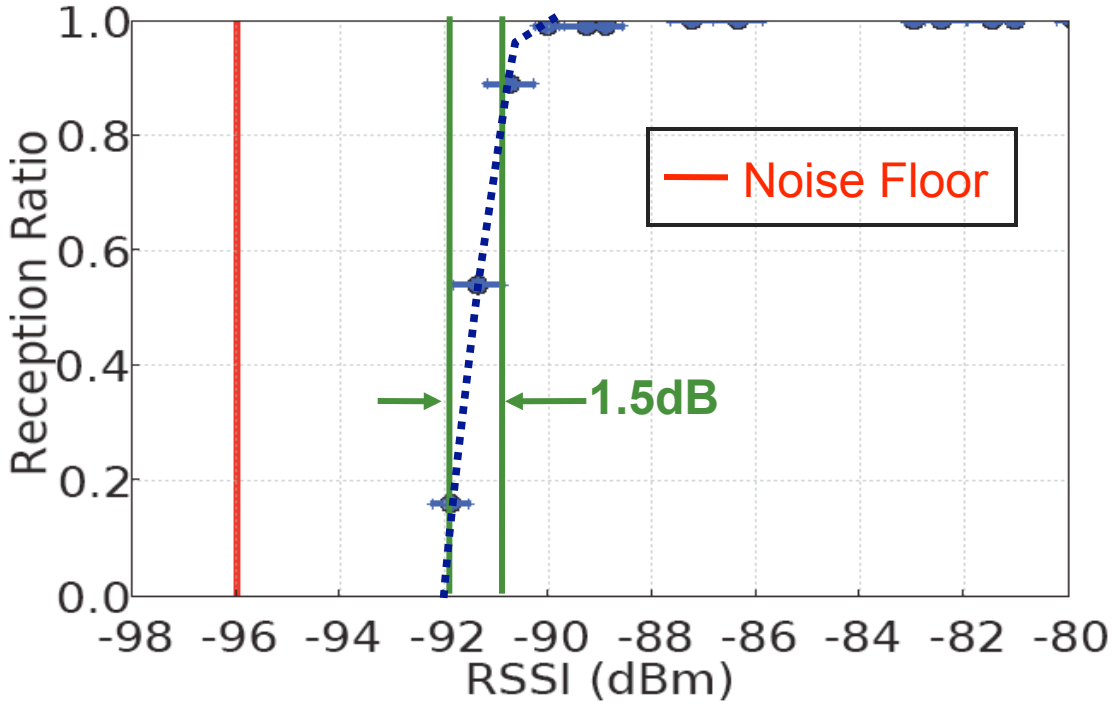
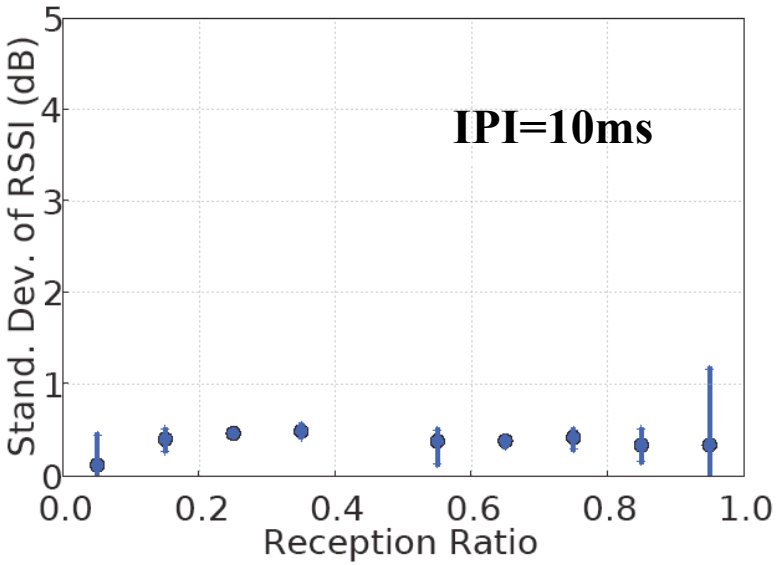


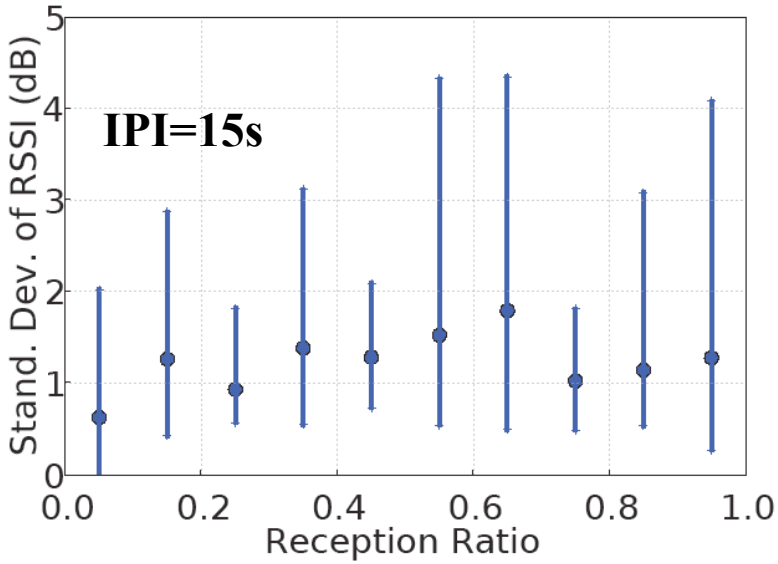


- Small variations in signal affects link PRR

Causes of Burstiness: RSSI

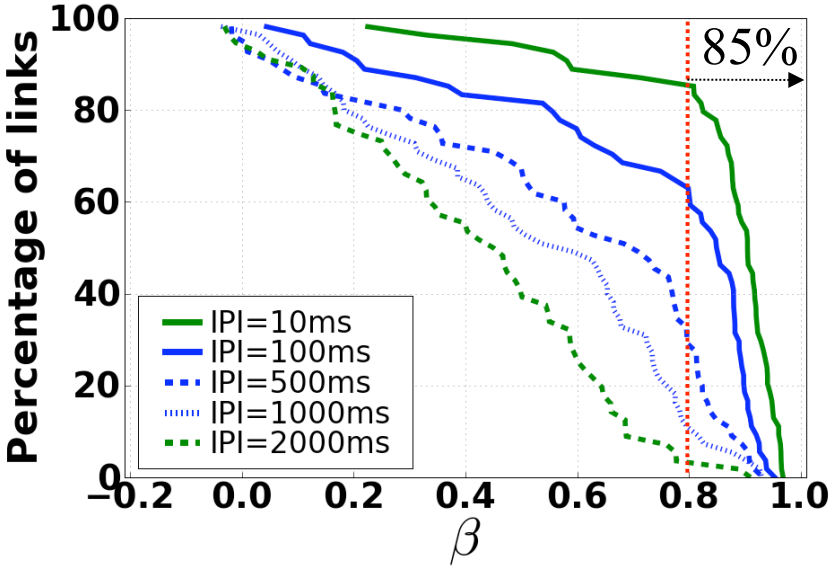
- RSSI is stable over short time spans
- RSSI varies over longer durations



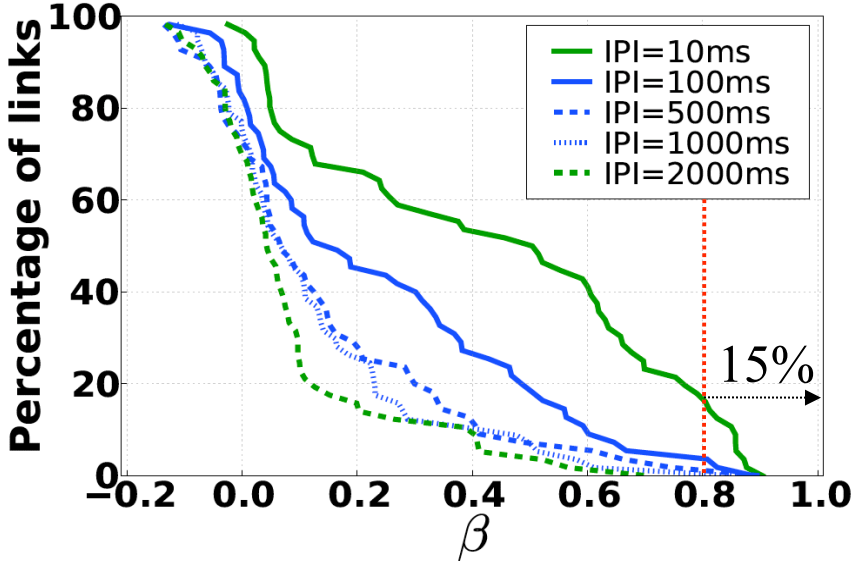


- Variation in signal strength is a possible cause of burstiness!

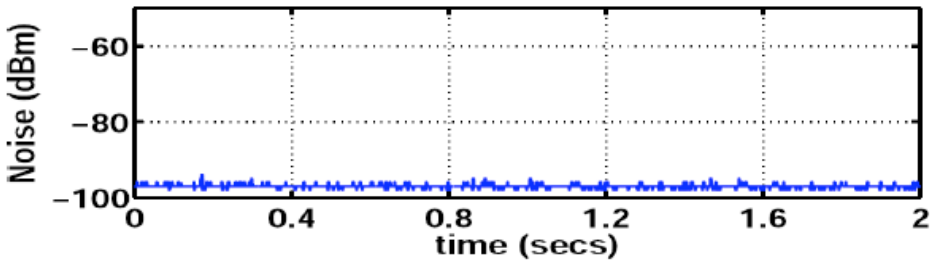
External Noise Reduces Burstiness

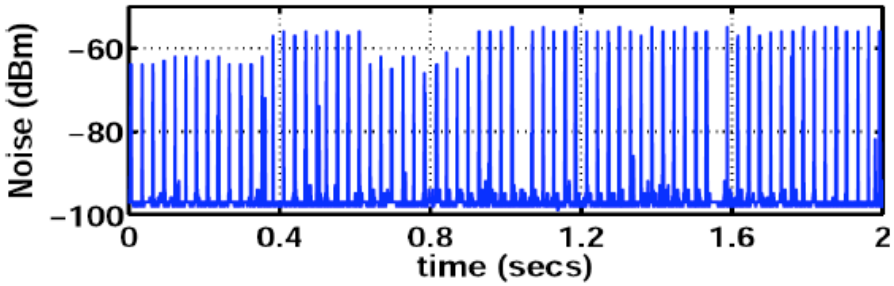


Channel 26



Channel 16





Summary

- Introduced a new burstiness metric
- Showed a way to use it to improve protocol performance
- Burstiness is caused by channel variations
  - Applicable to other link layers
  - Paper shows for 802.11: Roofnet

Moving Forward

- As a community, come up with more metrics
  - Stanford Wireless Analysis Tool (SWAT) in demo
- Report these metrics in our evaluations
  - “We tested protocol X on a Network with α=45, β=0.6 and σ=-10”

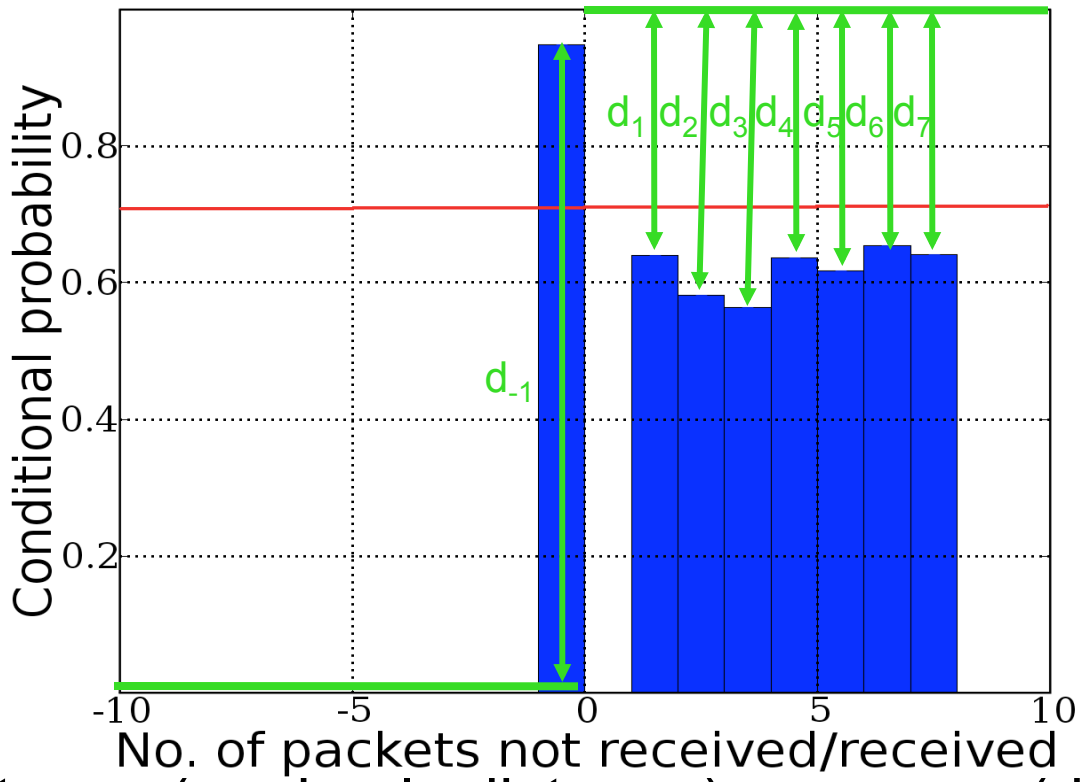
Thank You!

Questions or Comments?

Beta code: http://sing.stanford.edu/srikank/betacalc.py
SWAT tool: http://sing.stanford.edu/swat

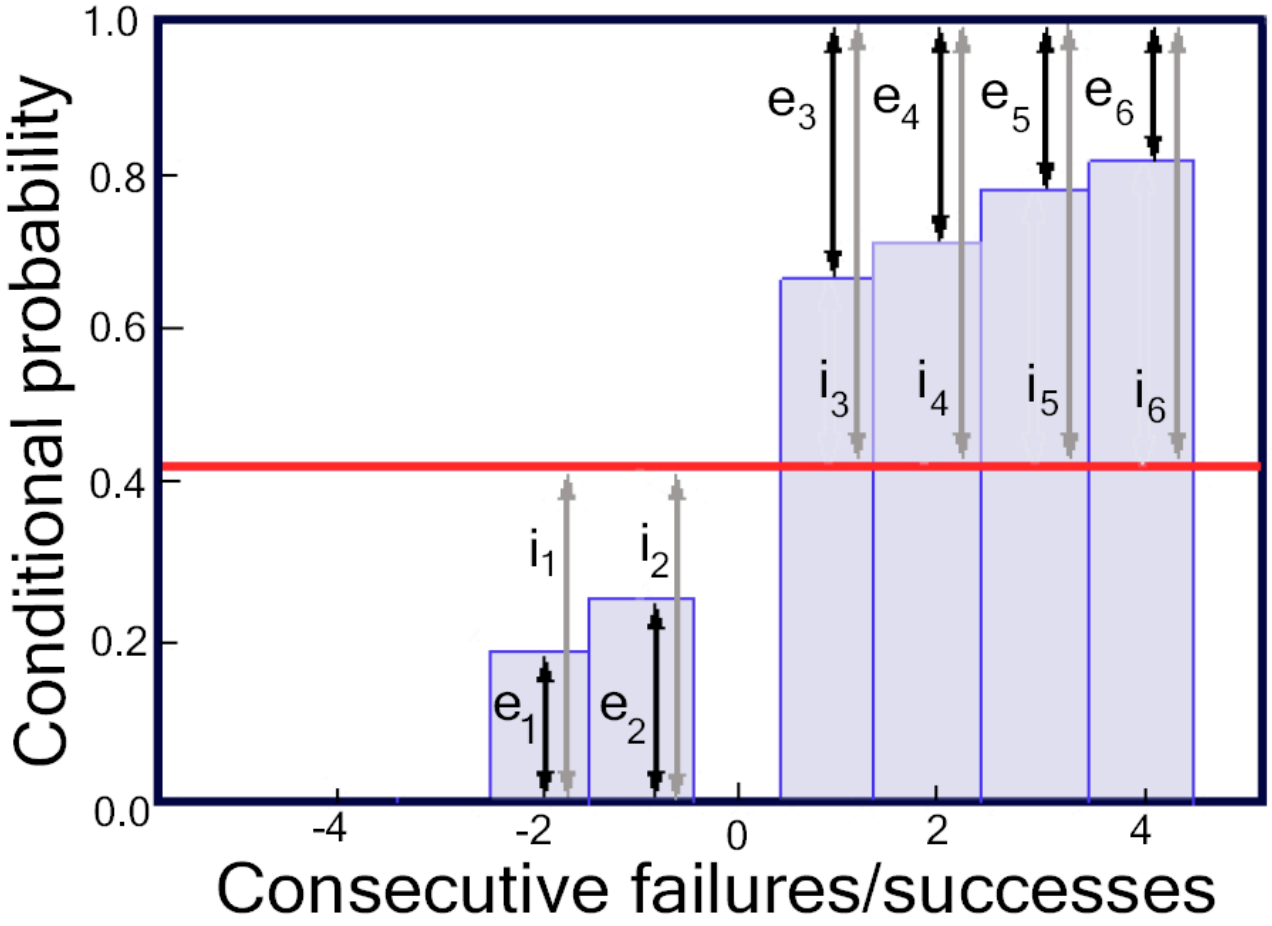
Back-Up Slides

KW Distance: How Far From Being Bursty?



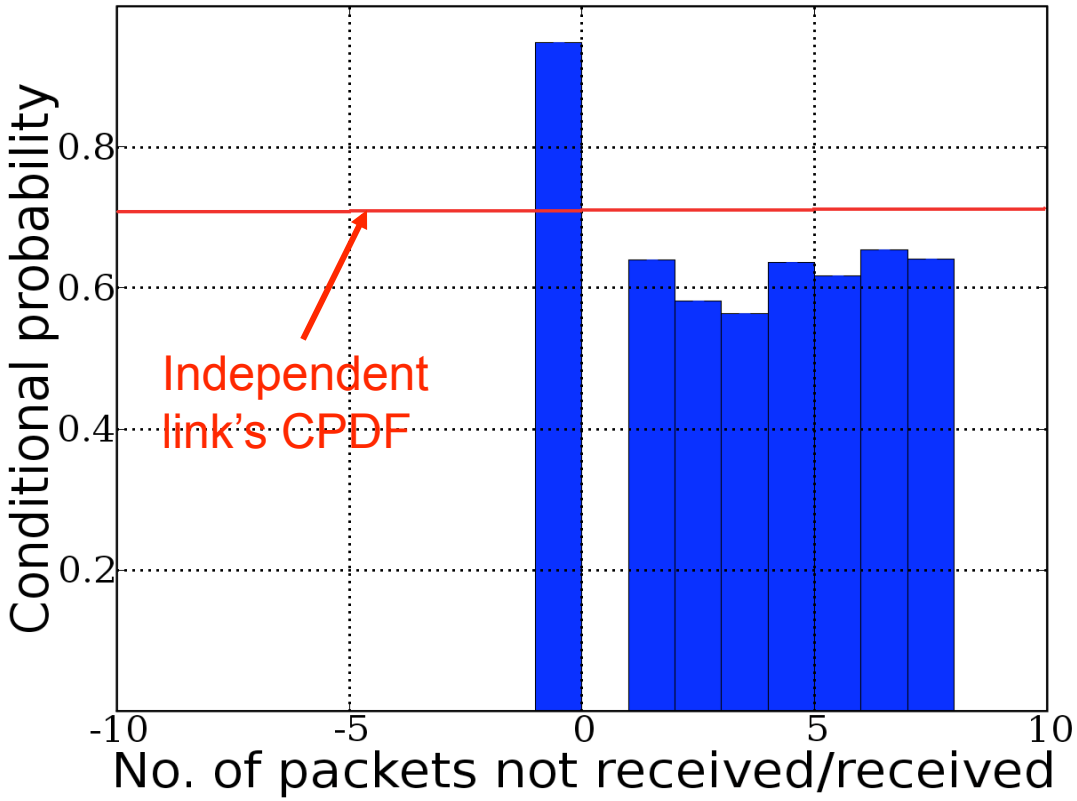
KW Distance (or simply distance) = average(d_{-1}, $d_1 \ldots d_7$)

β Calculation



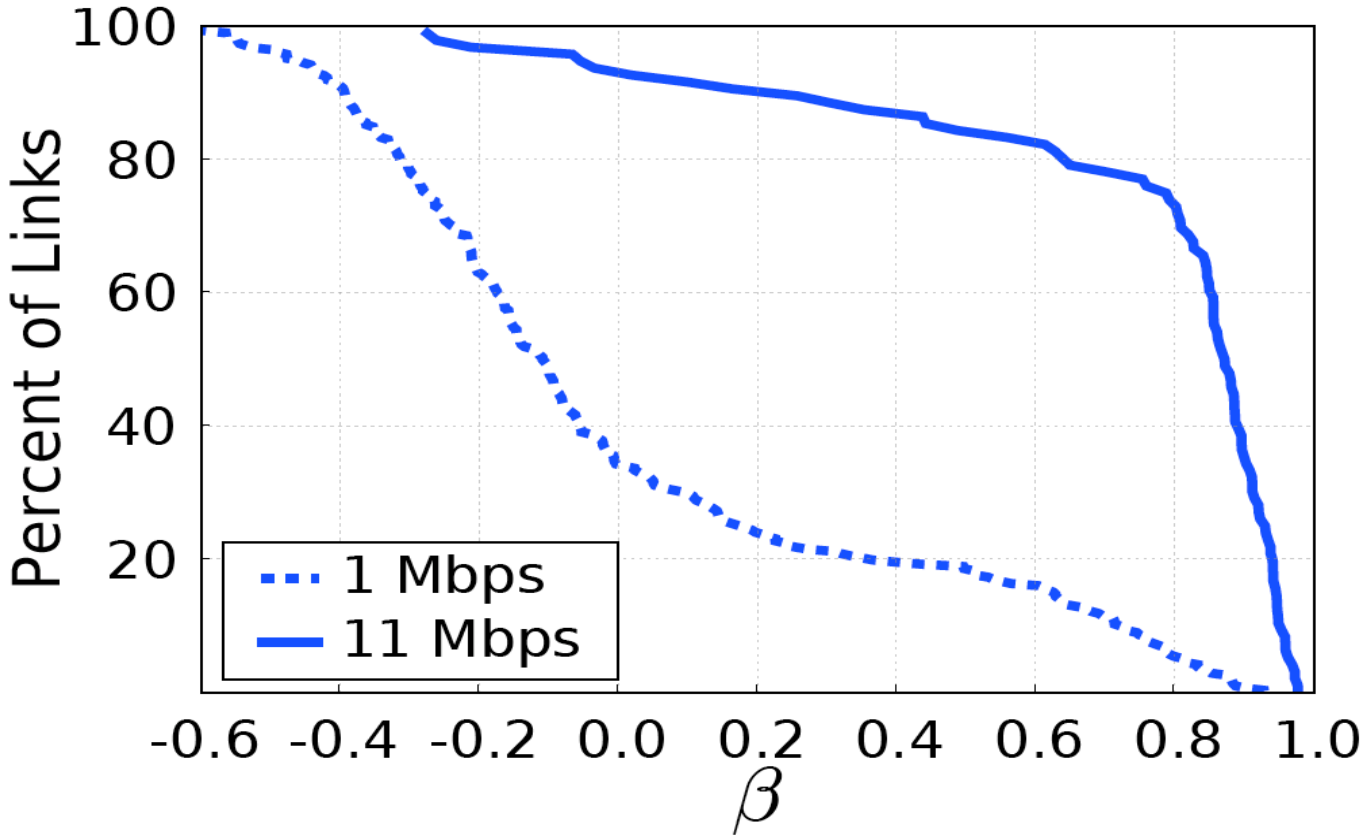
Burstiness: The β-Factor

- β can be negative!



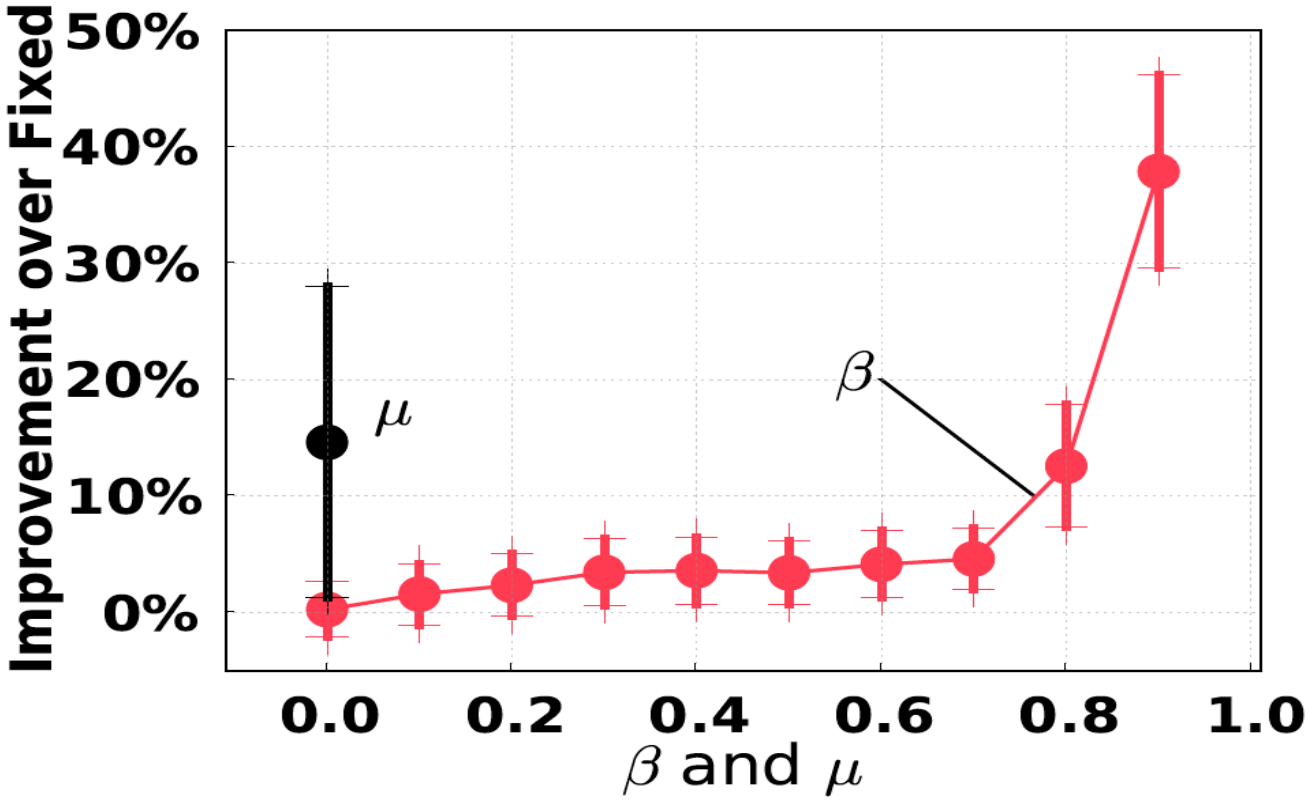
$KW = 0.45, \beta = -0.36$

Roofnet

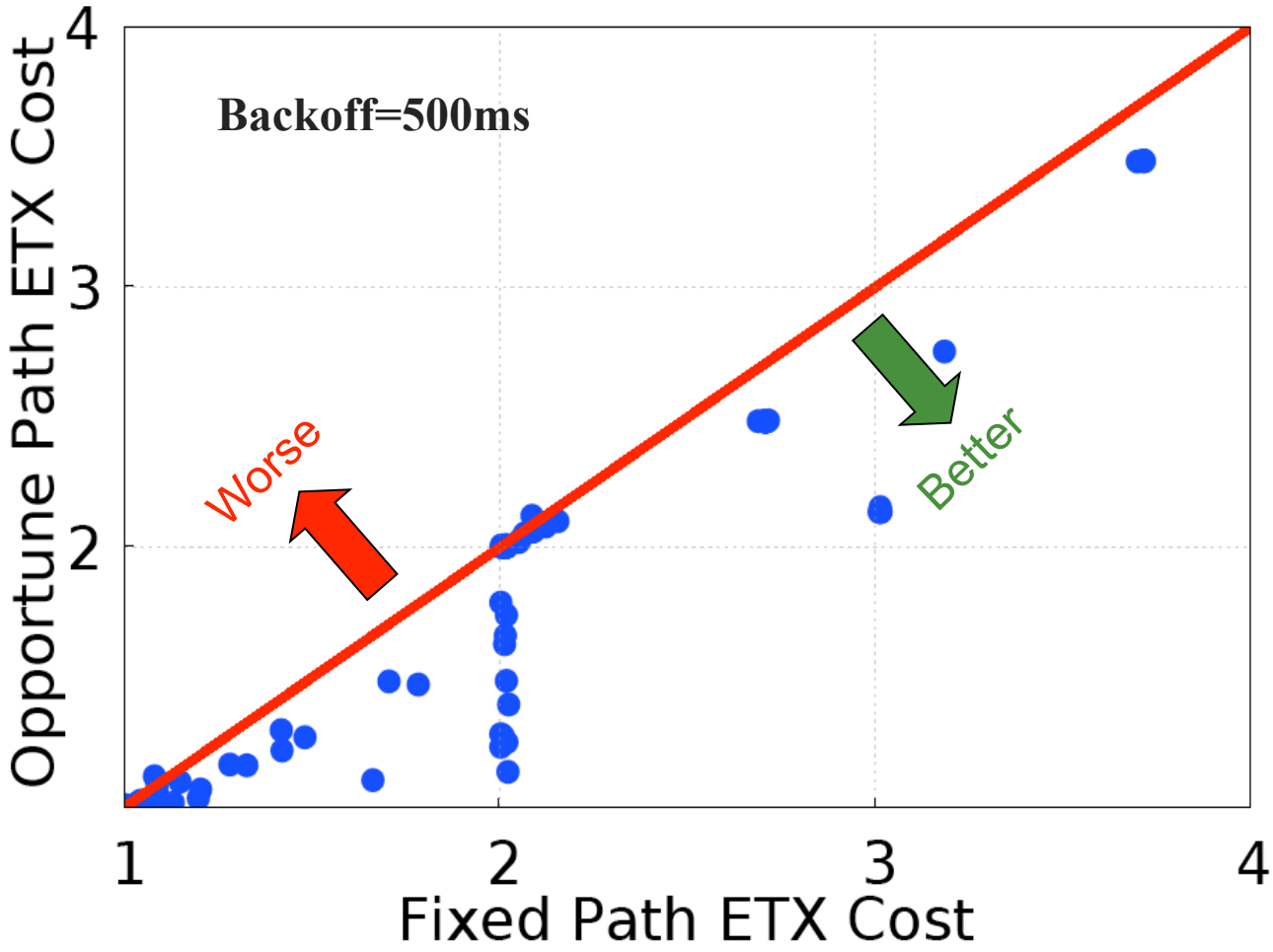

100
80
60
40
20
Percent of Links
1 Mbps
11 Mbps
-0.6
-0.4
-0.2
0.0
0.2
0.4
0.6
0.8
1.0
β

Measuring Burstiness: Related Work

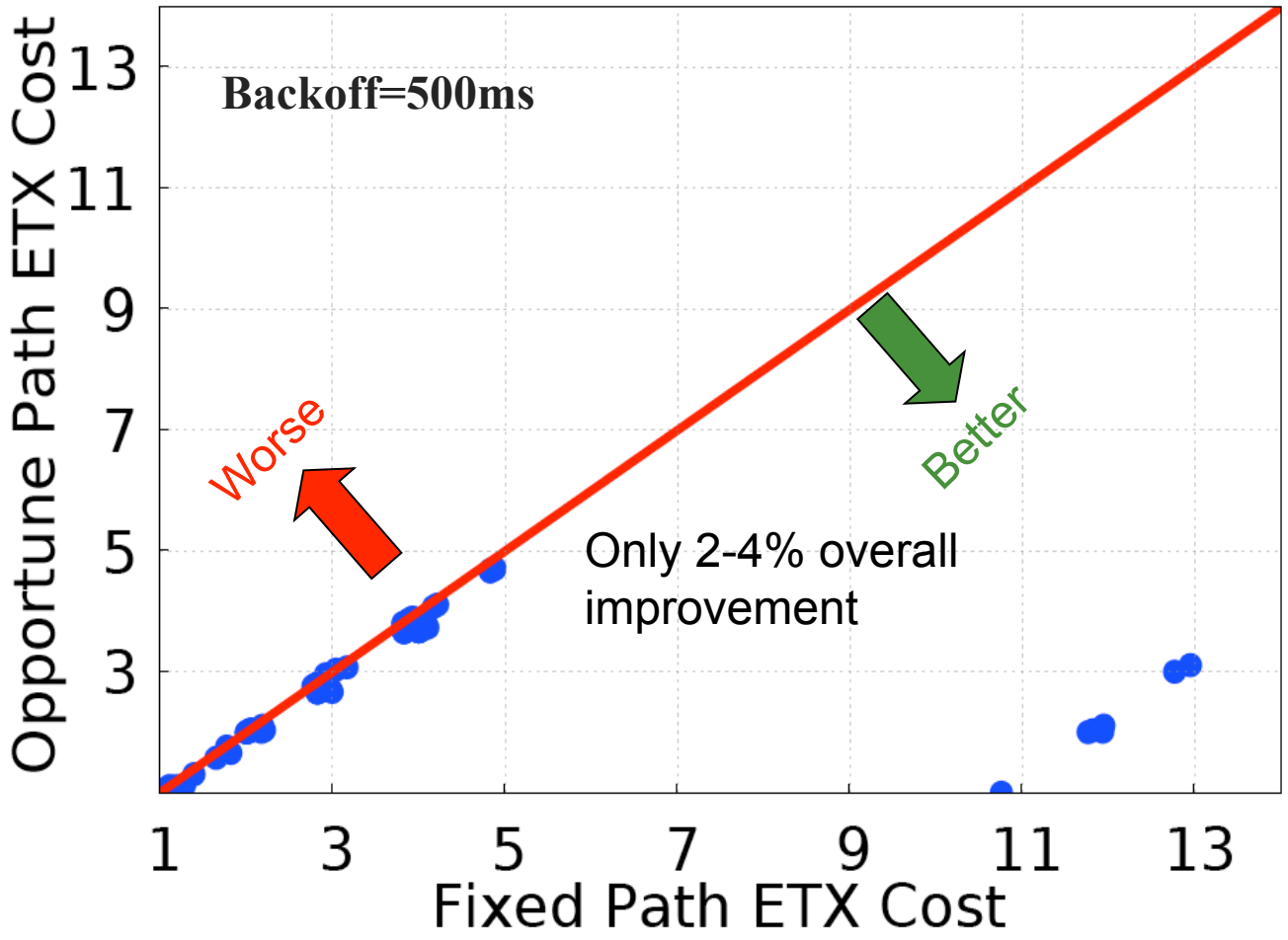
- μ: the G-E model parameter



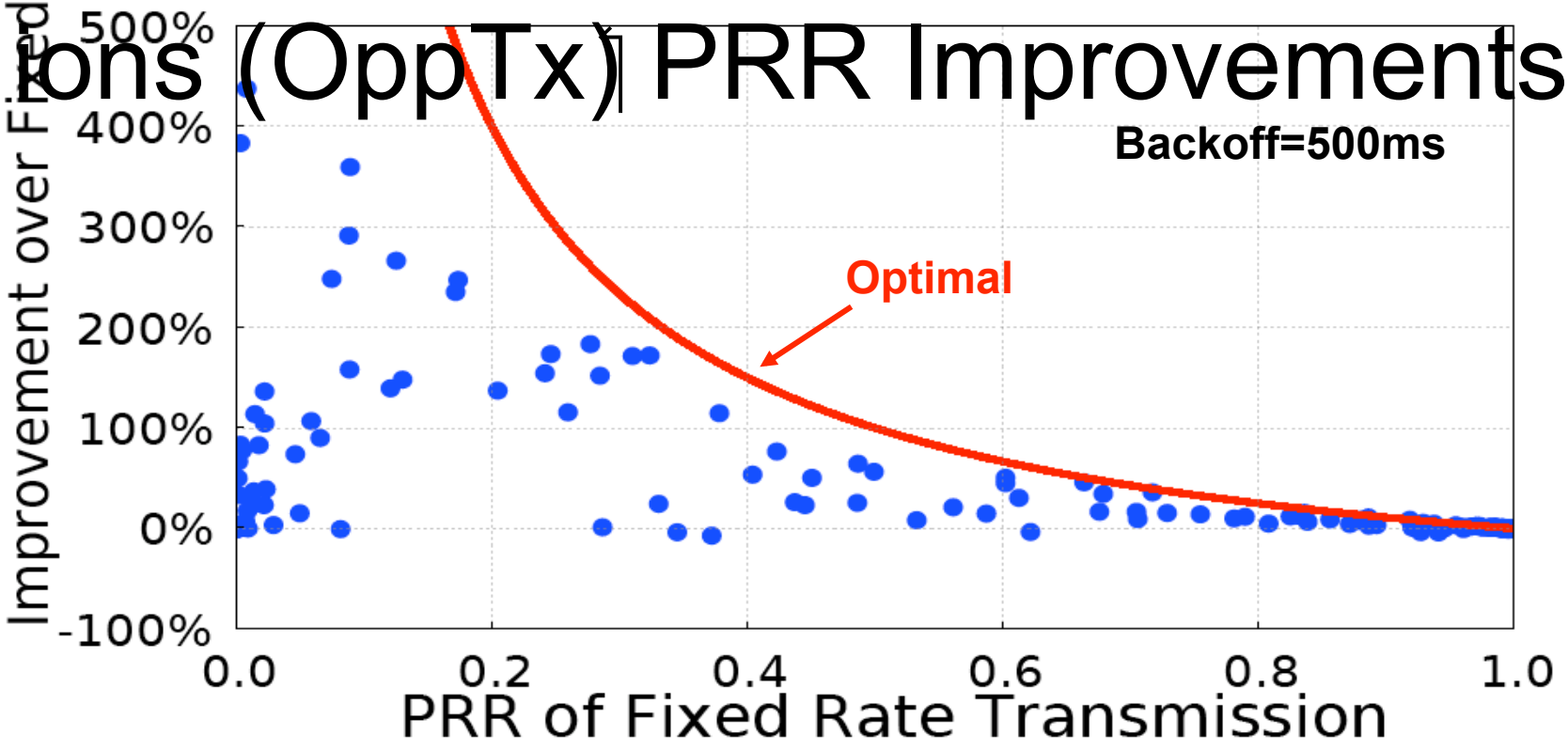
End-to-end OppTx



End-to-end OppTx: Lower Power



Opportune Transmissions (OppTx) PRR Improvements



Opportune Transmissions (OppTx) PRR Improvements