Understanding the Processing Delay of Peer-to-Peer Relay Nodes

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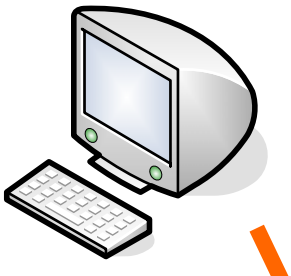
Motivation

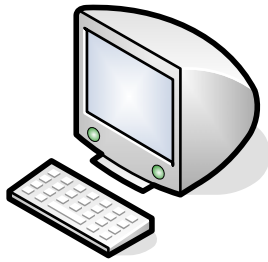
Peer-to-peer relaying is commonly used

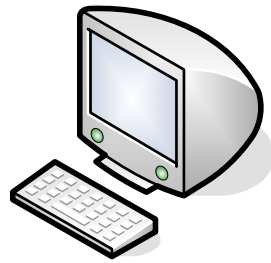
- Purpose
  - overlay routing (for better quality)
  - connection establishment (for peers behind NAT/firewall)
  - data aggregation (lower bandwidth usage)
- Application
  - Conferencing:
  - Video Streaming:

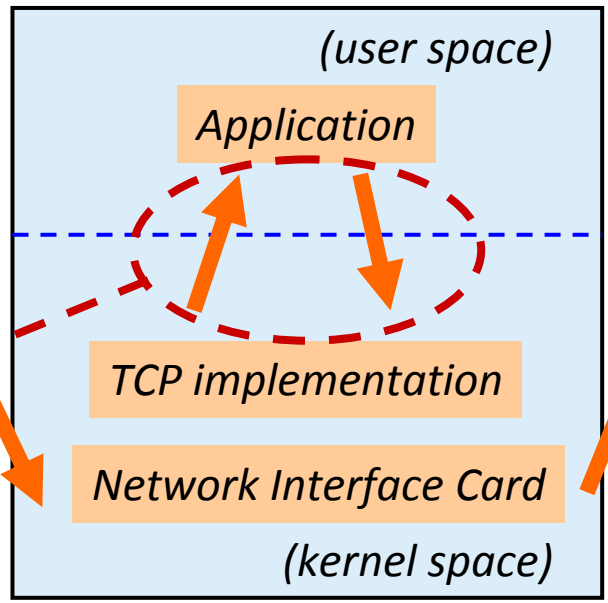
The Problem

currently relaying is achieved at
application-level









scheduling delay (depending on workload and scheduler)

What We Do

- Measure the processing delays at relay nodes

  proposed a measurement methodology and performed a large-scale Internet measurement (> 1000 nodes)

- Understand the characteristics of processing delays

  unreliable and predictable

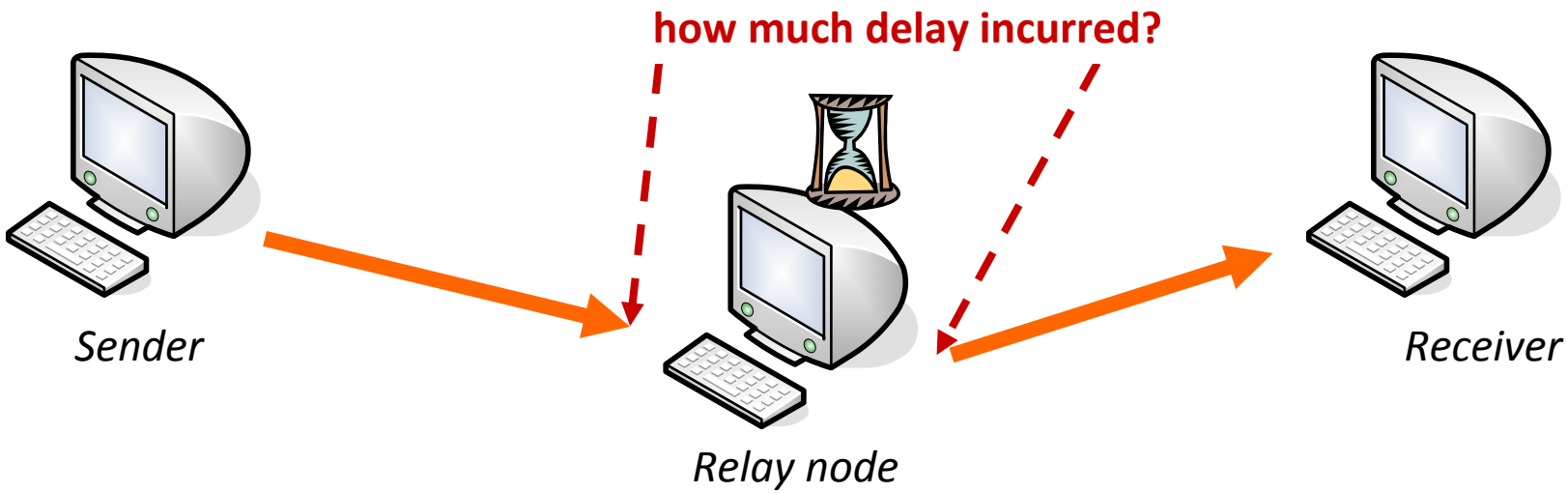
- Examine whether these processing delays degrade application quality

  yes, they can significantly affect VoIP quality

Talk Progress

- Overview
- Measuring processing delay (PD)
- Large-scale measurement
- PD characterization
- Impact of PD on VoIP quality
- Conclusion

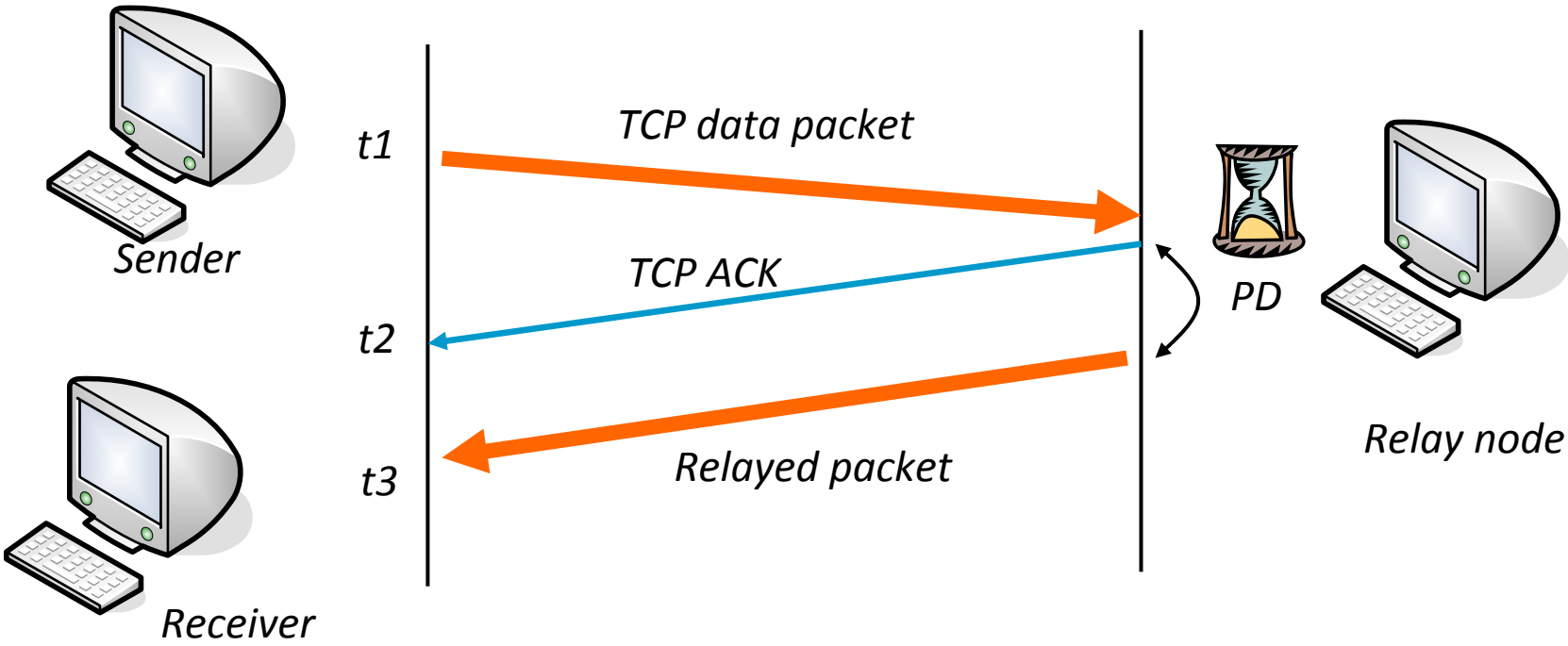
Our Basic Method for Measuring PD



Assumptions

- No intentional delays at the relay node
- Source transmits packets with TCP
- TCP implementation is running at high priority, while application is running at low priority
- Sender and receiver are colocated at the same place

The Idea



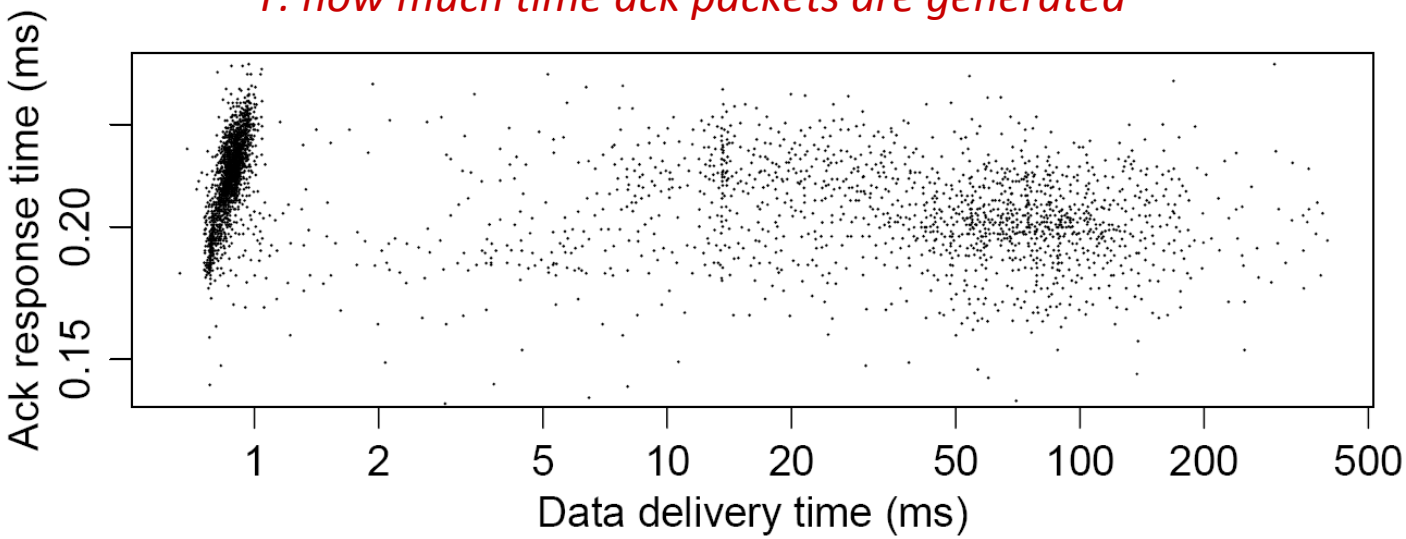
$$PD = t3 - t2$$

if network delay is approximately constant

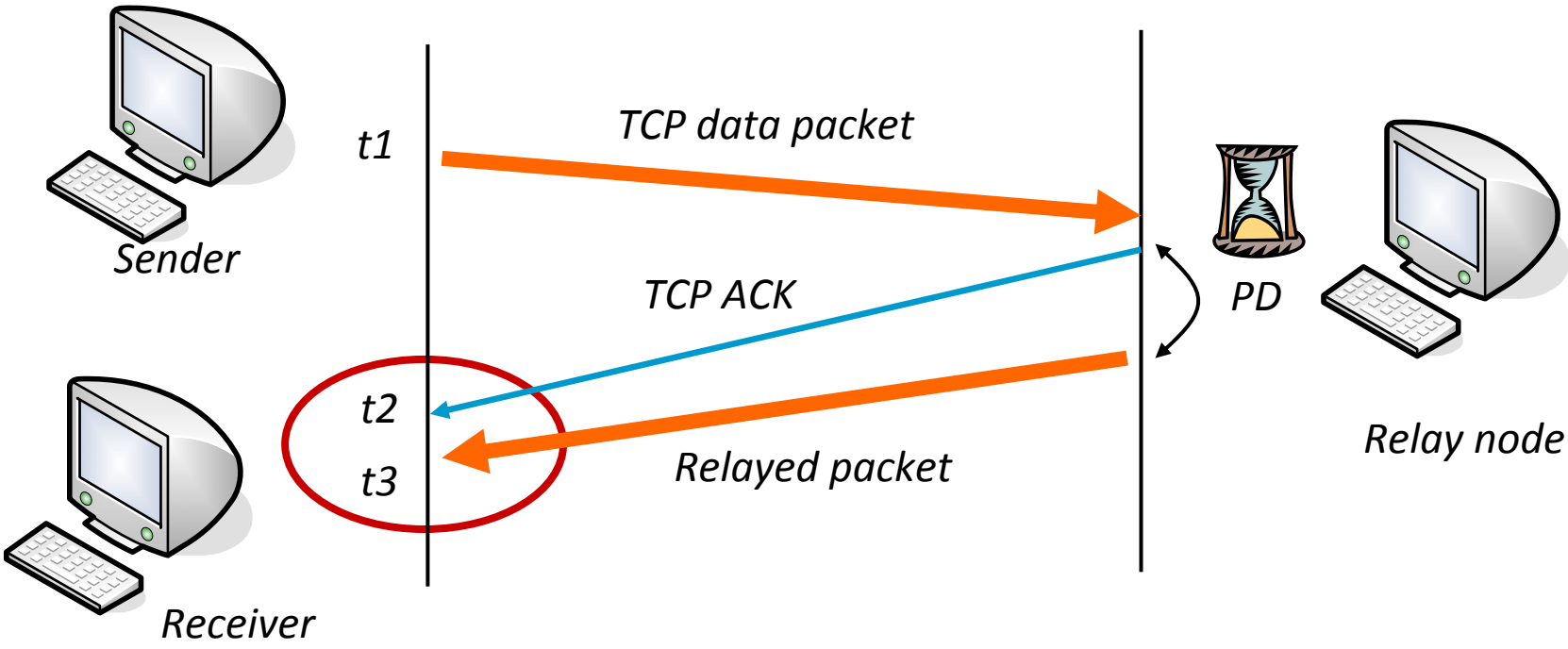
Verifying The Assumption: "Is TCP implemetation running at high priority?"

- LAN experiment
- Windows XP on commodity PC
- 200-byte packets sent at 30pkt/sec
- 10 random movie clips to simulate workload

X: how much time relay packets are generated
Y: how much time ack packets are generated



The Problem of Our Basic Method



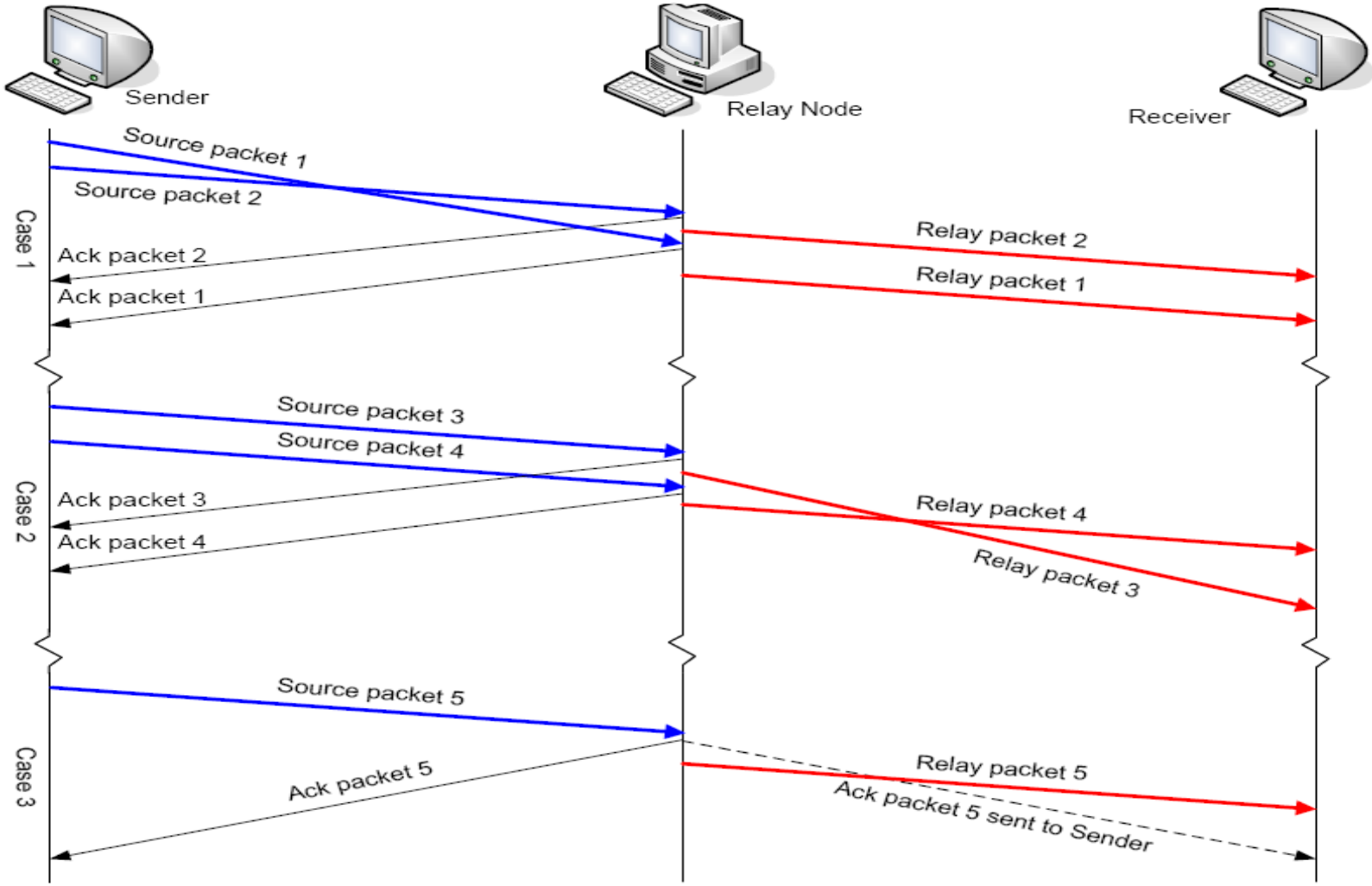
Network delays are NOT constant
(mostly because of queueing delays)
➔ t3 – t2 != PD

Proposed Improvement: IPID Filtering

- Filter out seriously delayed packets
- IPID: the ID field of IP packets
  - monotonically increasing
  - infer the order of data packets generated by the sender
  - infer the order of ack packets generated by the relay node
  - infer the order of relay packets generated by the relay node

- If any pair of packets is reordered along their transmission
  ➔ discarding both packets
  - LIS (longest increasing subsequence) algorithm

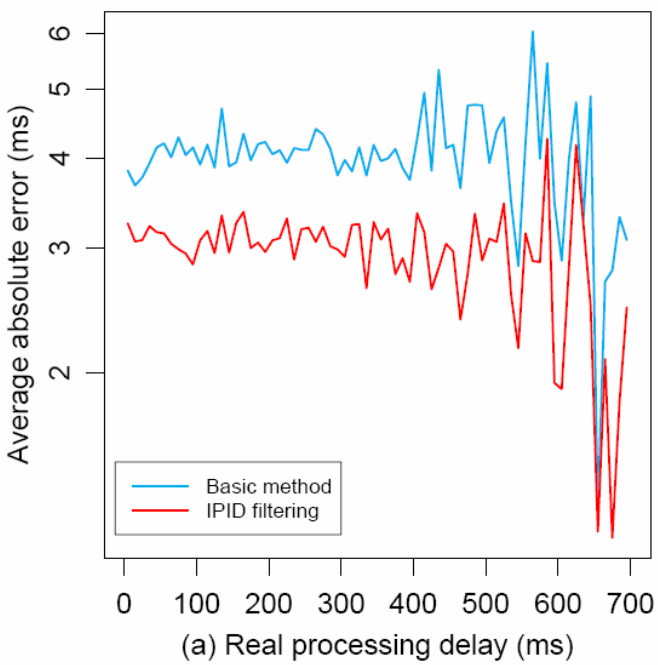
Some Common Network Reordering Scenarios



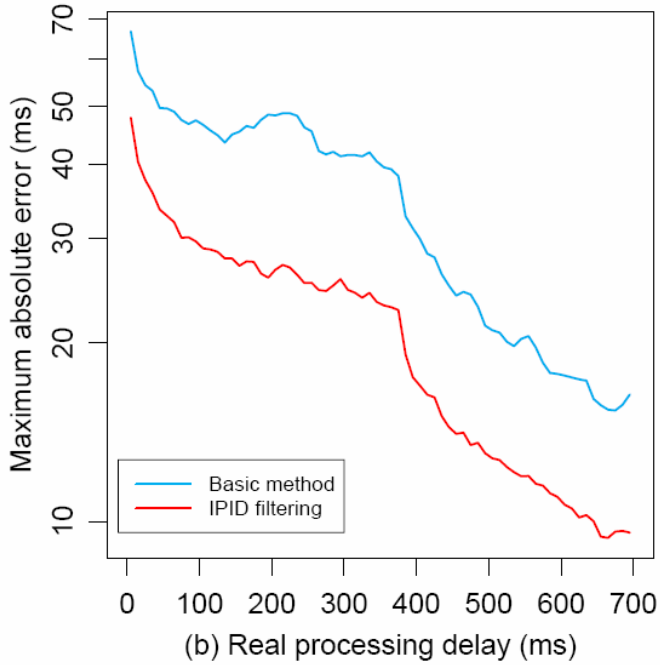
Effectiveness of IPID Filtering

- LAN experiments
- Evaluate the differences between measured PD and true PD

Average error of inferred PD



Maximum error of inferred PD



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Large-Scale Measurement

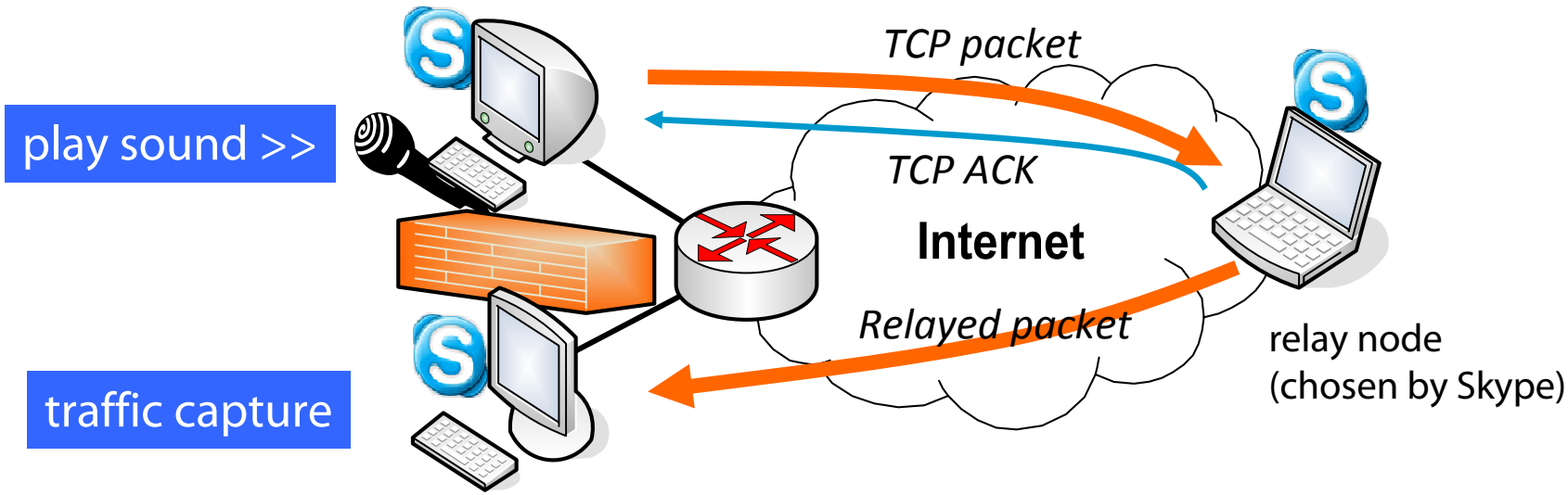
- Goal: To understand PD at real-life relay nodes

- Testbed: 

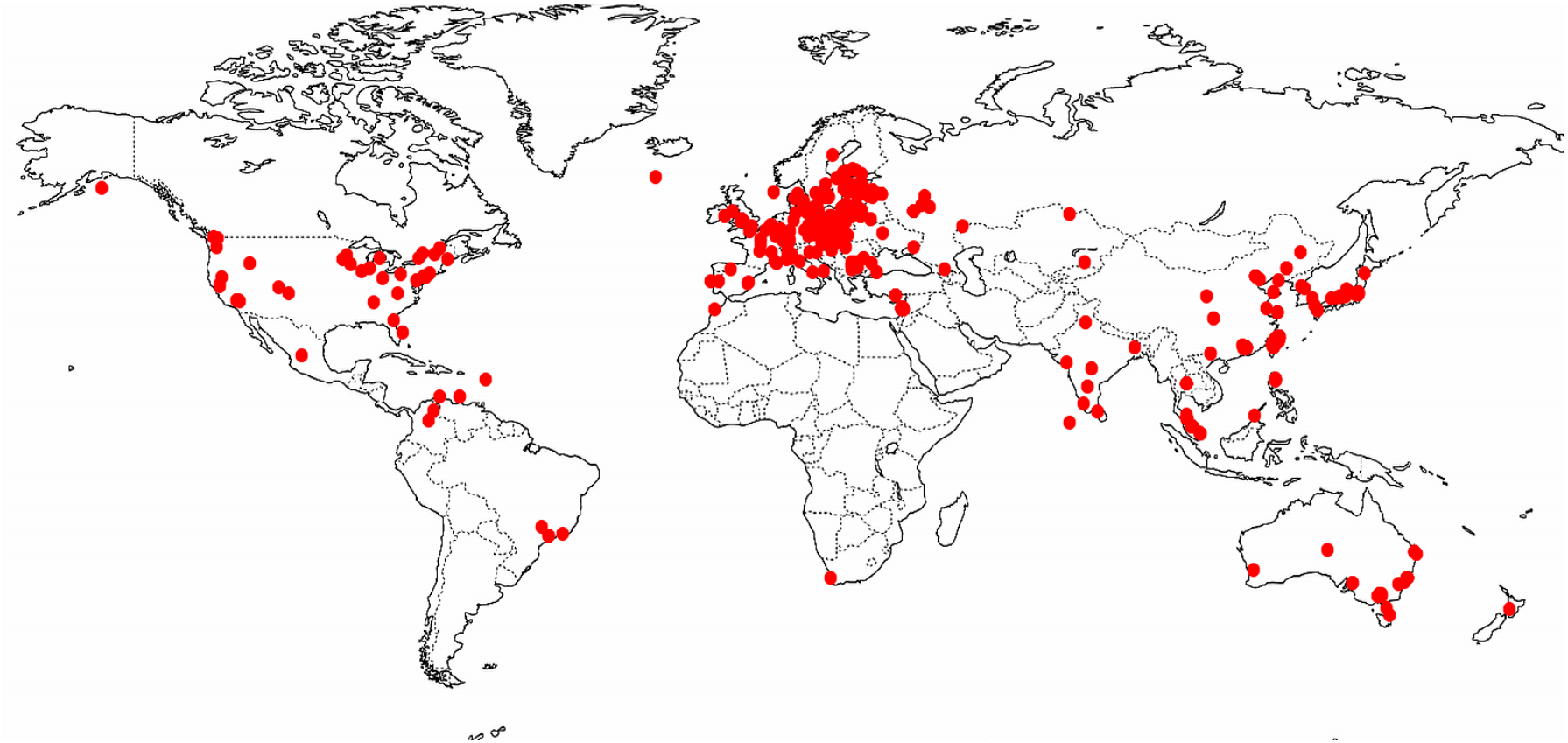
  - > 200 thousands super nodes available anytime
  - Skype finds a usable relay node automatically if the caller cannot reach the calle
  - We can force Skype to pick an alternate super node for relaying a VoIP call

Collection Methodology

- Automatically call establishment and drop (10 min each)
- Human speech recordings form Open Speech Repository
- Use firewall to block caller <-> callee direct connection
- We block used relay nodes to force Skype find a new one



Geographical Diversity of Observed Relay Nodes



Call Information

# Calls	Time	# Pkts/call	ART	DDT
1,115	10 min	19,210 pkts	203 ms	212 ms

On average, data packets incur 9 ms PD

Estimated Processing Delays

# Samp.	Samp. dens.	PD (Avg / Max / SD)
15,739 per call	26 samp. / sec	5 ms / 239 ms / 7 ms

On average, maximum PD is around 240 ms

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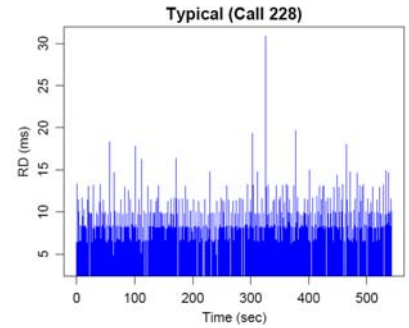
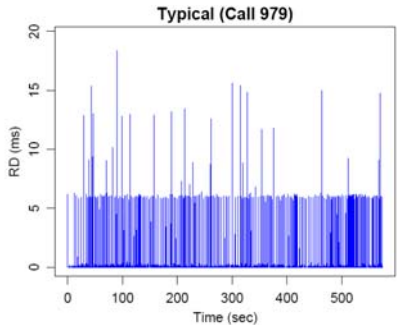
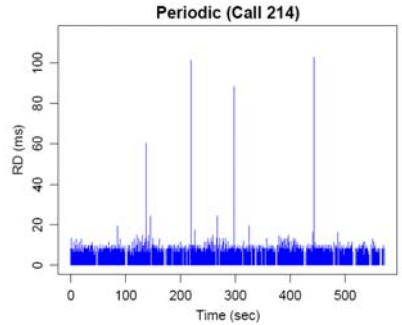
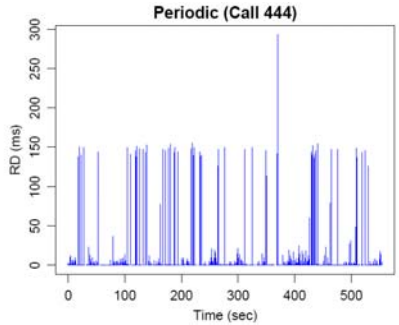
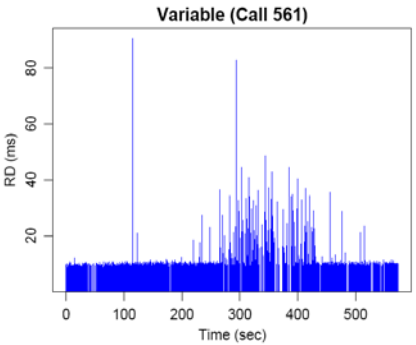
A Classification of PD Patterns

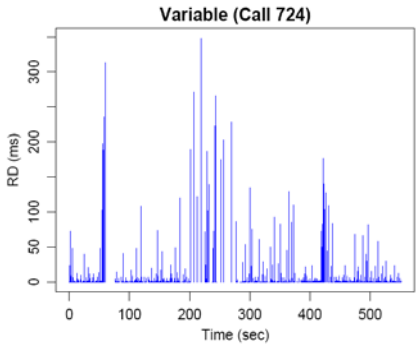


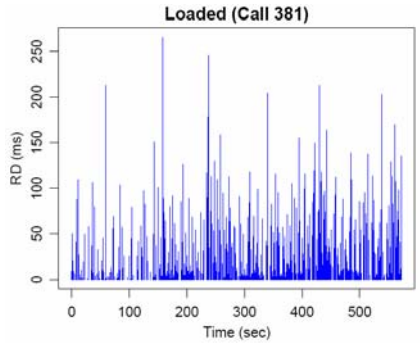


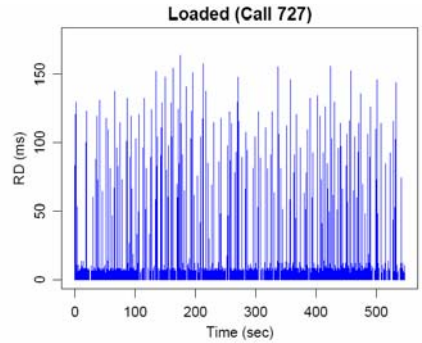


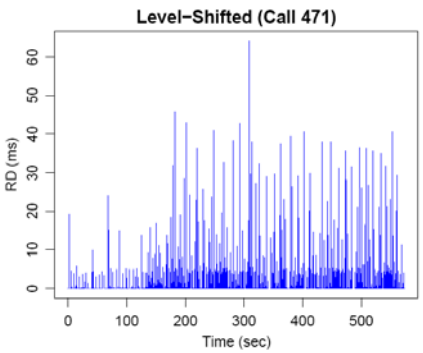


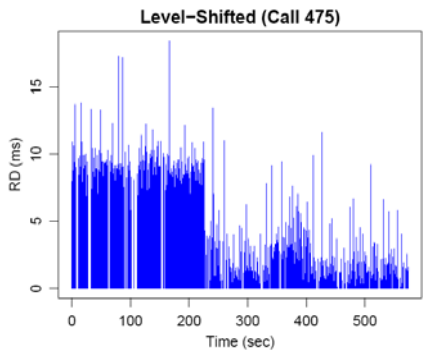






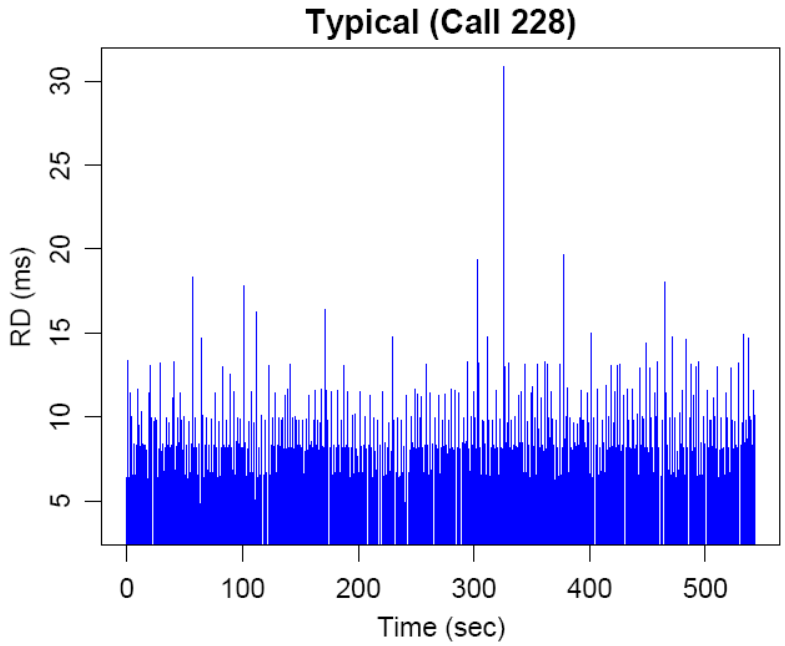


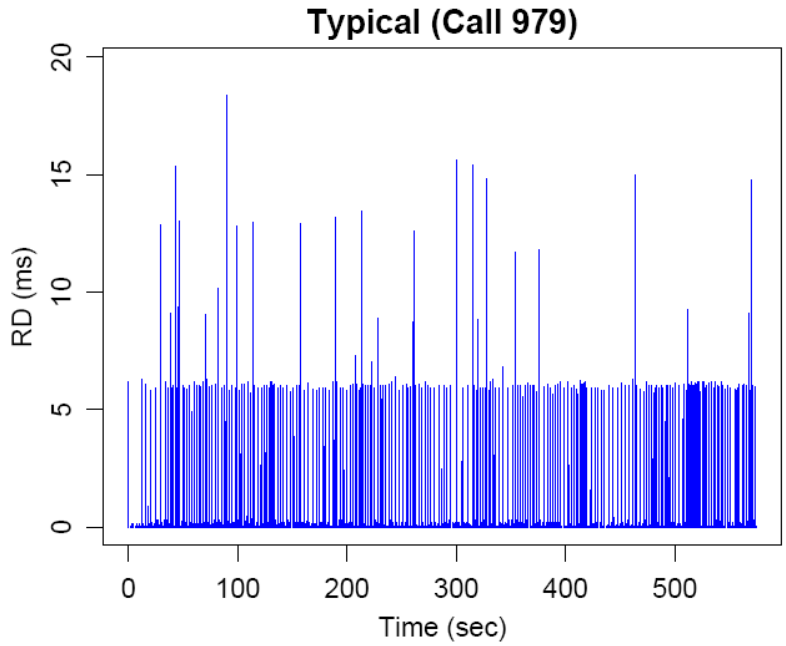




A Classification of PD Patterns (1)

Typical Processing Delays



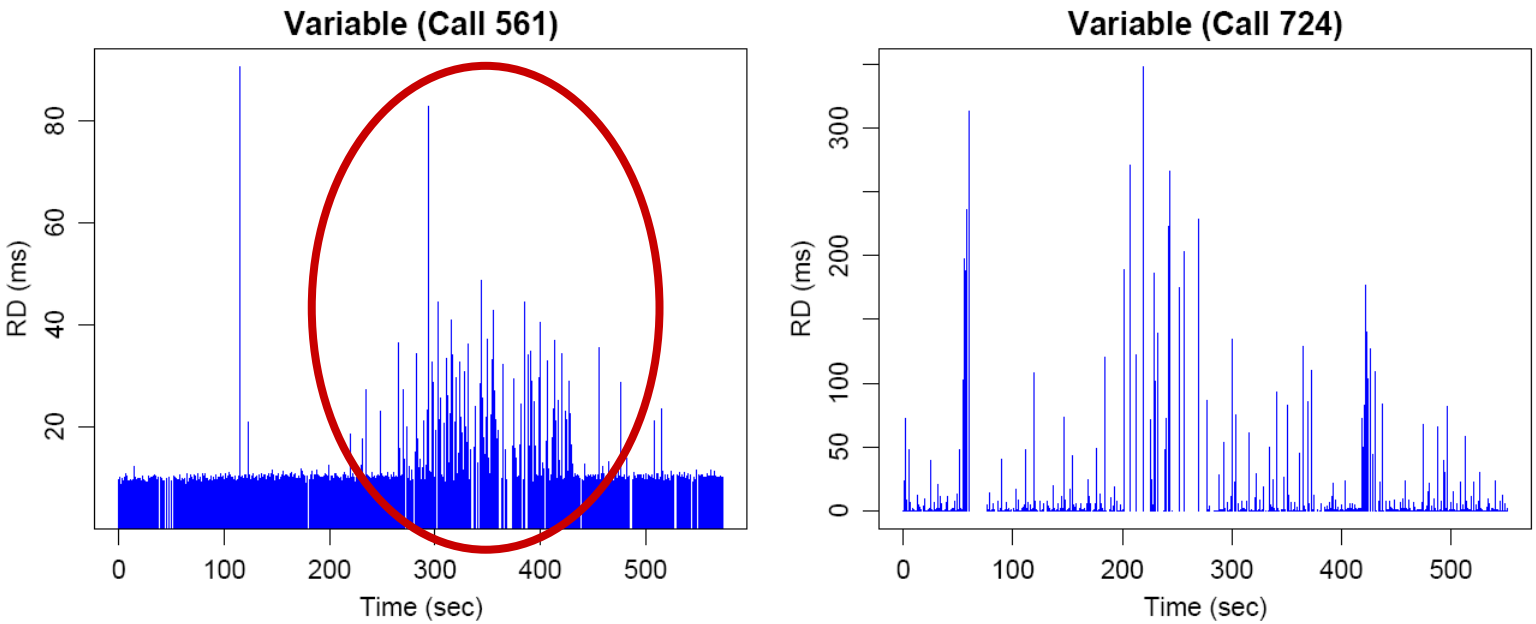


- *variation of PDs is small*
- *magnitude is rarely higher than 20 ms*

➔ *the relay node is lightly-loaded and the computer is not in use*

A Classification of PD Patterns (2)

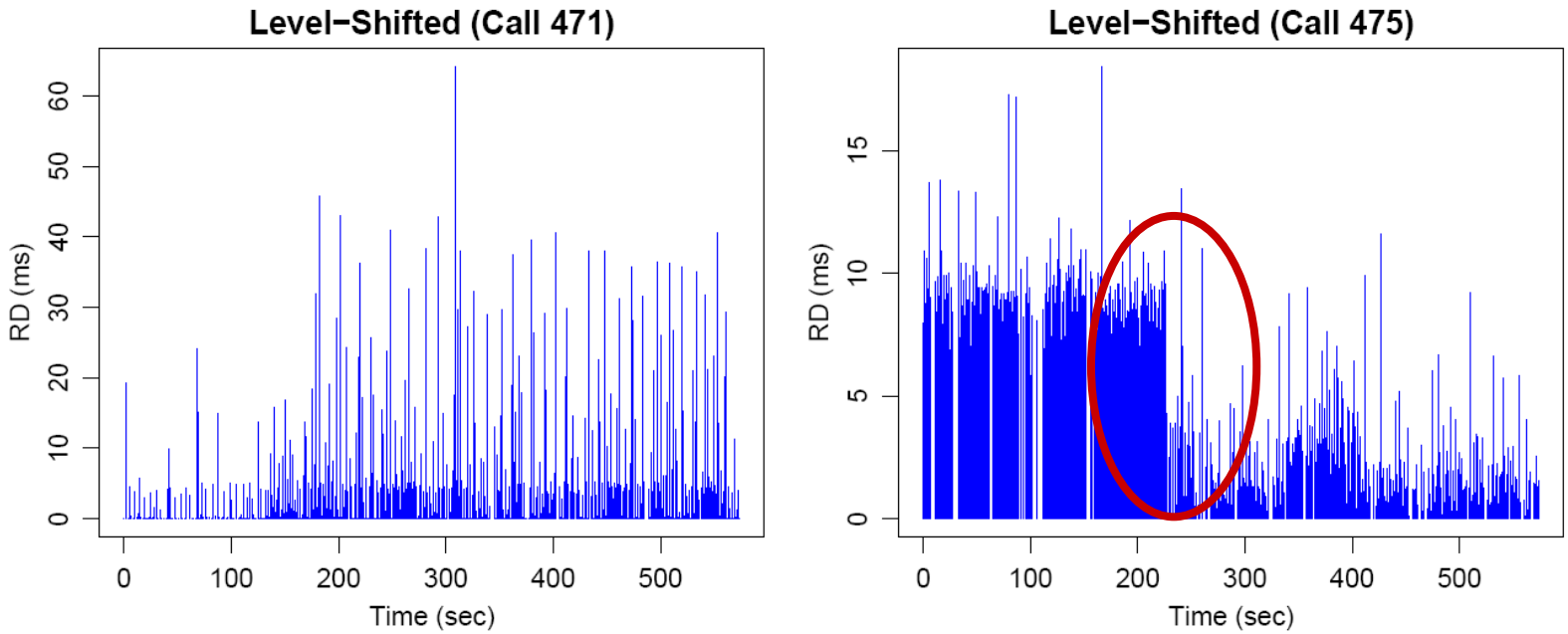
Varible Processing Delays



- *PDs are stable most of time, but occasionally very different*
- *e.g., the PDs of call 561 are relatively high during the 250–450 ms period, which is likely due to a person using the computer, or an application with a time-varying workload is running.*

A Classification of PD Patterns (3)

Level-shifted Processing Delays

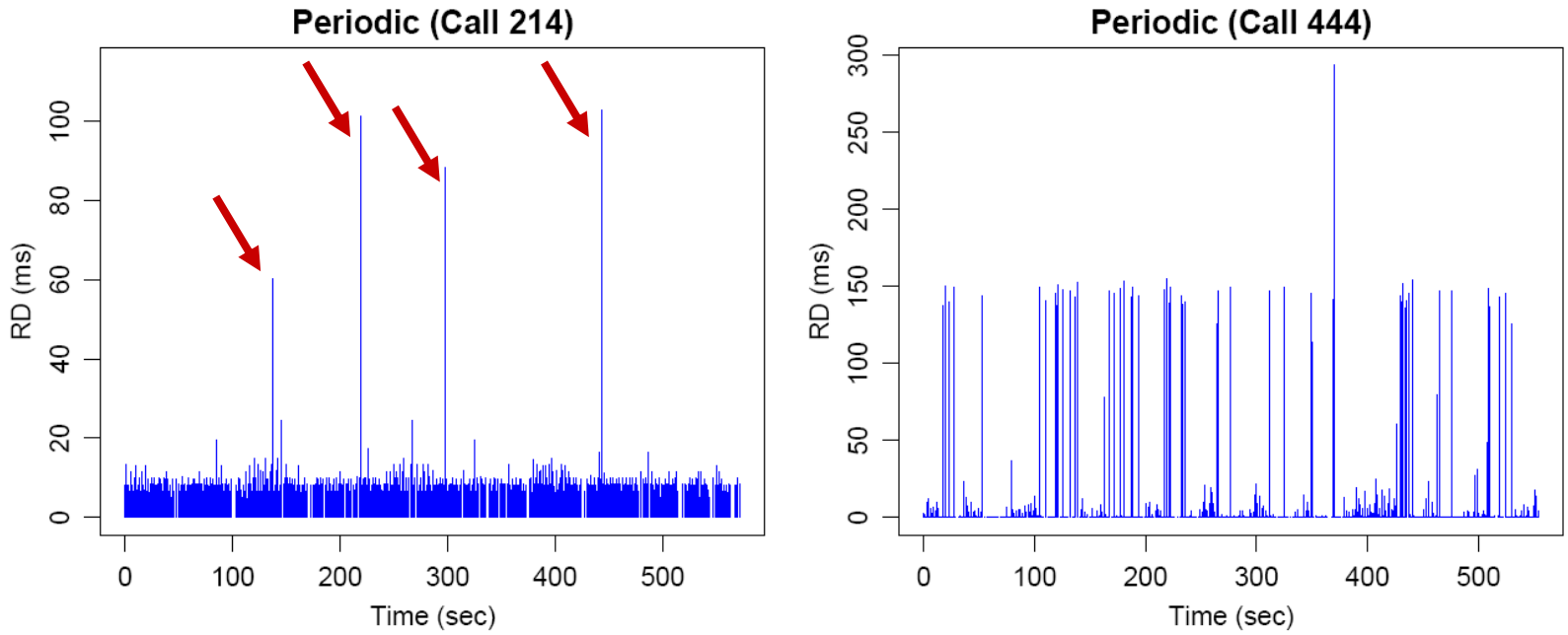


- *The levels of PDs are increased or decreased by a significant magnitude, say, larger than 10 ms*

➔ *likely a heavily loaded task starts or stops running on the relay node*

A Classification of PD Patterns (4)

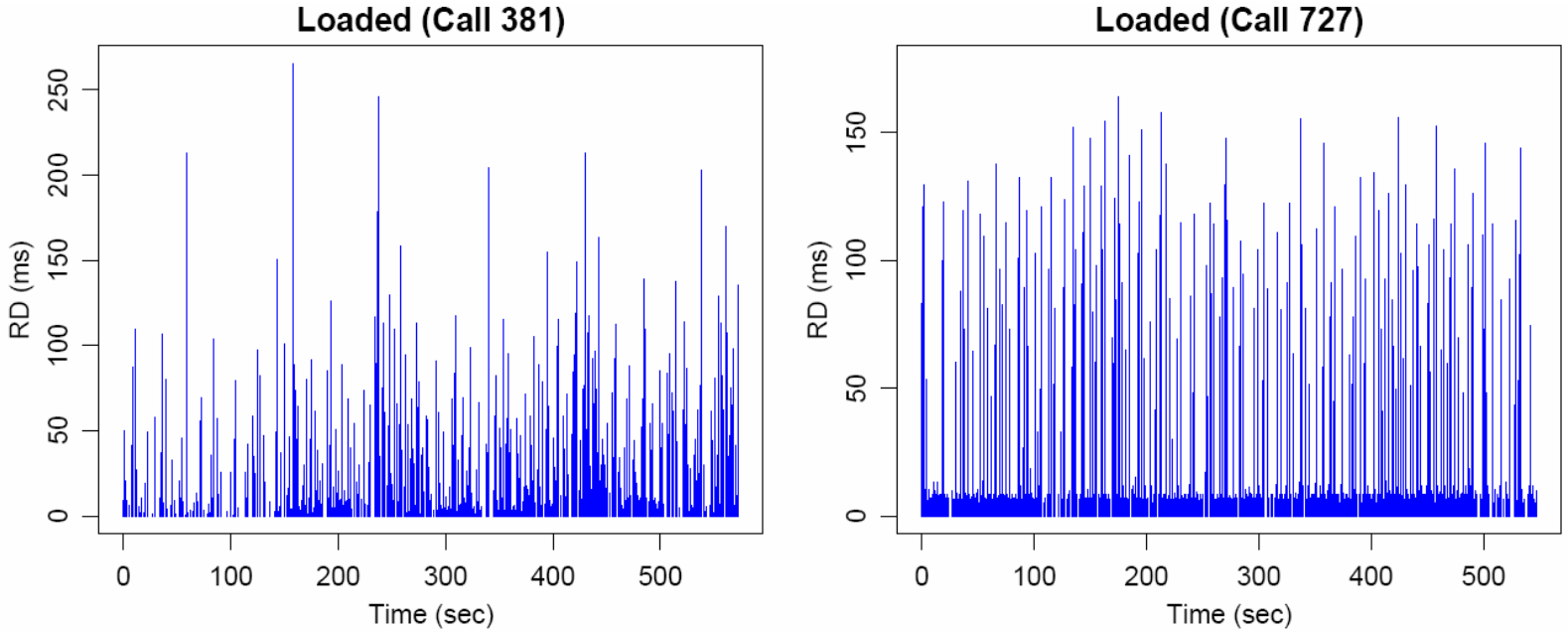
Periodic Processing Delays



- *Bursts of high PDs occur at regular intervals, possibly because of the behavior of an application.*
- *e.g., the 1-minute interval in Call 214 may be caused by an email notification program with a one-minute check interval.*

A Classification of PD Patterns (5)

Loaded Processing Delays



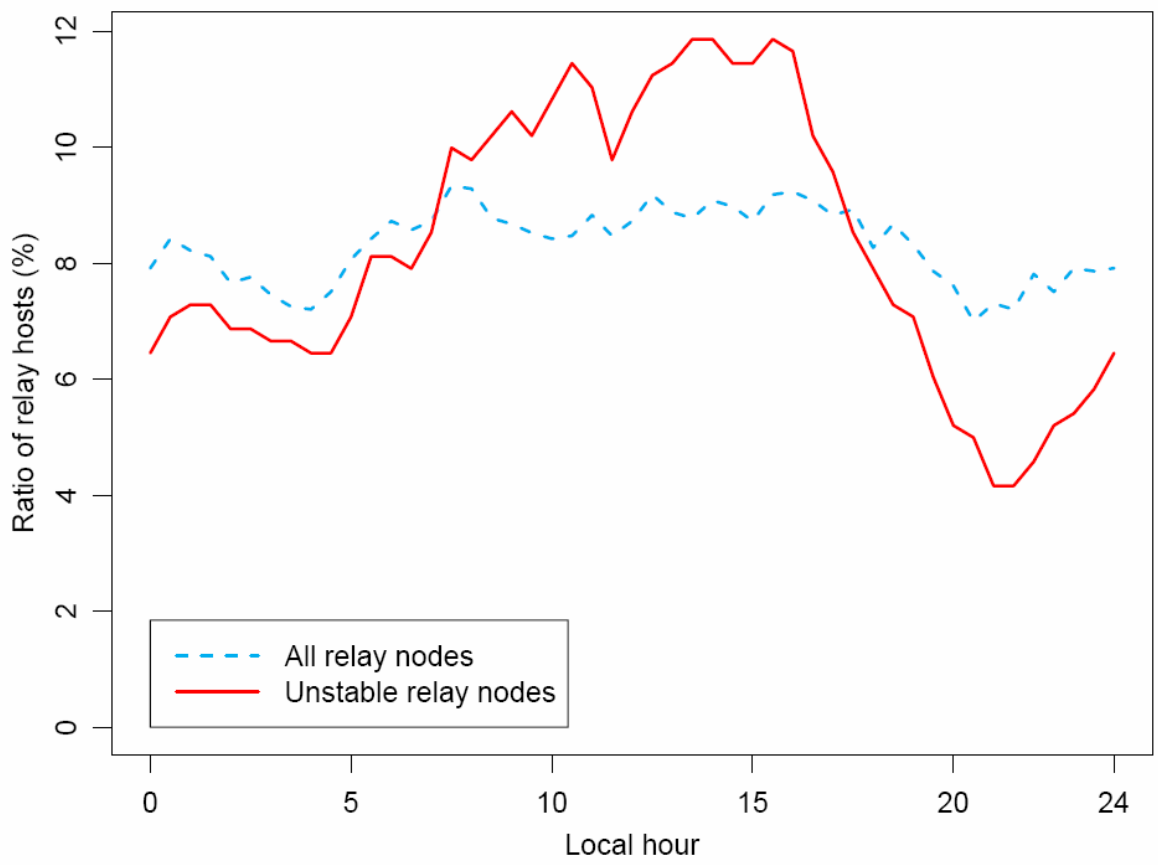
- *The level of PDs remains large, say 100 ms or higher.*

➔ *the relay node should be running computation- or I/O- intensive applications*

Busy Levels

- The level of workload on the relay node
- 95% percentile of PD within a 10-second window
  - Lightly-load host: application always serviced when needed
  - Even on a heavily load machine, the PD incurs by relay packets are not always large
    - A packet arrives just before the application's execution quantum ➔ get serviced immediately
    - otherwise ➔ has to wait some time
- If busy level changes > 10 ms in successive 10-second windows ➔ unstable relay nodes

Average Ratios of All Relay Nodes and Unstable Relay nodes



Unstable nodes are mostly observed in work hours at local time

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Impact of PD on VoIP Quality

- p2p relaying is commonly used by VoIP applications
  - bypass firewall/NAT
  - network latency may be reduced by overlay routing
  - VoIP bandwidth requirement is not high, e.g., 32 Kbps

- Use trace-driven simulations to assess the impact of PD
  - combine different network delays and processing delays
  - simulate VoIP calls with and without processing delays
  - examine their differences in VoIP quality

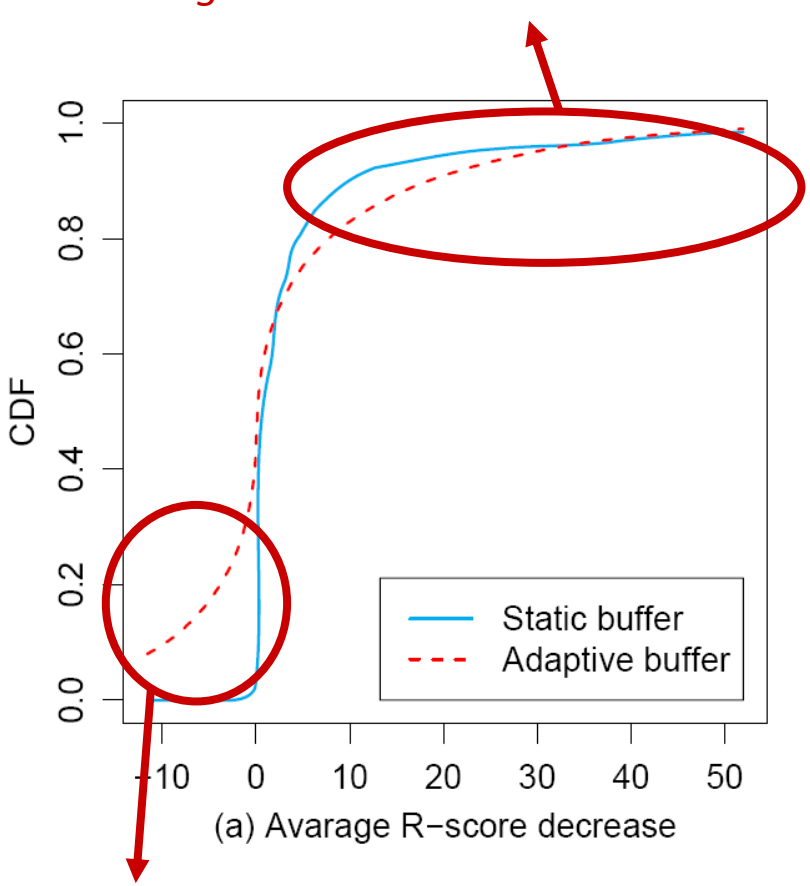
Methodology

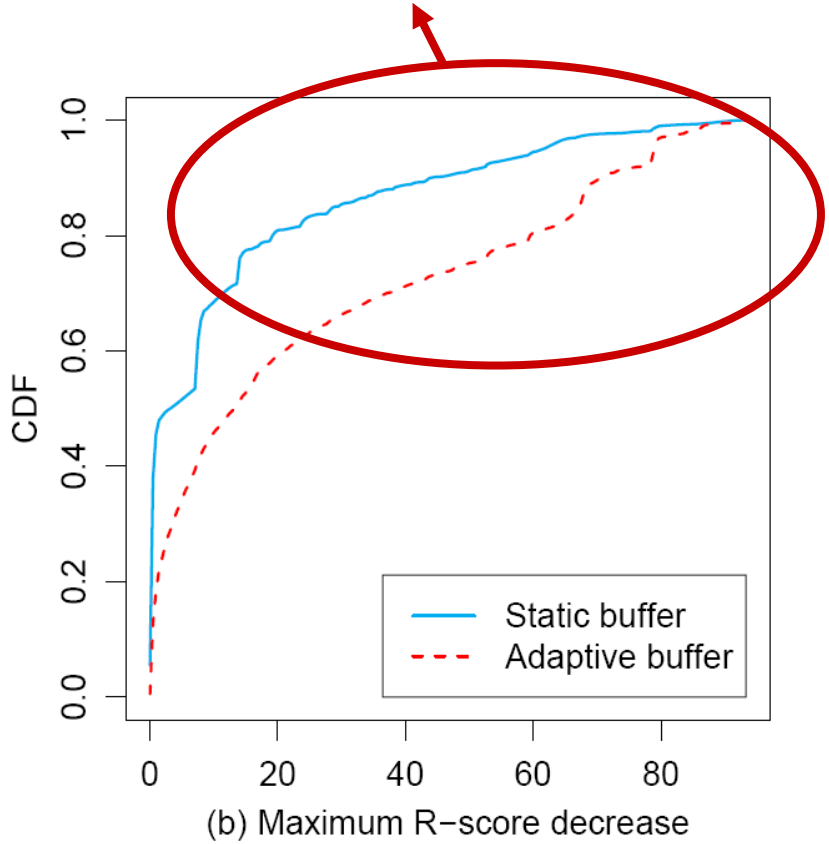
- Measuring VoIP quality degradation
  - ITU-T E-model (G.711) based on delay and loss rate
  - yields a R-score ranges from 0 -- 100
  - R-score > 80 ➔ satisfactory
  - R-score < 70 ➔ unacceptable
- Two classes of VoIP playout buffer sizing schemes
  - static buffer (60 ms according to Skype)
  - adaptive buffer (according to Ramjee INFOCOM'94)
    - size = mean delay + 4 x standard deviation of delays
    - mean and std dev are derived from EWMA processes
- 50,000 random samples from 1,243,225 (1,115 x 1,115) possible configurations

R-scores Decrease due to PD

20% of calls incur significant average R-score decrease

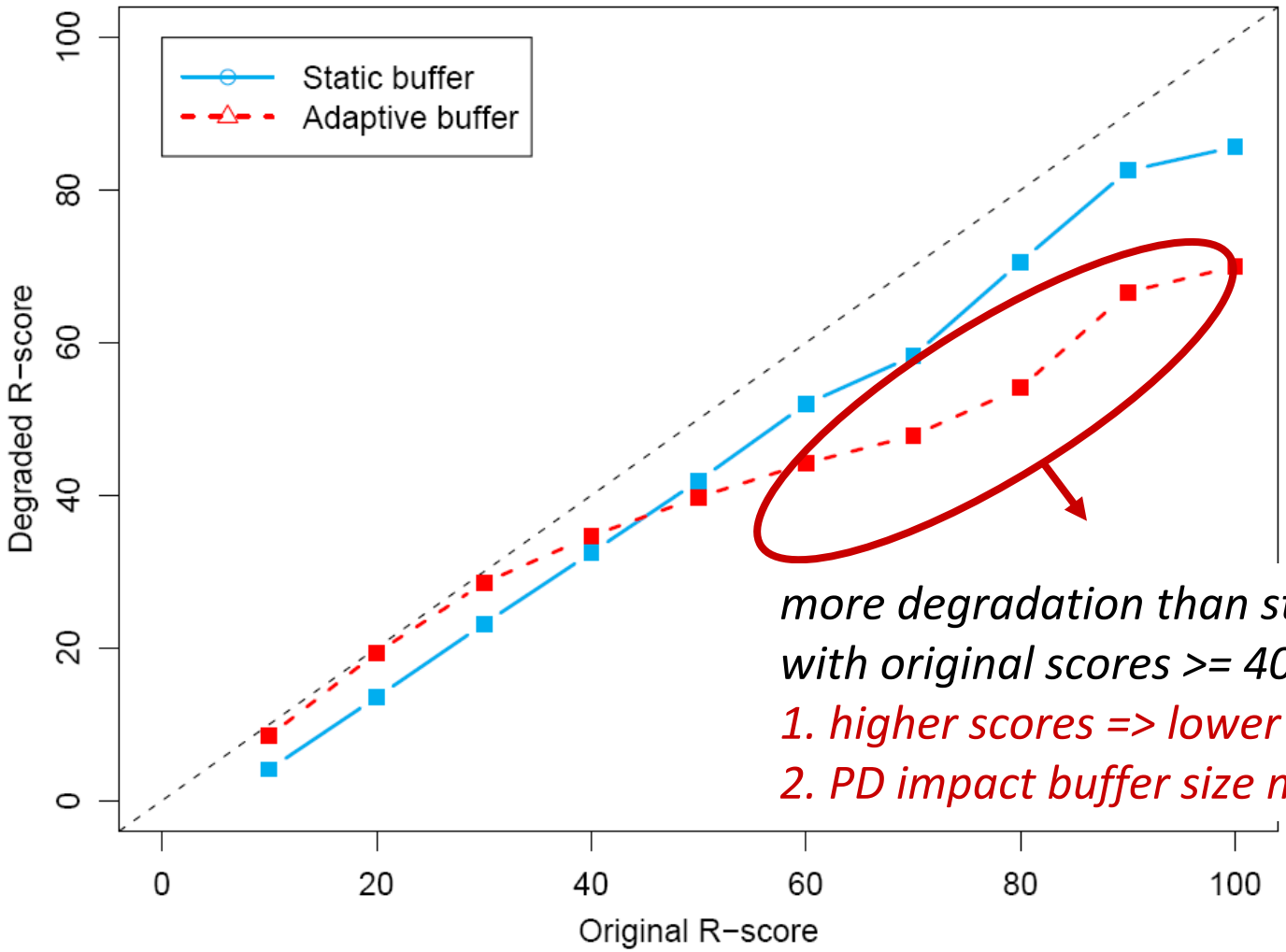
40% and 60% of calls incur significant maximum R-score decrease





PD leads to larger playout buffer that leads to lower e2e packet loss rate

Original R-scores vs. Average R-scores



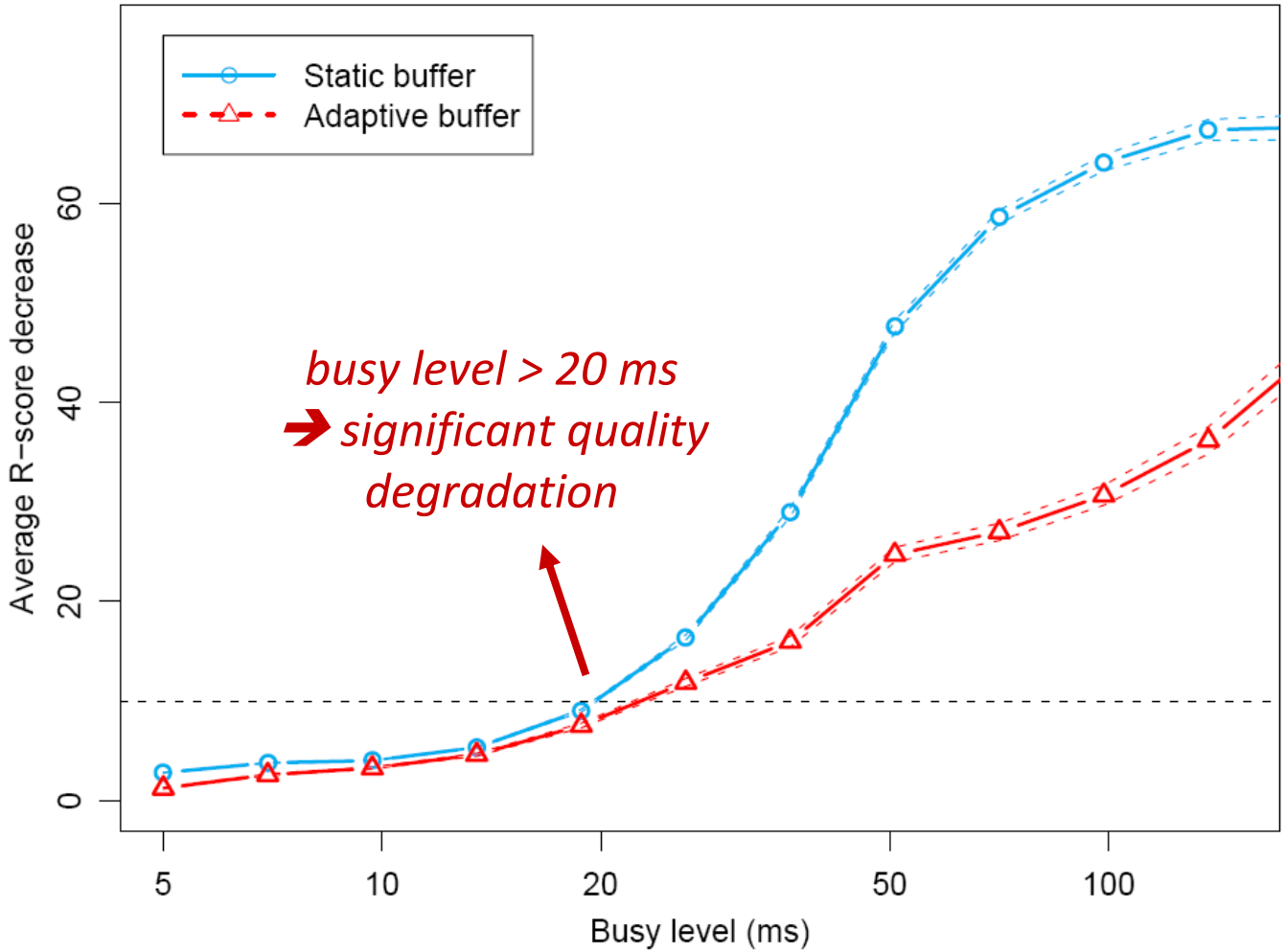
more degradation than static buffer with original scores >= 40

1. higher scores => lower net delay

2. PD impact buffer size more

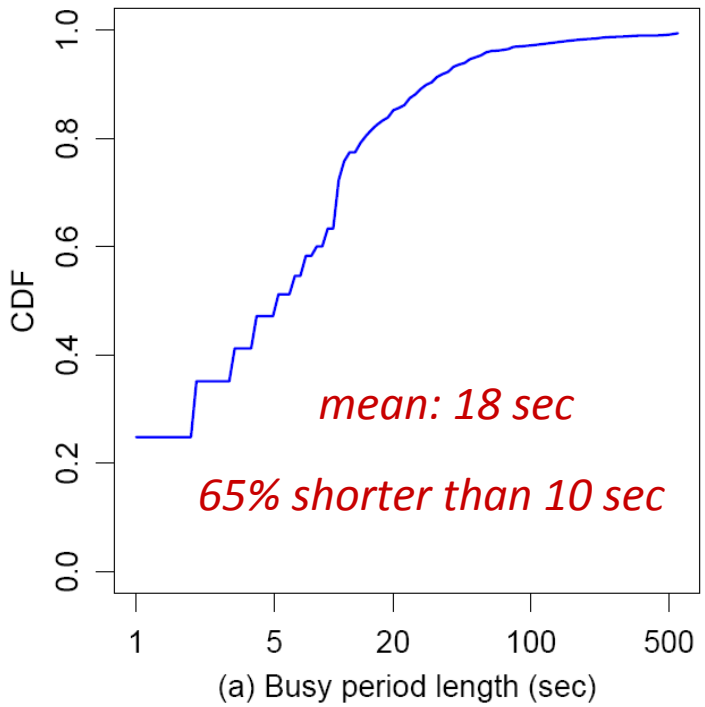
Impact of Busy Levels

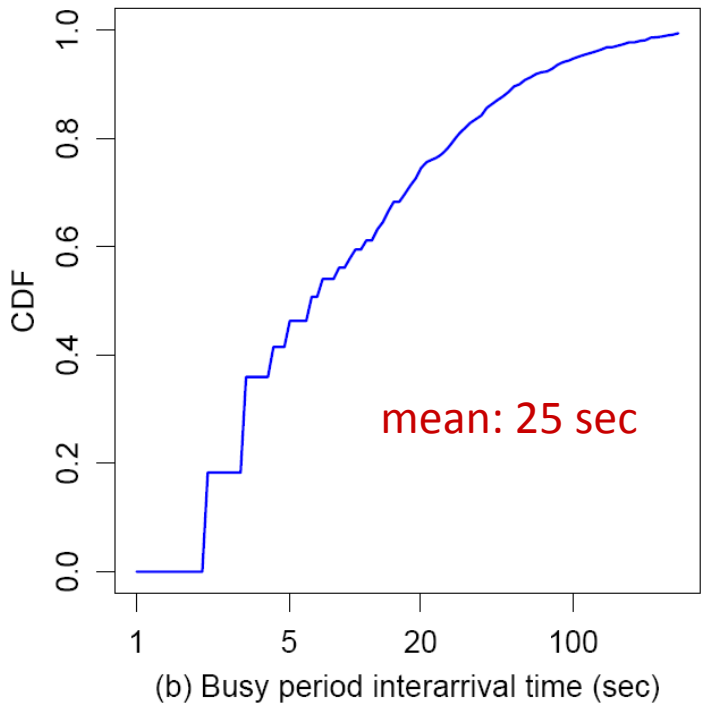
What busy levels of PD would significantly impact VoIP quality?



Busy Period Characterization

- We define a node as busy when its busy level is higher than 20 ms
- 23% of relay nodes were ever busy during a 10-minute call





The nodes tend to switch between busy and non-busy states frequently

Summary

- consider a hidden aspect of peer-to-peer relaying --- processing delays at relay nodes
- PD can be determental to VoIP quality
- we should avoid a relay node with a busy level higher than 20 ms
- we have to monitor the processing delays of a relay node continuously (like we do for the network delays)

Questions?

Thank You!

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