VIA: Improving Internet Telephony Quality Using Predictive Relay Selection

Junchen Jiang, Rajdeep Das, Ganesh Ananthanarayanan, Philip A. Chou, Venkata N. Padmanabhan, Vyas Sekar, Esbjorn Dominique, Marcin Goliszewski, Dalibor Kukoleca, Renat Vafin, Hui Zhang

Key takeaways in one minute

We studied **430 million** Skype calls and found...

One fifth of calls use paths with **poor** network performance

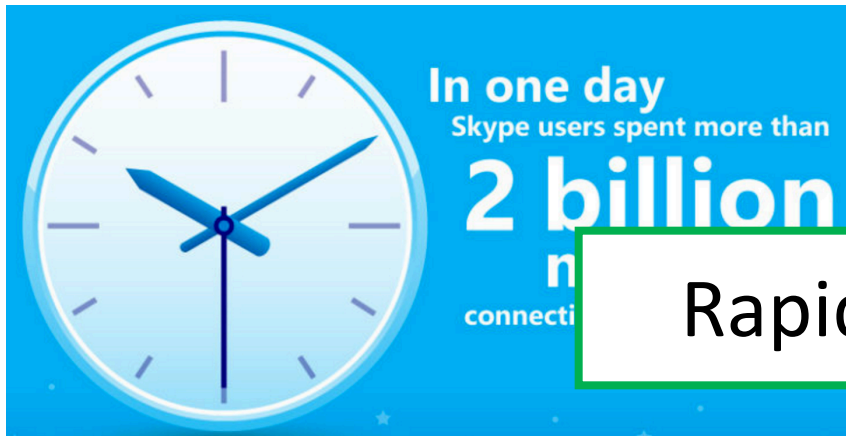**"Managed Overlay"** could alleviate **over half** of calls on these paths

VIA: Data-driven relaying can realize most Managed Overlay's potential
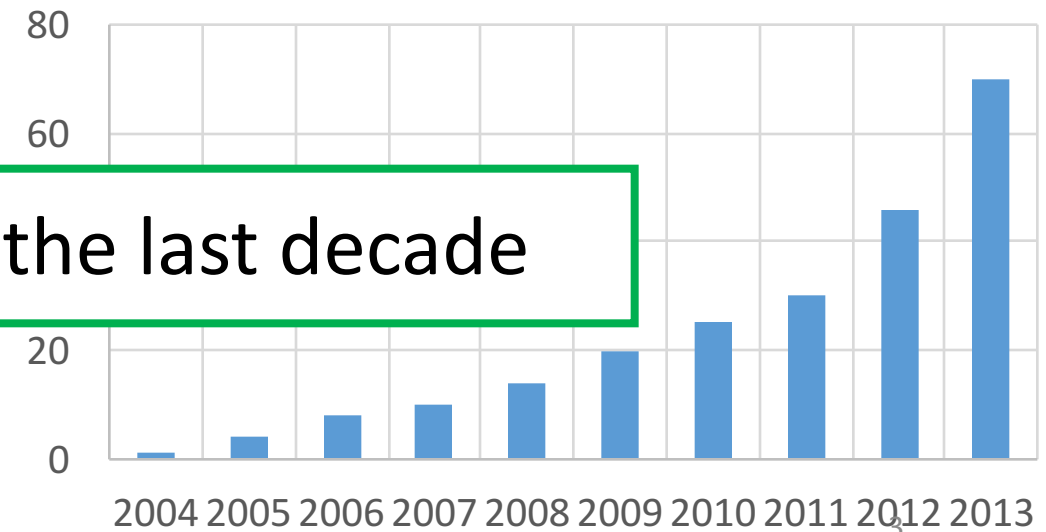
Internet telephony is everywhere!

skype

WhatsApp

HANGOUTS

WeChat

More apps focusing on Internet telephony

In one day
Skype users spent more than
2 billion
n
connecti

Rapid growth over the last decade

Peak # of users concurrent online on Skype

80

60

20

0

2004 2005 2006 2007 2008 2009 2010 2011 2012 2013

3

https://blogs.skype.com/2013/04/03/thanks-for-making-skype-a-part-of-your-daily-lives-2-billion-minutes-a-day/

https://www.statista.com/chart/1417/skype-usage/

Call quality is sensitive to bad network performance

Datasets: Avg RTT, loss rate, jitter for each call of 430 million Skype calls
Small fraction has user-provided quality scores ★★★★☆

320ms

1.2%

12ms
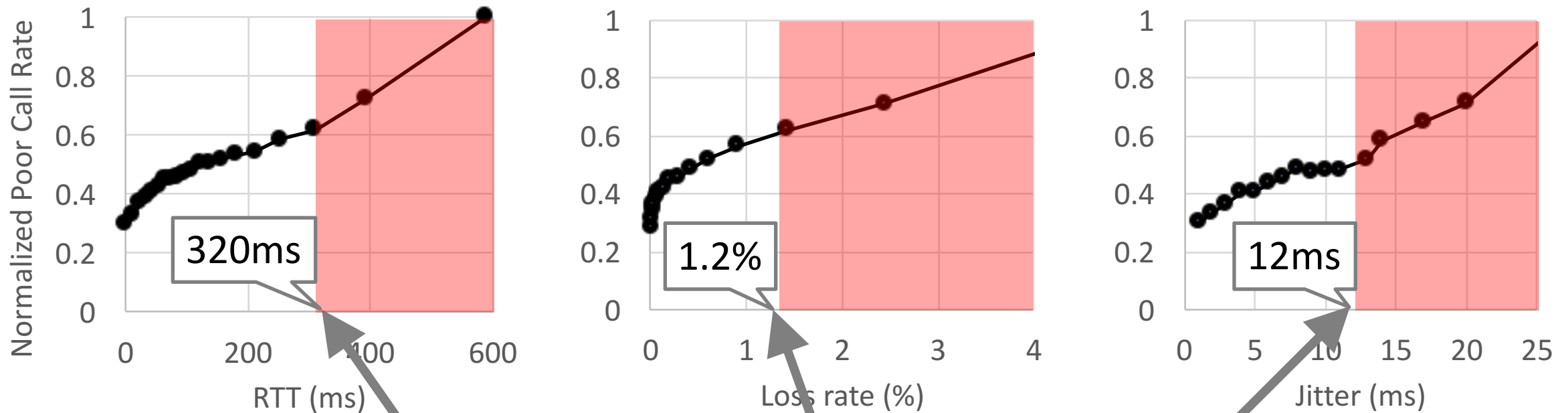
Thresholds of poor network performance

Many calls have poor network performance

One fifth of calls have **poor** network performance

Our goal: **Alleviate poor network performance for Skype**

RTT (ms)   Loss rate (%)   Jitter (ms)

Thresholds of poor network performance

Outline

- <u>Problem:</u> Network performance of Skype is bad

➔ **<u>Opportunity:</u> Managed Overlay has huge potential**

- <u>Solution:</u> VIA for optimal relay selection

- <u>Evaluation:</u> VIA is close-to-optimal

Revisiting Overlay Networks by Managed Overlay

Managed Overlay has new benefits
- *World-wide* distributed *DCs* as relays
- *Well connected*
- *Deployed* by many providers
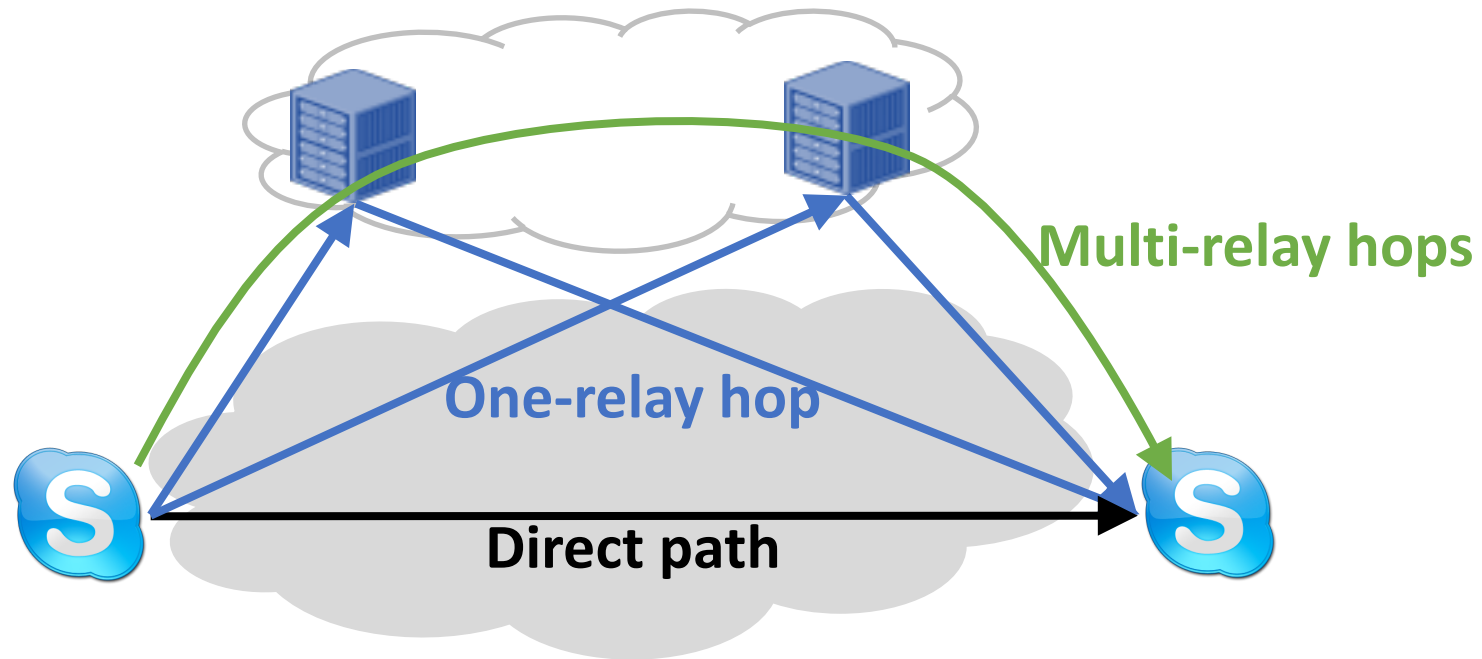- *Single* administrative entity

How much can Internet telephony benefit from it?

AWS Global Infrastr

GovCloud (US ITAR) US West (Northern) US West (Oregon) US East (Northern) So... Ame...

Google Cloud Platform

AWS Regions
AWS Edge Locations

Selecting the best relay option

Multi-relay hops

One-relay hop

S **S**

Direct path

Key is to select the best **relay option** (direct, one-relay, or multi-relay)

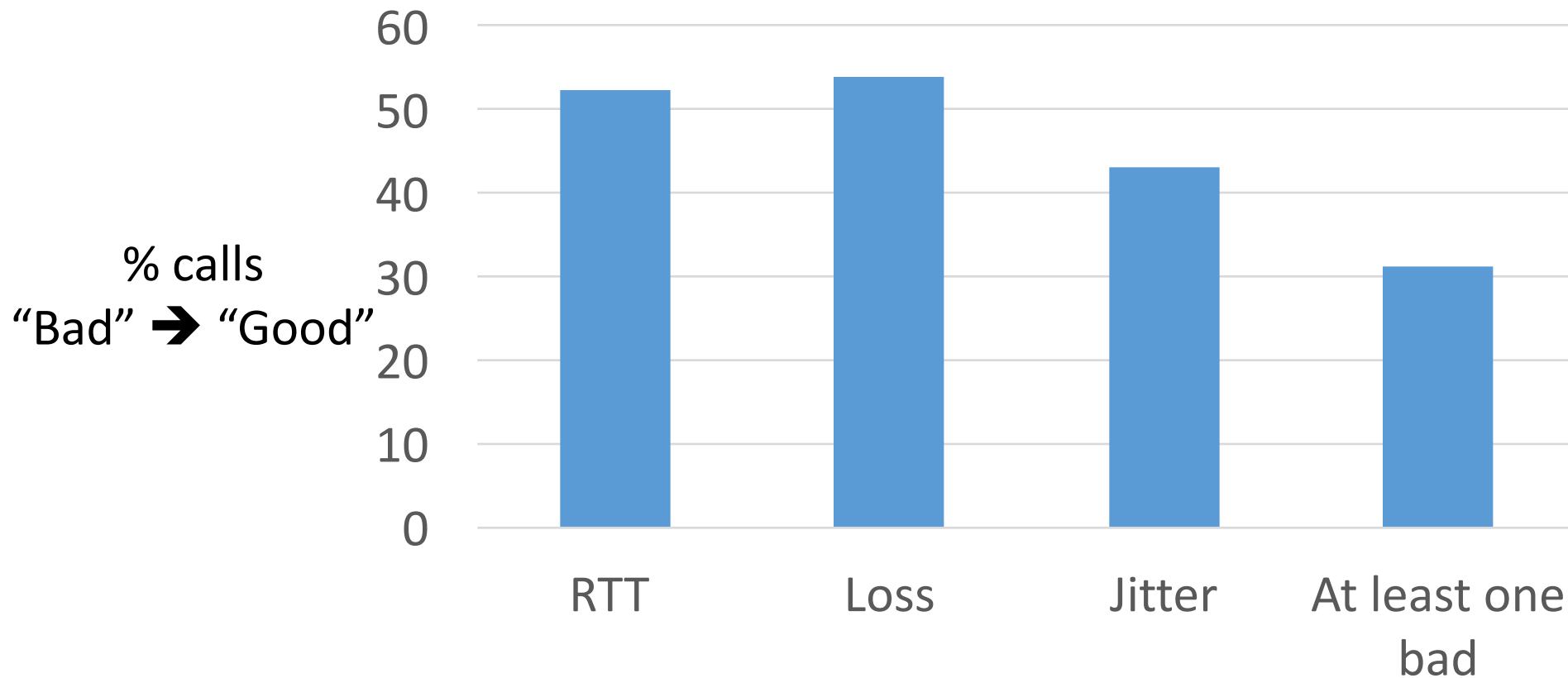Q1: *Does picking best relay option have significant impact?*
Q2: If so, *how to pick the best relay option?*

Managed Overlay has huge potential benefit

Consider an oracle that picks the best relay option for each src-dst AS pair in 24 hours

Poor performance: RTT > 320ms; Loss rate > 1.2%; Jitter > 12ms

% calls
"Bad" ➔ "Good"
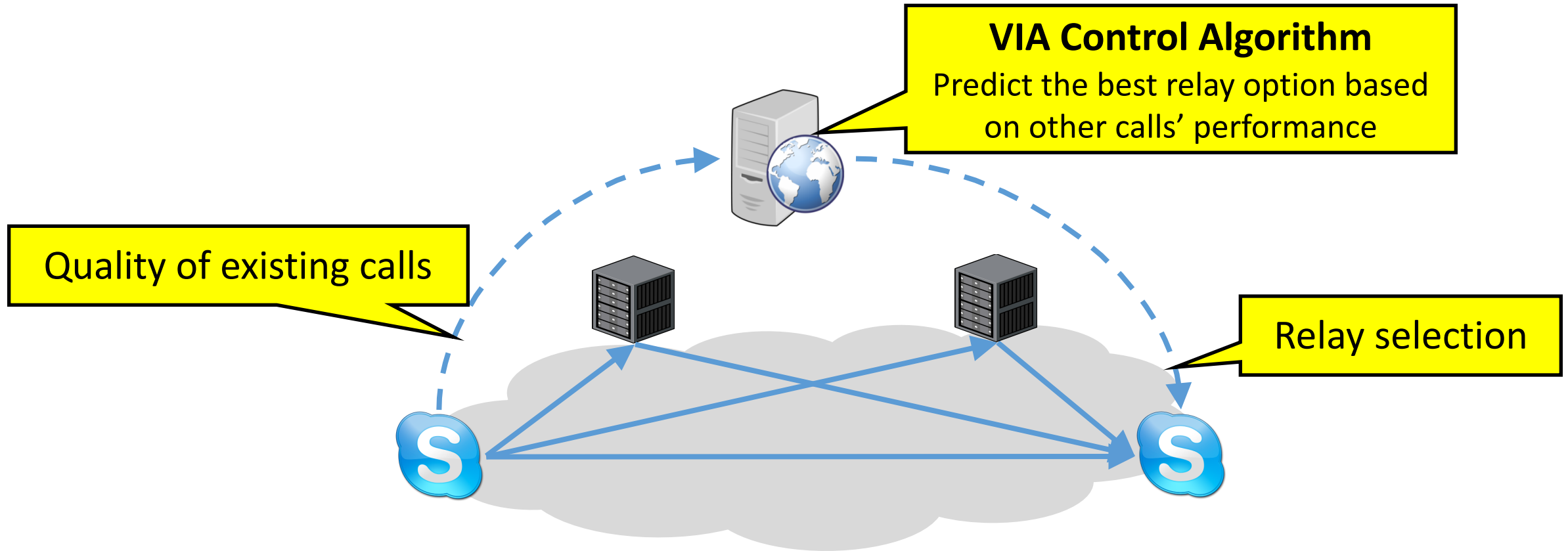

Substantial fraction of bad-performance calls *could* be alleviated

Outline

- Problem: Network performance of Skype is bad

- Opportunity: Managed Overlay has huge potential

➜ **Solution: VIA for optimal relay selection**

- Evaluation: VIA is close-to-optimal

VIA: Realizing the benefit of Managed Overlay using Centralized Predictive Control

VIA Control Algorithm
Predict the best relay option based on other calls' performance

Quality of existing calls

Relay selection

Strawman 1: Pure prediction-based

Use long-term history to predict performance

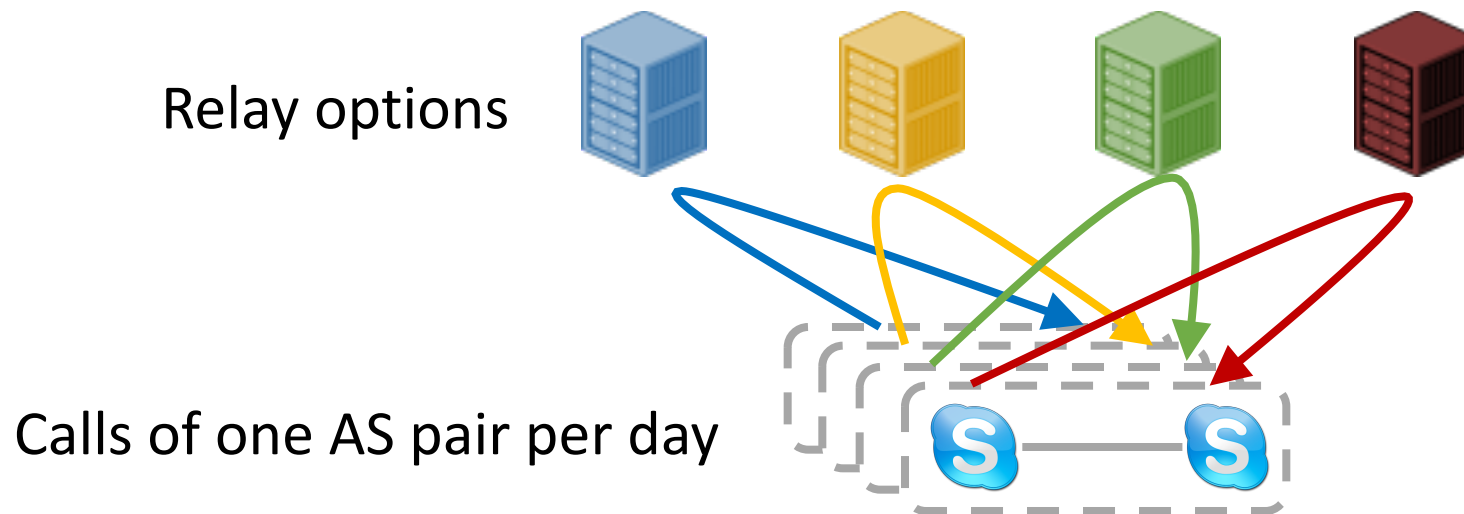Relay options

Call history

Quality prediction

A new call
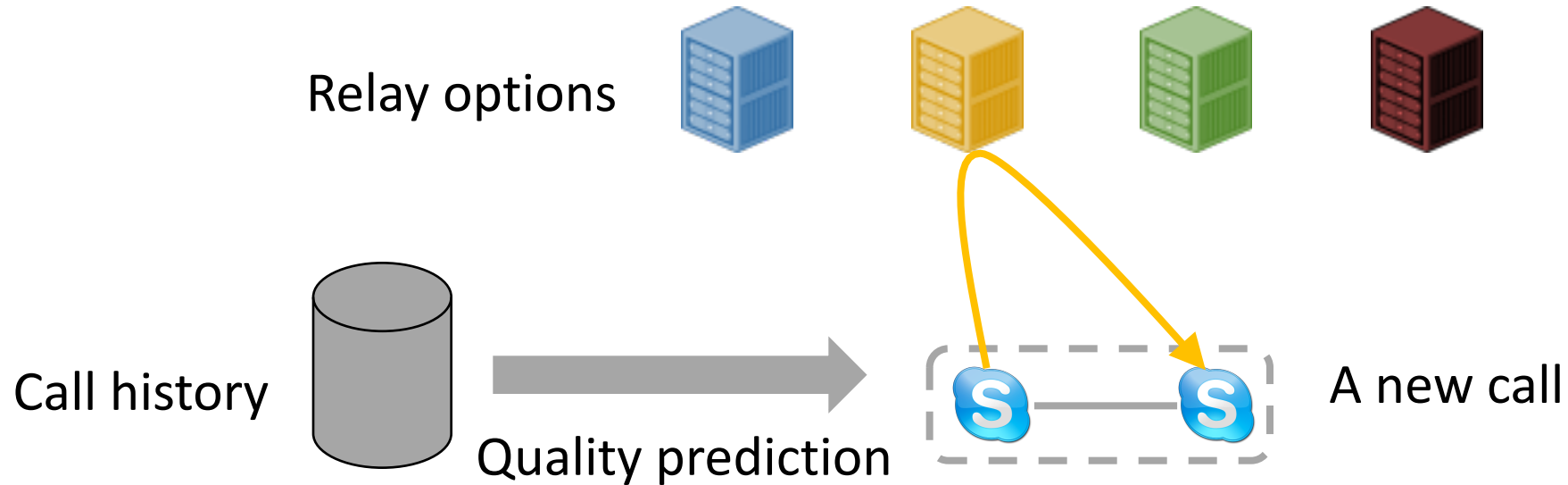
Problem: Call performance has great inherent variance

E.g., predicting "next day" using "last week" leads to over 30% error on latency.

Strawman 2: Pure exploration-based

In a short time window, explore relay options, then exploit the best one

Relay options

Calls of one AS pair per day

Problem: Call distribution is highly skewed
"# of actual calls >> # of relay options" NOT true for most AS pairs
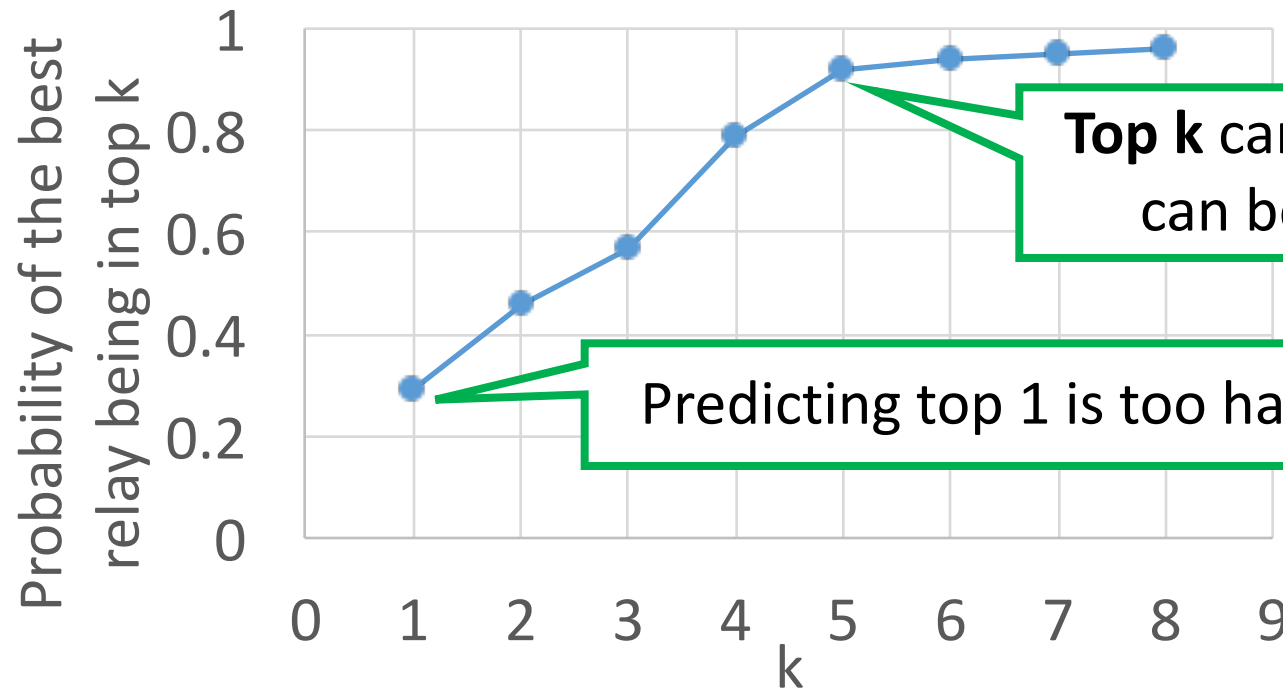
Key idea: Guided exploration

VIA = Prediction-based + Exploration-based

Probability of the best relay being in top k (y-axis), k (x-axis)

Top k can be more **easily predicted** and can be more **efficiently explored**!
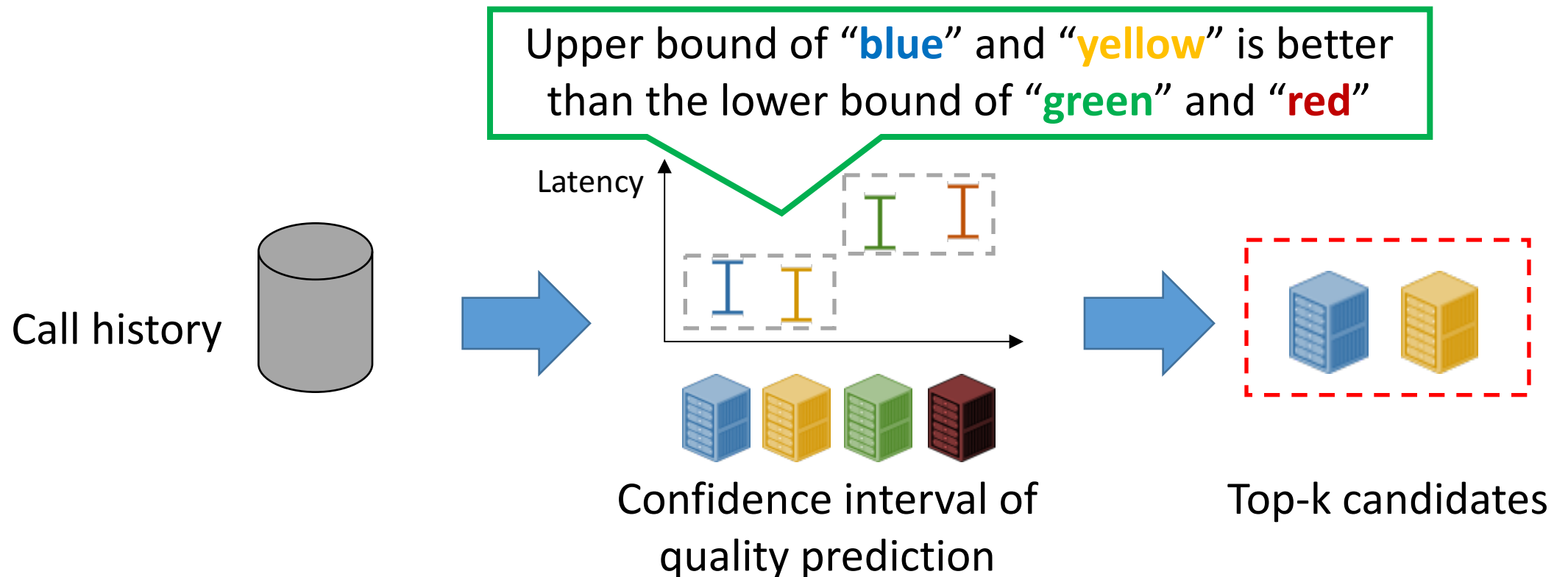
Predicting top 1 is too hard

VIA's idea: **Guided Exploration**
Rough prediction can still identify top *k* candidates, which can be explored efficiently.

Step 1: Prediction-based pruning
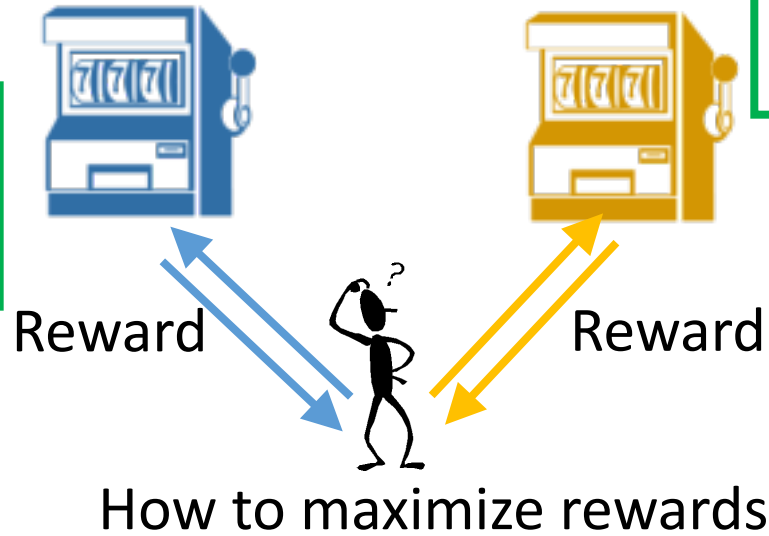
Focus on relay options whose *confidence intervals* are better than those of others.
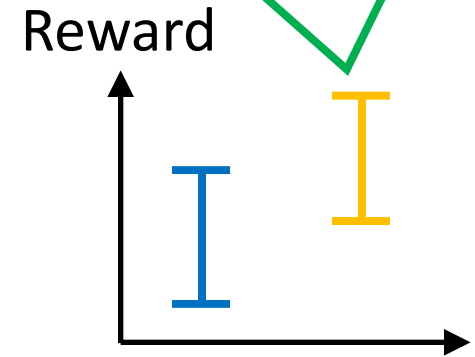
Upper bound of "**blue**" and "**yellow**" is better than the lower bound of "**green**" and "**red**"

Call history

Latency

Confidence interval of quality prediction

Top-k candidates

Step 2: Exploring top-k candidates

Multi-armed bandit process
Upper Confidence Bounds (UCB1)
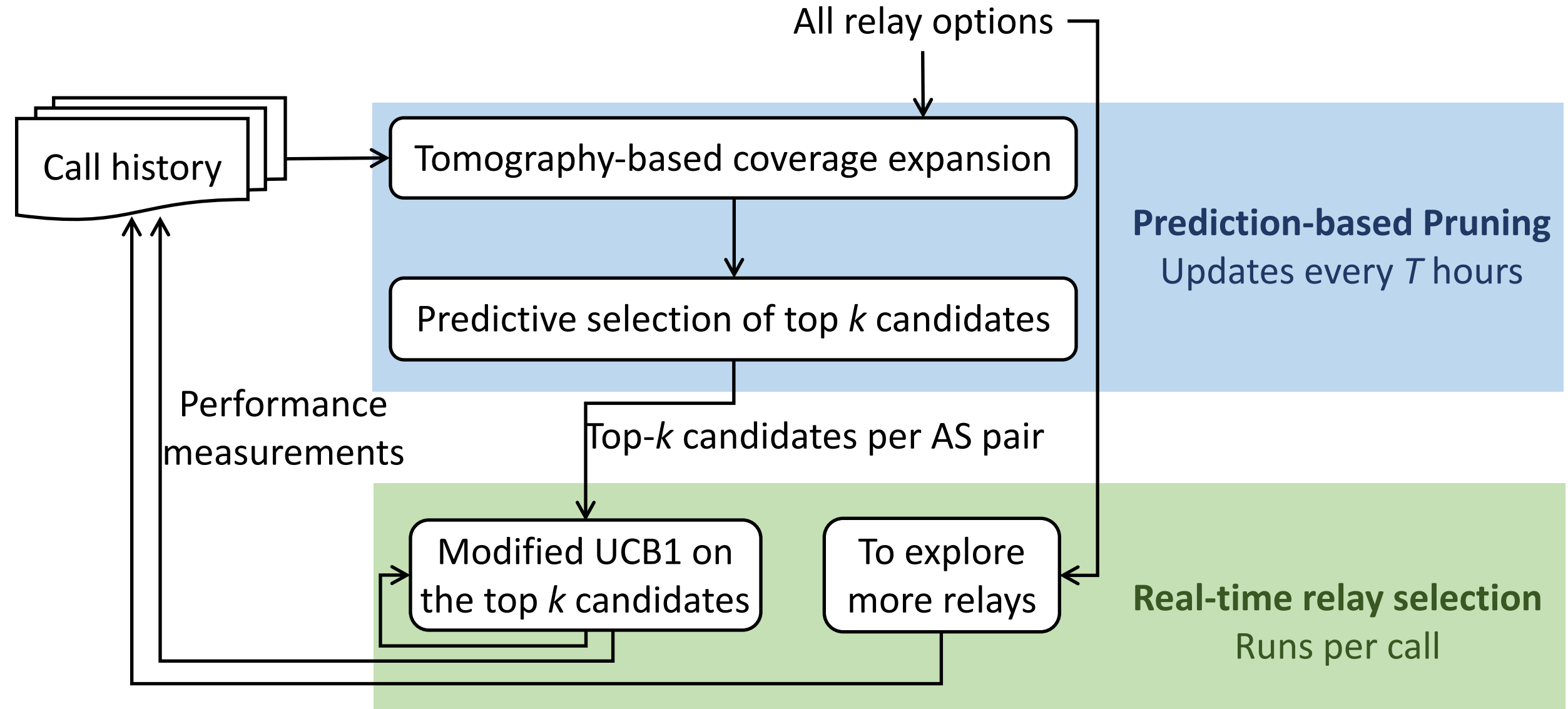
UCB1: Always pick the one with the highest UCB

Reward

Reward

Reward

How to maximize rewards?

Our problem looks like MAB
UCB1 with domain-specific twists

How to minimize latency?
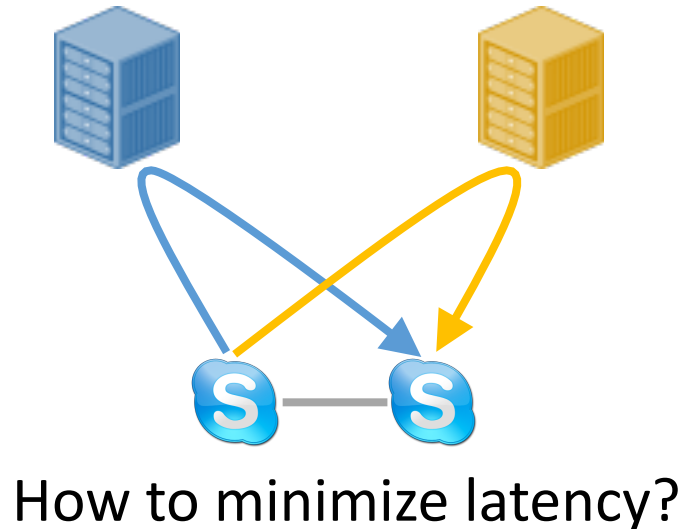
Putting them together: *Guided Exploration in action*

More in our paper

- Budgeted relaying

- Network tomography

- Granularity of prediction

- International vs. domestic calls

VIA: Improving Internet Telephony Call Quality Using Predictive Relay Selection

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[1] Microsoft, [2] CMU, [3] Conviva

ABSTRACT

The use of the Internet for voice calls is here to stay. In spite of the volume and importance of Internet telephony, we have little understanding of (1) how network performance impacts user-perceived call quality, and (2) why and where such quality problems occur in the wild. To bridge this gap, we analyze a data set of 430 million calls from Skype, with clients across 1900 ASes and 126 countries. We observe that call quality problems are quite pervasive. More importantly, these problems are *significantly spread out* geographically and over time, thereby making simple fixes targeted at specific "pockets" of poor performance largely ineffective.

To alleviate call quality problems, we present an architecture called VIA that revisits the use of classical overlay techniques to relay calls. We argue that this approach is both timely and pragmatic given the emergence of private back-

CCS Concepts

•Applied computing → *Internet telephony;* •Networks → *Overlay and other logical network structures; Network performance analysis; Network measurement;*

Keywords

Internet telephony; Quality of experience; Predictive relay selection; Managed overlay networks
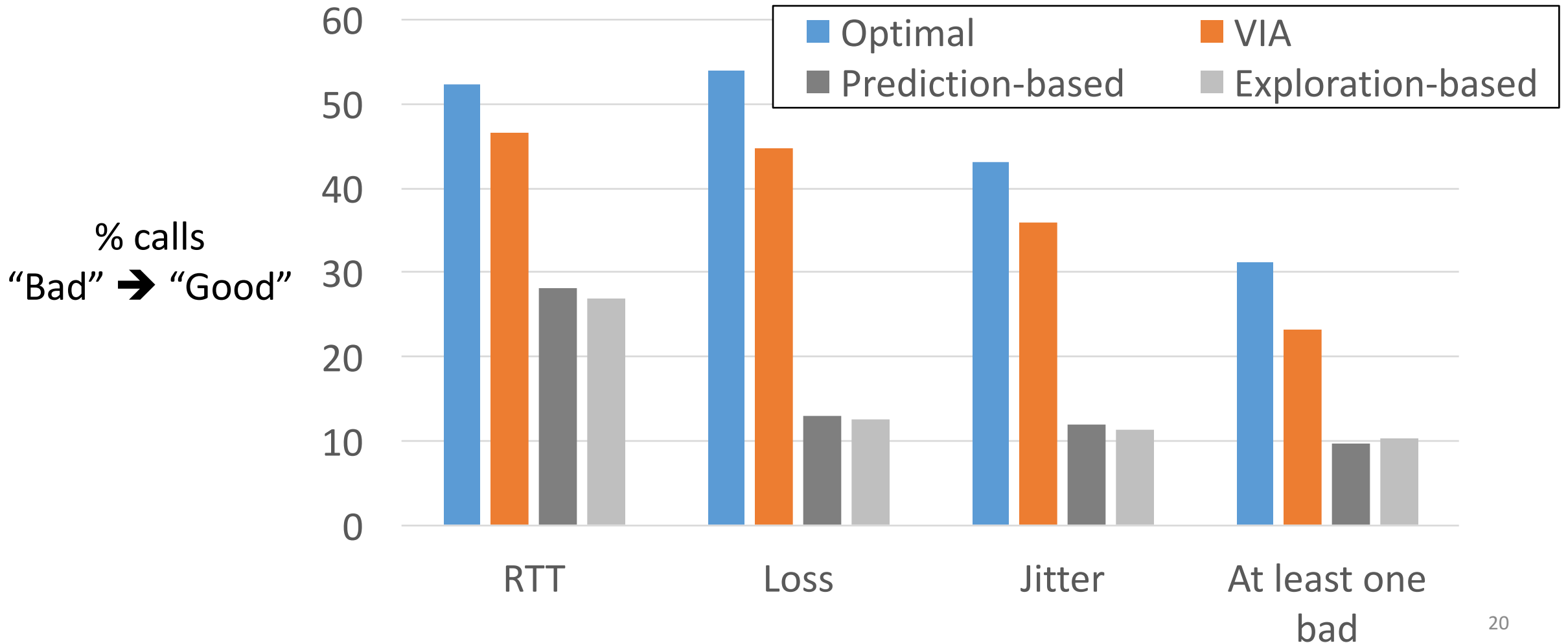
1 Introduction

Over the last several years, we have seen a dramatic rise in Internet-based telephony, especially for long-distance international calling [5, 6]. The importance of audio calling is evident as almost all major content and social networking platforms today offer some form of Internet calling capability (e.g., Skype, Google Hangouts, Facebook Messenger,
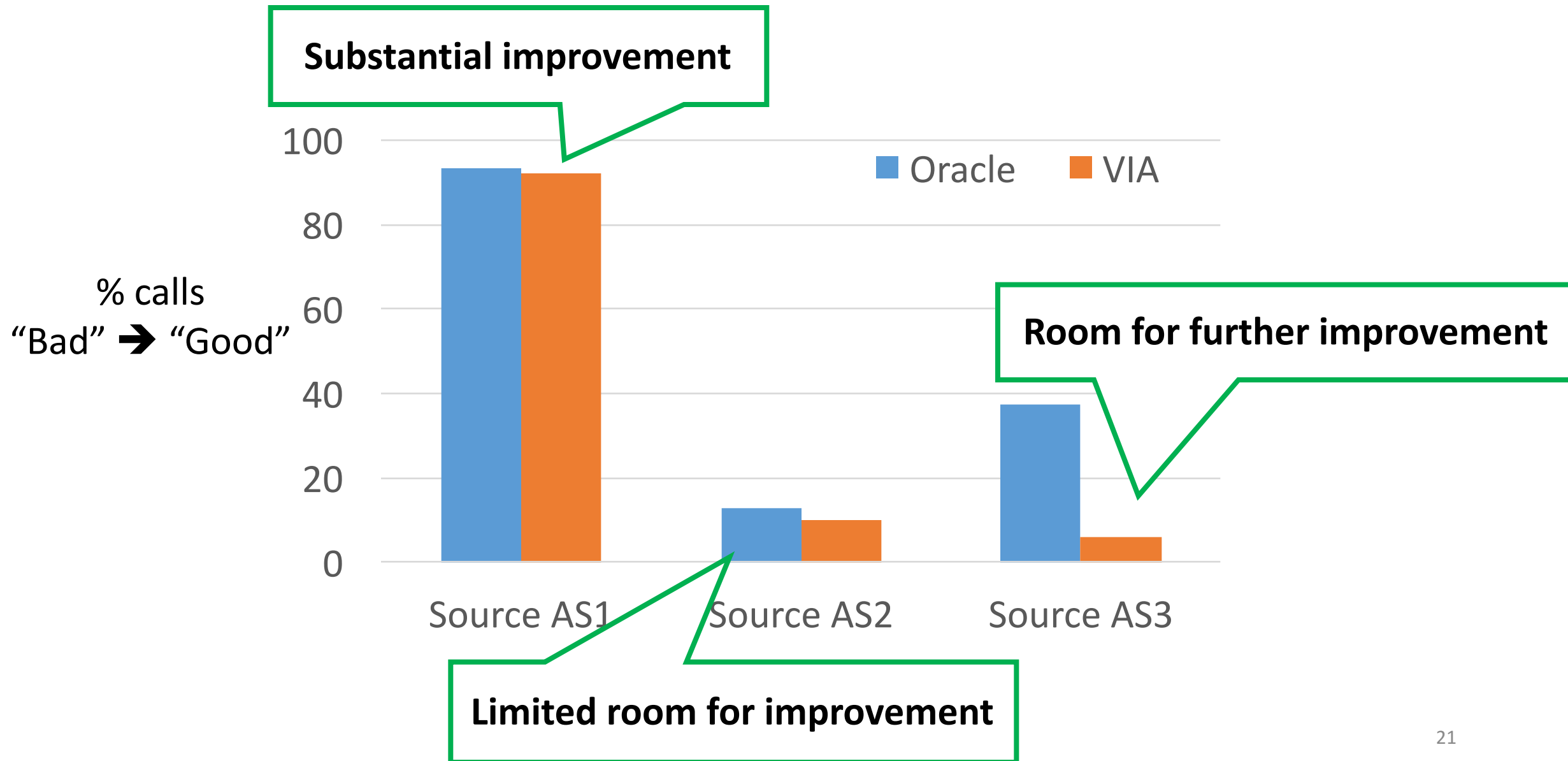
Outline

- <u>Problem:</u> Network performance of Skype is bad

- <u>Opportunity:</u> Managed Overlay has huge potential

- <u>Solution:</u> VIA for optimal relay selection

- ➔ **<u>Evaluation:</u> VIA is close-to-optimal**

VIA achieves close-to-optimal performance

Poor performance: RTT > 320ms; Loss rate > 1.2%; Jitter > 12ms

% calls
"Bad" ➔ "Good"

20

Benefit varies across ASes

Substantial improvement

Room for further improvement

Limited room for improvement

% calls
"Bad" ➔ "Good"

Oracle   VIA

100

80

60

40

20

0

Source AS1   Source AS2   Source AS3

Conclusion

- **Internet telephony** is here to stay

- Problem: **One fifth** of calls have bad network performance.

- Opportunity: **Managed Overlay** *could* significantly reduce bad-performance calls.

- Challenges: Optimal relay selection
Pure prediction and pure exploration won't work!

- Solution: **VIA** can realize most of the benefit of Managed Overlay.

  Key idea: **Guided exploration**:

  Predictive pruning of relay options + Exploration over top k candidates