# Measurement-based Inter-domain Traffic Engineering

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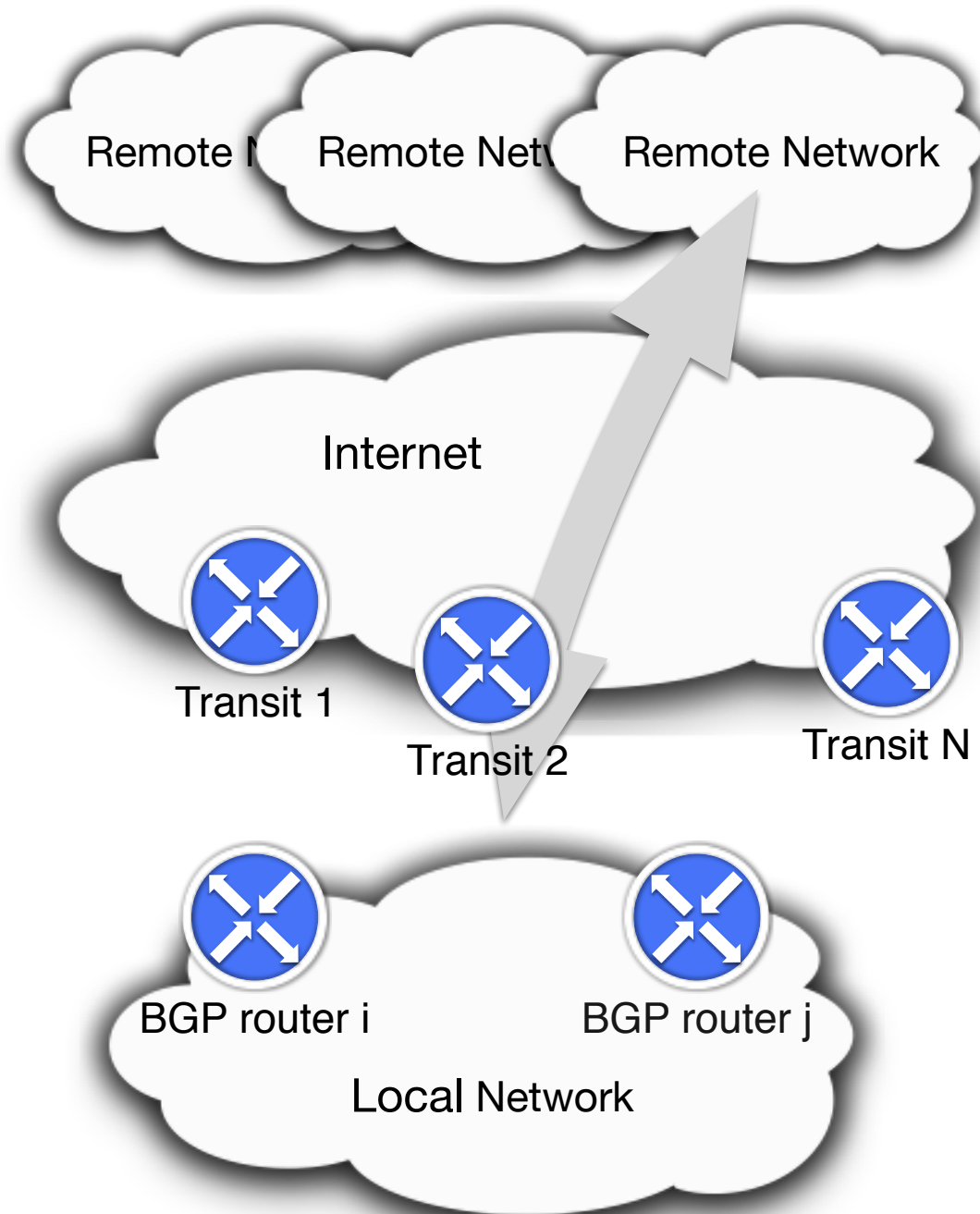*member of University of Paris-Saclay*

F. Devienne, M. Viste
*Border 6*

NANOG 67
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# Outline

- **Measurement-based** inter-domain traffic engineering

- A problem of scalability

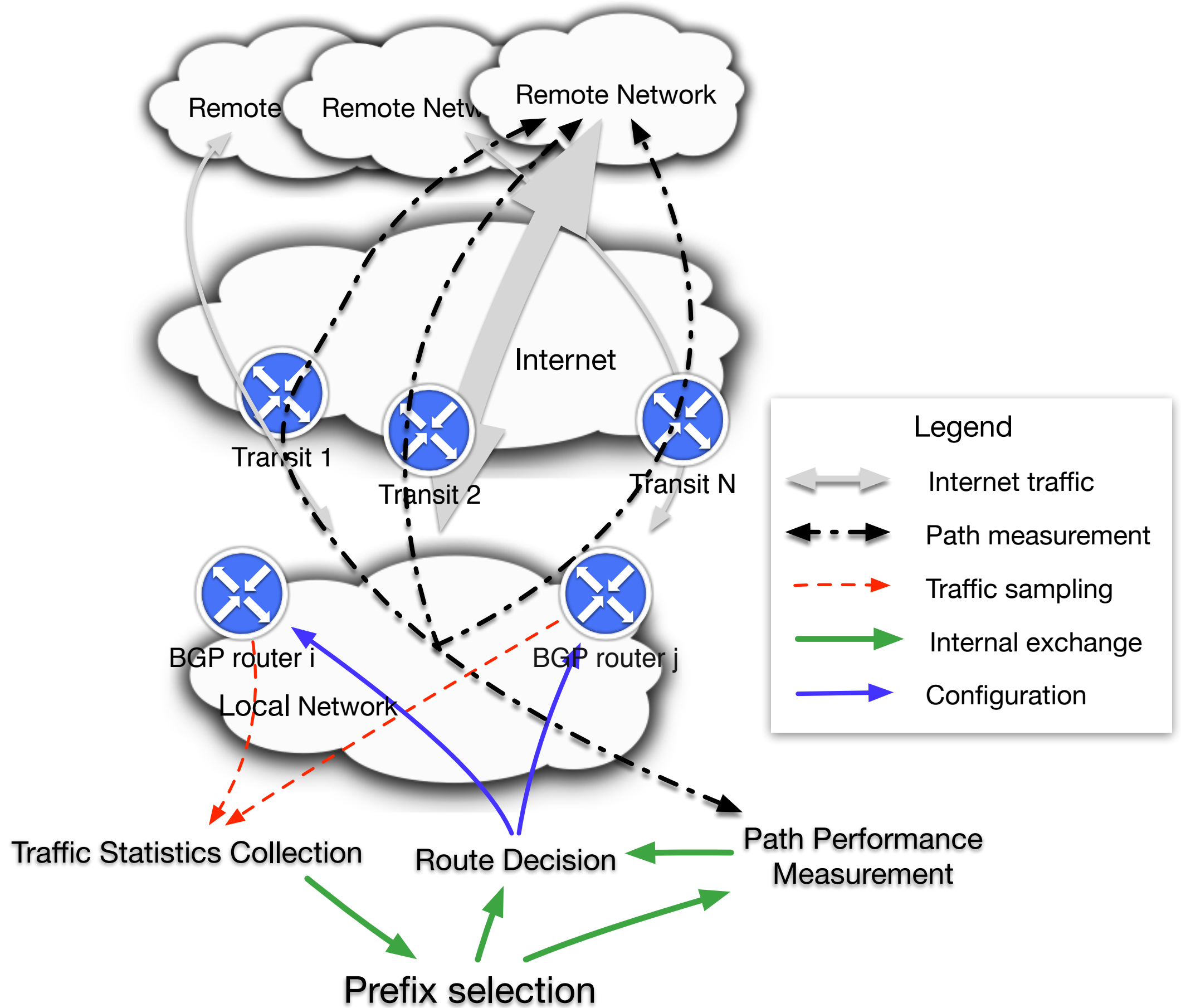# A scenario: Out-bound TE for multi-homed stub AS



1. Local_Pref
2. AS_Path
3. MED
4. eBGP > iBGP
5. tie-breaking
   1. IGP costs
   2. oldest path
   3. etc

# An old scenario

- N. Feamster, D. G. Andersen, H. Balakrishnan, and M. F. Kaashoek, "**Measuring the effects of internet path faults on reactive routing**," ACM SIGMETRICS, vol. 31, no. 1, p. 126, **2003**.
- A. Akella, B. Maggs, S. Seshan, A. Shaikh, and R. Sitaraman, "**A measurement-based analysis of multihoming**," SIGCOMM, **2003**.
- D. K. Goldenberg, L. Qiu, H. Xie, Y. R. Yang, and Y. Zhang, "**Optimizing cost and performance for multihoming**," CCR, vol. 34, no. 4, p. 79, Oct. **2004**.
- A. Akella, B. Maggs, S. Seshan, and A. Shaikh, "**On the Performance Benefits of Multihoming Route Control**," IEEE/ACM Trans. Netw., vol. 16, no. 1, pp. 91–104, Feb. **2008**.

Remote Network  Remote Network  Remote Network

Internet

Transit 1  Transit 2  Transit N

BGP router i  BGP router j

Local Network

Legend

Internet traffic

Path measurement

Traffic sampling

Internal exchange

Configuration

Traffic Statistics Collection  Route Decision  Path Performance Measurement

Prefix selection

5

# Traffic statistics collection

**Purpose**: to select a set of 'managed prefix', i.e. destinations of importance;

**Collector**: netflow/sflow collector, PMACCT;

**Storage**: RAM, PostgreSQL.

# Active measurements

**Target**: probes discovered in 'managed' prefixes

**Method**: TCP SYN -> RTT and loss;

**Path**: via **all available** BGP next-hops;

**Steering**: source-based routing, SDN, etc;

**Storage**: RAM, PostgreSQL.

# Route decision

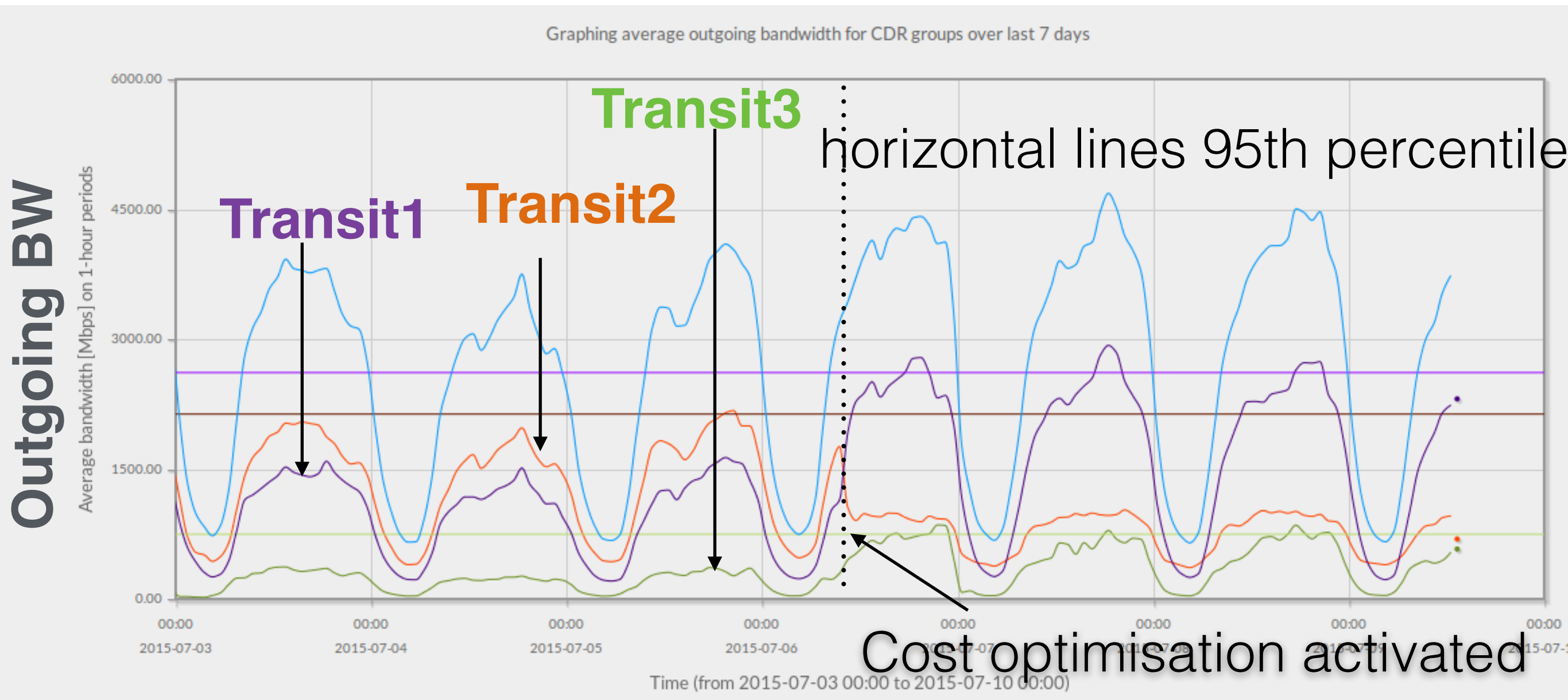**Objective**: performance, availability & transit cost;

**Metrics**: RTT, loss and BW w.r.t. CDR;

**Algorithm**: depends on user's needs;
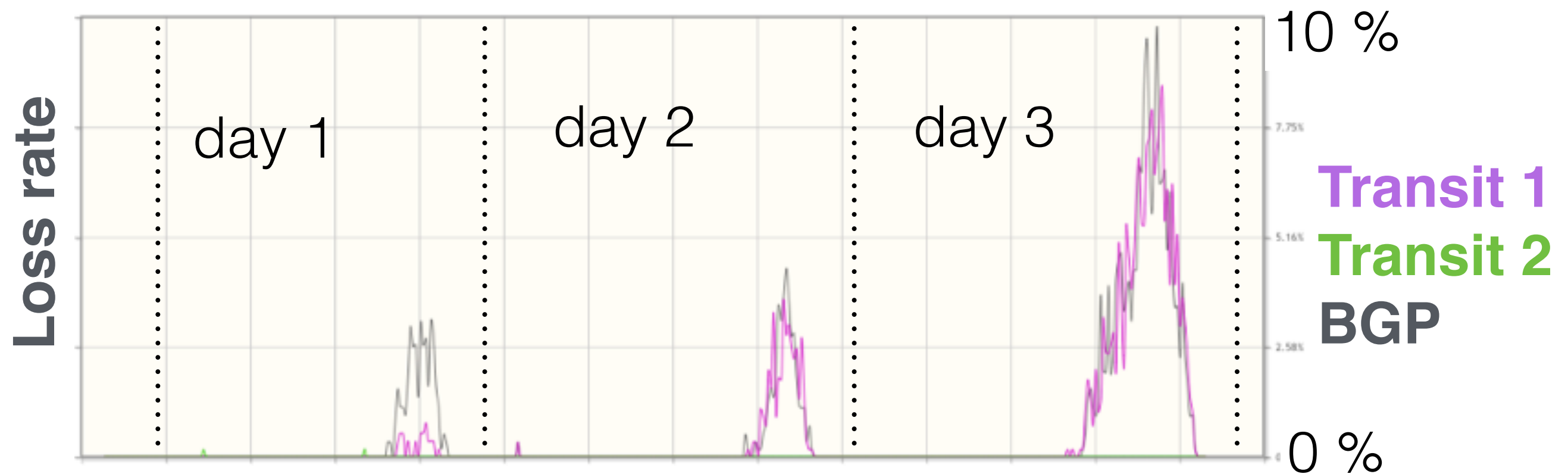
**Steering**: BGP as SDN southbound interface.

# Algo example—Cost

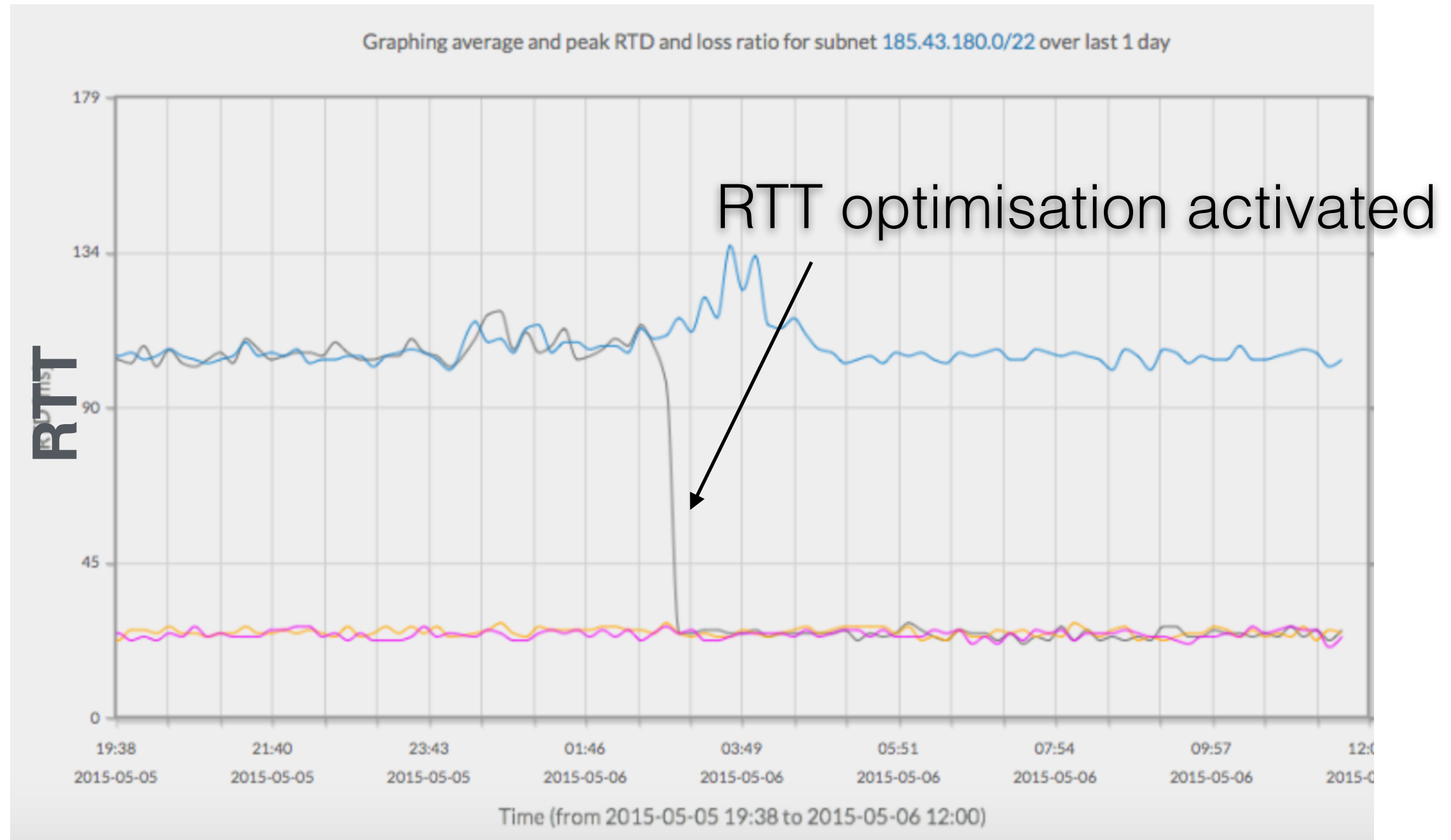**Total**     **Transit1**     **Transit2**     **Transit3**

Graphing average outgoing bandwidth for CDR groups over last 7 days

**Transit3**

horizontal lines 95th percentile

**Transit1**     **Transit2**

Cost optimisation activated

**Transit1** has the lowest BW price.

# Algo example—Availability



day 1     day 2     day 3

10 %

**Transit 1**
**Transit 2**
**BGP**

0 %

Loss rate

Packet loss due to **consistent congestion**
can be avoided
by simply change a BGP next-hop.

# Algo example—smaller RTT

**Transit 1**    **Transit 2**    **BGP**



Graphing average and peak RTD and loss ratio for subnet 185.43.180.0/22 over last 1 day

RTT optimisation activated

Time (from 2015-05-05 19:38 to 2015-05-06 12:00)

# For Inbound as well…

Route Preference Protocol (RPP) for **Inbound** TE

1. Tell traffic sourcing AS what is you favourite ingress point;
2. Traffic sourcing AS then does its best.



source

AS 1

AS 2

destination

http://rpp.border6.com/
https://github.com/border6/rpp
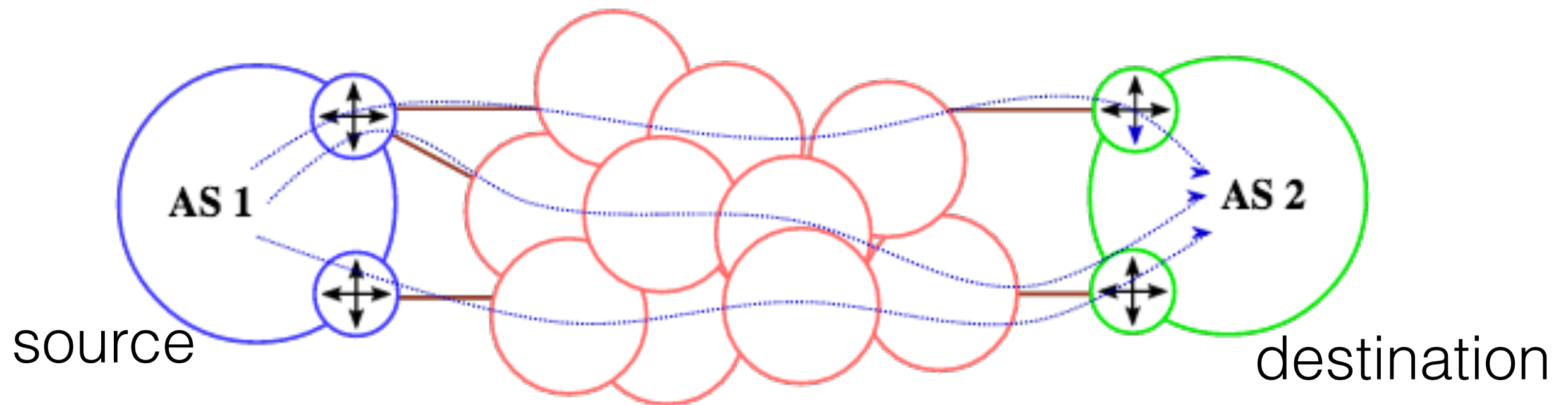
# the scalability problem
# ~600K BGP prefixes
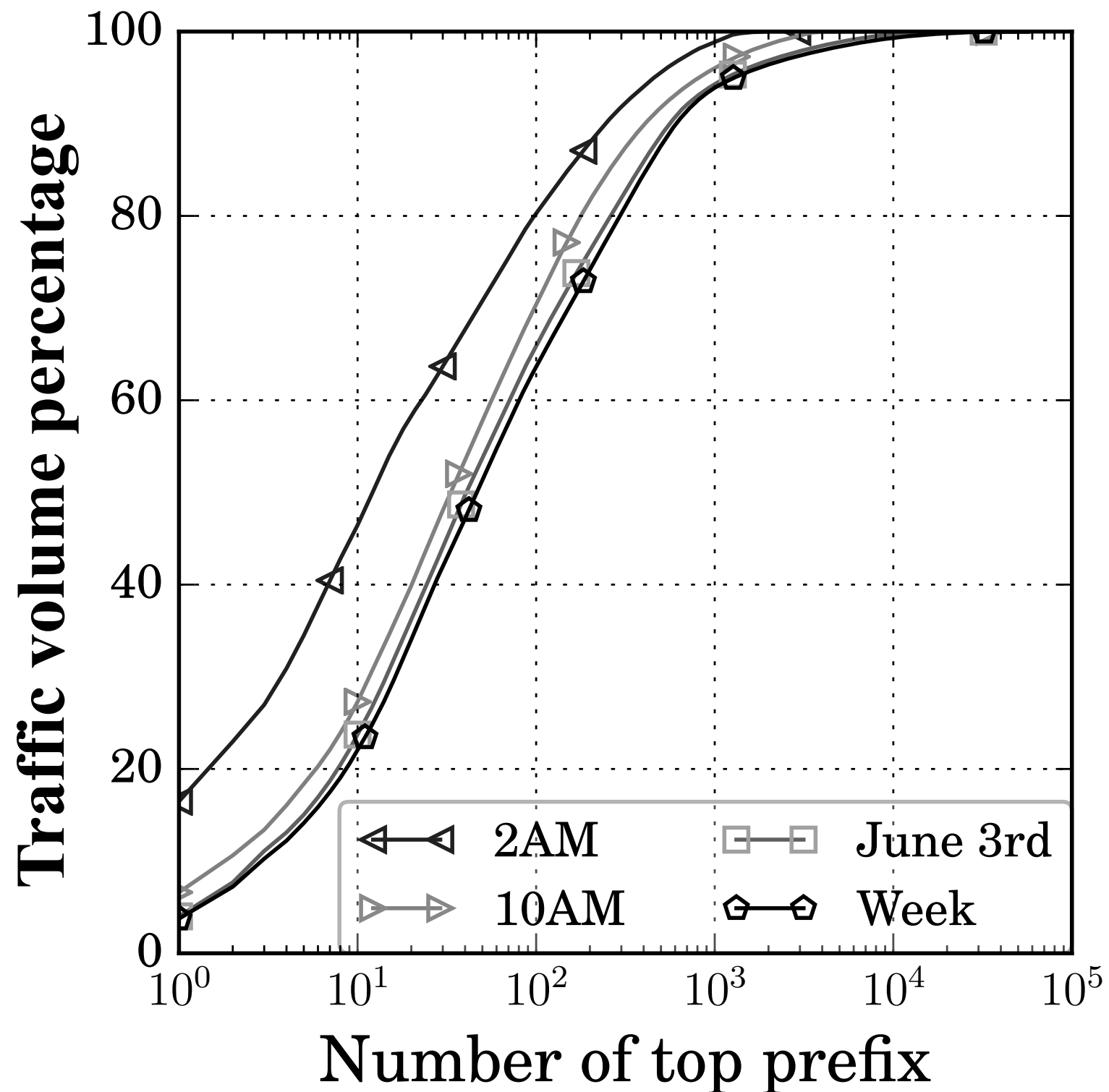
# How to **select prefixes** of importance?

W. Shao, L. Ianonne, J.L. Rougier, F. Devienne, and M. Viste, "**Scalable BGP Prefix Selection for Effective Inter-domain Traffic Engineering**," IEEE/IFIP NOMS, 2016.

# A large portion traffic is concentrated on a small number of prefixes (log-log graph not CDF)
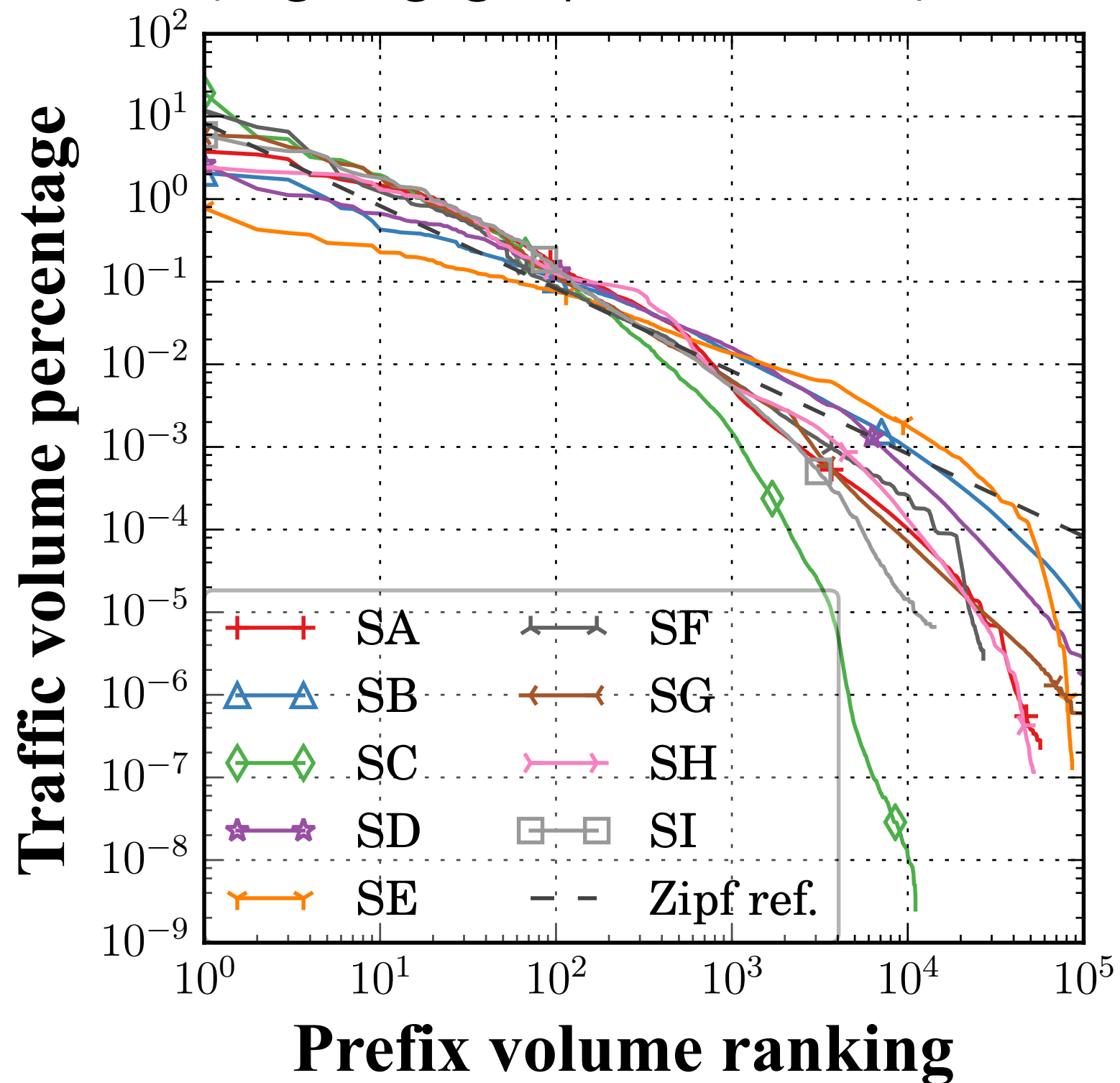
# However…

traffic value associated to each prefix evolves over time.

# However…

we have **some ten thousands** of time-series/prefixes to predict.

**Predictively** select BGP destination prefixes that stand for **a large portion** of traffic, with a **simple and efficient** method.

Wisely save sources for measurement and optimization.

# Save resources of **data plane** as well.

full BGP routing table    ⟶    one optimized route
for each selected prefix
+
one default route for the rest

expensive edge router    ⟶    cheaper DC switch/
white-box SDN switch

# FIB caching/prediction

- W. Zhang, J. Bi, J. Wu, and B. Zhang, "**Catching popular prefixes at AS border routers with a prediction based method**," Comput. Networks, vol. 56, no. 4, pp. 1486–1502, Mar. 2012.
  - **GM(1,1)** outperforms LFU, LRU

**David Barroso**, Spotify
*Building an extensible **SDN** Internet Router with commodity hardware*
https://youtu.be/o1njanXhQqM

# **Difference** from FIB caching/prediction

Basically, a matter of time scales

FIB caching, 5min interval or less, memory of hours;
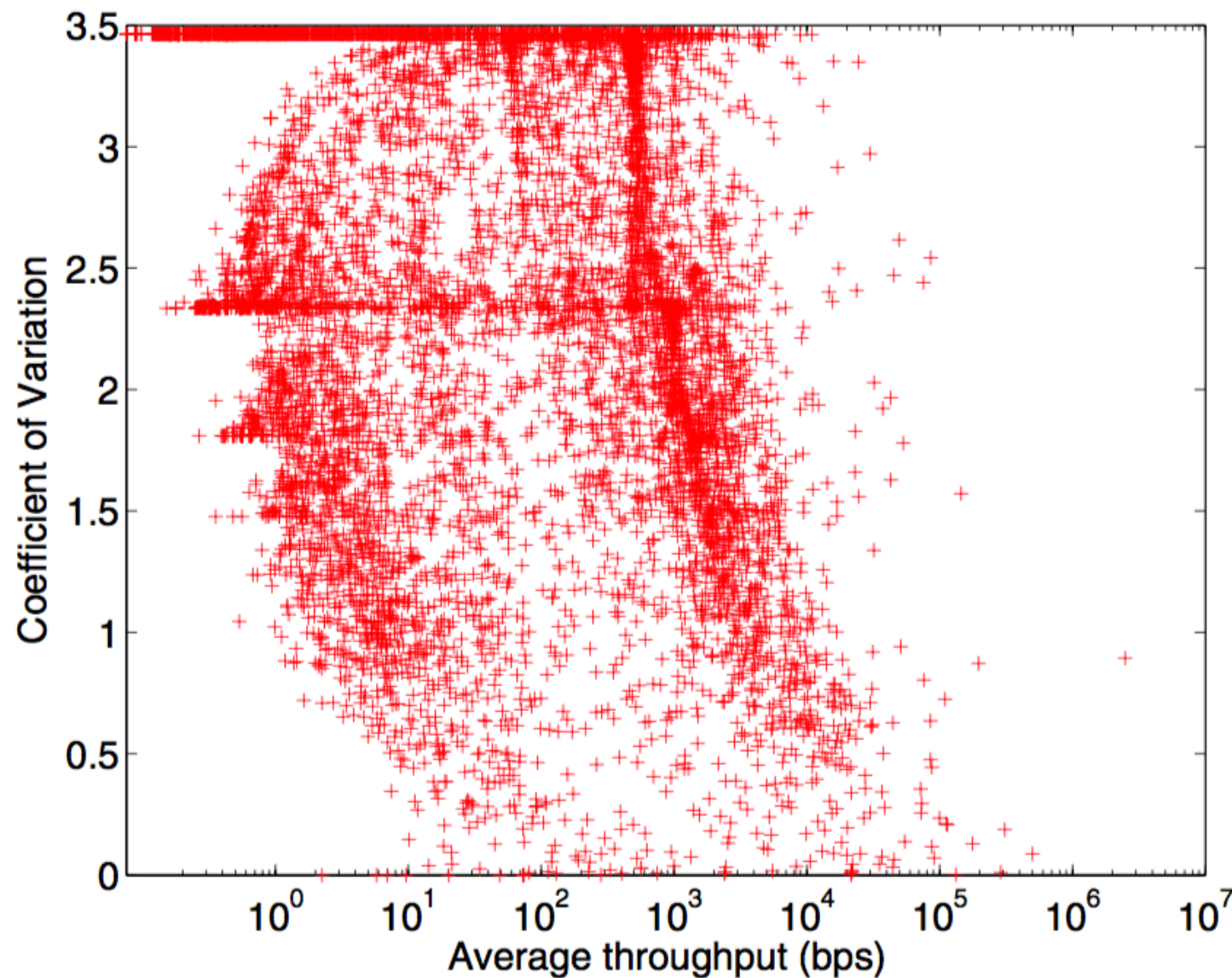Prefix selection, 1 hour interval, memory of days till weeks.

**Why?**
Not only data-plane is involved.
Probes discovery, probe selection, long term pattern and bursty-traffic, prefix churn, etc.

And **more** than that….

# Traffic dynamism



K. Papagiannaki, N. Taft, and C. Diot, "**Impact of Flow Dynamics on Traffic Engineering Design Principles**," INFOCOM, 2004.

"… shows that there is no clear correlation between the mean and the coefficient of variation of the bandwidth of a network prefix flow."
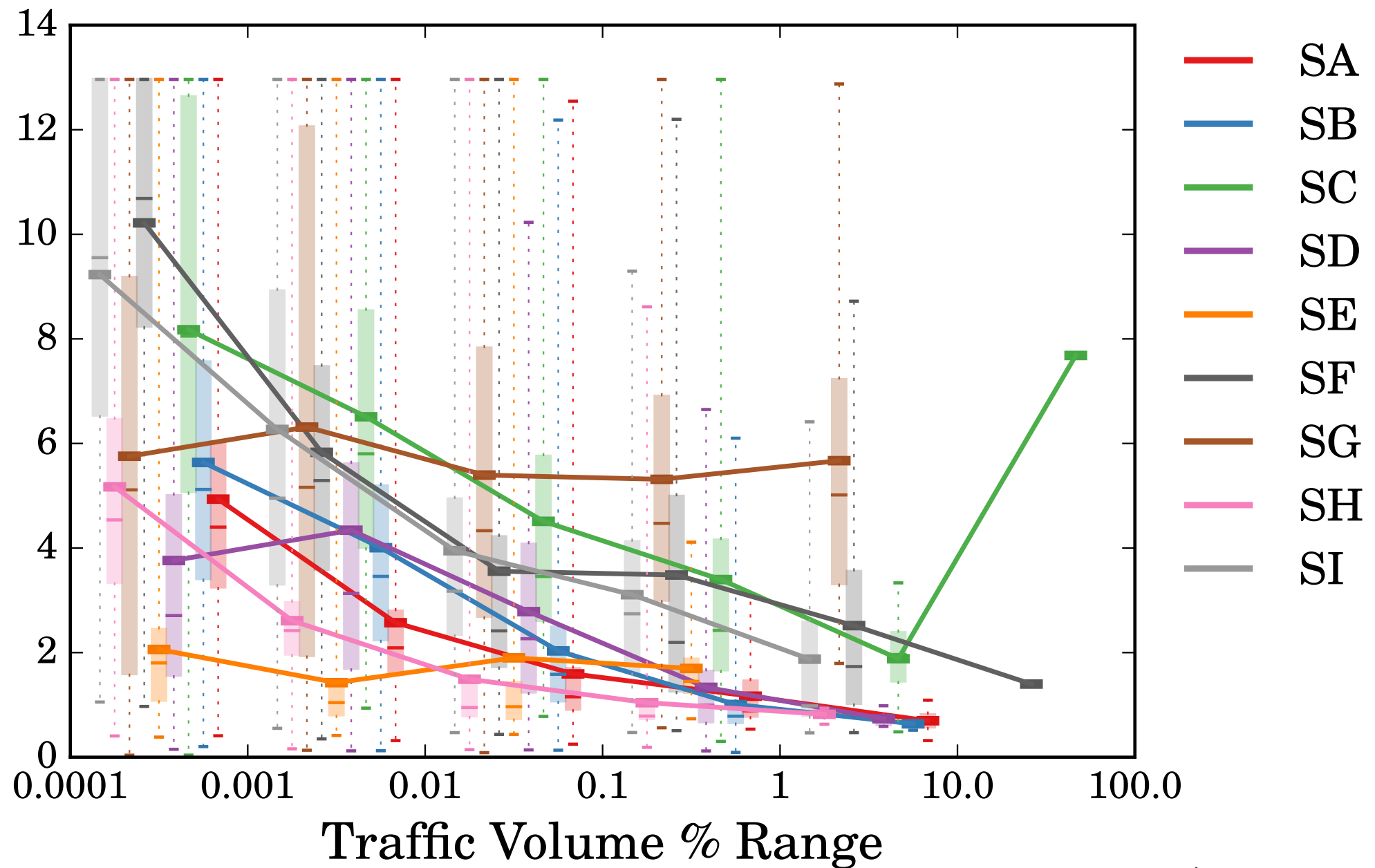
# What is case for traffic aggregated by BGP prefix over longer interval?

# Volume importance vs predictability
## Prefix volume share — Cv
## Cv = std/mean

# A solution

# as simple as
# **Moving Average**

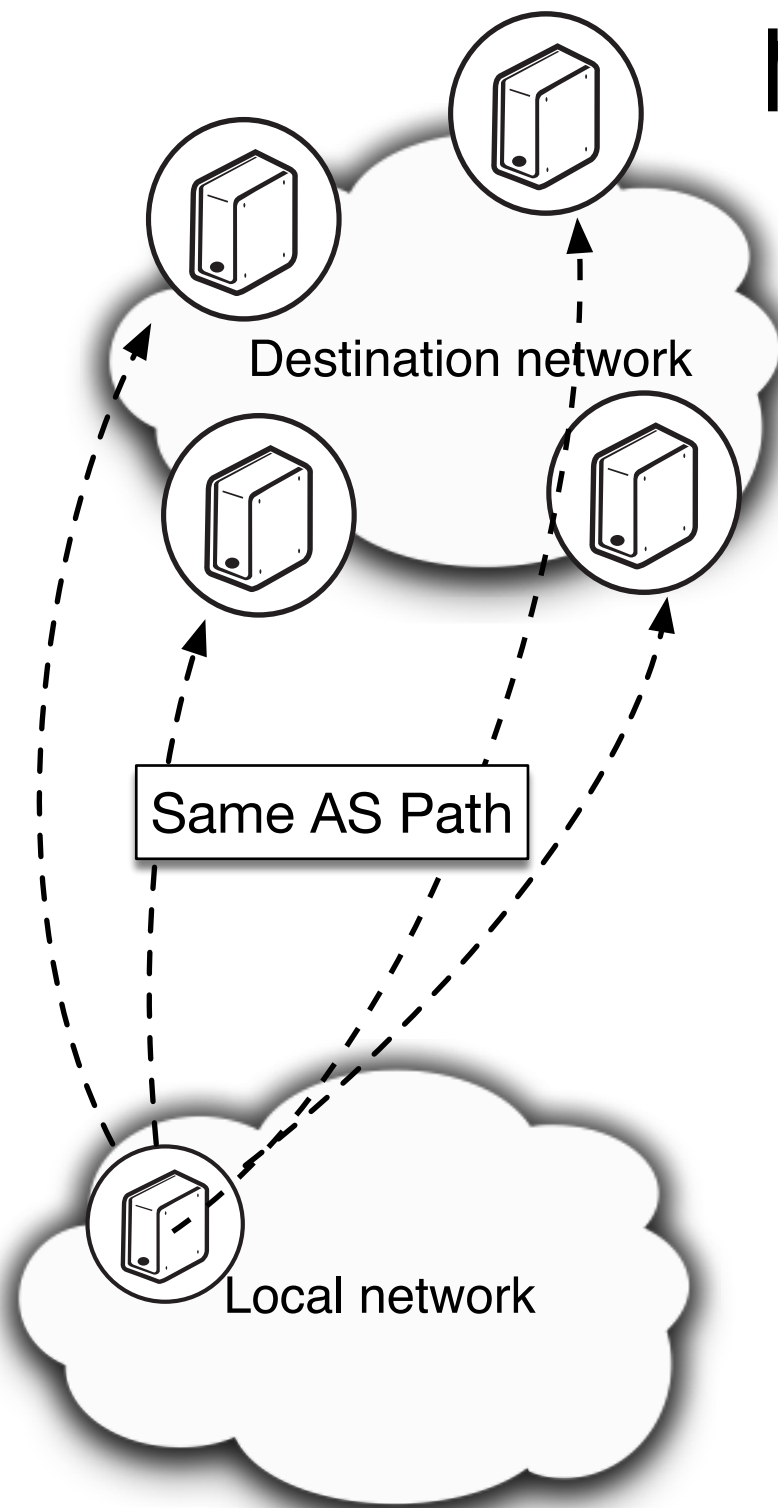Volume coverage of **MV** compared to Grey Model **GM(1,1)**
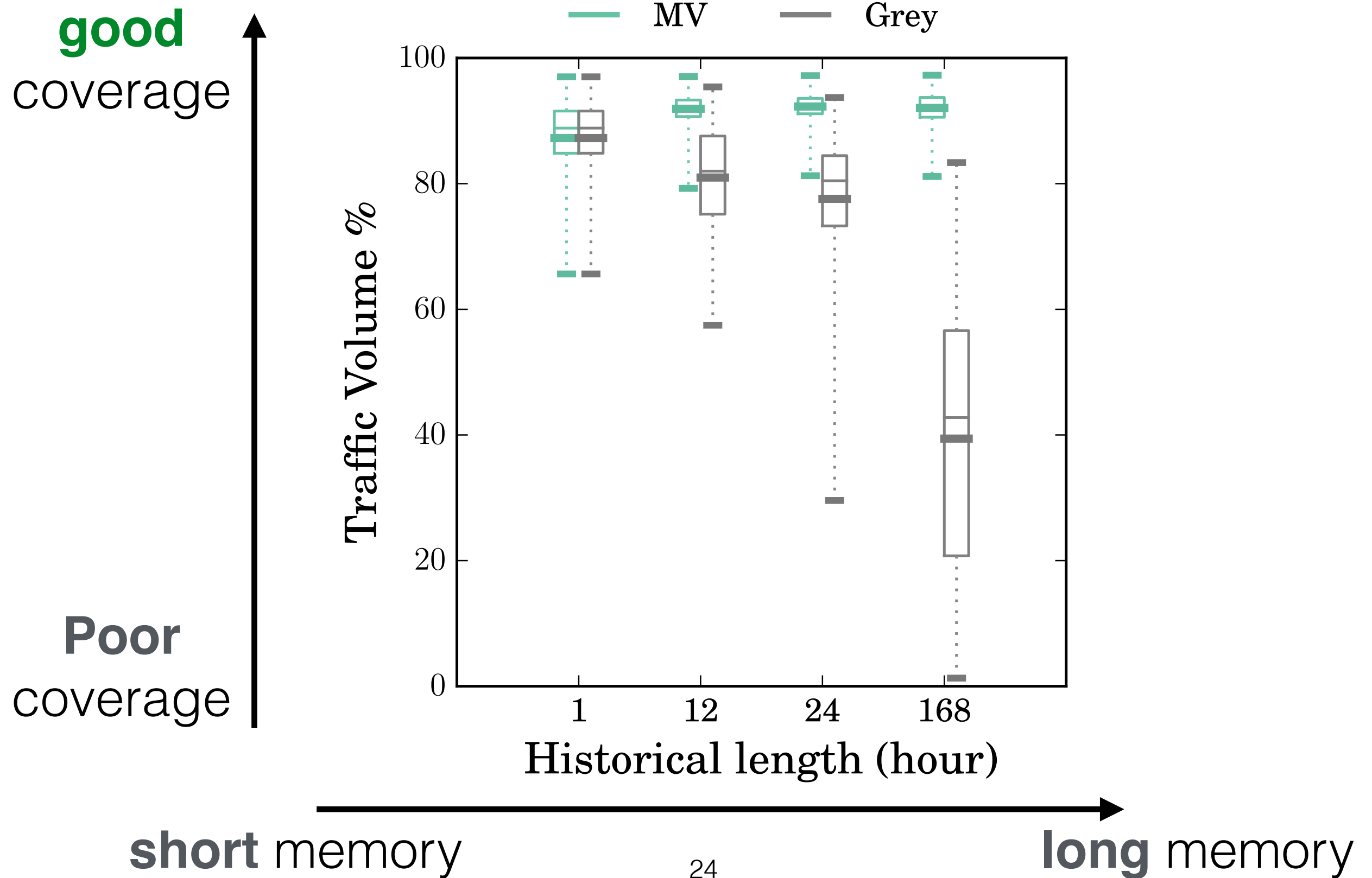
# Summary

- An old scenario with many remaining challenges;

- A possible approach realizing it.

# Many other challenges…

# Measure a same AS path with multiple probes



Destination network

Same AS Path

Local network
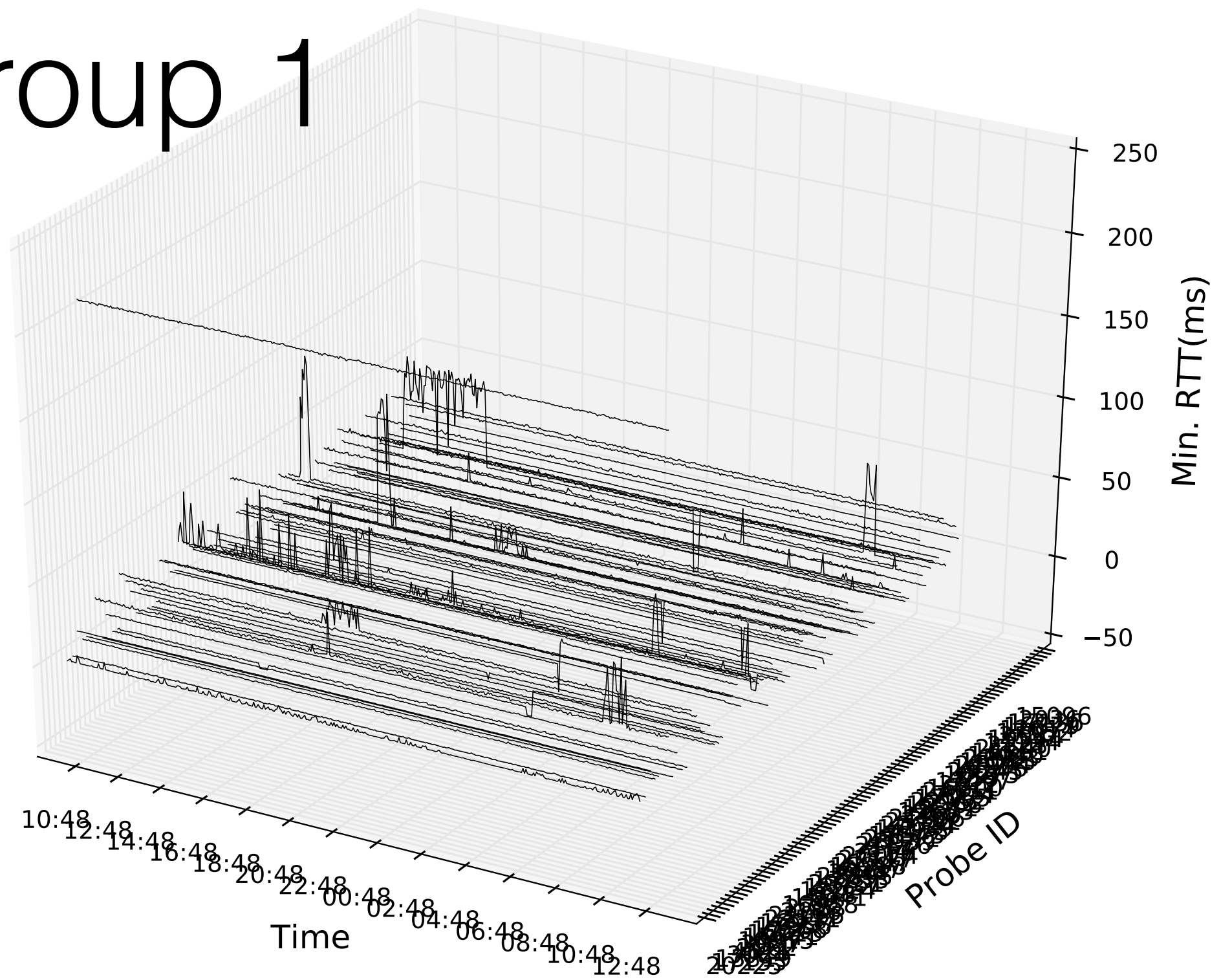
Are these measurements different? How?

Where does the difference take place?

Which probe should we use?

W. Shao, J.L. Rougier, F. Devienne, and M. Viste, "**Improve RTT Measurement Quality via Clustering in Inter-Domain TE** ," IEEE/IFIP AnNet, 2016.
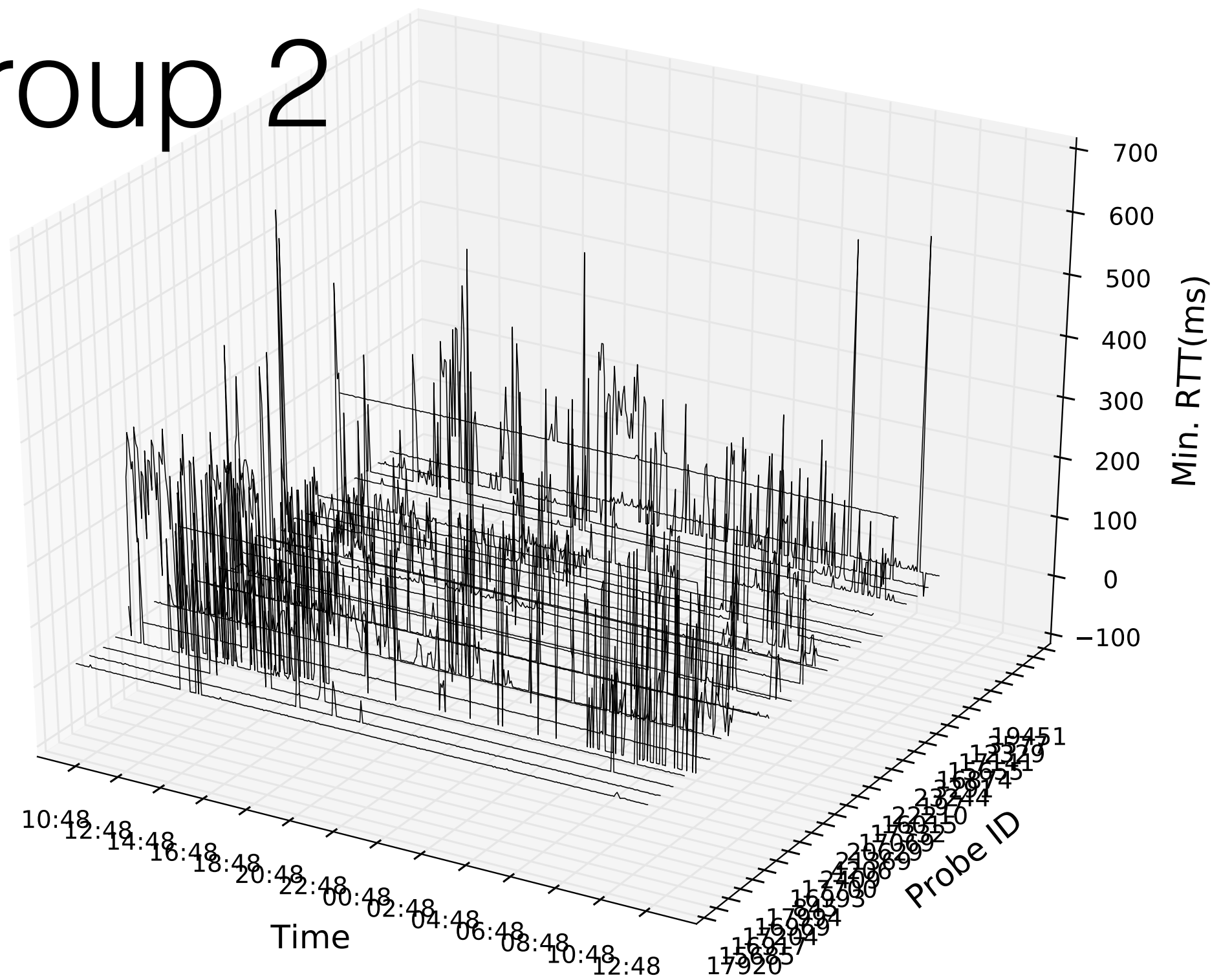
# end2end RTT Group 1

# end2end RTT Group 2

To measure is to see.

To see is to understand.

Understanding allows automation.

# Q&A

# Appendix

Not all references are given.
The listed ones could be a good starting point.

https://github.com/WenqinSHAO/NANOG67_prez.git

# Appendix-I

## Measurement-based Inter-domain TE

- N. Feamster, D. G. Andersen, H. Balakrishnan, and M. F. Kaashoek, "Measuring the effects of internet path faults on reactive routing," ACM SIGMETRICS Perform. Eval. Rev., vol. 31, no. 1, p. 126, 2003.
- A. Akella, B. Maggs, S. Seshan, A. Shaikh, and R. Sitaraman, "A measurement-based analysis of multihoming," SIGCOMM, 2003.
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- W. Shao, L. Ianonne, J.L. Rougier, F. Devienne, and M. Viste, "Scalable BGP Prefix Selection for Effective Inter-domain Traffic Engineering," IEEE/IFIP NOMS, 2016.

# Appendix-II

## Traffic volume forecasting

- ARMA family, e.g. ARIMA, SARIMA, FARIMA, $O(L^2)$, pre-process needed for each individual trace, L being historical record length.
- Artificial Neural Network family, e.g. TLFN, $O(L*M)$, M for number of hidden nodes, usually bigger than L.
- Wavelet,$O(L)$, pre-process needed, less accurate than FARIMA and ANN. H. Feng and Y. Shu, "Study on network traffic prediction techniques," Proceedings. Int. Conf. Wirel. Commun. Netw. Mob. Comput., vol. 2, no. 3, pp. 995-998, 2005.
- Grey model GM(1,1) predicts the accumulated value of a time series, $O(L)$. D. Julong, "Introduction to Grey System Theory,'' J. Grey Syst., vol. 1, pp. 1-24, 1989.

# Appendix-III

## Traffic dynamism

- K. Papagiannaki, N. Taft, and C. Diot, "Impact of Flow Dynamics on Traffic Engineering Design Principles," INFOCOM, 2004.
  - no clear correlation between throughput and its stability.

- J. J. Wallerich and A. Feldmann, "Capturing the variability of internet flows across time," INFOCOM, 2006.
  - throughput ranking of flows can change drastically over time.

- W. Zhang, J. Bi, J. Wu, and B. Zhang, "Catching popular prefixes at AS border routers with a prediction based method," Comput. Networks, vol. 56, no. 4, pp. 1486–1502, Mar. 2012.
  - assumed positive correlation between popularity and stability.

# Appendix-IV

## FIB caching

- L. Iannone and O. Bonaventure, "On the cost of caching locator/ID mappings," CoNEXT, 2007.
- C. Kim, M. Caesar, A. Gerber, and J. Rexford, "Revisiting route caching: The world should be flat," PAM, 2009.
- H. Ballani, P. Francis, T. Cao, and J. Wang, "Making routers last longer with ViAggre," NSDI, pp. 453–466, 2009.
- N. Sarrar, S. Uhlig, A. Feldmann, R. Sherwood, and X. Huang, "Leveraging Zipf's law for traffic offloading," CCR, vol. 42, no. 1, p. 16, Jan. 2012.
- W. Zhang, J. Bi, J. Wu, and B. Zhang, "Catching popular prefixes at AS border routers with a prediction based method," Comput. Networks, vol. 56, no. 4, pp. 1486–1502, Mar. 2012.
  - GM(1,1) outperforms LFU, LRU