Towards the Science of Network Measurement

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Network measurement problems

- Topology characterization
- Geolocation problems
- Performance problems
- Reliability problems
- Routing problems
- Security problems
- …

Why measuring network path?

Performance metrics

Latency

Delay variation (jitter)

Connectivity

Packet loss/reordering

Link/path capacity

Available Bandwidth

TCP throughput

Router hop (count)

Packet duplication

…

Applications

Traffic engineering

- Network tomography
- Path fingerprinting
- Routing optimization
- QoS routing, admission control, channel assignment in WLAN

User profiling

- Network resource planning
- SLA verification

Application performance tuning

- Rate adaption for VoIP/video streaming apps
- Distance/location prediction for overlay networks, P2Ps, CDNs

…

Approaches to path performance measurement

- Passive
  - Per flow
  - Per packet
- Active
  - Client side vs server side
  - One-sided vs two-sided
- Passive-active
  - Passively waiting for incoming packet for active measurement

Current state of active measurement

- Two-sided: OWAMP and TWAMP
- One sided: *Best-effort* measurement (e.g., ping, ping, ping …)
  - Connectionless
  - Not reliable in terms of measurability and accuracy
  - Measuring the wrong thing

Best-effort measurement

- Best-effort measurement is designed for reachability test.
- Wrongly extending reachability test performance test:
  - ICMP packets measure IP's control plane (not the data plane)
  - TCP SYN/RST segments measure TCP's control plane (not the data plane)
- Do not differentiate between system delay and network delay.

Beyond best-effort measurement

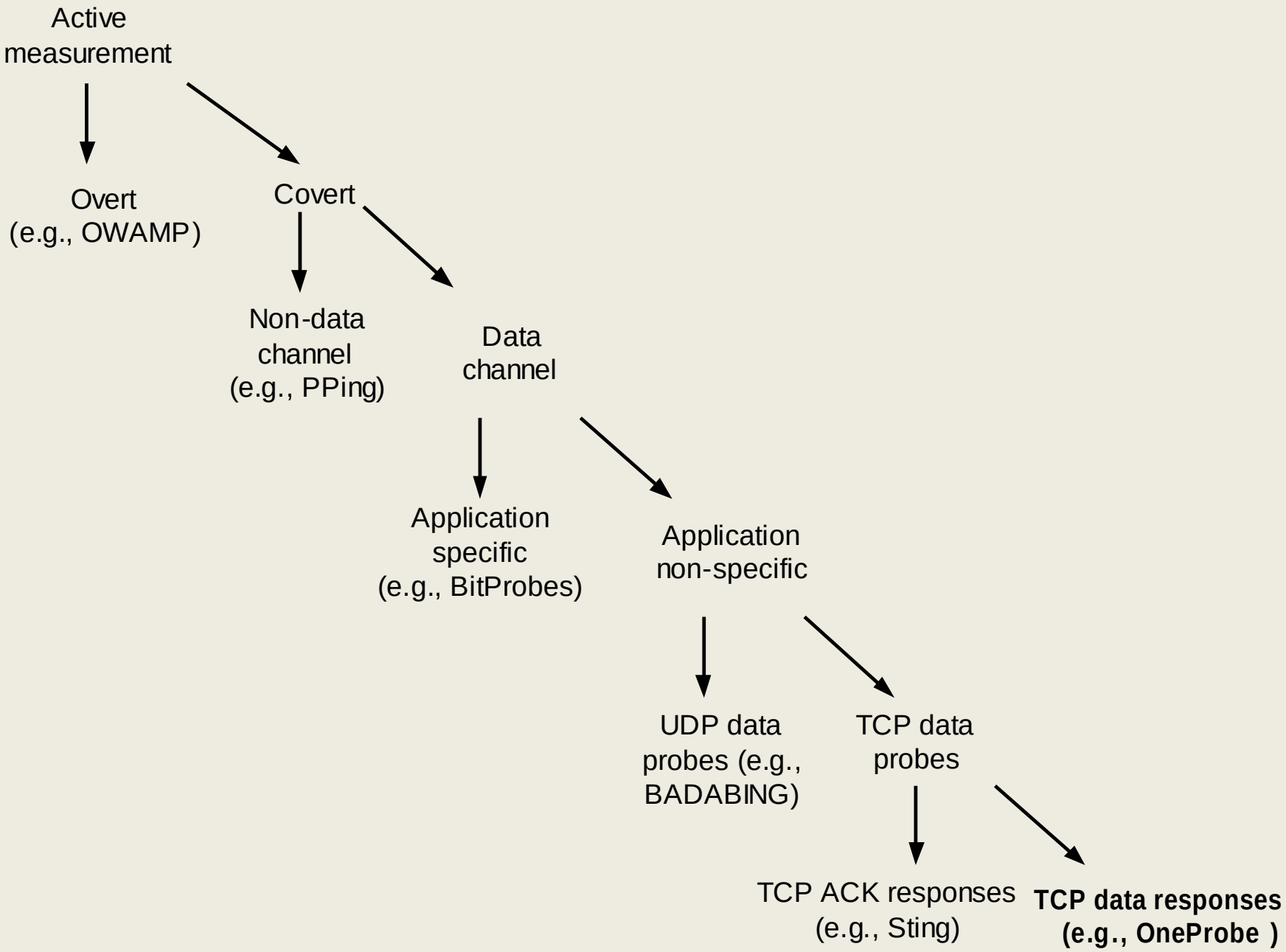
- Measuring the data path
  - In-band vs out-of-band
  - Transport/application specific
  - Load-balancing/traffic engineering below L3
- Measuring the network part
  - Mitigate the impacts of the network nodes
  - Measuring paths to proxies or original servers
- The manner of measurement
  - Sampling patterns and rates
  - Avoid self-induced measurement results
  - Choice of packet sizes

Where to start?

- A possibility is a two-side measurement tool, such as OWAMP in perfSONAR.
  - A complete control of the measurement parameters
  - But not measuring application-specific data paths
  - Deployment is costly.

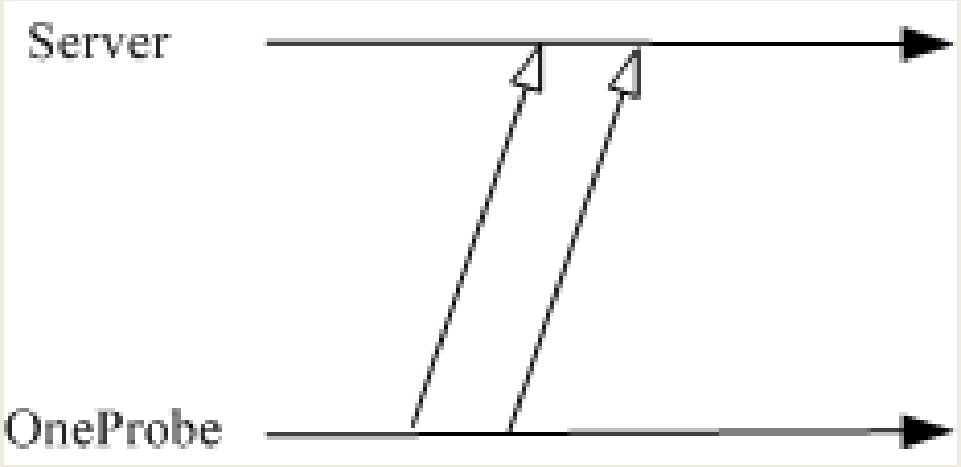
Our starting point

- OneProbe: A TCP-data-channel measurement approach
  - Stateful measurement
  - Can control the size of the probe and response data packets
  - Can control sampling rate and pattern by using multiple TCP connections
  - A single observation based on
    - Two probe data packets and elicited response data packets


Active measurement
Overt (e.g., OWAMP)
Covert
Non-data channel (e.g., PPing)
Data channel
Application specific (e.g., BitProbes)
Application non-specific
UDP data probes (e.g., BADABING)
TCP data probes
TCP ACK responses (e.g., Sting)
TCP data responses (e.g., OneProbe)

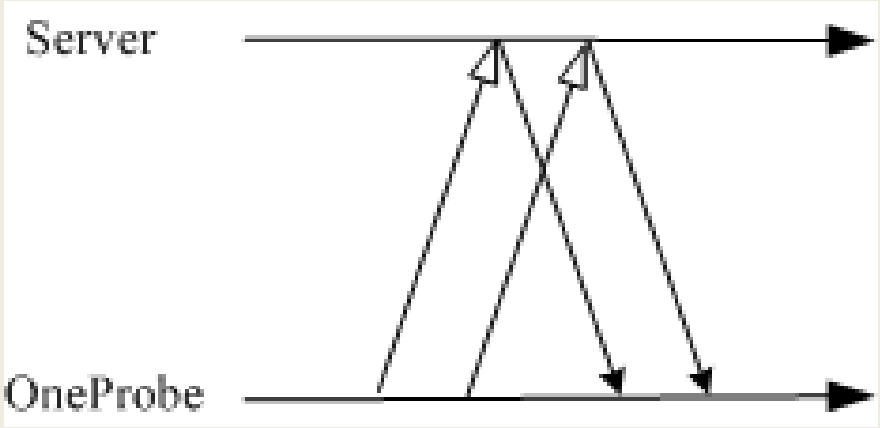
OneProbe's primitive operation

- Send two back-to-back probe data packets.
  - Capacity measurement based on packet-pair dispersion
  - At least two packets for packet reordering
  - Determine which packet is lost.



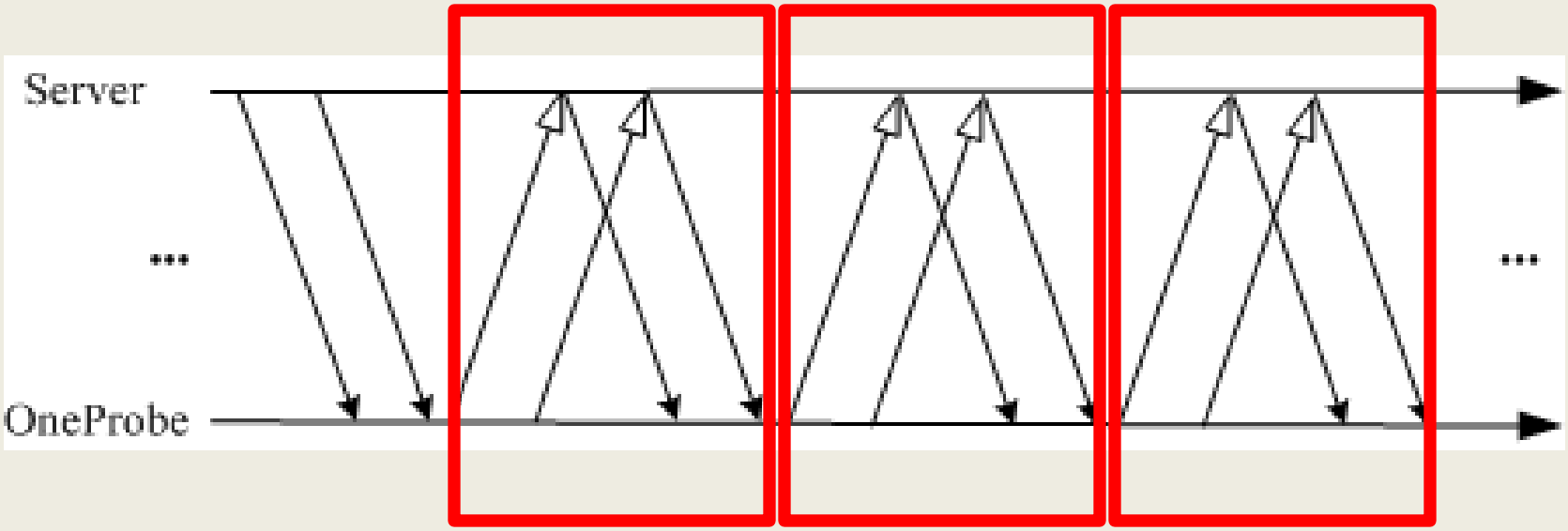
The probe design (cont'd)

- Similarly for the response packets

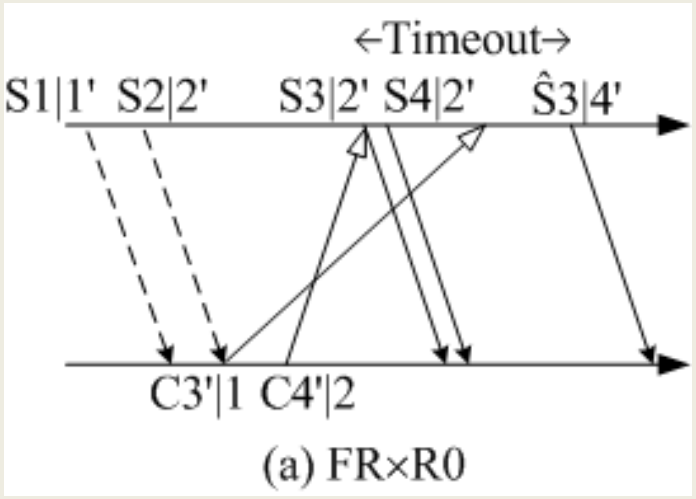


- Each probe packet elicits a response packet.
  - Adv. Window = 2 and acknowledge only 1 packet.

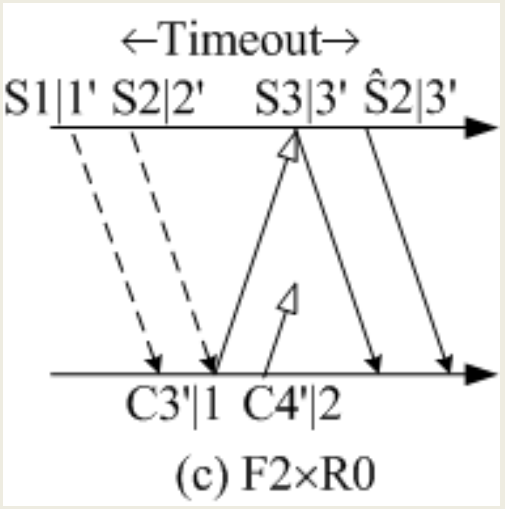
Bootstrapping and continuous monitoring



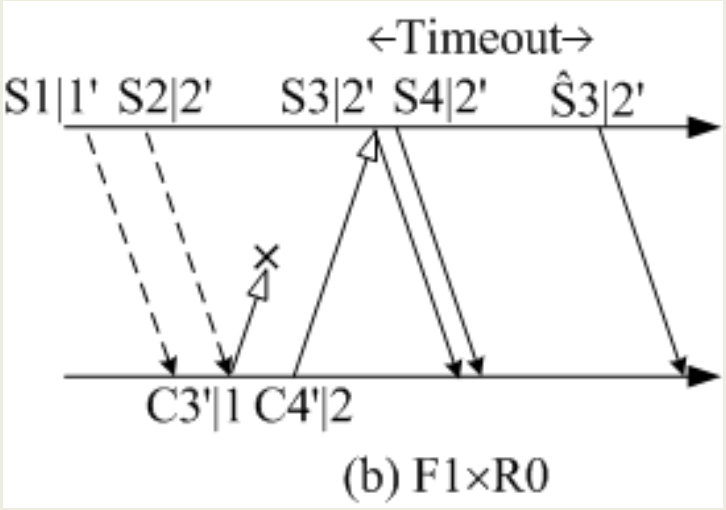
Loss and reordering measurement via response diversity



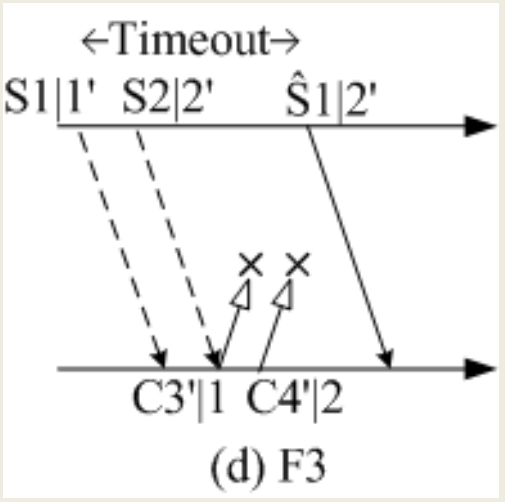
(a) FR×R0



(c) F2×R0



(b) F1×R0



(d) F3

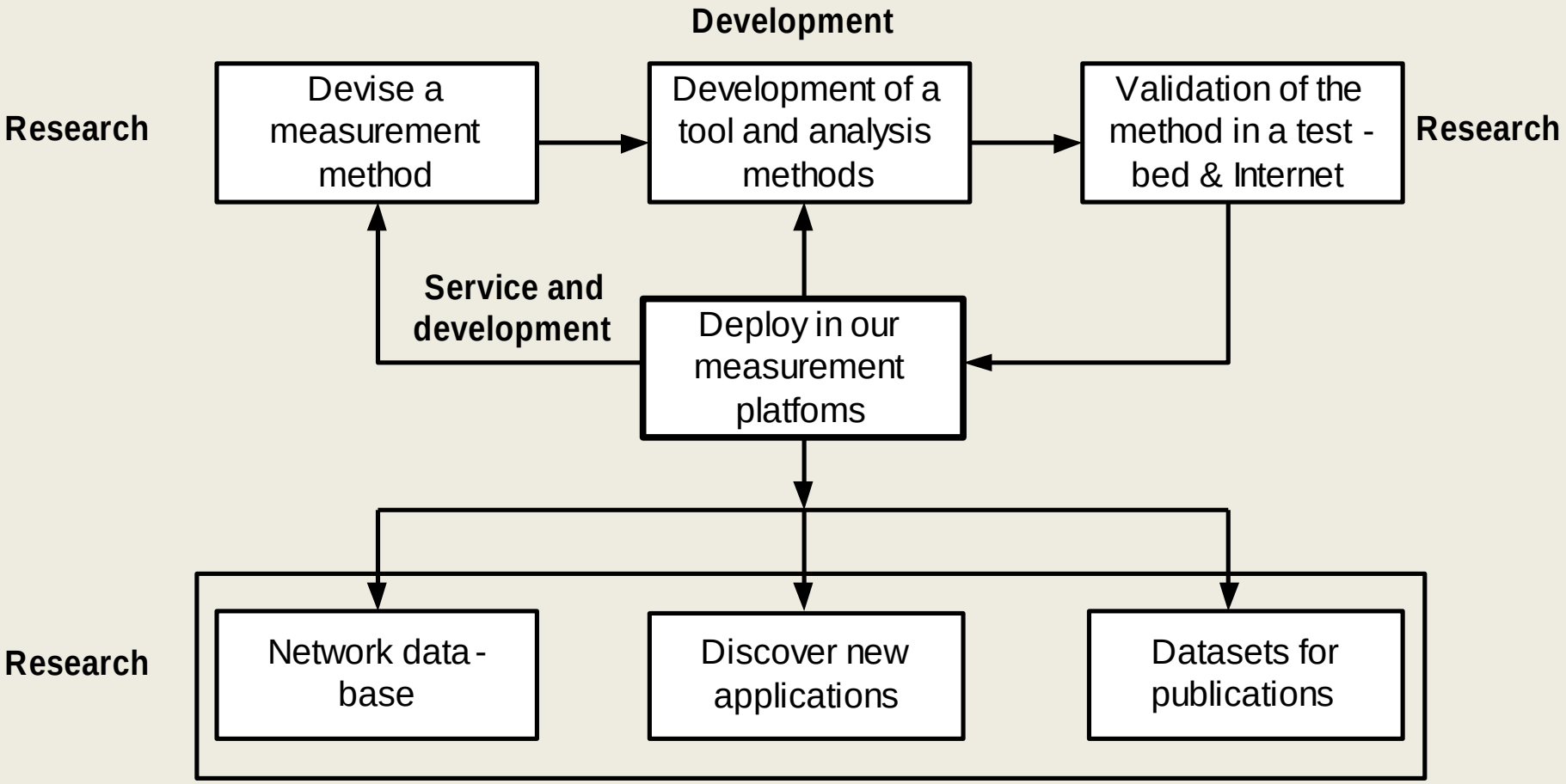
18 possible path events

	R0	RR	R1	R2	R3
F0	√	√	√	√	√
FR	√	√	√	√	√
F1	√	√	√	√	√
F2	√	–	√	–	–
F3	–	–	–	–	–

Based on their response packets

Path events	1st response packets	2nd response packets	3rd response packets
1. F0×R0	$S3\|3'$	$S4\|4'$	–
2. F0×RR	$S4\|4'$	$S3\|3'$	–
3. F0×R1	$S4\|4'$	$\widehat{S3}\|4'$	–
4. F0×R2	$S3\|3'$	$\widehat{S3}\|4'$	–
5. F0×R3	$\widehat{S3}\|4'$	–	–
6. FR×R0	$S3\|2'$	$S4\|2'$	$\widehat{S3}\|4'$
7. FR×RR	$S4\|2'$	$S3\|2'$	$\widehat{S3}\|4'$
8. FR×R1	$S4\|2'$	$\widehat{S3}\|4'$	–
9. FR×R2	$S3\|2'$	$\widehat{S3}\|4'$	–
10. FR×R3	$\widehat{S3}\|4'$	–	–
11. F1×R0	$S3\|2'$	$S4\|2'$	$\widehat{S3}\|2'$
12. F1×RR	$S4\|2'$	$S3\|2'$	$\widehat{S3}\|2'$
13. F1×R1	$S4\|2'$	$\widehat{S3}\|2'$	–
14. F1×R2	$S3\|2'$	$\widehat{S3}\|2'$	–
15. F1×R3	$\widehat{S3}\|2'$	–	–
16. F2×R0	$S3\|3'$	$\widehat{S2}\|3'$	–
17. F2×R1	$\widehat{S2}\|3'$	–	–
18. F3	$\widehat{S1}\|2'$	–	–

Our research model



Measurement methods

- RTT, bi-directional loss rate, bi-directional reordering rate, and delay jitter
  - *Proc. USENIX Annual Tech. Conf.* 2009.
- Bi-directional bottleneck capacity
  - *Proc. ACM CoNEXT* 2011
  - *Proc. ACM CoNEXT* 2009
- Loss-delay analysis
  - *ACM/USENIX IMC* 2010
- Fast available bandwidth estimate
  - *ACM Multimedia Systems Conf.* 2012

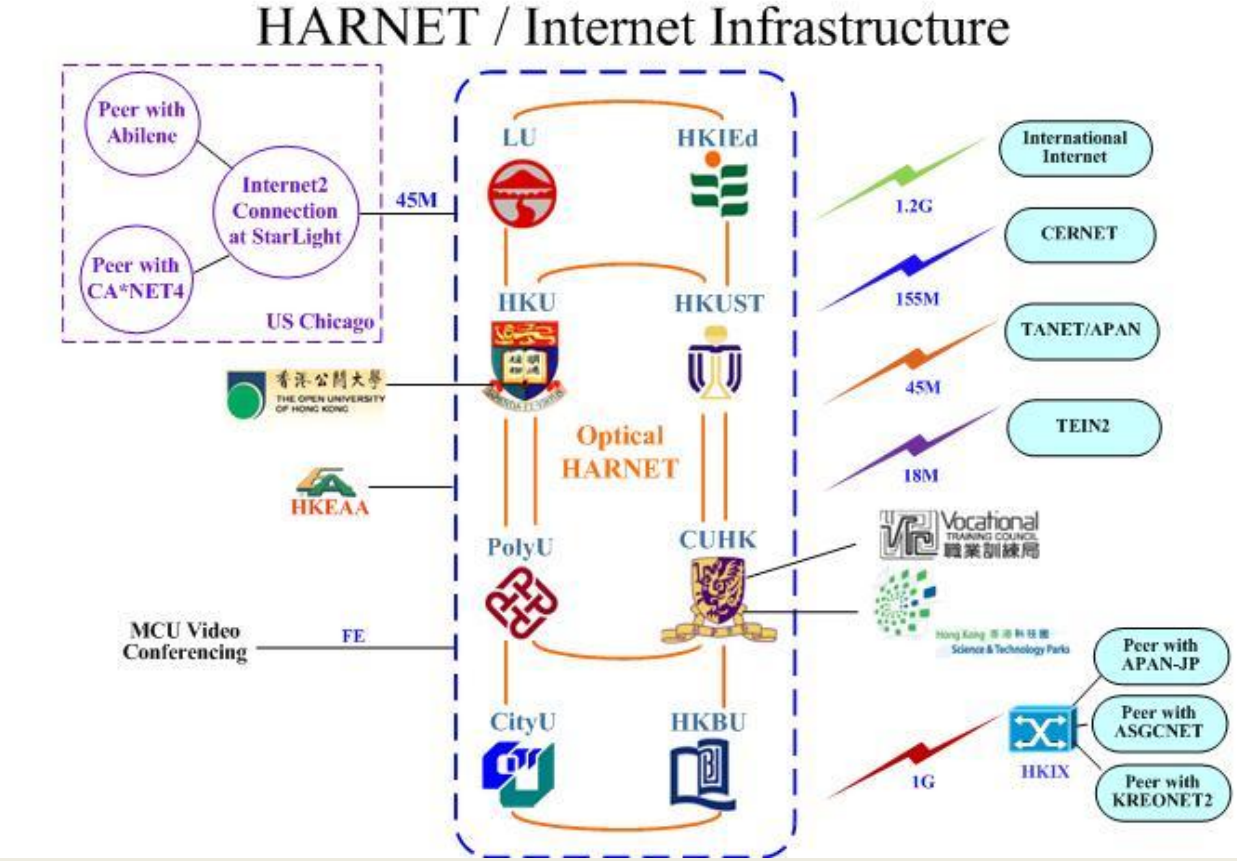
Datasets are used in

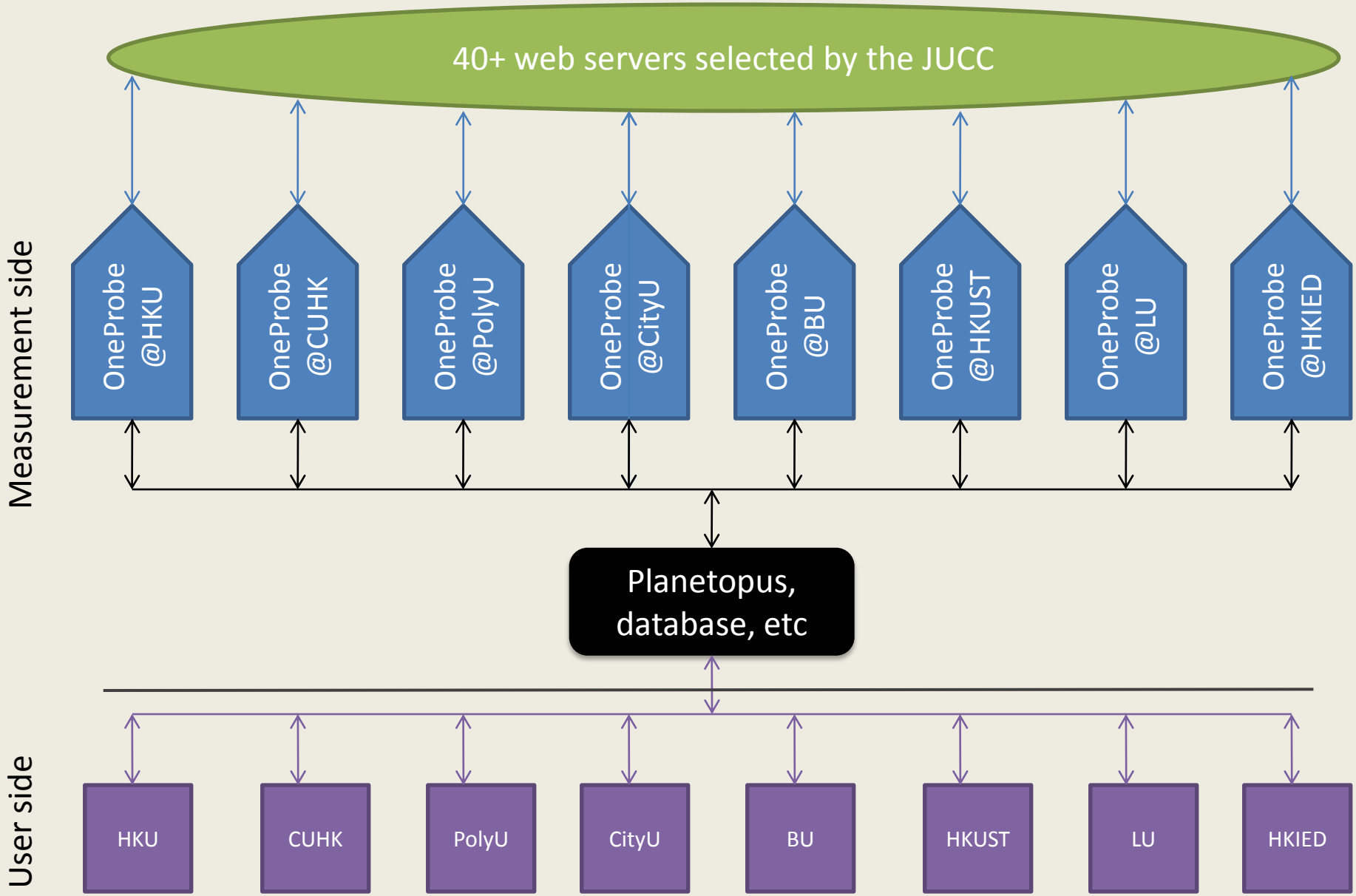
- “An Efficient Approach to Multi-level Route Analytics,” *Proc. IFIP/IEEE IM 2013*.
- “MonoScope: Automated Network Faults Diagnosis Based on Active Measurements,” *Proc. IFIP/IEEE IM 2013*.
- “Characterizing Inter-domain Rerouting after Japan Earthquake,” *Proc. IFIP NETWORKING 2012*.
- “Non-cooperative Diagnosis of Submarine Cable Faults,” *Proc. PAM 2011*.
- “Could Ash Cloud or Deep-Sea Current Overwhelm the Internet?" *Proc. USENIX HotDep 2010*.

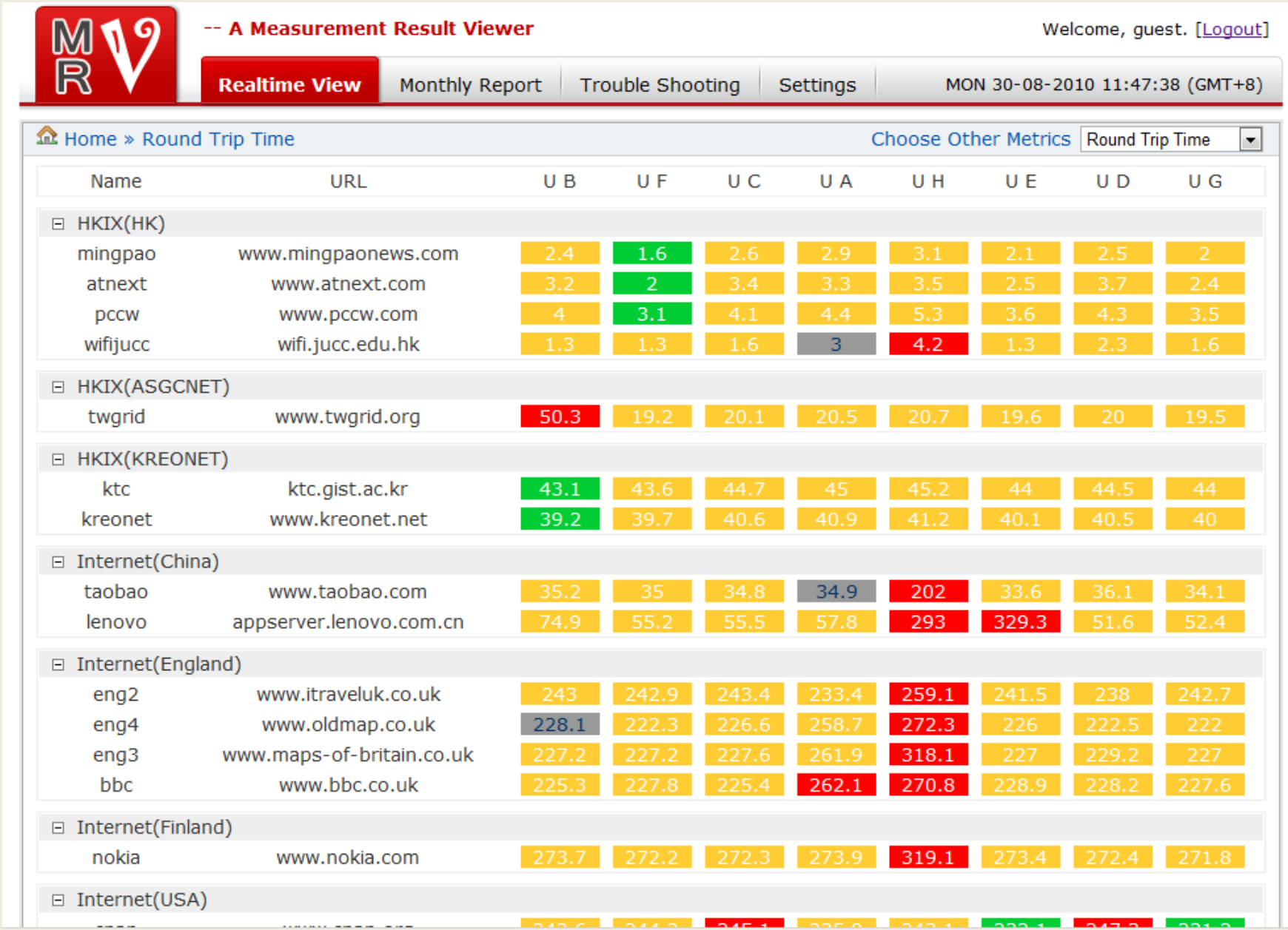
Measurement platforms

- “Performance Monitoring and Measurement of HARNET," funded by the Joint Universities Computer Centre, since January 2009.
- “Performance Monitoring of Critical Network and Service Infrastructure in Hong Kong” 2013.

HARNET measurement platform

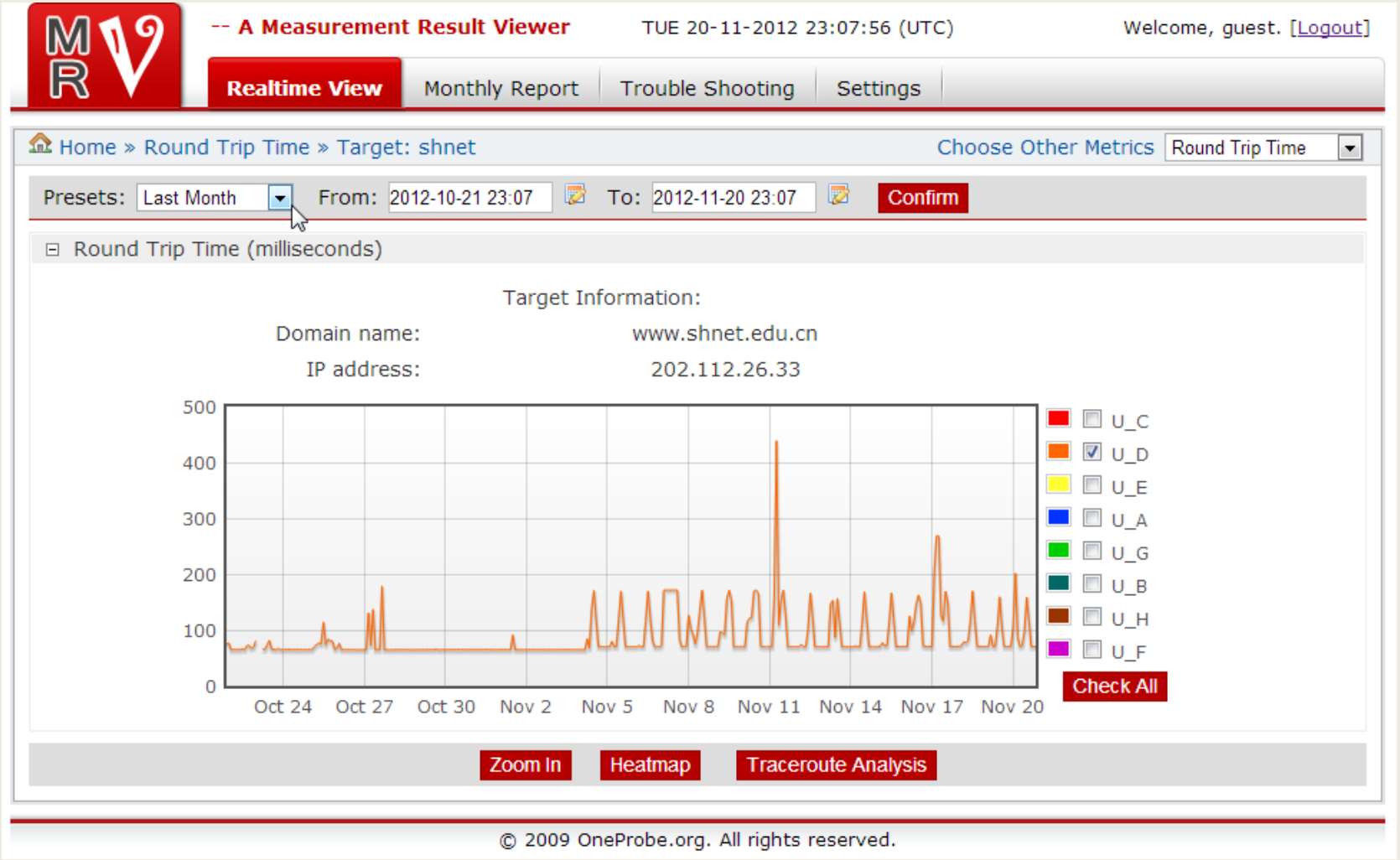



40+ web servers selected by the JUCC
Measurement side
OneProbe @HKU
OneProbe @CUHK
OneProbe @PolyU
OneProbe @CityU
OneProbe @BU
OneProbe @HKUST
OneProbe @LU
OneProbe @HKIED
Planetopus, database, etc
User side
HKU
CUHK
PolyU
CityU
BU
HKUST
LU
HKIED

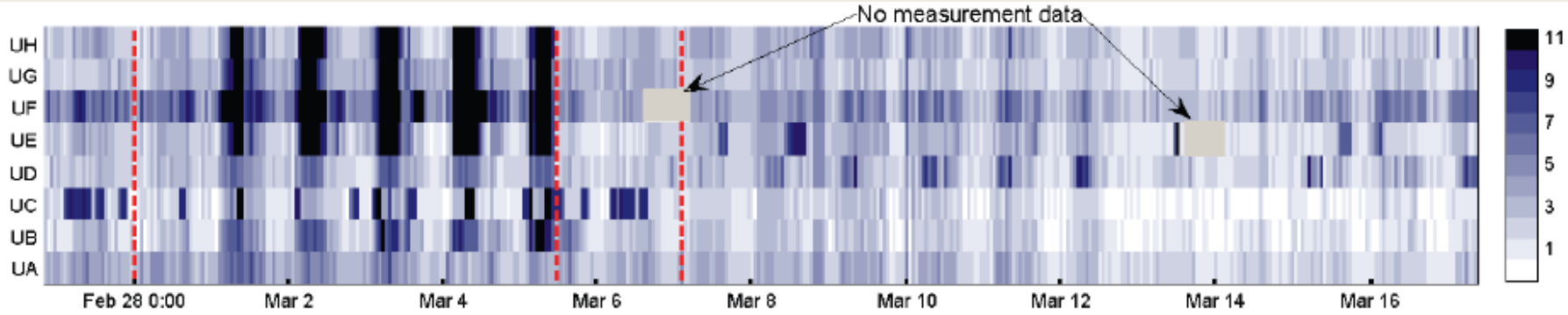


Name	URL	U B	U F	U C	U A	U H	U E	U D	U G
HKIX(HK)									
mingpao	www.mingpaonews.com	2.4	1.6	2.6	2.9	3.1	2.1	2.5	2
atnext	www.atnext.com	3.2	2	3.4	3.3	3.5	2.5	3.7	2.4
pccw	www.pccw.com	4	3.1	4.1	4.4	5.3	3.6	4.3	3.5
wifijucc	wifi.jucc.edu.hk	1.3	1.3	1.6	3	4.2	1.3	2.3	1.6
HKIX(ASGCNET)									
twgrid	www.twgrid.org	50.3	19.2	20.1	20.5	20.7	19.6	20	19.5
HKIX(KREONET)									
ktc	ktc.gist.ac.kr	43.1	43.6	44.7	45	45.2	44	44.5	44
kreonet	www.kreonet.net	39.2	39.7	40.6	40.9	41.2	40.1	40.5	40
Internet(China)									
taobao	www.taobao.com	35.2	35	34.8	34.9	202	33.6	36.1	34.1
lenovo	appserver.lenovo.com.cn	74.9	55.2	55.5	57.8	293	329.3	51.6	52.4
Internet(England)									
eng2	www.itraveluk.co.uk	243	242.9	243.4	233.4	259.1	241.5	238	242.7
eng4	www.oldmap.co.uk	228.1	222.3	226.6	258.7	272.3	226	222.5	222
eng3	www.maps-of-britain.co.uk	227.2	227.2	227.6	261.9	318.1	227	229.2	227
bbc	www.bbc.co.uk	225.3	227.8	225.4	262.1	270.8	228.9	228.2	227.6
Internet(Finland)									
nokia	www.nokia.com	273.7	272.2	272.3	273.9	319.1	273.4	272.4	271.8
Internet(USA)									

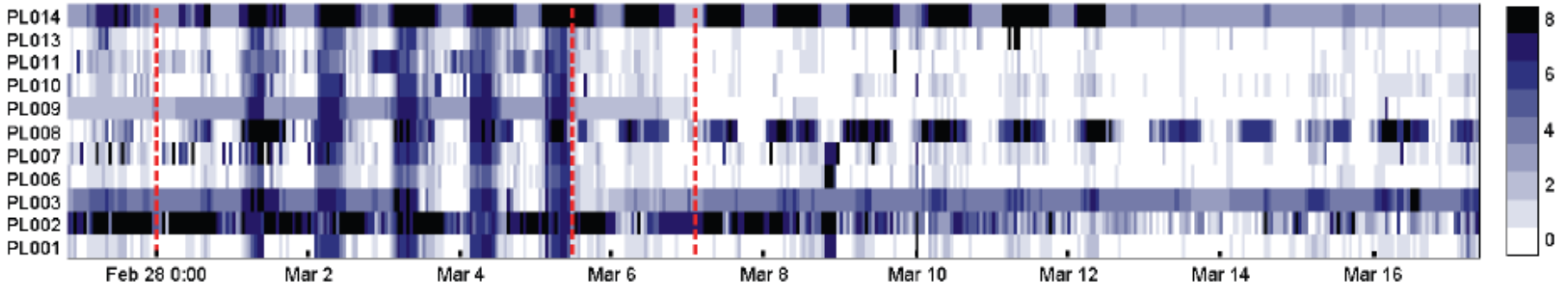
Time-series plots



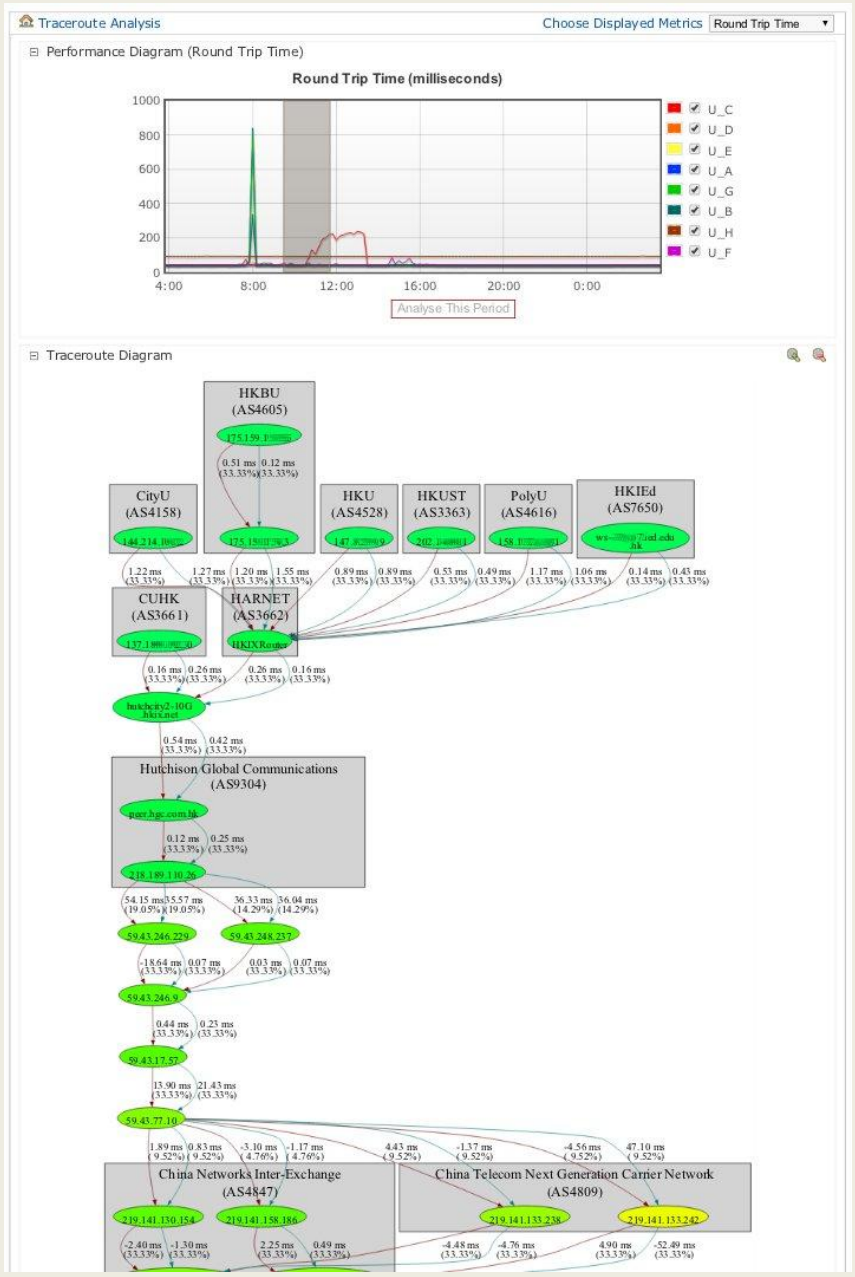
Time-series heat map



(c) Reverse paths (grouped by sources).



(d) Reverse paths (grouped by destinations).


Traceroute Analysis
Choose Displayed Metrics
Round Trip Time
Performance Diagram (Round Trip Time)
Round Trip Time (milliseconds)
1000
800
600
400
200
0
4:00
8:00
12:00
16:00
20:00
0:00
U_C
U_D
U_E
U_A
U_G
U_B
U_H
U_F
Analyse This Period
Traceroute Diagram
HKBU
(AS4605)
CityU
(AS4158)
HKU
(AS4528)
HKUST
(AS3363)
PolyU
(AS4616)
HKIEd
(AS7650)
CUHK
(AS3661)
HARNET
(AS3662)
HKIXRouter
Hutchison Global Communications
(AS9304)
China Networks Inter-Exchange
(AS4847)
China Telecom Next Generation Carrier Network
(AS4809)

Offering network path measurement as a service

- “Design and Implementation of a Unified Box for Offering Network Path Measurement as a Service,” Funded by ITF
- Major deliverables:
  - Novel network measurement boxes
  - Novel network measurement platforms
    - Residential broadband measurement
    - IPv6 measurement

New measurement platforms

A service and research platform

- Performance problems
  - E.g., QoE measurement of HTTP video (“QDASH: A QoE-Aware DASH System”)
- Reliability problems
  - E.g., fault localization (“MonoScope: Automated Network Faults Diagnosis Based on Active Measurements”)
- Routing problems
- Security problems

Conclusions

- Network measurement is a primitive in network science and applications.
- But the current status is very much best-effort measurement.
- Not enough skepticism on the measurement accuracy
- What we need are reliable measurement apparatus and platform.
- Network science =? Network data science

March 18-20, 2013

PAM 2013 | HONG KONG

Passive and Active Measurement Conference

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Welcome to PAM 2013!

The organizing committee is excited to invite you to take part in the 14th Passive and Active Measurement conference will be held March 18-20, 2013 in Hong Kong at The Hong Kong Polytechnic University.

RECENT UPDATES

June 22, 2012
The official website of PAM 2013 is online.

PARTNERS

SOCIAL NETWORKS

Thanks
(oneprobe.org)