KNOM Tutorial 2003

Internet Traffic Measurement and Analysis

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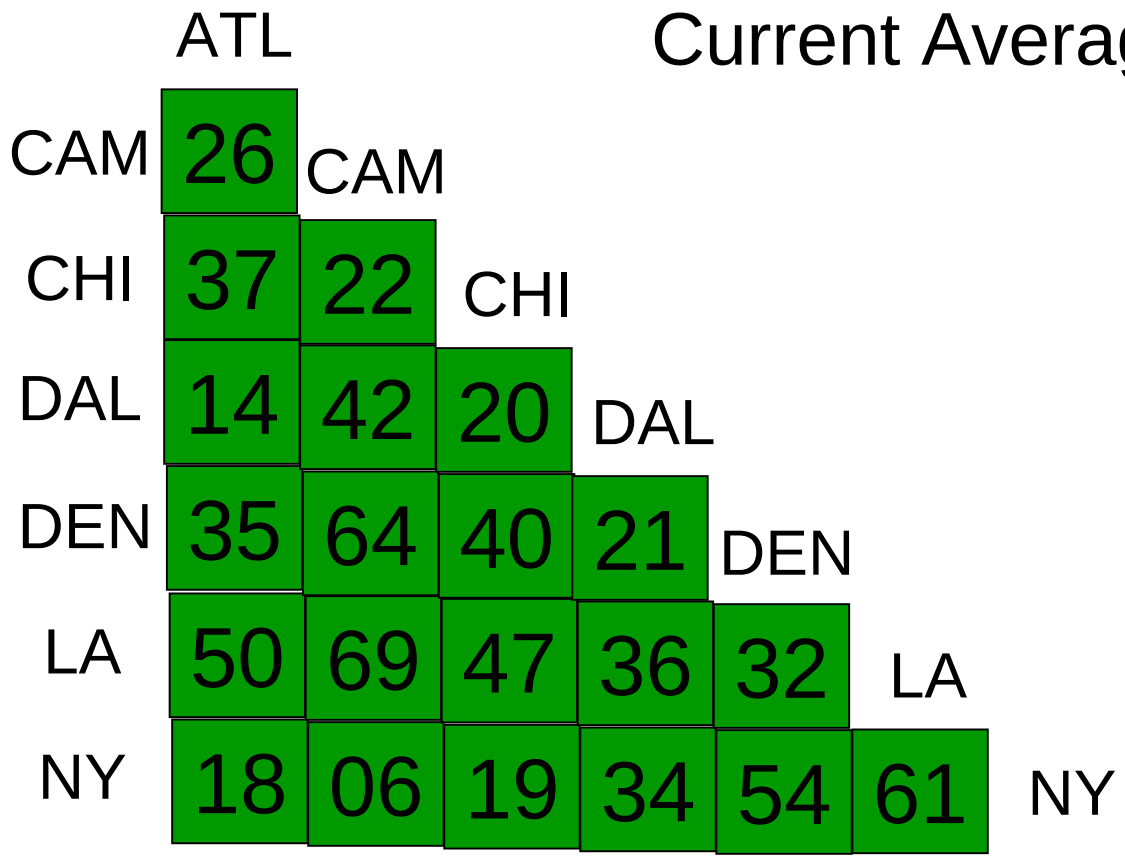
Overview

- Definition of Traffic Matrix
  - Traffic demand, delay, loss
- Applications of Traffic Matrix
  - Engineering, research, SLAs
- Challenges in Obtaining Traffic Matrix
  - Limitation of NetFlow and active probes
  - Challenges in measurement and modeling
- Summay & Future Work

Definition of Traffic Matrix

- What is a traffic matrix?
  - A matrix built on metric of interest
  - Traffic demand matrix
    - How much traffic flows from point A to point B
    - Granularity: PoP, router, link, prefix
  - Delay matrix
    - How much delay from point A to point B
    - Granularity: PoP, router, link, end hosts
  - Loss matrix
    - How many packets are dropped from point A to point B
    - Granularity: PoP, router, end hosts

Example : AT&T Latency Matrix



Current Average : 35 msec

Latency in milliseconds

Traffic Demand Matrix

- Not part of SLAs
  - Hard to obtain
  - Few available publicly

Delay Matrix

- Usually a matrix of average delay of *ping*s between routers of random selection per PoP
  - Average of all PoP-to-PoP delays => SLA
- At end hosts
  - Easy to get using *ping*s between hosts of interest

Loss Matrix

- Usually a matrix of average loss rate of *ping*s between routers of random selection per PoP
  - Average of all PoP-to-PoP loss rates => SLA
- At end hosts
  - Easy to get using *ping*s between hosts of interest

Applications of Traffic Matrix

- Marketing/Sales
  - How much traffic does customer A send from point #1 to point #2?
    - Where should customer A buy more capacity from us?
  - Is most traffic originating in Korea stay within Korea?
    - What is the trend in international traffic growth?
  - What is the performance that customer A sees?
    - Do we have an edge over our competitors?

Applications of Traffic Matrix

- Network Operators
  - Capacity Planning
    - How much traffic do we have from point A to point B?
    - How much capacity should we add?
    - When should we add more capacity?
  - Network Engineering
    - Where is the hot spot? – From SNMP
    - What if a link fails from point A to point B?
    - What if we move traffic from point A to point B?

Applications of Traffic Matrix

- Customers: SLAs
  - What quality of service am I getting?
    - How much delay do I get from ISP A?
    - How much loss do I experience from ISP A?
    - Can I get delay under X ms from ISP A?
    - What is the most popular destination of my traffic?

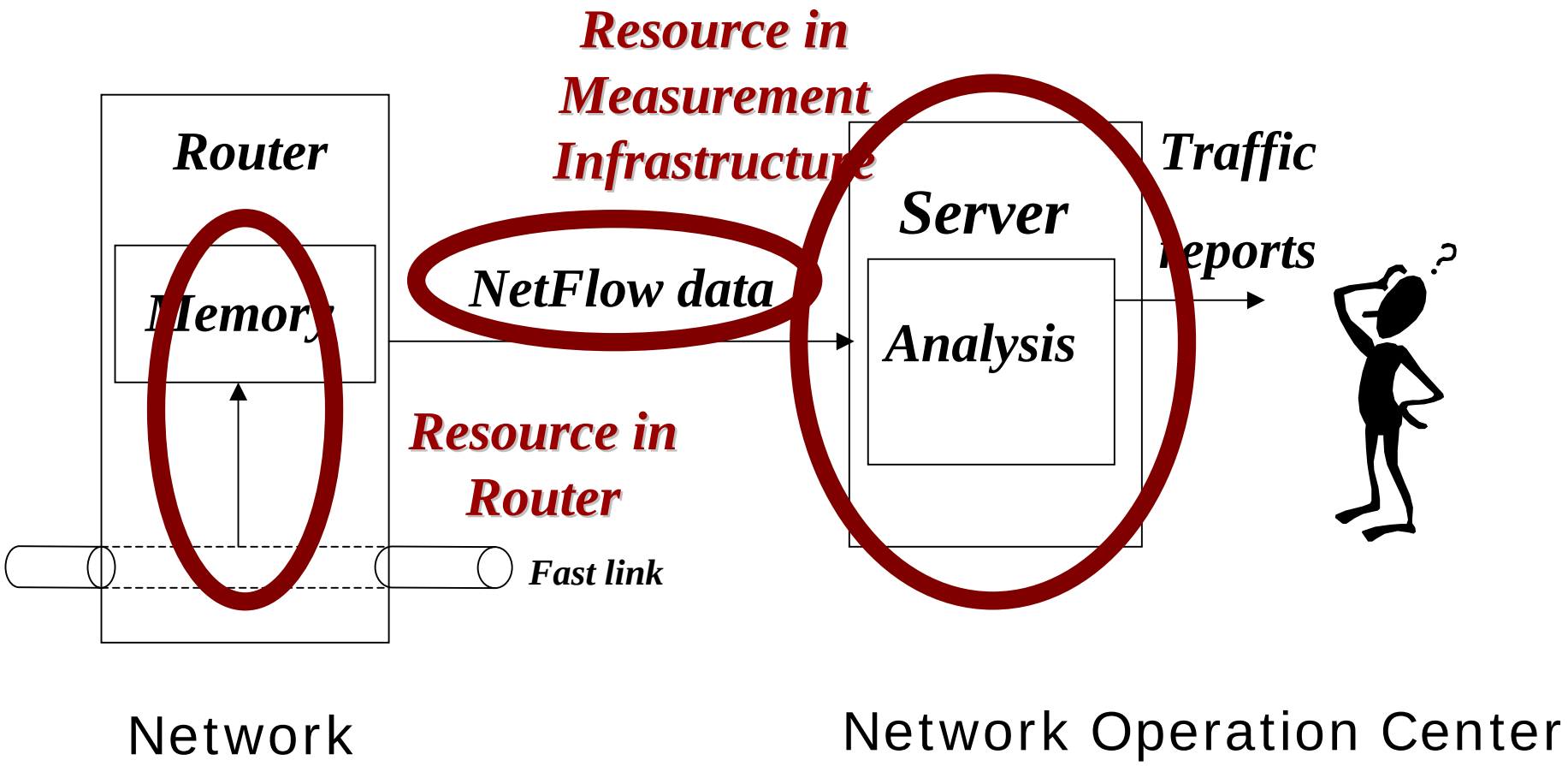
Applications of Traffic Matrix

- Researchers
  - Traffic modeling
    - How does TM evolve over time?
    - What is the fanout factor of traffic?
    - How much more capacity do we expect between point A and point B?
  - Example: IP over WDM
    - Given physical topology of routers and optical nodes, what is the “best” virtual topology?
    - Based on traffic demand matrix

Challenges in Obtaining Traffic Matrix

- Traffic Demand Matrix
  - resource requirements in routers
    - # of concurrently active flows
  - resource requirements in measurement infrastructure
    - production rate of flow statistics
  - traffic characterization
    - packet/byte rate of original traffic
    - rate o f occurrence of original flows
    - average packet/bytes per original flow

Resource Requirements



Most Popular Tools of Choice?

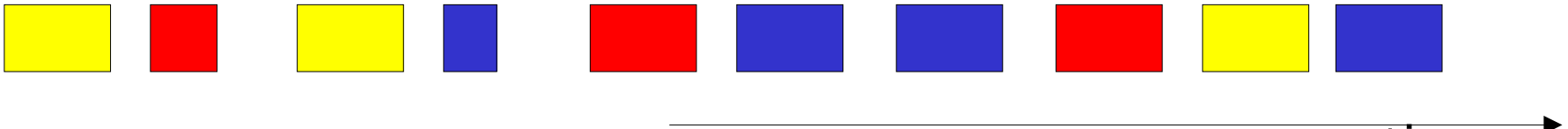
- NetFlow for traffic demand matrix
- ping for delay and loss matrix

NetFlow

- Cisco's "proprietary" tool
  - Not an IETF standard
- Basic idea
  - Based on (src ip, src port, dst ip, dst port, proto)
  - Records byte/packet/duration per flow
  - Cannot keep up with high speed links
  - Can sample every N^{th} packet

NetFlow Sampling

Original Packets



time

flow #1 flow #2 flow #3

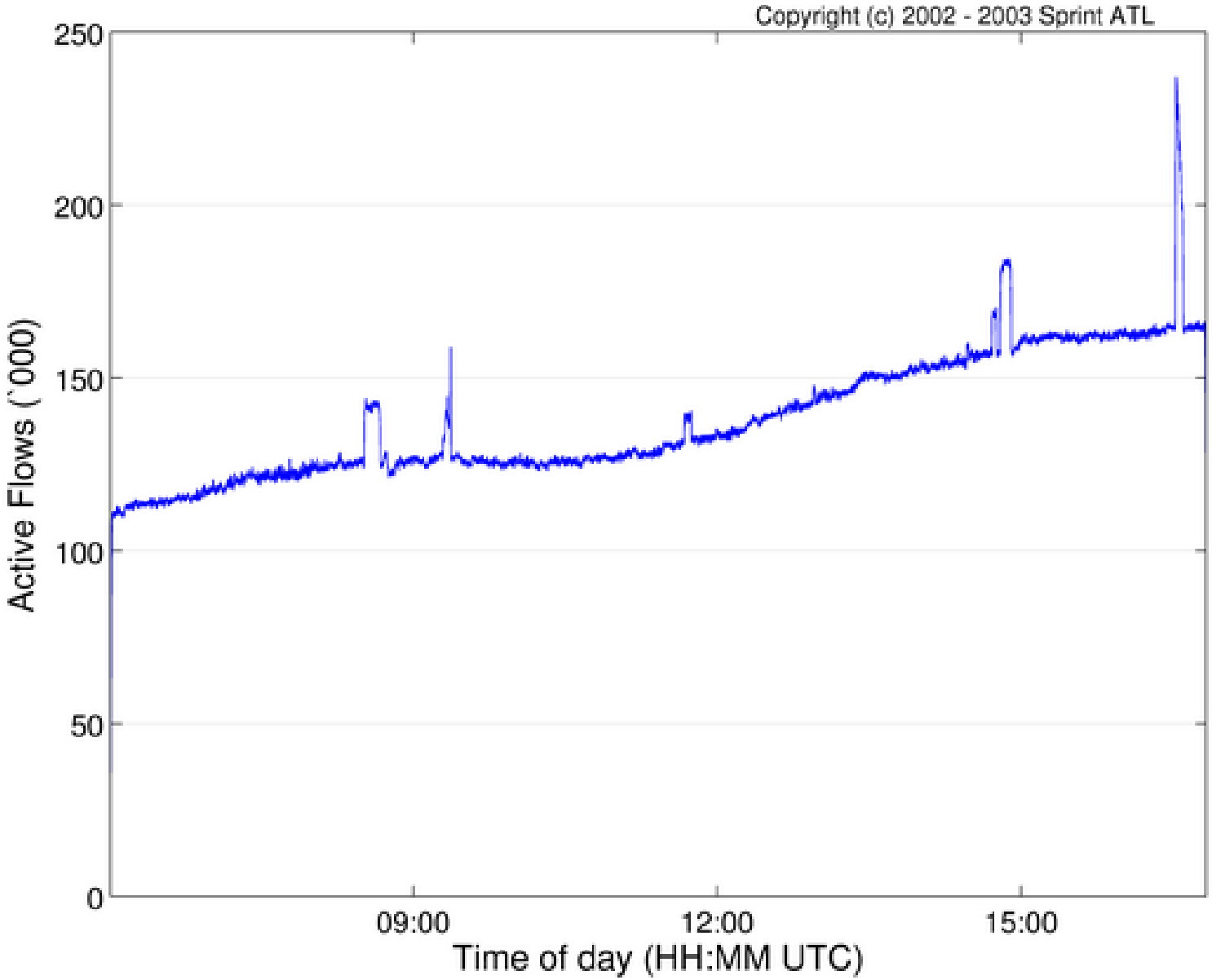
Sampled Packets (every 1/N, N=3)

time

Limitation of NetFlow

- Scalability
  - Historically NetFlow had a “performance issue”
  - Never deployed at the core
  - Number of flows in case of DDoS attacks beyond capacity
    - Network melt down

Number of Active Flows on a OC-48 Link

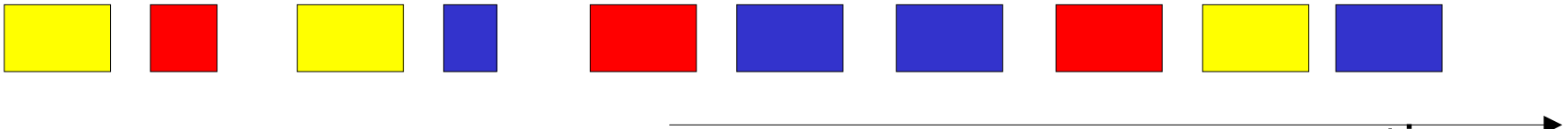


Limitation of NetFlow

- Representativeness
  - Can we estimate # of total flows from # of sampled flows accurately?
  - Can we estimate # of total WWW flows from # of sampled WWW flows accurately?
  - Metrics of interest:
    - # of flows, flow rate,
  - Packet sampling
    - reduce effective packet rate
    - save cost: slower memory sufficient (DRAM vs SRAM)

NetFlow Sampling

Original Packets



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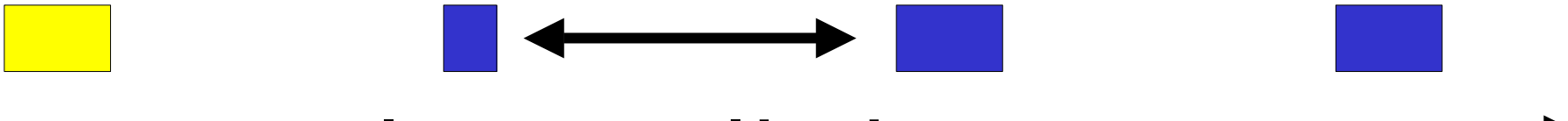
Sampled Packets (every 1/N, N=3)



Flow Splitting

time

Comparison of sparse and non-sparse applications

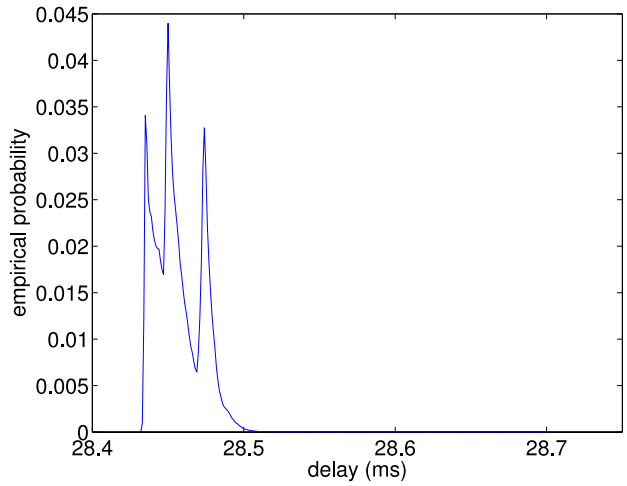
- Flow definition
  - 5-tuple = (src ip, src port, dst ip, dst port, proto)
  - interflow timeout = T
- Increase timeout T
  - potentially less splitting
  - fewer measured flows, more active flows
- Sparse vs. non-sparse flows
  - napster vs. www
  - # of mean active flows change differently over T
  - No simple model of rate and # active flows based on aggregate traffic rates
  - Model sparse and non-sparse flows separately [Duffield03]

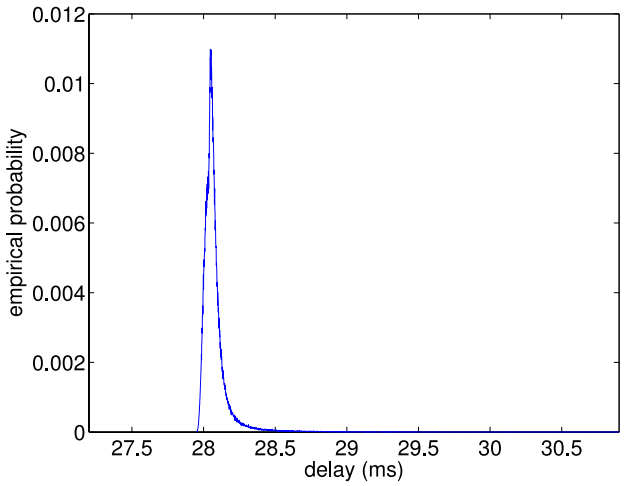
Challenges in Delay Monitoring

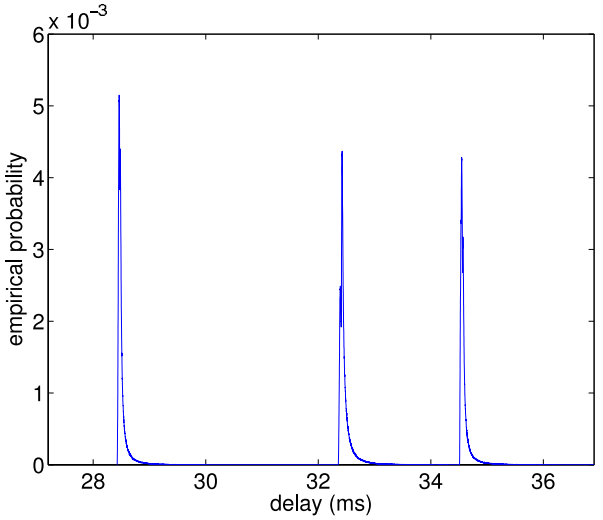
- Not much is known about delay within ISP
  - People think they know delay, but ...
  - Cisco SAA implementation on GSR did not consider clock synchronization, and outputs meaningless numbers
- Too many paths to cover
  - hop-by-hop addition not yet possible

Limitation of Active Probes

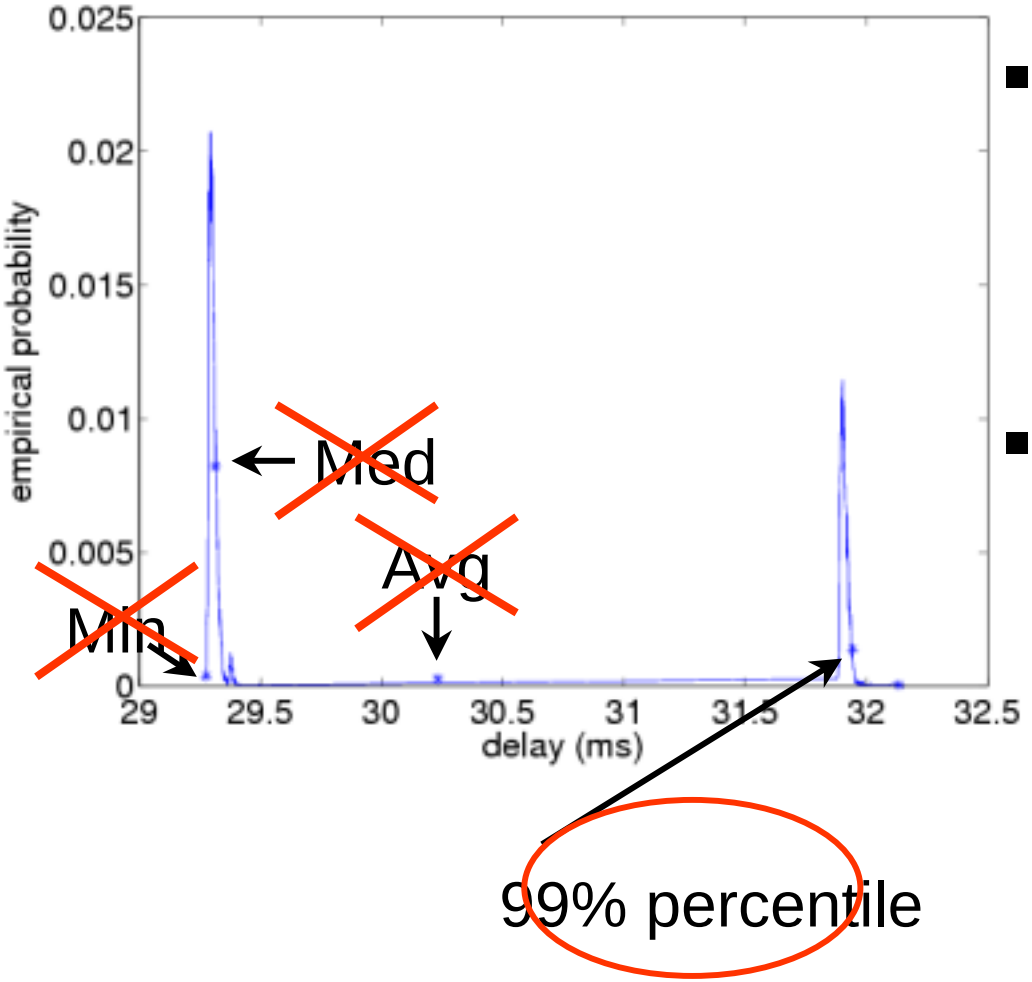
- Representativeness [Choi04]
  - Average? Median?







Suitable Statistic: Percentile!



- ~~Mode~~ detection is hard
  - Difficult to distinguish *small from big*
  - Don't know *how many ahead* of them
- High-percentile
  - represents upper bound for "most" delay
  - requires a very small number of probes to estimate

Sampling for Demand Matrix

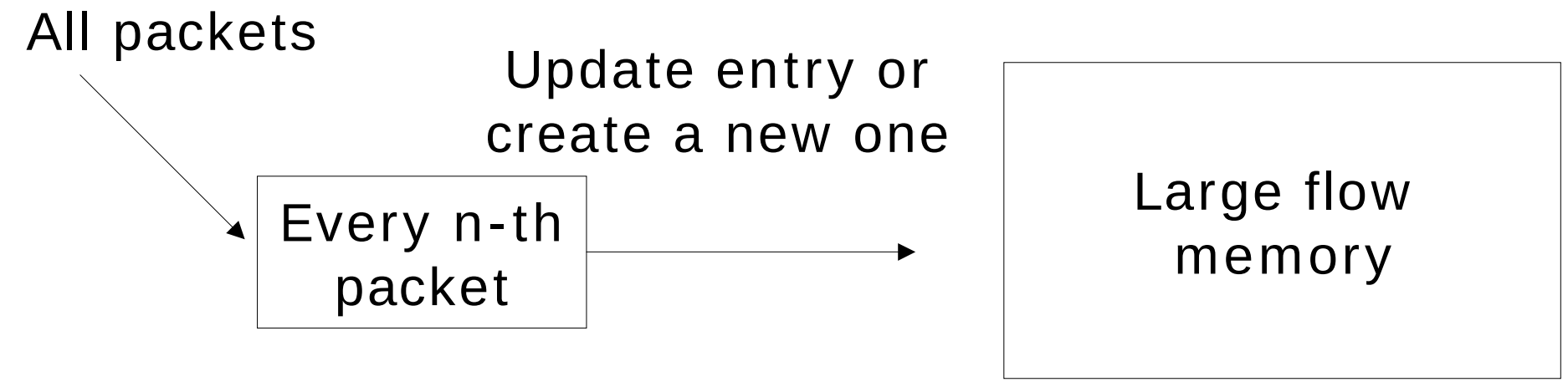
- Periodic sampling does not answer:
  - What are the top 10 flows?
  - What is the most dominant application and who is the heaviest user?
  - What is the total # of packet for every flow?

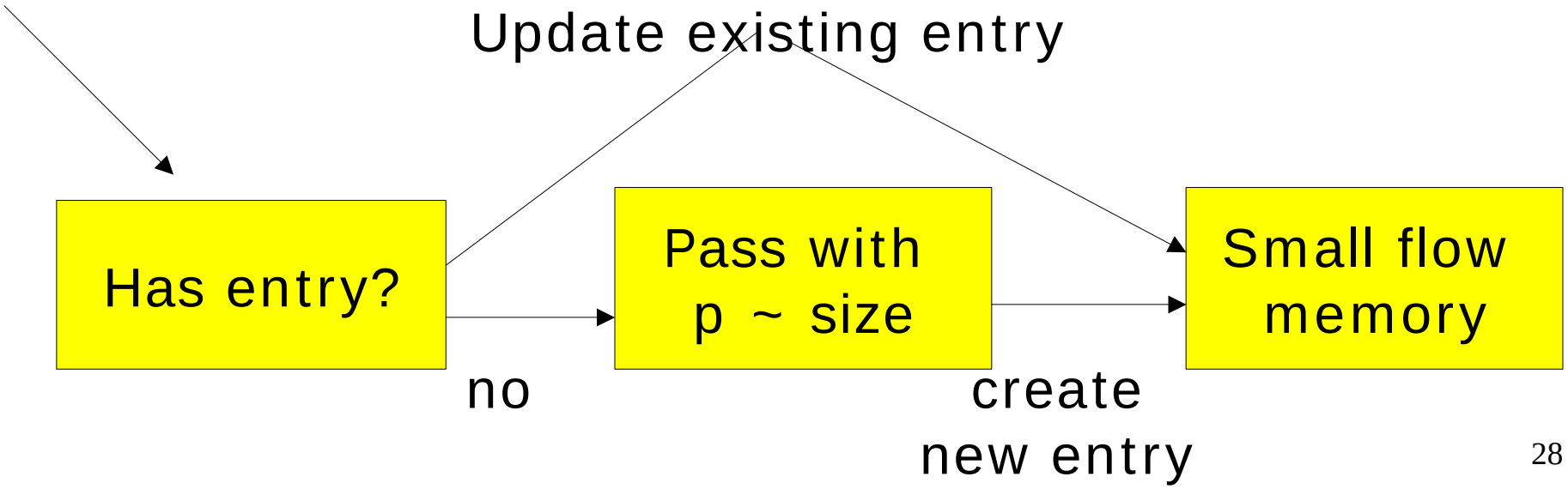
Hash Function

- Mapping from a very large space to a smaller space
  - h: X →Y where |X| >> |Y|
  - IP address to 10-bit hashed key
  - 5-tuple address to 30-bit hashed key
- Load factor = collision probability

What are the top 10 flows?

Sampling for Elephants [Estan02]





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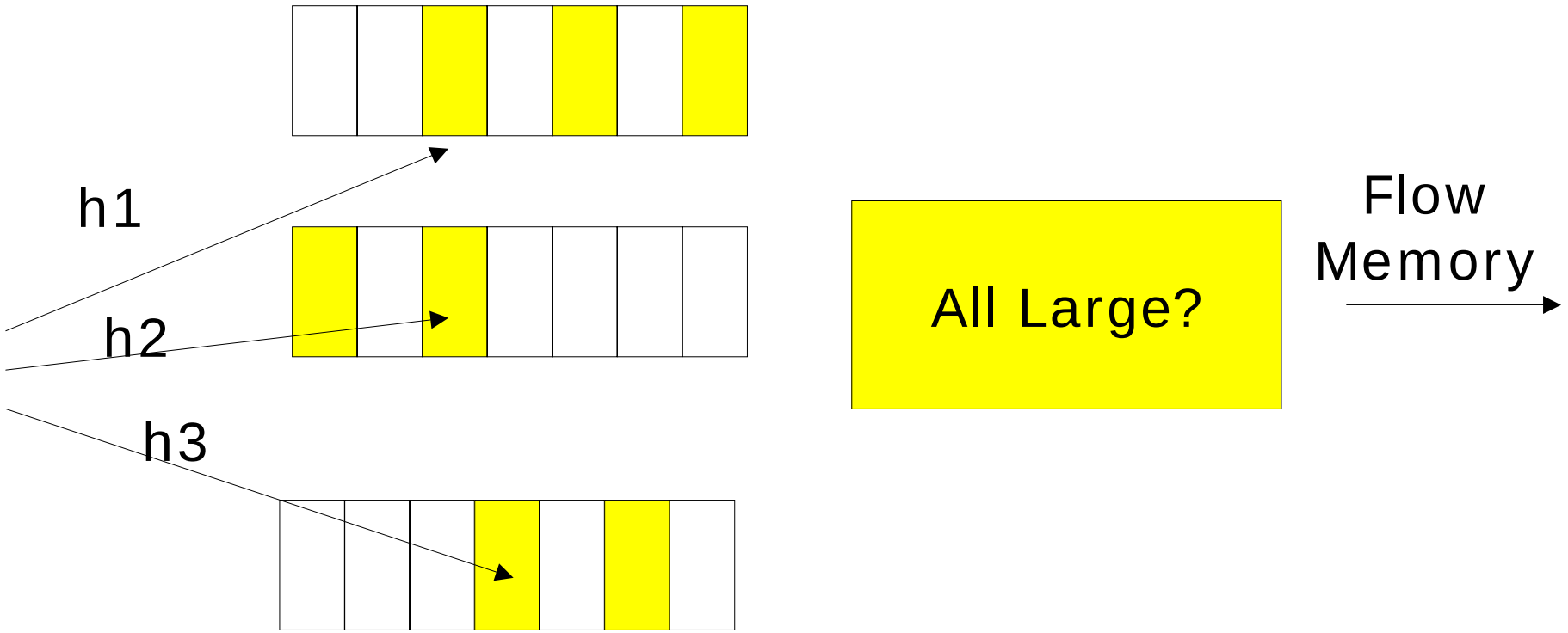
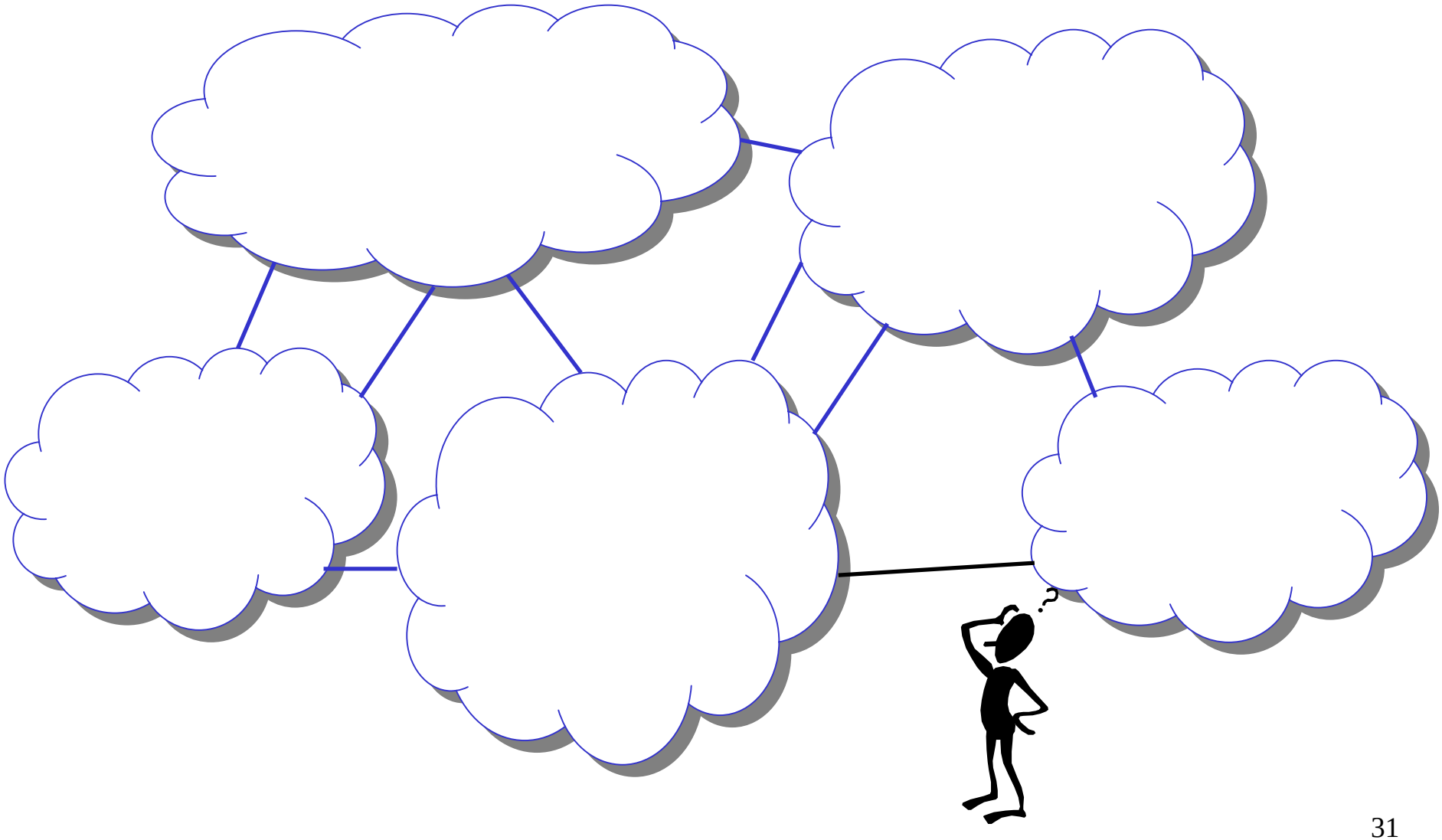
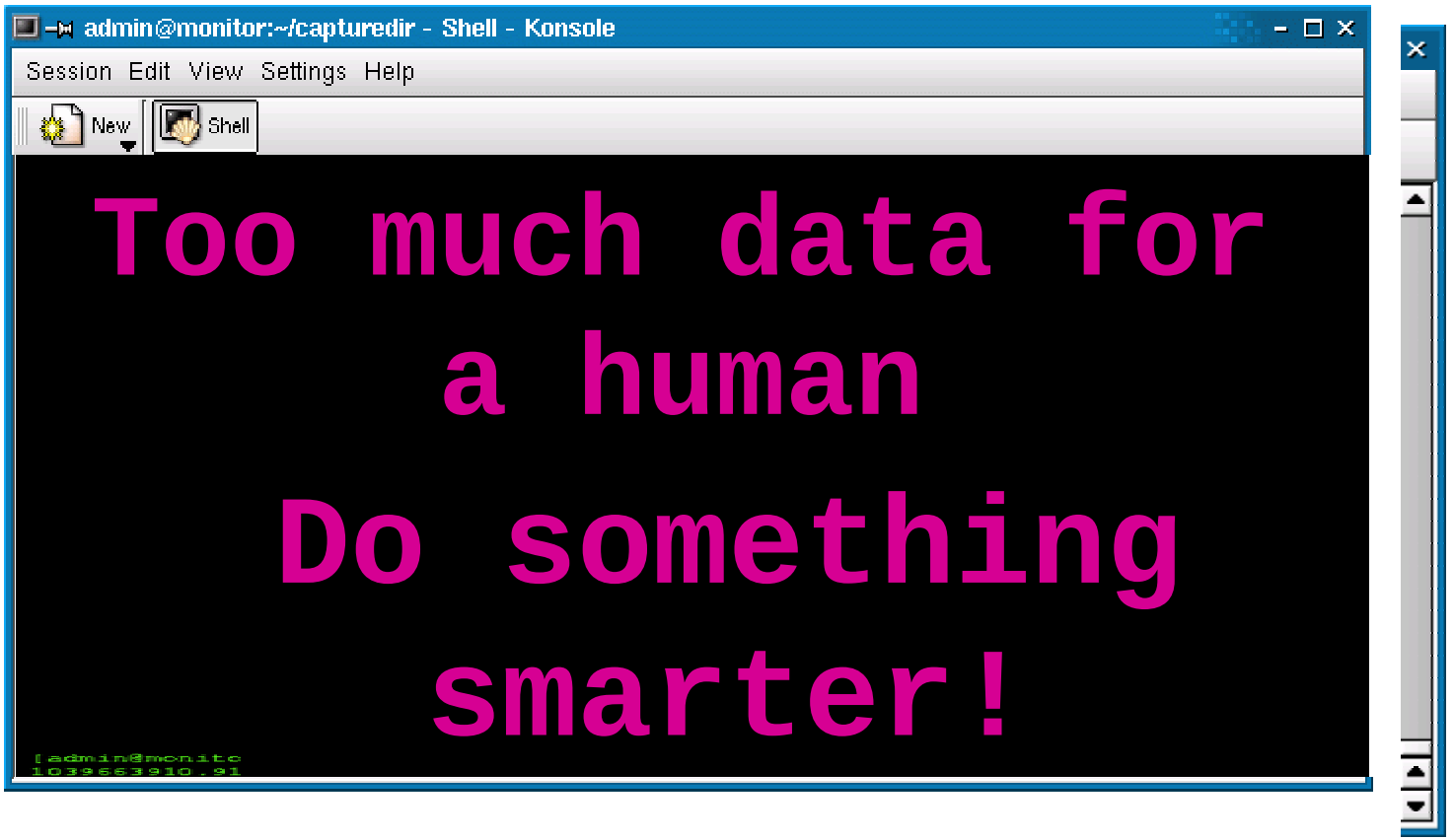


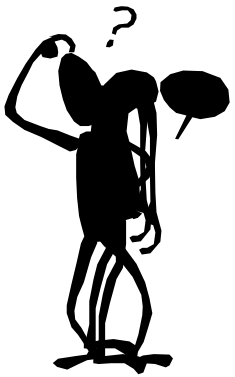
What is the most dominant application and who is the heaviest user?

Who is using my link?

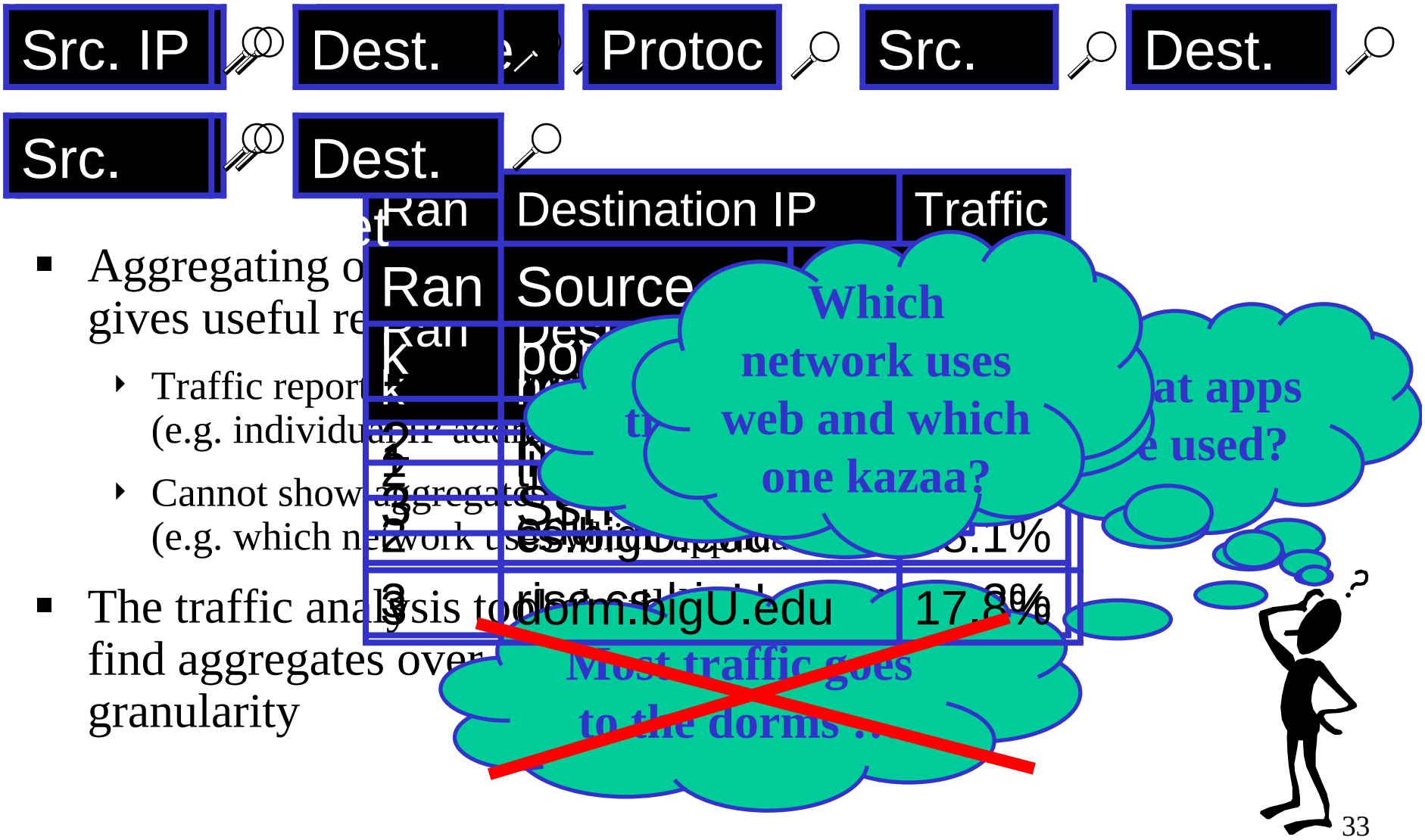


Looking at the traffic





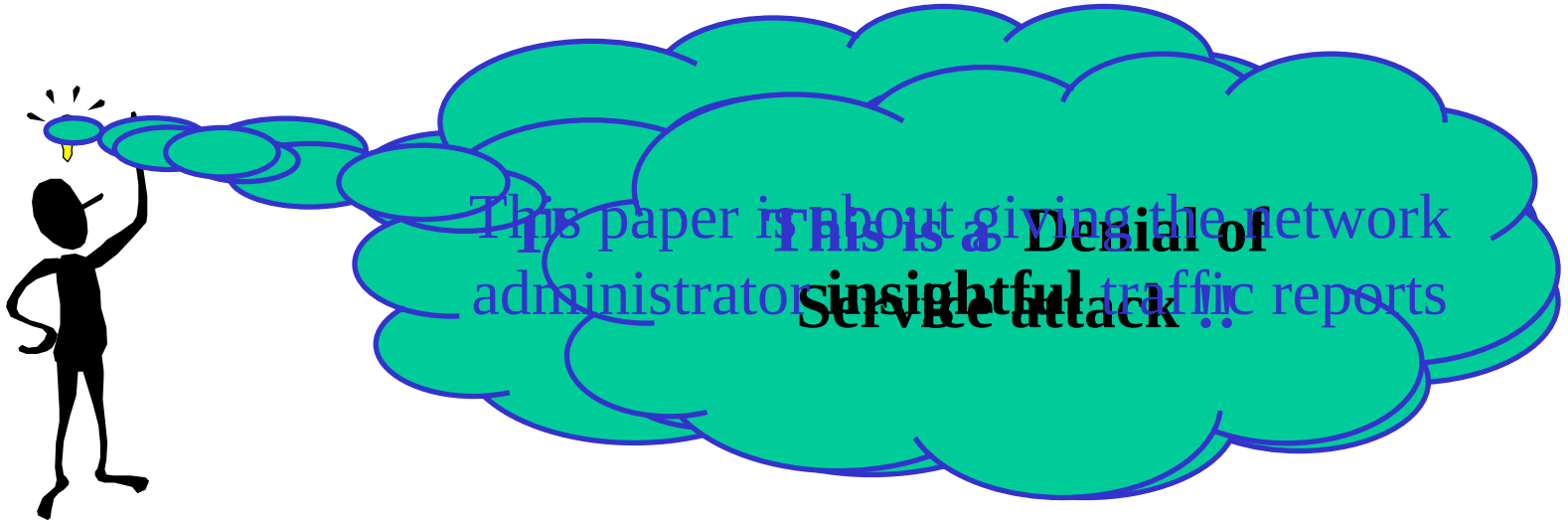
Looking at traffic aggregates



- Aggregating o
  gives useful re
  - Traffic report
    (e.g. individual IP addr
  - Cannot show aggregates
    (e.g. which network u
- The traffic analysis tool
  find aggregates over
  granularity

Ideal traffic report

Traffic aggregate	Traffic
Web traffic	42.1%
Web traffic to library.bigU.edu	26.7%
Web traffic from www.schwarzenegger.com	13.4%
ICMP traffic from sloppynet.badU.edu to jeff.dorm.bigU.edu	11.9%

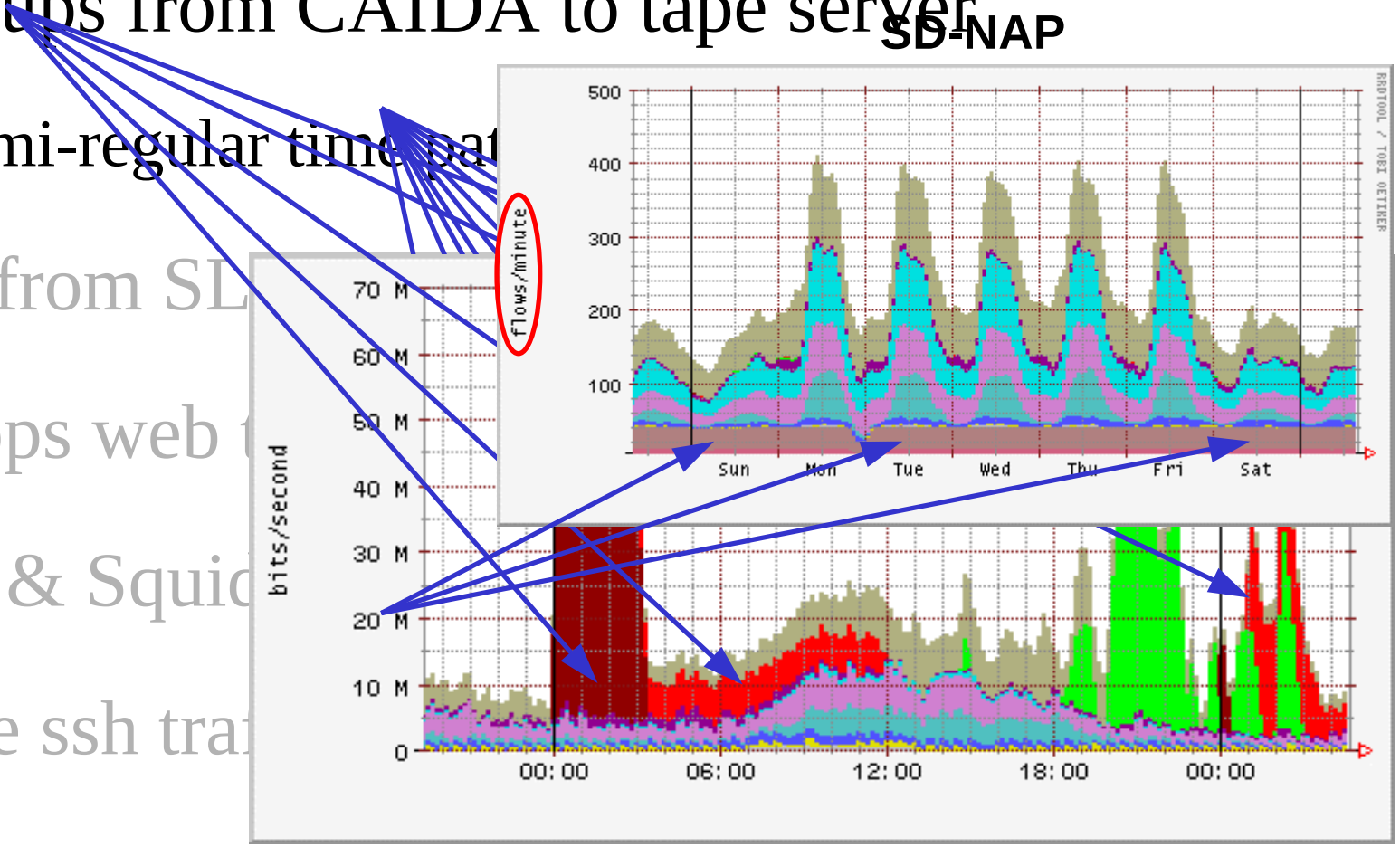


Traffic Clusters and Reports

- Traffic clusters are multidimentional aggregates.
- Traffic reports give volume of chosen clusters
- Only those over threshold are reported
- To avoid redundant data, compress inferrable data (up to error H)
- Highlight non-obvious aggregates with unexpectedness label

Structure of regular traffic mix

- Backups from CAIDA to tape server
  - Semi-regular time pat
- FTP from SL
- Scripps web t
- Web & Squic
- Large ssh tra
- Steady ICMP probing from CAIDA



Space-Code Bloom Filter

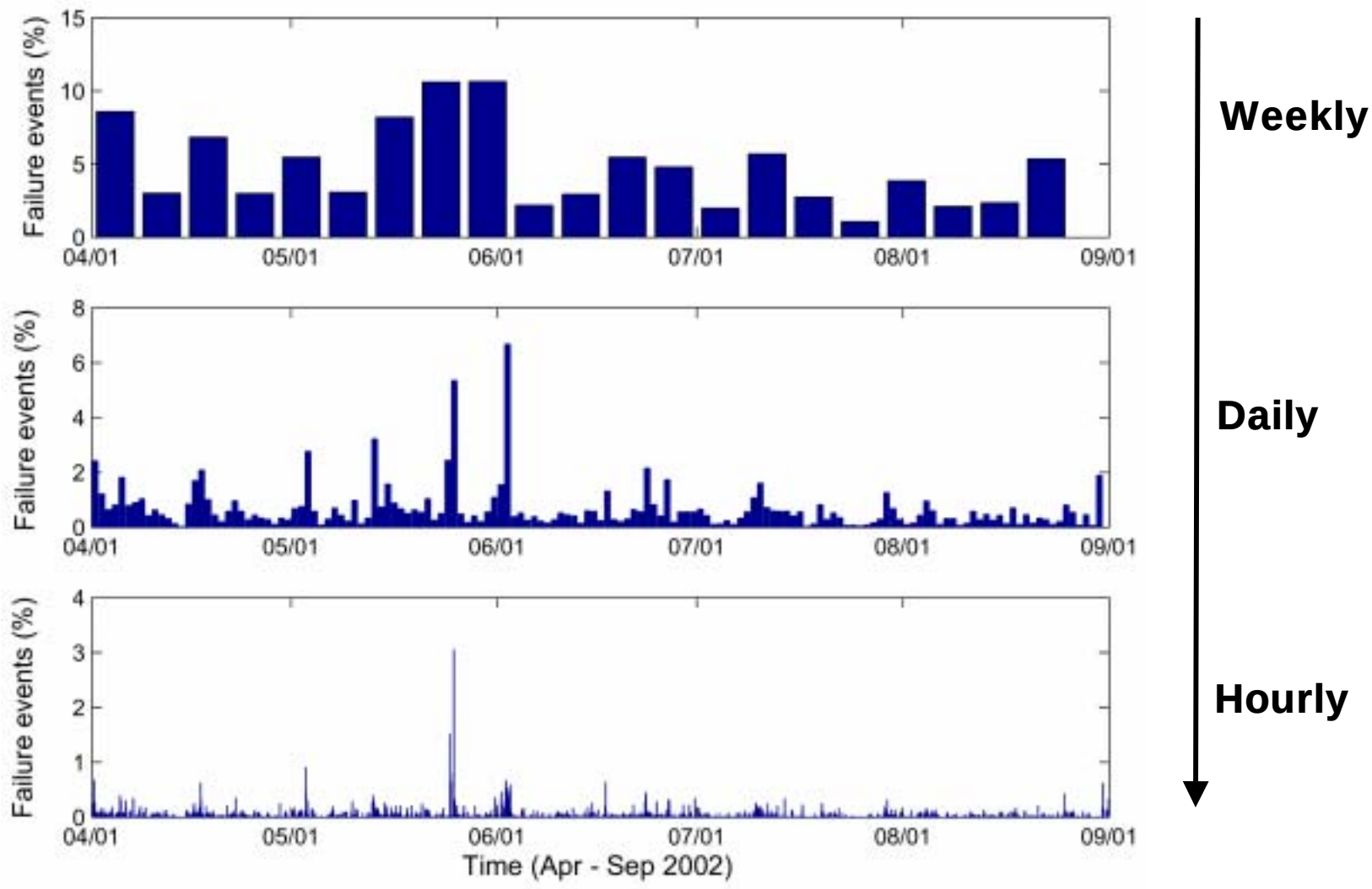
- Bloom filter answers set-membership.
- Space-code bloom filter answers multiset-membership
- Use a number of “virtual Bloom-filters, spread multiplicity information over space.
- Write-only
- At OC768, it can work at 5ns SRAM
- What about storage space at the router?

What is the total # of packet of every flow?

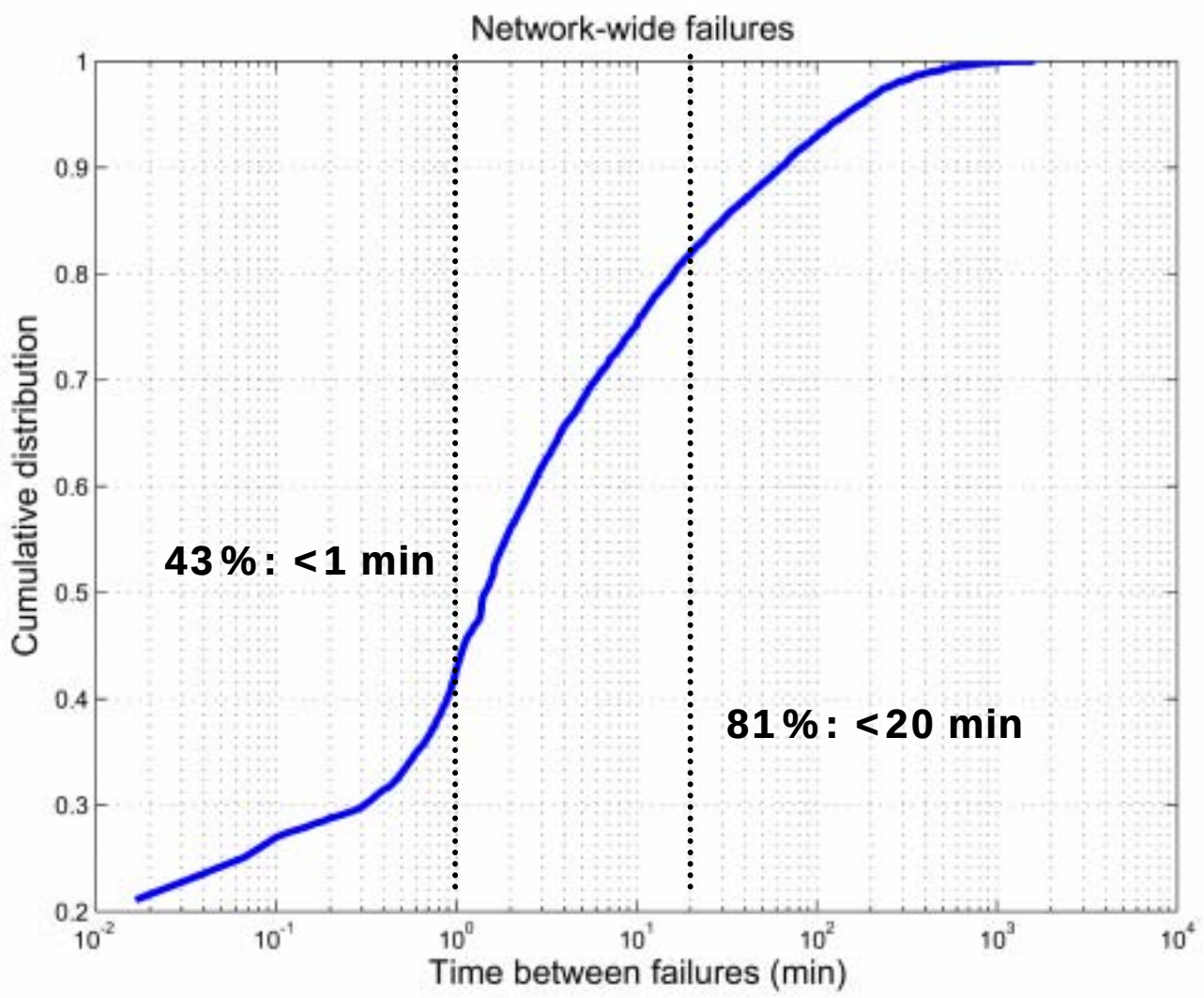
Future Work

- One traffic matrix to rule?
  - Can we answer all questions with one matrix?
- Continuous monitoring
  - data export in real-time
  - query over streaming data
- Availability/survivability
  - Impliations in SLAs?

Failures are part of everyday operations



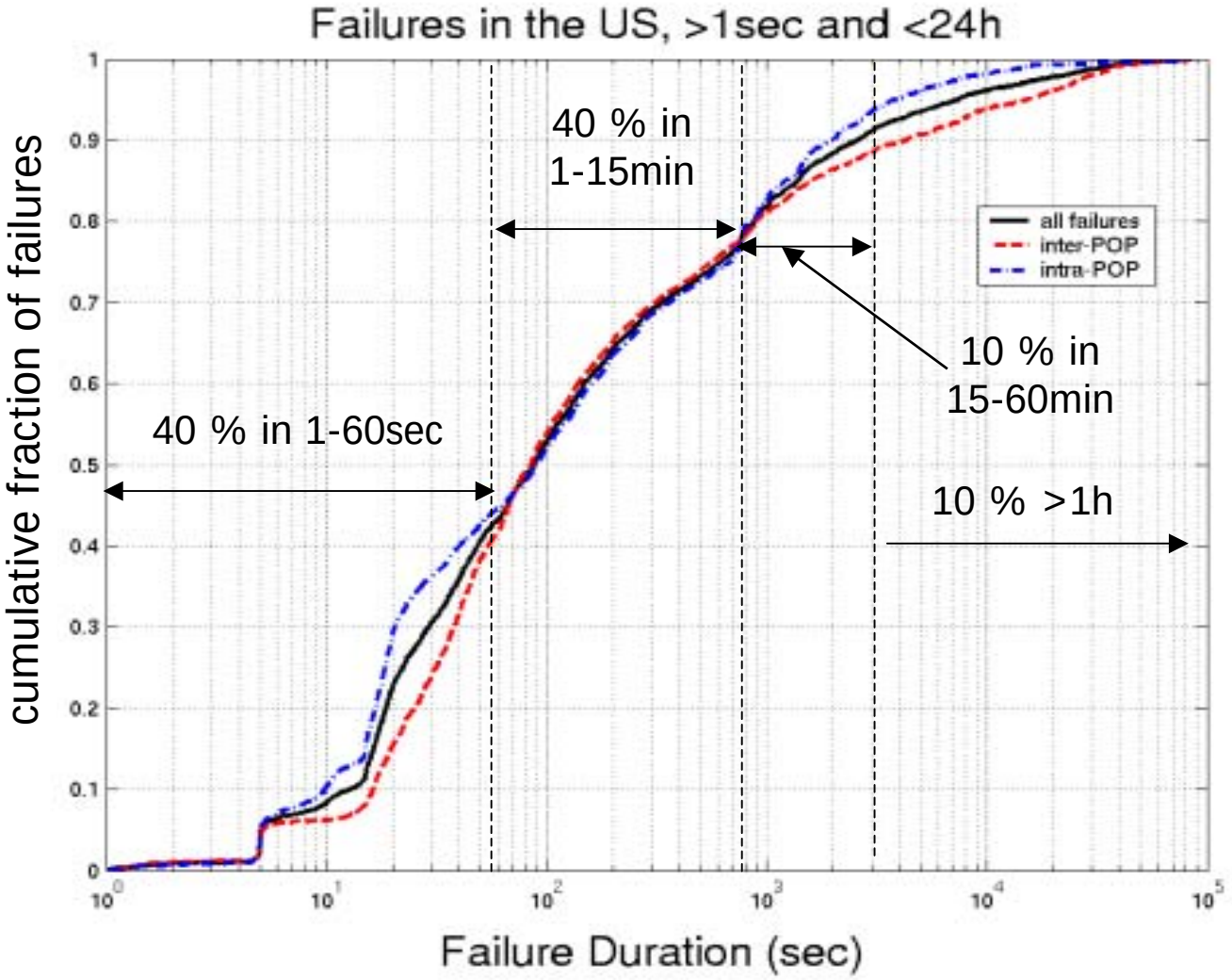
Time between Failures (network-wide)



Sources of failures

- Duration can provide hints, e.g.,
  - long (>1hour): fiber cuts, severe failures
  - medium (>10min): router/line card failures
  - short (>1min): line card resets
  - very short (<1min): software problems, optical equipment glitches
- Other hints
  - shared equipment (routers, optical)
  - router logs (e.g., SONET alarms), etc.

Network-wide Failure Duration



References

[Duffield03] N. Duffield, C. Lund, M. Thorup, “Properties and Prediction of Flow Properties from Sampled Packet Streams,” ACM SIGCOMM IMC, Miami, Oct., 2003

[Choi04] B.Y. Choi, S. Moon, Z.L. Zhang, C. Diot, “Analysis of Point-to-Point Packet Delay in an Operational Network,” IEEE INFOCOM, Hong Kong, Mar., 2004