the economics of network control

TUTORIAL

Best Practices for Determining the Traffic Matrix in IP Networks V 3.0

NANOG 39
Toronto

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Thomas Telkamp, *Cariden Technologies, Inc.*

Agenda

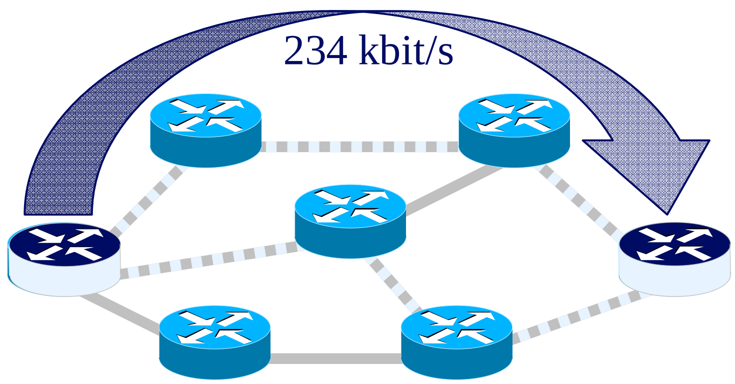
- Introduction
  - Traffic Matrix Properties
- Measurement in IP networks
  - NetFlow
  - BGP Policy Accounting
  - DCU (Juniper)
- MPLS Networks
  - RSVP based TE
  - LDP
    - Data Collection
    - LDP deployment in Deutsche Telekom
- Estimation Techniques
  - Theory
  - Example Data
  - Case-Study
    - Simulation
    - Metric Optimization
    - Adding p-t-p Measurements
- Traffic Matrices in Partial Topologies
- Multicast
- Summary

Contributors

- Stefan Schnitter, *T-Systems*
  - MPLS/LDP, Partial Topologies
- Benoit Claise, *Cisco Systems, Inc.*
  - Cisco NetFlow
- Tarun Dewan, *Juniper Networks, Inc.*
  - Juniper DCU
- Mikael Johansson, *KTH*
  - Traffic Matrix Properties
- Simon Leinen, *SWITCH*
  - BGP Policy Accounting, SNMP

Traffic Matrix

- Traffic matrix: the amount of data transmitted between every pair of network nodes
  - Demands
  - "end-to-end" in the core network
- Traffic Matrix can represent peak traffic, or traffic at a specific time
- Router-level or PoP-level matrices



Determining the Traffic Matrix

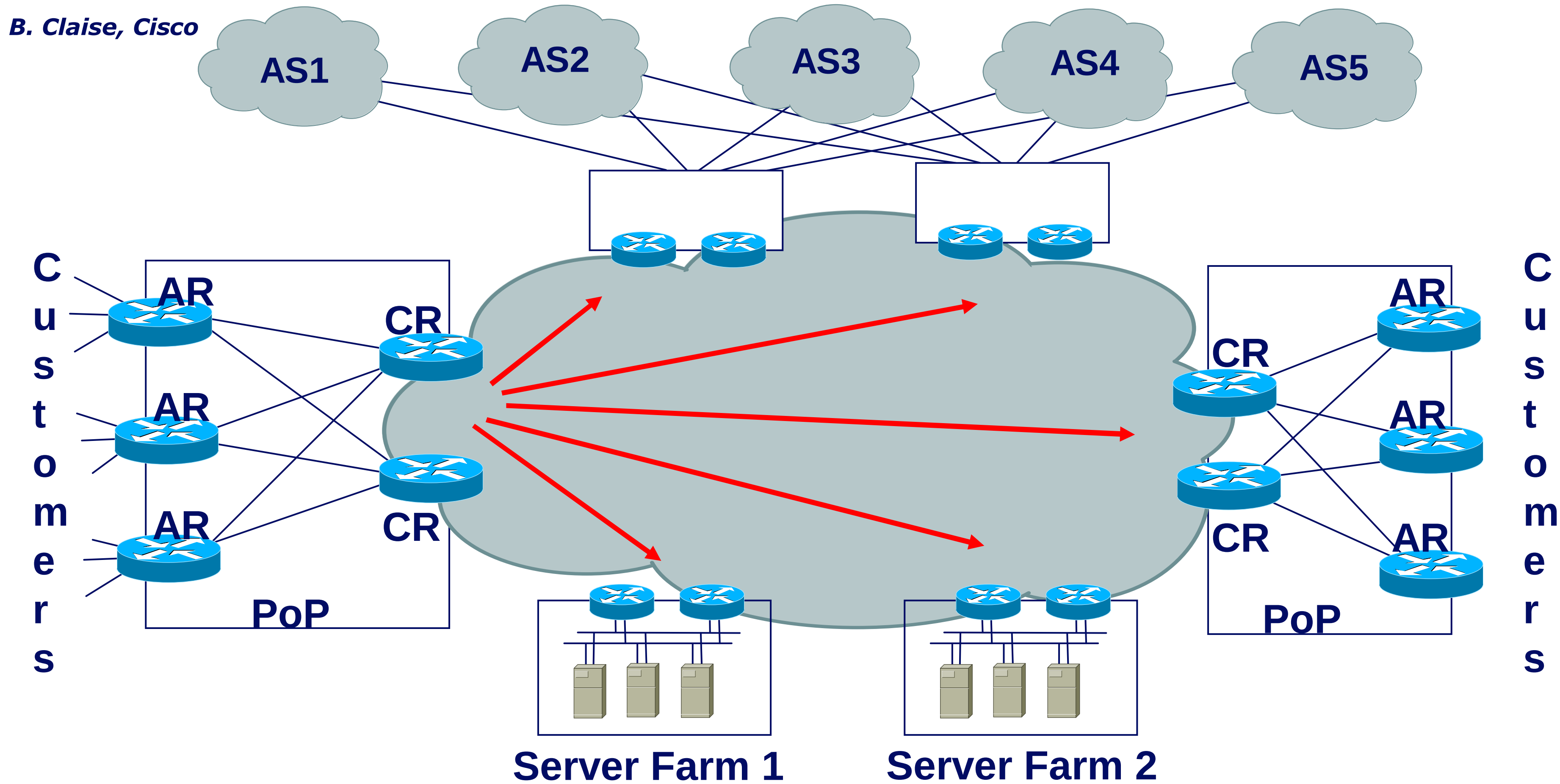
- For what purpose?
  - Analysis and Evaluation of other network states than the current:
  - Capacity Planning
    - network changes
    - “what-if” scenarios
    - Could be per class
  - Resilience Analysis
    - network under failure conditions
  - Optimization
    - Topology
      - Find bottlenecks
    - OSPF/IS-IS metric optimization/TE
    - MPLS TE tunnel placement

Types of Traffic Matrices

- Internal Traffic Matrix
  - PoP to PoP matrix
    - Can be from core (CR) or access (AR) routers
  - Class based

- External Traffic Matrix
  - PoP to External AS
    - BGP
    - Origin-AS or Peer-AS
      - Peer-AS sufficient for Capacity Planning and Resilience Analysis
    - Useful for analyzing the impact of external failures on the core network (capacity/resilience)
    - See RIPE presentation on peering planning [8]

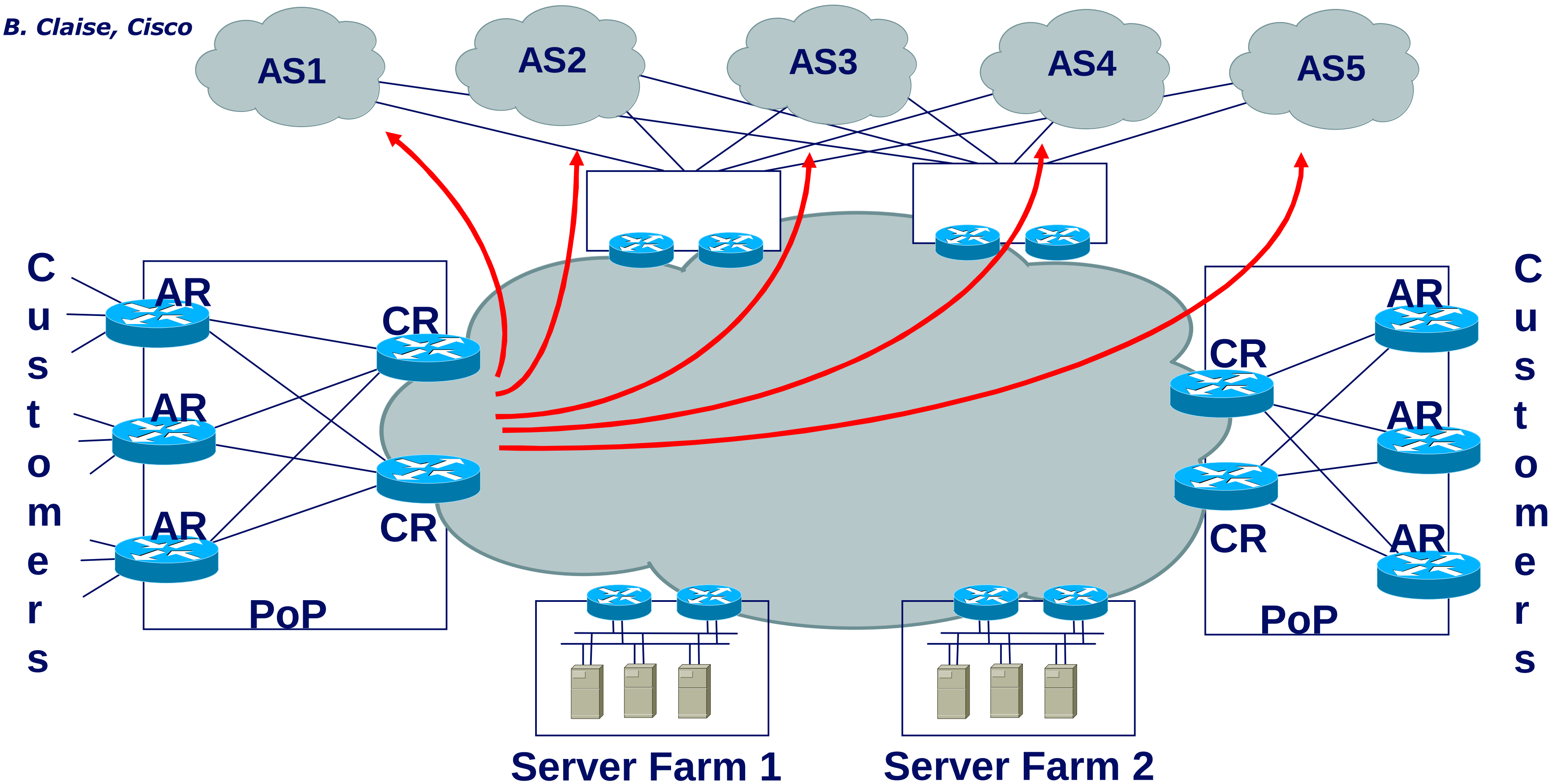
Internal Traffic Matrix



"PoP to PoP", the PoP being the **AR** or **CR**

External Traffic Matrix

B. Claise, Cisco



From "PoP to BGP AS", the PoP being the **AR** or **CR**

The external traffic matrix can influence the internal one

Traffic Matrix & Routing

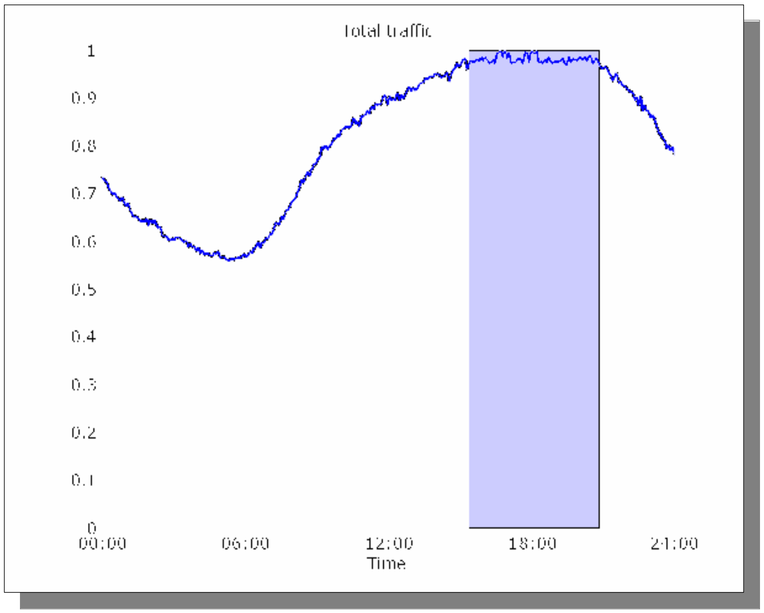
- Presented at NANOG35 ([7]; Jacobson, Yu, Mah):
  - Observation: traffic doesn’t just go everywhere, most of it goes to a few places
  - Routing data:
    - BGP neighbor AS
      - Customers, transit providers, peers, etc.
    - BGP IGP next-hop
      - Locations where they attach
  - Combine IGP/BGP routing data with traffic data
  - Provides more info than just the matrix itself

Traffic Matrix Properties

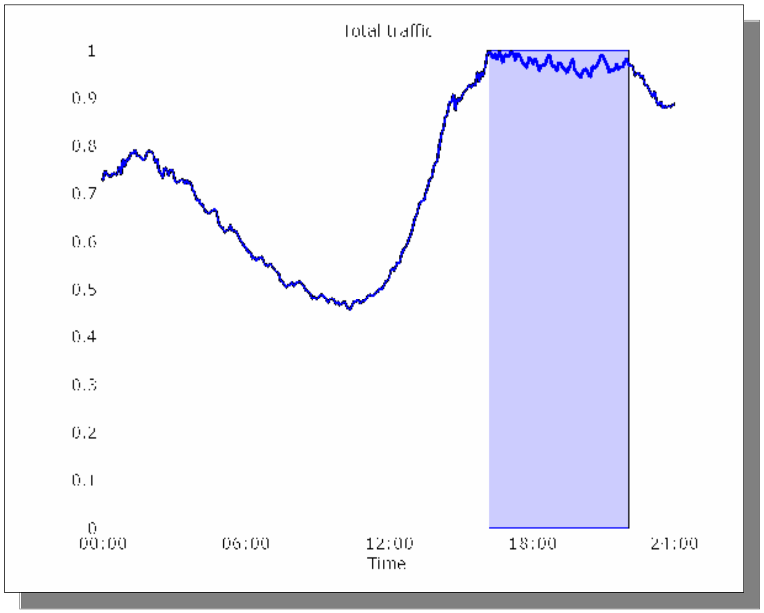
- Example Data from Tier-1 IP Backbone
  - Measured Traffic Matrix (MPLS TE based)
  - European and American subnetworks
  - 24h data
  - See [1]
- Properties
  - Temporal Distribution
    - How does the traffic vary over time
  - Spatial Distribution
    - How is traffic distributed in the network?
  - Relative Traffic Distribution
    - “Fanout”

Total traffic and busy periods

European subnetwork



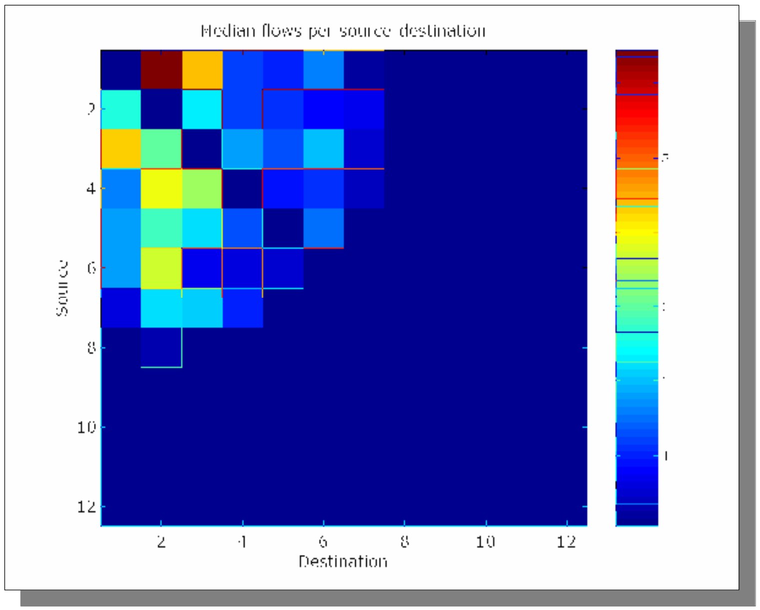
American subnetwork



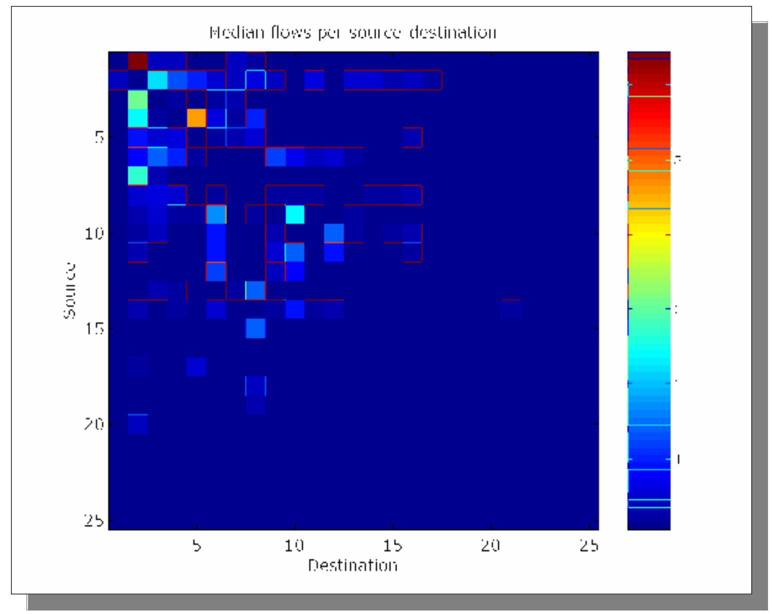
Total traffic very stable over 3-hour busy period

Spatial demand distributions

European subnetwork



American subnetwork

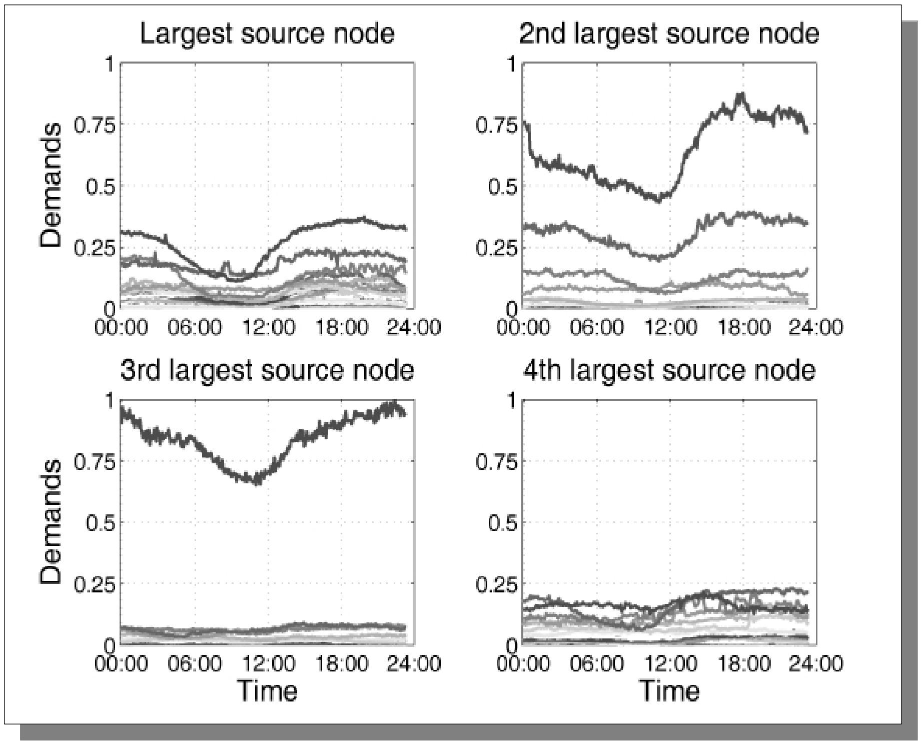


Few large nodes contribute to total traffic (20% demands – 80% of total traffic)

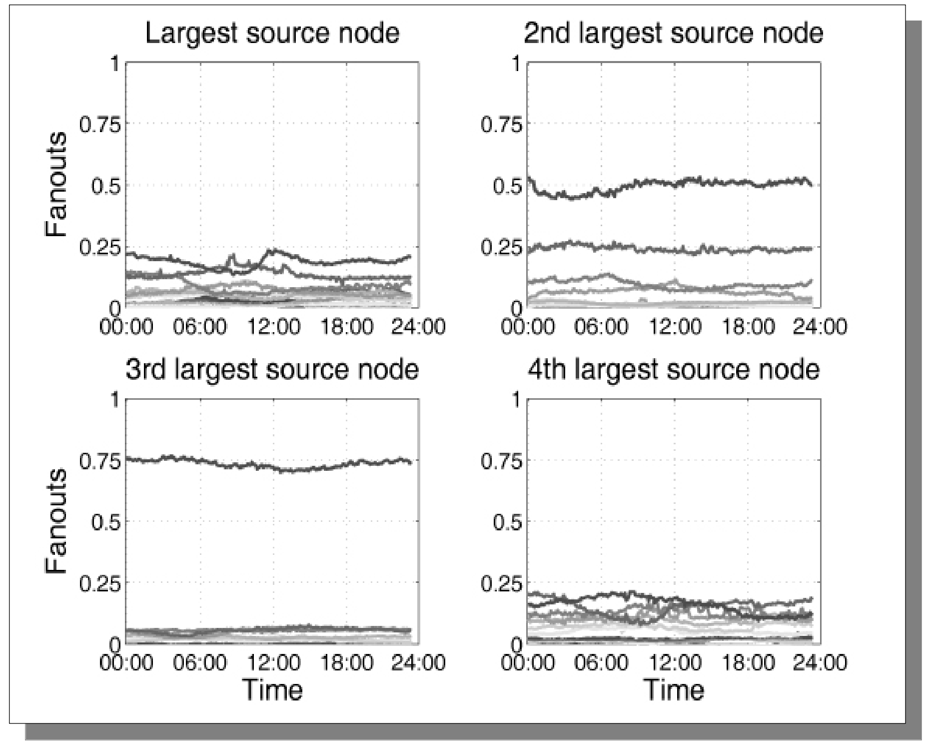
Fanout factors

Fanout: relative amount of traffic (as percentage of total)

Demands for 4 largest nodes, USA



Corresponding fanout factors



Fanout factors much more stable than demands themselves!

Traffic Matrix Collection

- Data is collected at fixed intervals
  - E.g. every 5 or 15 minutes
- Measurement of *Byte Counters*
  - Need to convert to rates
  - Based on measurement interval
  - Counter roll-over issues
- Create Traffic Matrix
  - Peak Hour Matrix
    - 5 or 15 min. average at the peak hour
  - Peak Matrix
    - Calculate the peak for every demand
    - Real peak or 95-percentile

Collection Methods

- NetFlow
  - Routers collect “flow” information
  - Export of raw or aggregated data
- BGP Policy Accounting/DCU
  - Routers collect aggregated destination statistics
- MPLS
  - RSVP
    - Measurement of Tunnel/LSP counters
  - LDP
    - Measurement of LDP counters
- Estimation
  - Estimate Traffic Matrix based on Link Utilizations

NetFlow based Methods

NetFlow

- A “Flow” is defined by
  - Source address
  - Destination address
  - Source port
  - Destination port
  - Layer 3 Protocol Type
  - TOS byte
  - Input Logical Interface (ifIndex)
- Router keeps track of Flows and usage per flow
  - Packet count
  - Byte count

NetFlow Versions

- □Version 5
  - the most complete version
- Version 7
  - on the switches
- Version 8
  - the Router Based Aggregation
- Version 9
  - the new flexible and extensible version

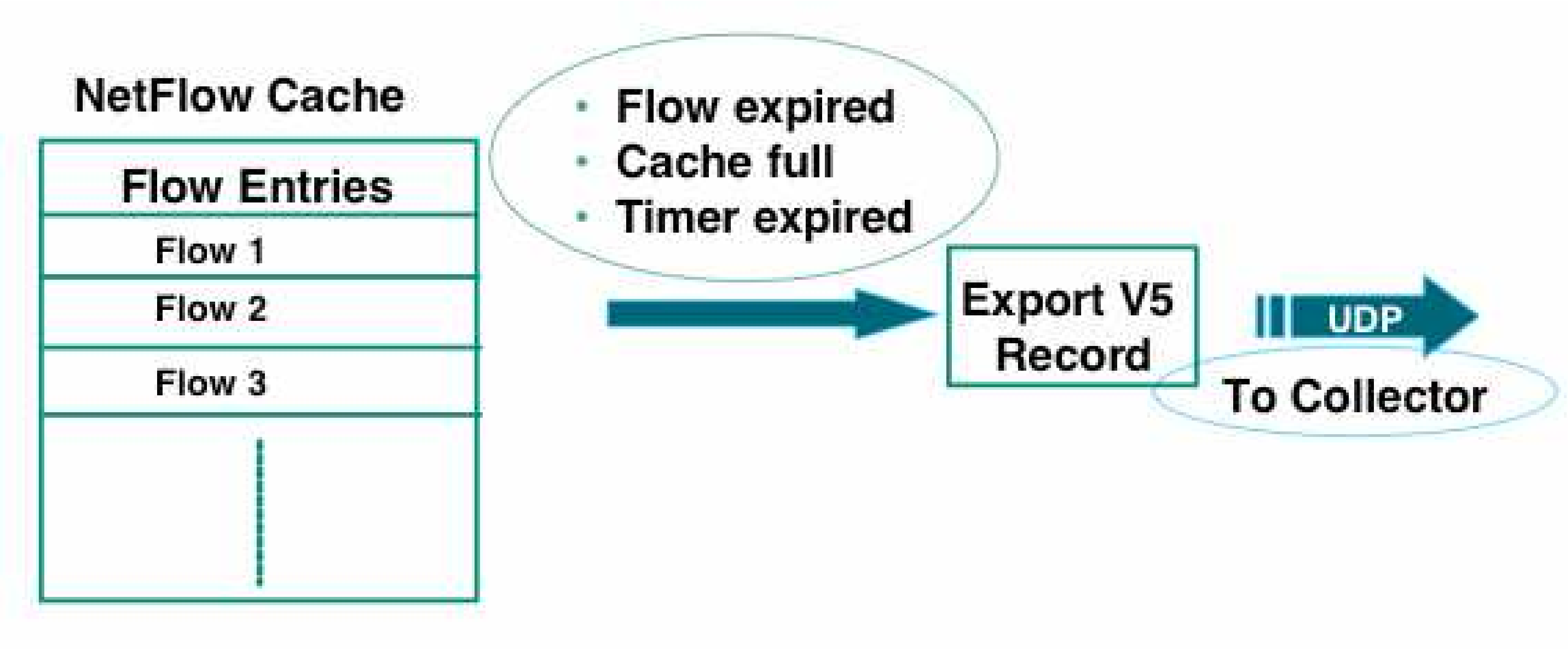
- Supported by multiple vendors
  - Cisco
  - Juniper
  - others

NetFlow Export

- A Flow is exported when
  - Flow expires
  - Cache full
  - Timer expired
- Expired Flows are grouped together into "NetFlow Export" UDP datagrams for export to a collector
  - Including timestamps
- UDP is used for speed and simplicity
- Exported data can include extra information
  - E.g. Source/Destination AS

NetFlow Export

B. Claise, Cisco



NetFlow Deployment

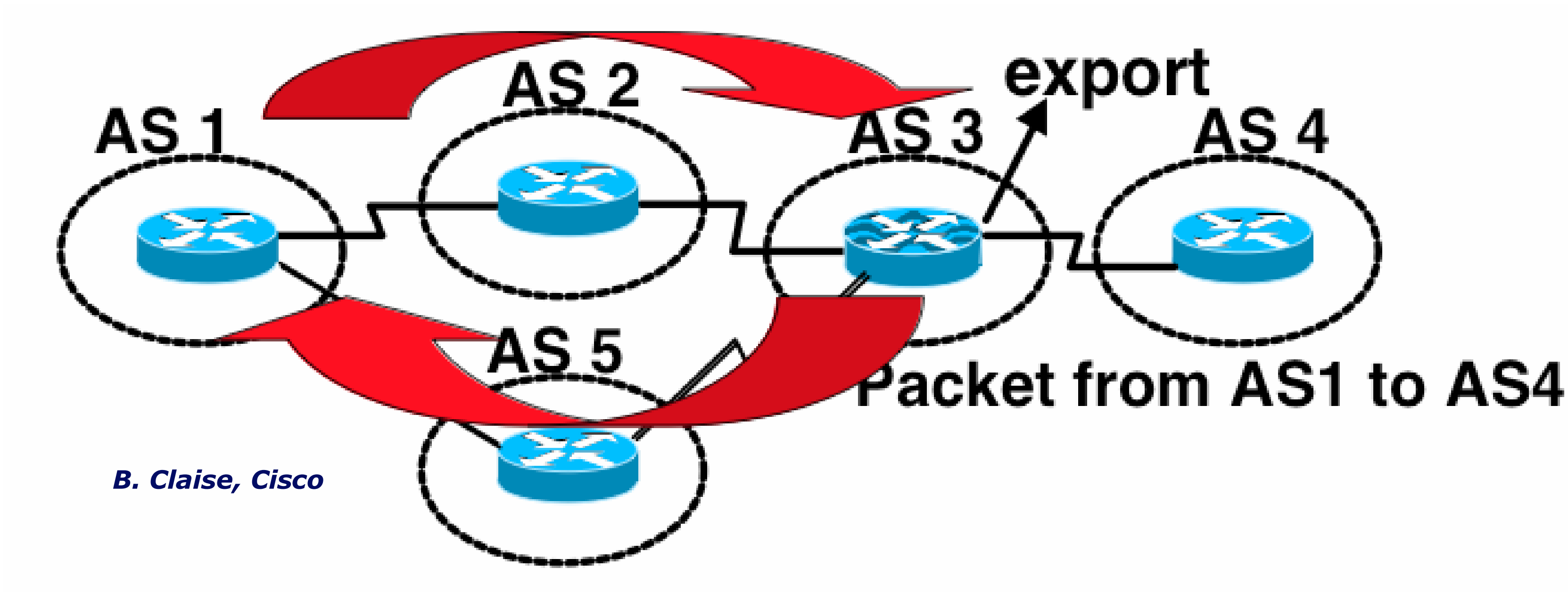
- How to build a Traffic Matrix from NetFlow data?
  - Enable NetFlow on all interfaces that source/sink traffic into the (sub)network
    - E.g. Access to Core Router links (AR->CR)
  - Export data to central collector(s)
  - Calculate Traffic Matrix from Source/Destination information
    - Static (e.g. list of address space)
    - BGP AS based
      - Easy for peering traffic
      - Could use "live" BGP feed on the collector
    - Inject IGP routes into BGP with community tag

BGP Passive Peer on the Collector

- Instead of exporting the peer-as or destination-as for the source and destination IP addresses for the external traffic matrix:
  - Don't export any BGP AS's
  - Export version 5 with IP addresses or version 8 with an prefix aggregation
- A BGP passive peer on the NetFlow collector machines can return all the BGP attributes:
  - source/destination AS, second AS, AS Path, BGP communities, BGP next hop, etc…
- Advantages:
  - Better router performance – less lookups
  - Consume less memory on the router
  - Full BGP attributes flexibility
  - See "Route-Flow Fusion" [7] again

NetFlow: Asymmetric BGP traffic

- Origin-as
  - Source AS1, Destination AS4
- Peer-as
  - Source AS5, Destination AS4 WRONG!
- Because of the source IP address lookup in BGP



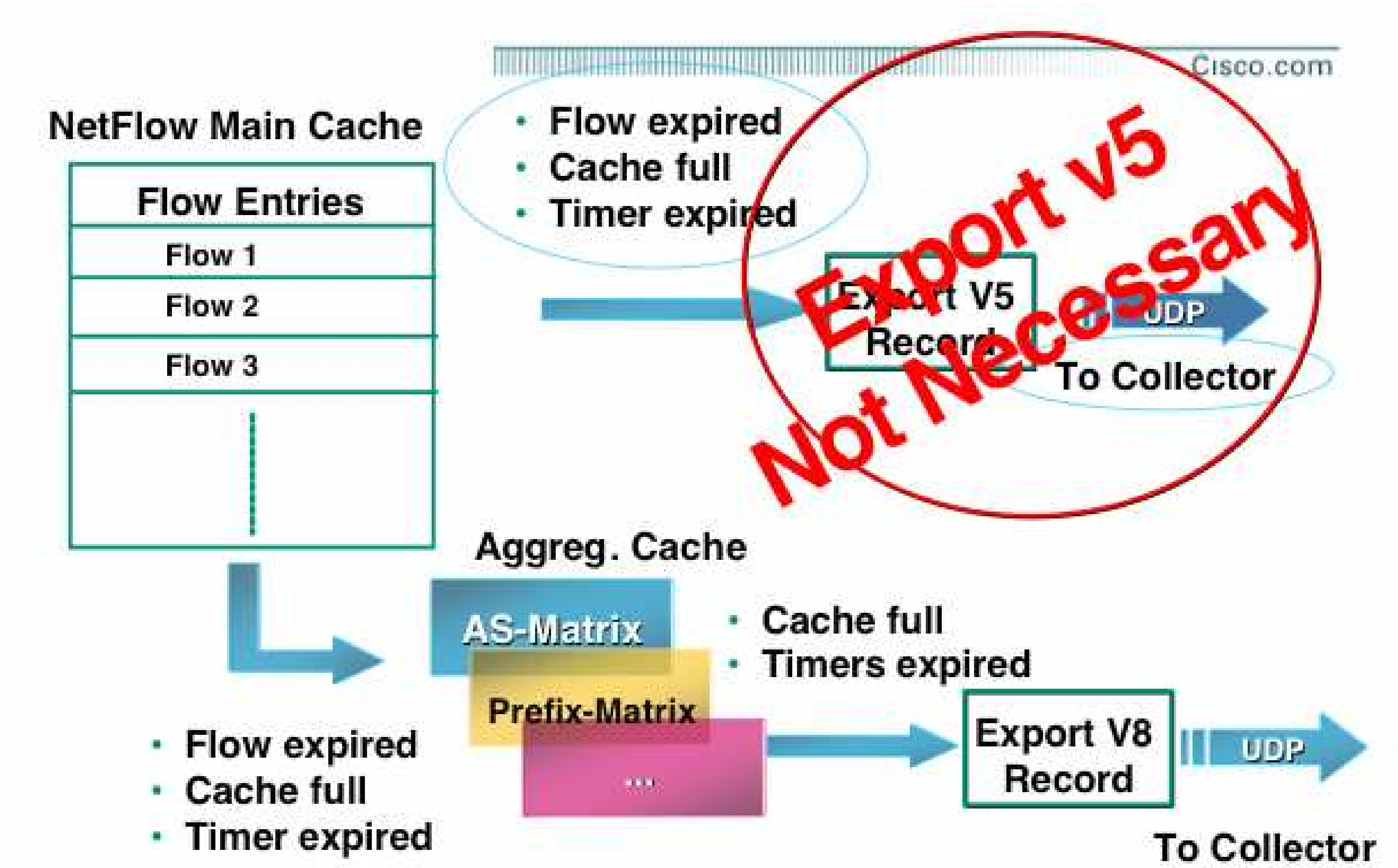
NetFlow Version 8

- Router Based Aggregation
- Enables router to summarize NetFlow Data
- Reduces NetFlow export data volume
  - Decreases NetFlow export bandwidth requirements
  - Makes collection easier

- Still needs the main (version 5) cache
- When a flow expires, it is added to the aggregation cache
  - Several aggregations can be enabled at the same time
- Aggregations:
  - Protocol/port, AS, Source/Destination Prefix, etc.

NetFlow: Version 8 Export

B. Claise, Cisco

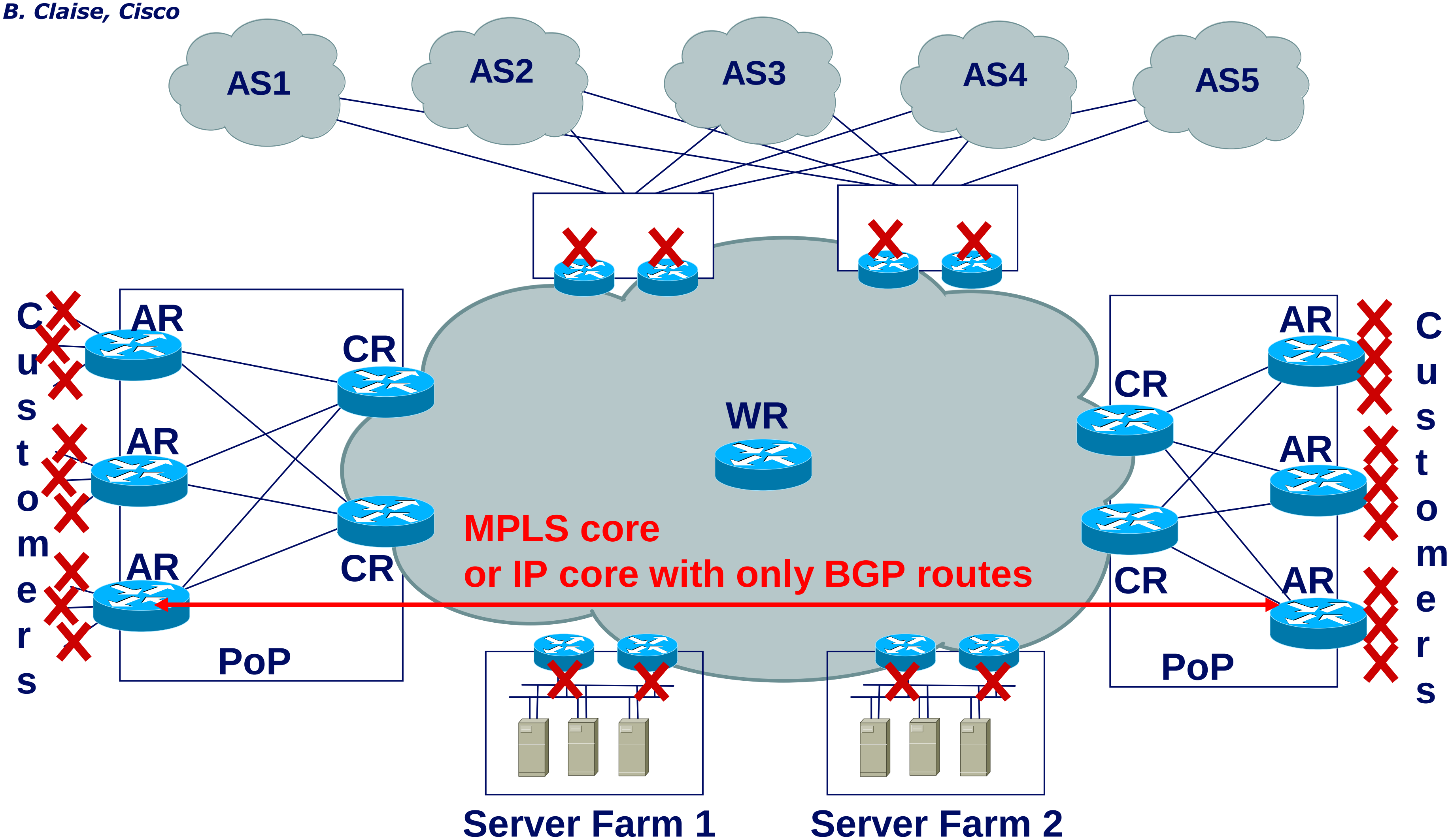


BGP NextHop TOS Aggregation

- New Aggregation scheme
  - Only for BGP routes
    - Non-BGP routes will have next-hop 0.0.0.0
- Configure on Ingress Interface
- Requires the new Version 9 export format
- Only for IP packets
  - IP to IP, or IP to MPLS

BGP NextHop TOS Aggregation

B. Claise, Cisco

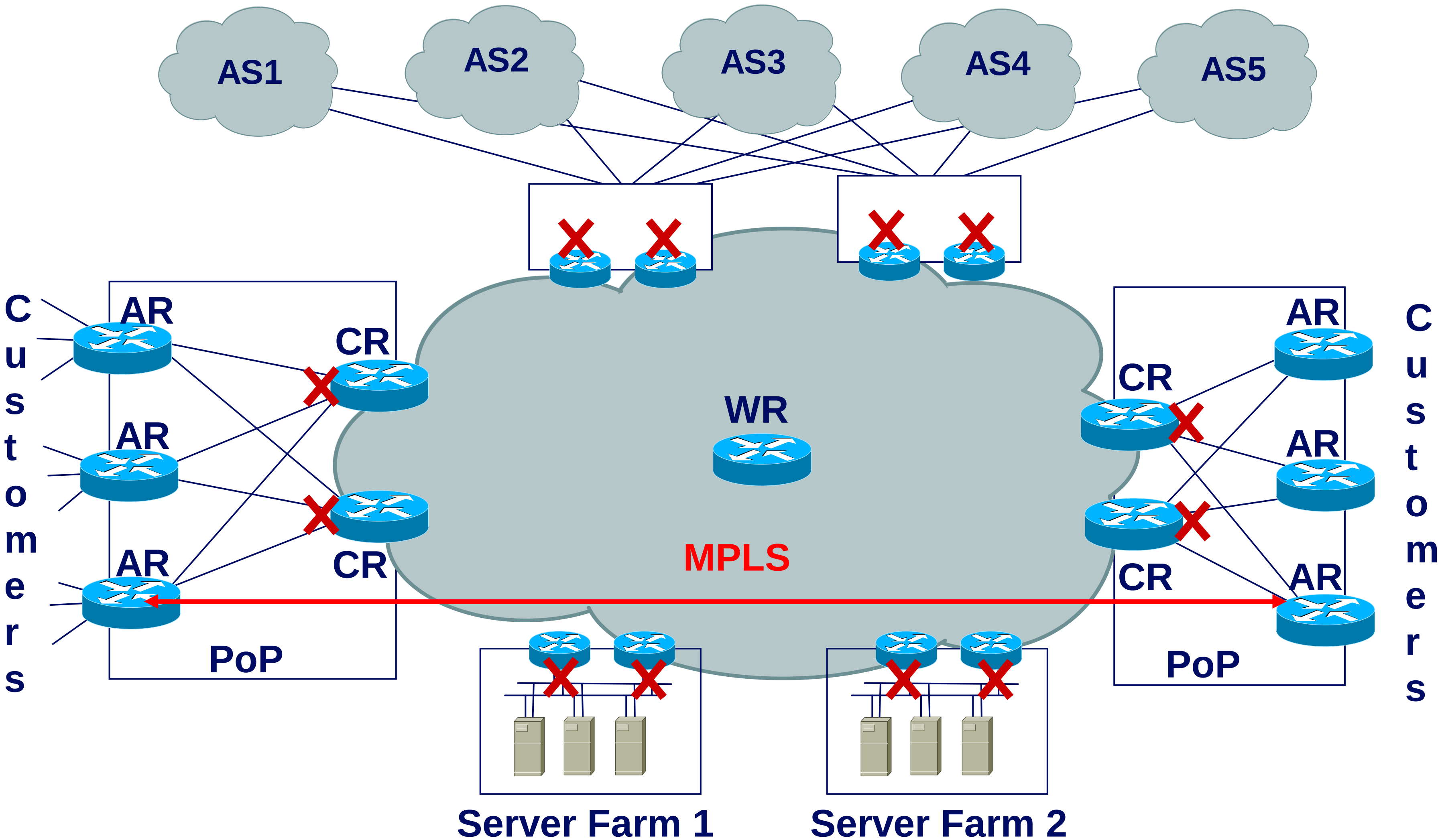


MPLS aware NetFlow

- Provides flow statistics per MPLS and IP packets
  - MPLS packets:
    - Labels information
    - And the V5 fields of the underlying IP packet
  - IP packets:
    - Regular IP NetFlow records
- Based on the NetFlow version 9 export
  No more aggregations on the router (version 8)
- Configure on ingress interface
- Supported on sampled/non sampled NetFlow

MPLS aware NetFlow: Example

B. Claise, Cisco



NetFlow Summary

- Building a Traffic Matrix from NetFlow data is not trivial
  - Need to correlate Source/Destination information with routers or PoPs
- "origin-as" vs "peer-as"
  - Asymmetric BGP traffic problem
- BGP NextHop aggregation comes close to directly measuring the Traffic Matrix
  - NextHops can be easily linked to a Router/PoP
  - BGP only
- NetFlow processing is CPU intensive on routers
  - Use Sampling
    - E.g. only use every 1 out of 100 packets
    - Accuracy of sampled data

NetFlow Summary

- Various other features are available
- Ask vendors (Cisco, Juniper, etc.) for details on version support and platforms
- Commercial collector systems are available:
  - Arbor
    - Also for other purposes, like DDoS
  - Adlex
  - Etc.
- For Cisco, see Benoit Claise's webpage:
  - http://www.employees.org/~bclaise/

BGP Policy Accounting

BGP Policy Accounting

- Accounting traffic according to the route it traverses
- Account for IP traffic by assigning counters based on:
  - BGP community-list
  - AS number
  - AS-path
  - destination IP address
- 64 buckets

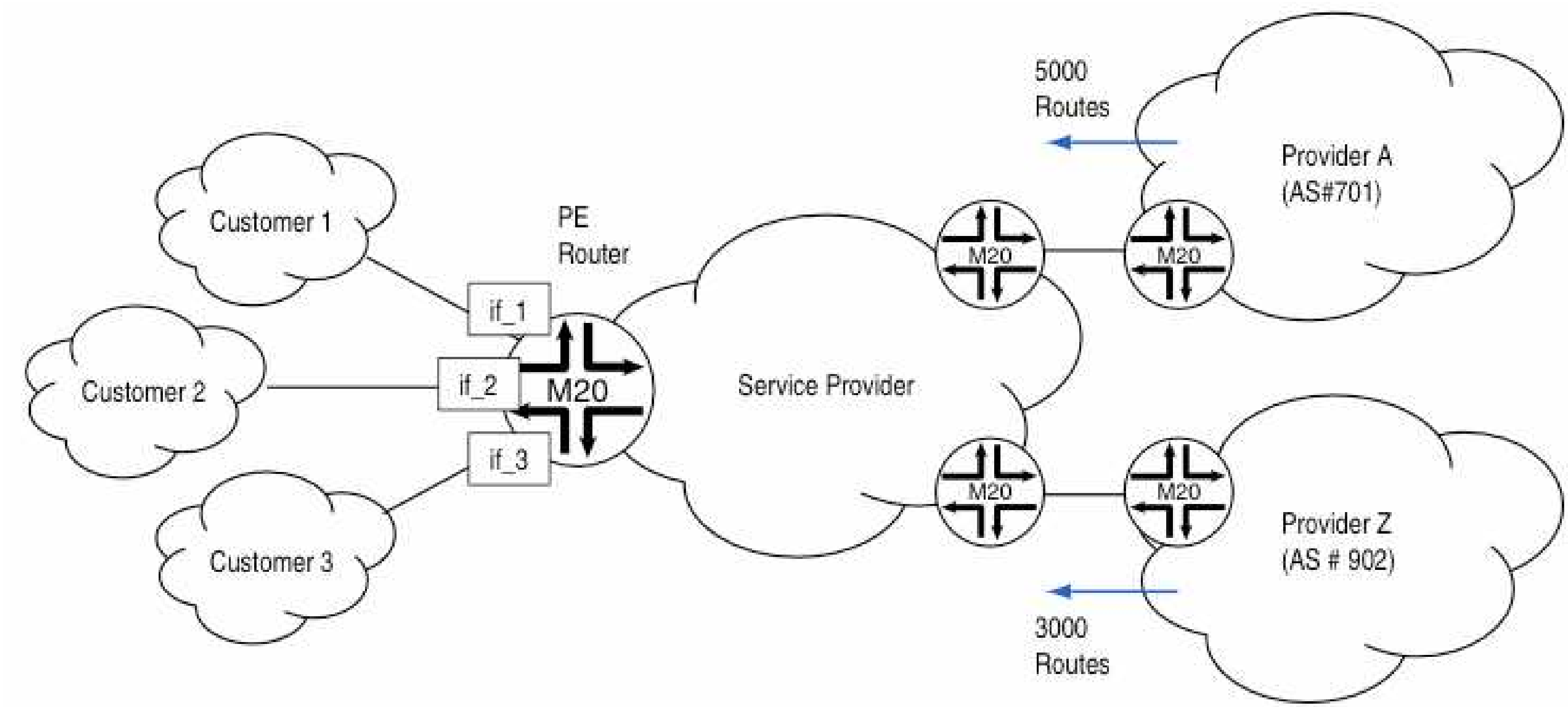
Destination Class Usage (DCU)

Destination Class Usage (DCU)

- Juniper specific!
- Similar to Cisco BGP Policy Accounting
  - Policy based accounting mechanism
  - For example based on BGP communities
- Supports up to 16 different traffic destination classes (126 in more recent releases)
- Maintains per interface packet and byte counters to keep track of traffic per class
- Data is stored in a file on the router, and can be pushed to a collector
- *16 destination classes is in most cases too limited to build a useful full Traffic Matrix, 126 is more realistic though.*

DCU Example

- Routing policy
  - associate routes from provider A with DCU class 1
  - associate routes from provider B with DCU class 2
- Perform accounting on PE



BGP Policy Accounting & DCU

- Easy to configure on the routers
- Results available via SNMP
  - MIBs:
    - CISCO-BGP-POLICY-ACCOUNTING-MIB
    - JUNIPER-DCU-MIB
  - See Simon Leinen's page on this subject [6]:

    http://www.switch.ch/misc/leinen/snmp/monitoring/bucket-accounting.html

MPLS Based Methods

MPLS Based Methods

- Two methods to determine traffic matrices:
  - Using RSVP-TE tunnels
  - Using LDP statistics

- Some comments on Deutsche Telekom's practical implementation

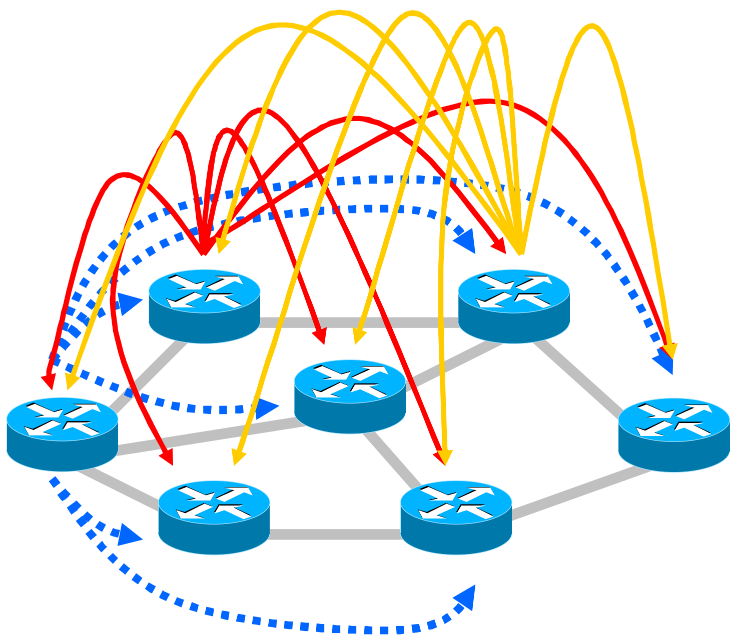
RSVP-TE in MPLS Networks

- RSVP-TE (RFC 3209) can be used to establish LSPs
- Example (IOS):

```
interface Tunnel99
 description RouterA => RouterB
 tag-switching ip
 tunnel destination 3.3.3.3
 tunnel mode mpls traffic-eng
 tunnel mpls traffic-eng priority 5 5
 tunnel mpls traffic-eng bandwidth  1
 tunnel mpls traffic-eng path-option 3 explicit identifier 17
 tunnel mpls traffic-eng path-option 5 dynamic
!
ip explicit-path identifier 17 enable
 next-address 1.1.1.1
 next-address 2.2.2.2
 next-address 3.3.3.3
!
```

RSVP-TE in MPLS Networks

- Explicitly routed Label Switched Paths (TE-LSP) have associated byte counters
- A full mesh of TE-LSPs enables to measure the traffic matrix in MPLS networks directly



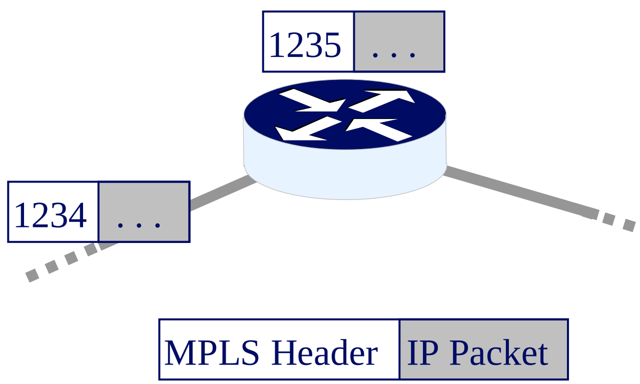
RSVP-TE in MPLS Networks

Pro’s and Con’s

- Advantages:
  - Method that comes closest a traffic matrix measurement
  - Easy to collect data
- Disadvantages:
  - A full mesh of TE-LSPs introduces an additional routing layer with significant operational costs;
  - Emulating ECMP load sharing with TE-LSPs is difficult and complex:
    - Define load-sharing LSPs explicitly;
    - End-to-end vs. local load-sharing;
  - Only provides Internal Traffic Matrix, no Router/PoP to peer traffic

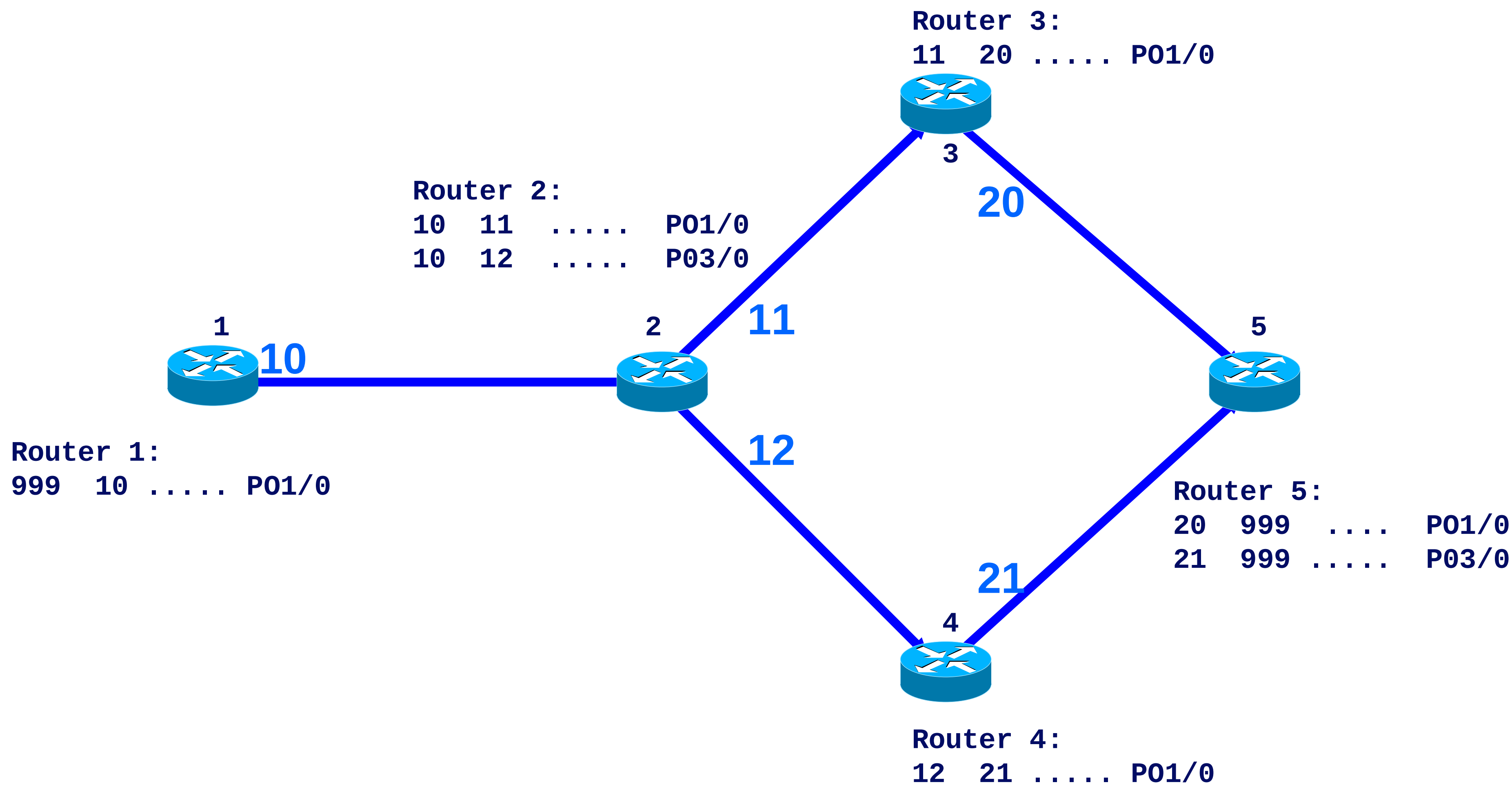
Traffic matrices with LDP statistics

- In a MPLS network, LDP can be used to distribute label information
- Label-switching can be used without changing the routing scheme (e.g. IGP metrics)
- Many router operating systems provide statistical data about bytes switched in each *forwarding equivalence class* (FEC):



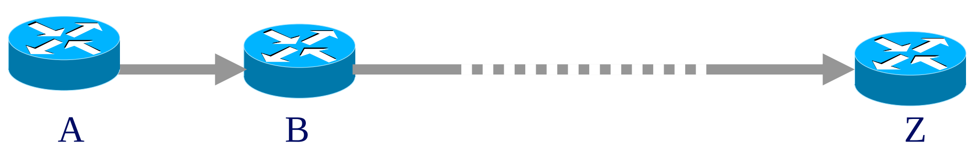
InLabel	OutLabel	Bytes	FEC	OutInt
1234	1235	**4124**	10.10.10.1/32	PO1/2
…	…	…		…

Traffic matrices with LDP statistics
Use of ECMP load-sharing



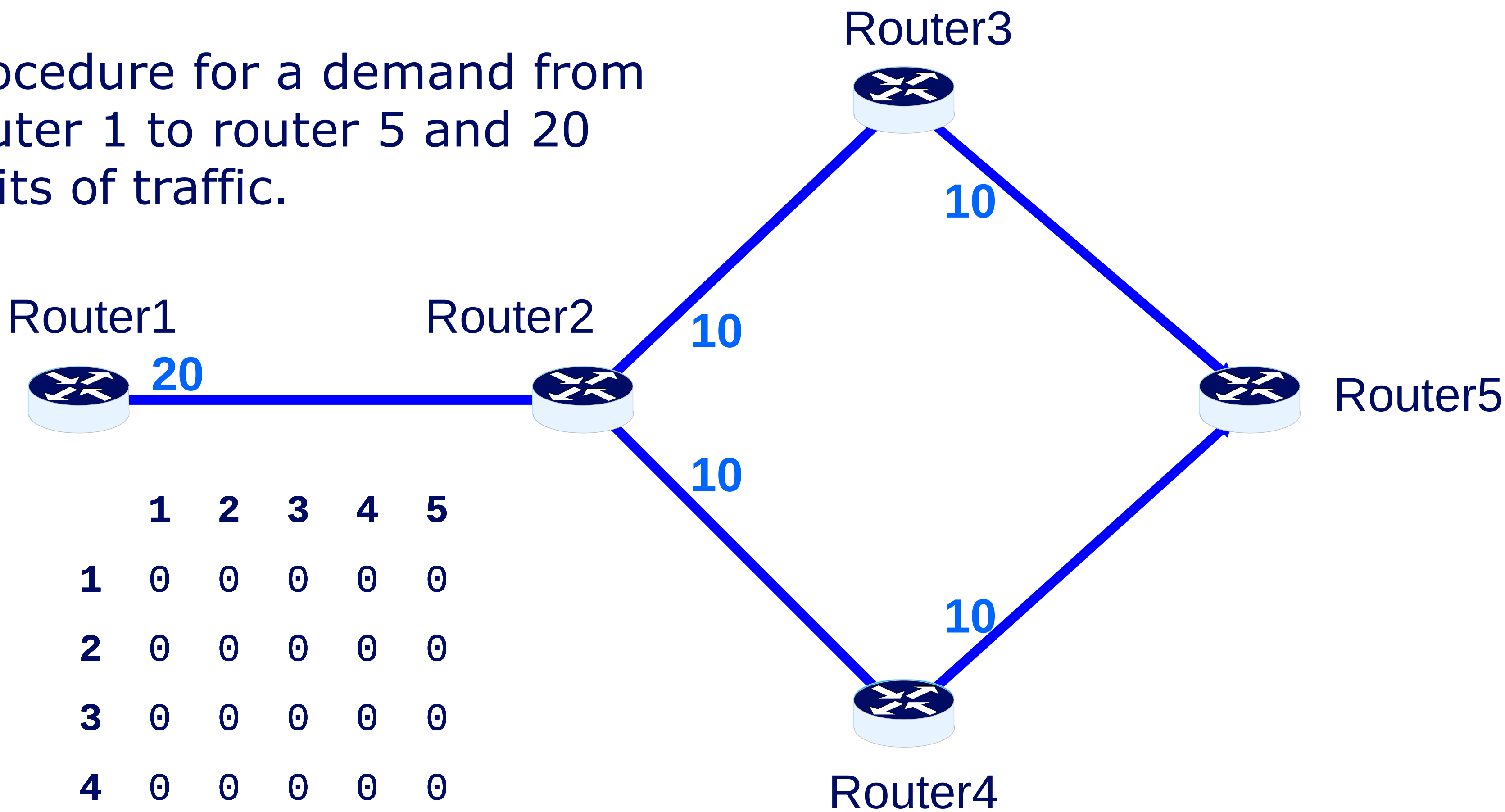
Traffic matrices with LDP statistics

- The given information allows for a forward chaining
- For each router and FEC a set of residual paths can be calculated (given the topology and LDP information)
- From the LDP statistics we gather the bytes switched on each residual path
- Problem: It is difficult to decide whether the router under consideration is the beginning or transit for a certain FEC
- Idea: For the traffic matrix *TM*, add the paths traffic to *TM(A,Z)* and subtract from *TM(B,Z)*. [4]



Traffic matrices with LDP statistics
Example

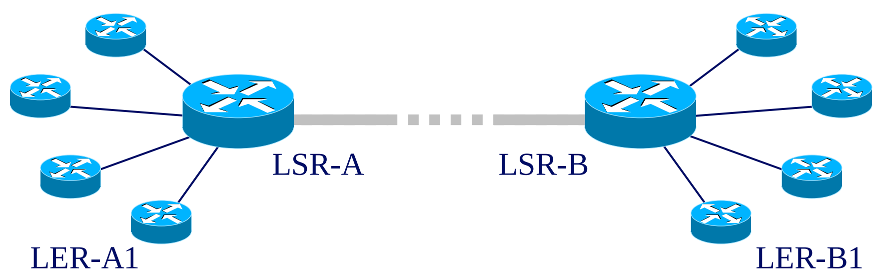
Procedure for a demand from router 1 to router 5 and 20 units of traffic.



	1	2	3	4	5
1	0	0	0	0	0
2	0	0	0	0	0
3	0	0	0	0	0
4	0	0	0	0	0
5	20	-20	10	10	0

Practical Implementation
Cisco IOS

- LDP statistical data available through "show mpls forwarding" command
- Problem: Statistic contains no ingress traffic (only transit)
- If separate routers exist for LER- and LSR-functionality, a traffic matrix on the LSR level can be calculated
- A scaling process can be established to compensate a moderate number of combined LERs/LSRs.



Practical Implementation
Cisco IOS

LDP statistics on IOS:

```
router# show mpls forwarding-table
Local   Outgoing    Prefix            Bytes tag  Outgoing   Next Hop
tag     tag or VC   or Tunnel Id      switched   interface
26      26          62.225.24.184/30  0          PO10/0     point2point
        46          62.225.24.184/30  0          PO13/1     point2point
27      Pop tag     62.225.17.203/32  56529738   PO2/0      point2point
[..]
```

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Practical Implementation
Juniper JUNOS

- LDP statistical data available through “show ldp traffic-statistics” command
- Problem: Statistic is given only per FECs and not per outgoing interface
- As a result one cannot observe the branching ratios for a FEC that is split due to load-sharing (ECMP);
- Assume that traffic is split equally
- Especially for backbone networks with highly aggregated traffic this assumption is met quite accurately

Practical Implementation
Juniper JUNOS

```
user@router> show ldp traffic-statistics
FEC                    Type      Packets        Bytes  Shared
 62.225.16.134/32      Transit   1236933    103984630  No
                       Ingress         0            0  No
[..]
user@router> show route table inet.3
[..]
62.225.16.134/32     *[LDP/9] 06:08:27, metric 1
                      > via so-0/0/0.0, Push 39
[..]
```

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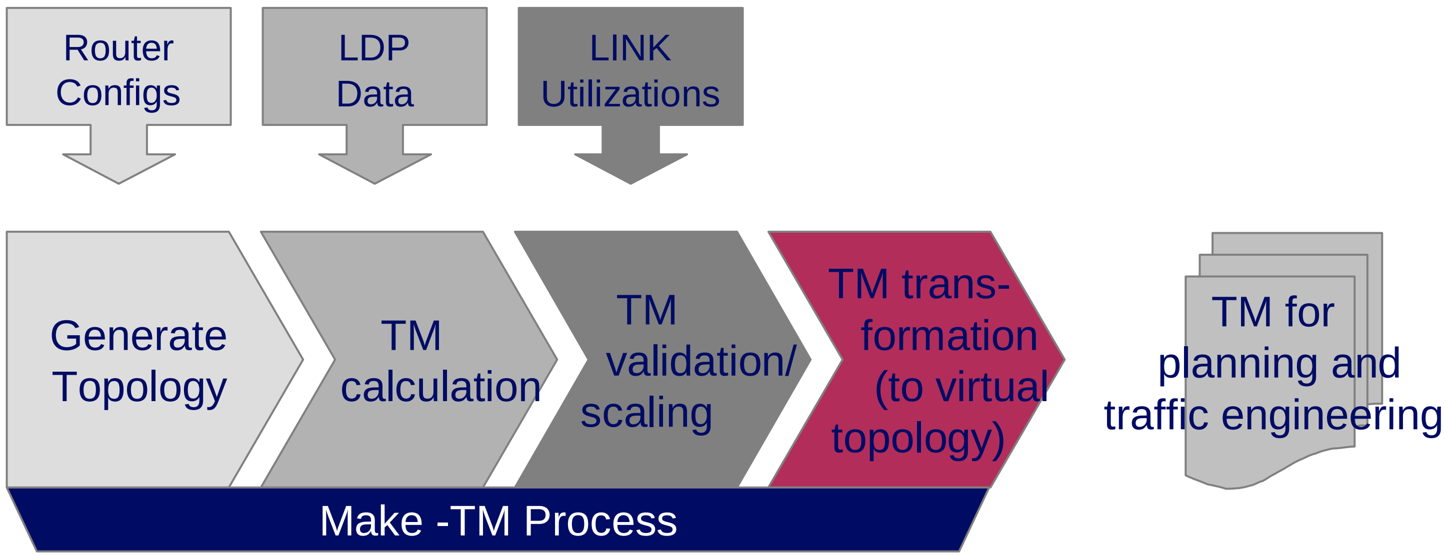
Practical Implementation
Results

- The method has been successfully implemented in Deutsche Telekom's global MPLS Backbone
- A continuous calculation of traffic matrices (15min averages) is accomplished in real-time for a network of 180 routers
- The computation requires only one commodity PC
- No performance degradation through LDP queries
- Calculated traffic matrices are used in traffic engineering and network planning

Practical Implementation
Deployment Process



Conclusions for LDP method

- This method can be implemented in a multi-vendor network
- It does not require the definition of explicitly routed LSPs
- It allows for a continuous calculation
- There are some restrictions concerning
  - vendor equipment
  - network topology
- See Ref. [4]

Estimation Techniques

What do we have?

- NetFlow
  - v5 deployment is complex
  - newer versions (aggregation, v8) not complete
- DCU (Juniper)
  - only 16/126 classes
- BGP Policy Accounting
  - only 64 classes, BGP only
- MPLS
  - TE tunnels
    - requires full TE mesh
  - LDP counters
    - nice solution, only minor issues (see [4])

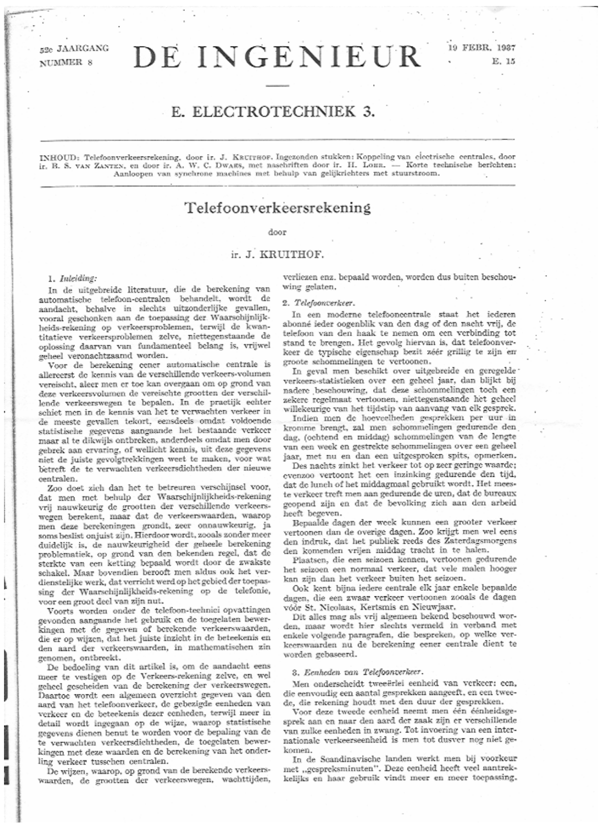
What do we want?

- Derive Traffic Matrix (TM) from easy to measure variables
  - No complex features to enable
- Link Utilization measurements
  - SNMP
  - easy to collect, e.g. MRTG
- Problem:

  Estimate point-to-point demands from measured link loads
- Network Tomography
  - Y. Vardi, 1996
  - Similar to: Seismology, MRI scan, etc.

Is this new?

- Not really...
- ir. J. Kruithof: *Telefoonverkeersrekening*, De Ingenieur, vol. 52, no. 8, feb. 1937 (!)



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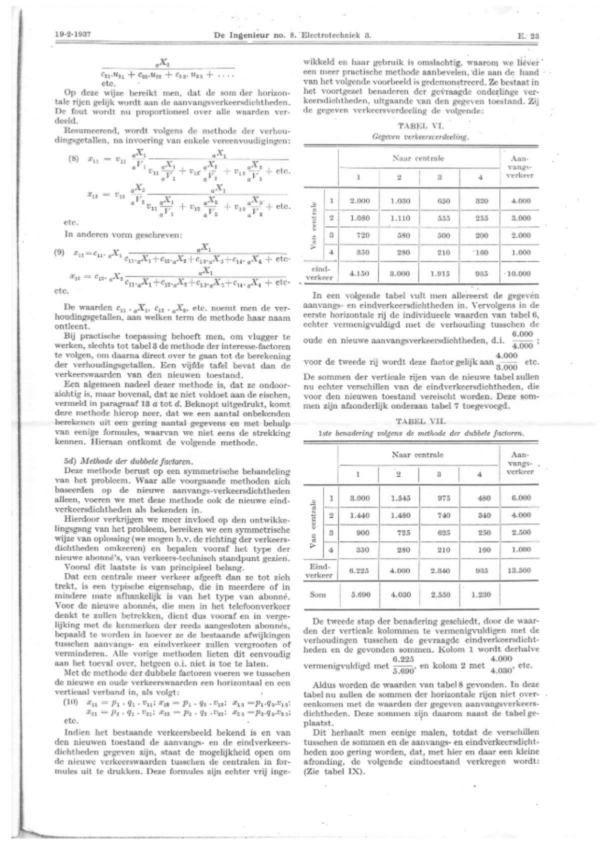

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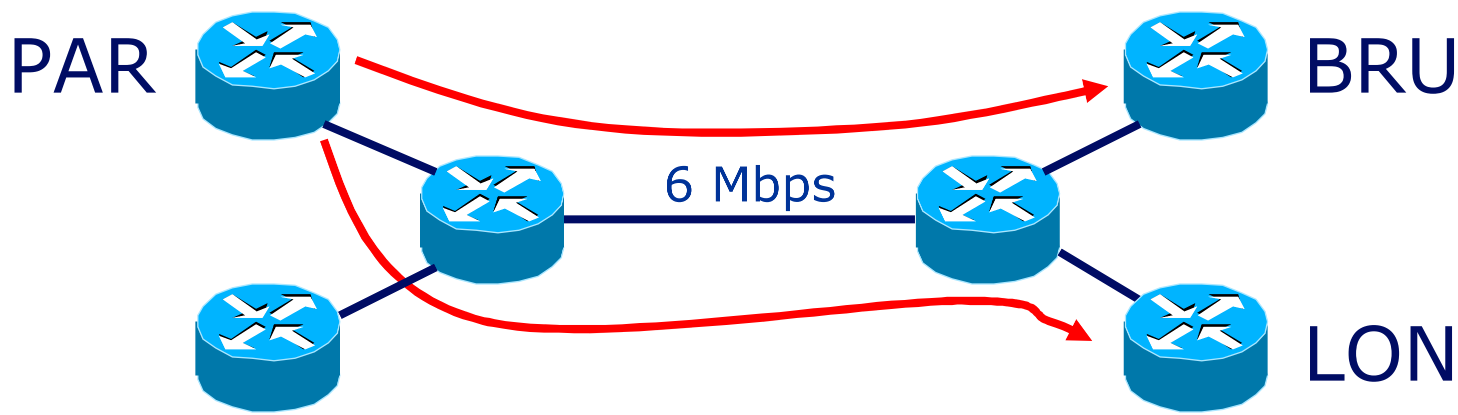
TABEL VI.

TABEL VII.

Demand Estimation

- Underdetermined system:
  - N nodes in the network
  - O(N) links utilizations *(known)*
  - $O(N^2)$ demands *(unknown)*
  - Must add additional assumptions (information)
- Many algorithms exist:
  - *Gravity model*
  - *Iterative Proportional Fitting (Kruithof's Projection)*
  - *Maximum Likelihood Estimation*
  - *Entropy maximization*
  - *Bayesian statistics (model prior knowledge)*
  - *Etc...!*
- Calculate the **most likely** Traffic Matrix

Example

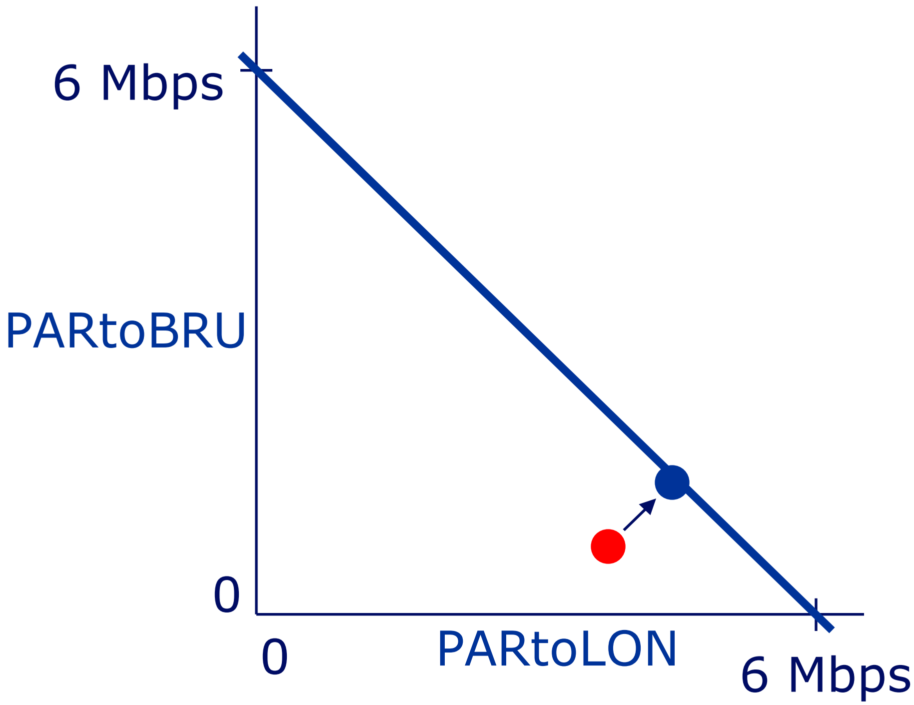


y: link utilizations
A: routing matrix
x: point-to-point demands

Solve: <u>y = Ax</u>
In this example: <u>6 = PARtoBRU + PARtoLON</u>

Example

Solve: y = Ax -> 6 = PARtoBRU + PARtoLON



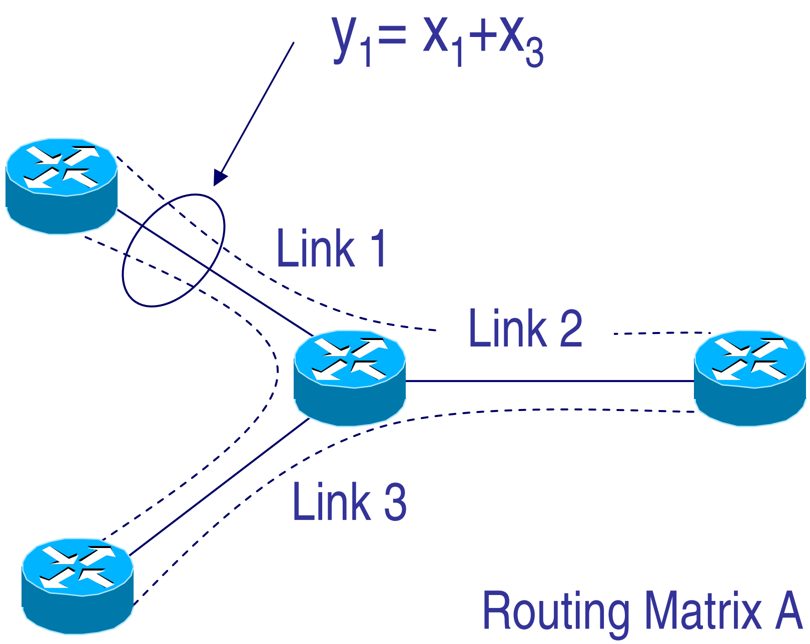
Additional information

E.g. Gravity Model (every source sends the same per-centage as all other sources of it's total traffic to a certain destination)

Example: Total traffic sourced at PAR is *50Mbps.* BRU sinks *2%* of total traffic, LON sinks *8%:*
PARtoBRU =1 Mbps and
PARtoLON =4 Mbps

Final Estimate: PARtoBRU = 1.5 Mbps and PARtoLON = 4.5 Mbps

General Formulation



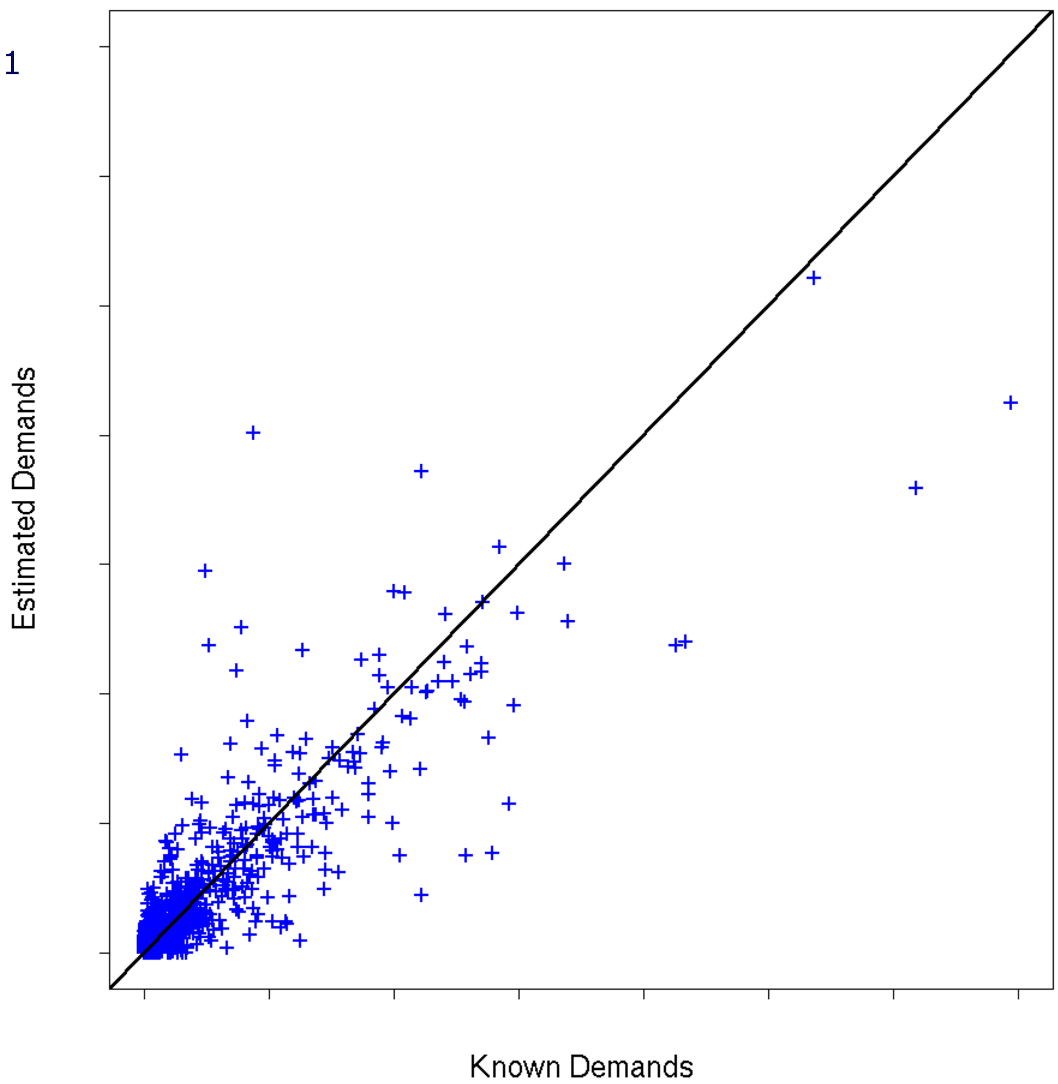
- The total traffic on each link is the sum of all the source destination flows that route over that link
- Given Y and the routing matrix A solve for X

Routing Matrix A

$$\begin{pmatrix} y_1 \\ y_2 \\ y_3 \end{pmatrix} = \begin{pmatrix} 1 & 0 & 1 \\ 1 & 1 & 0 \\ 0 & 1 & 1 \end{pmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix}$$

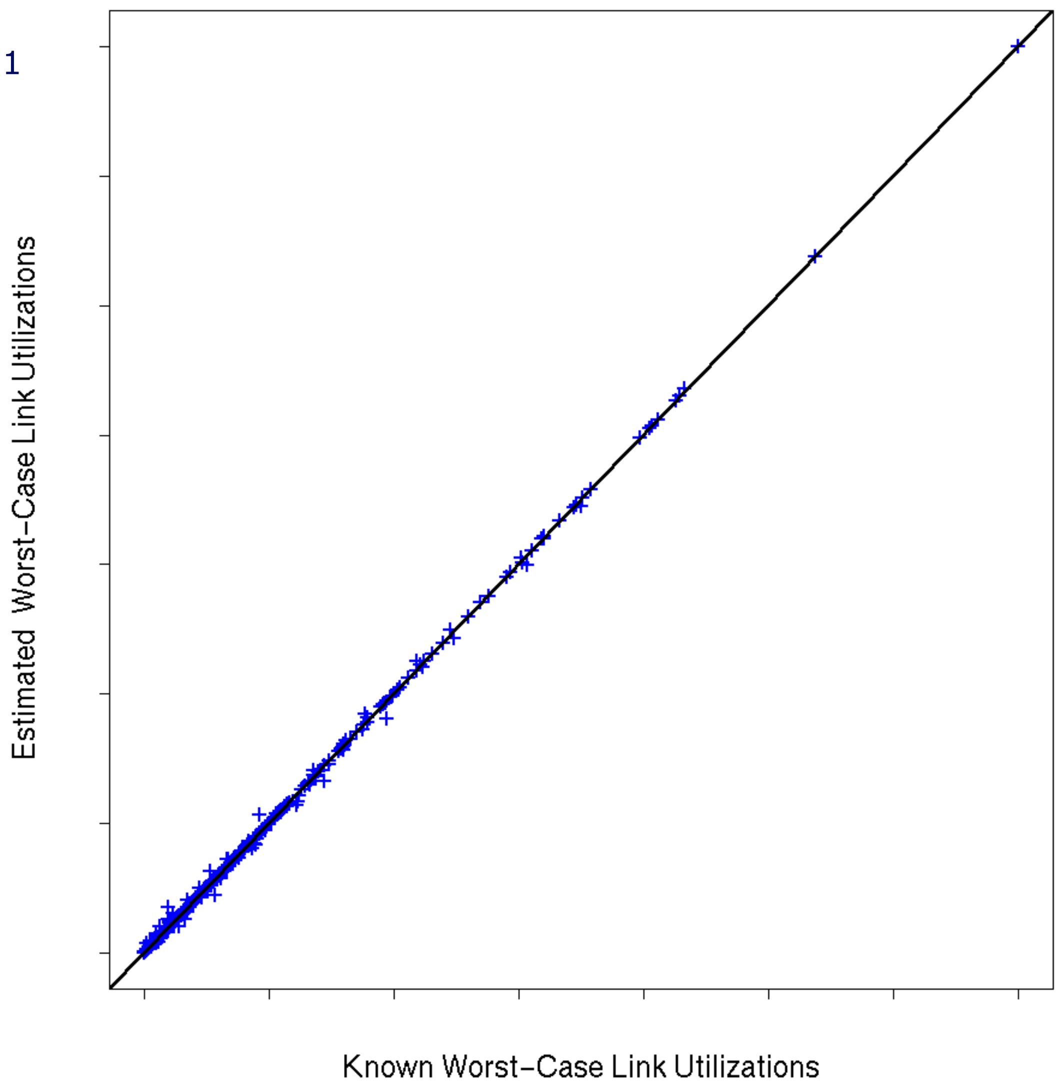
Network Results: Estimated Demands

International Tier-1
IP Backbone



Estimated Link Utilizations!

International Tier-1
IP Backbone



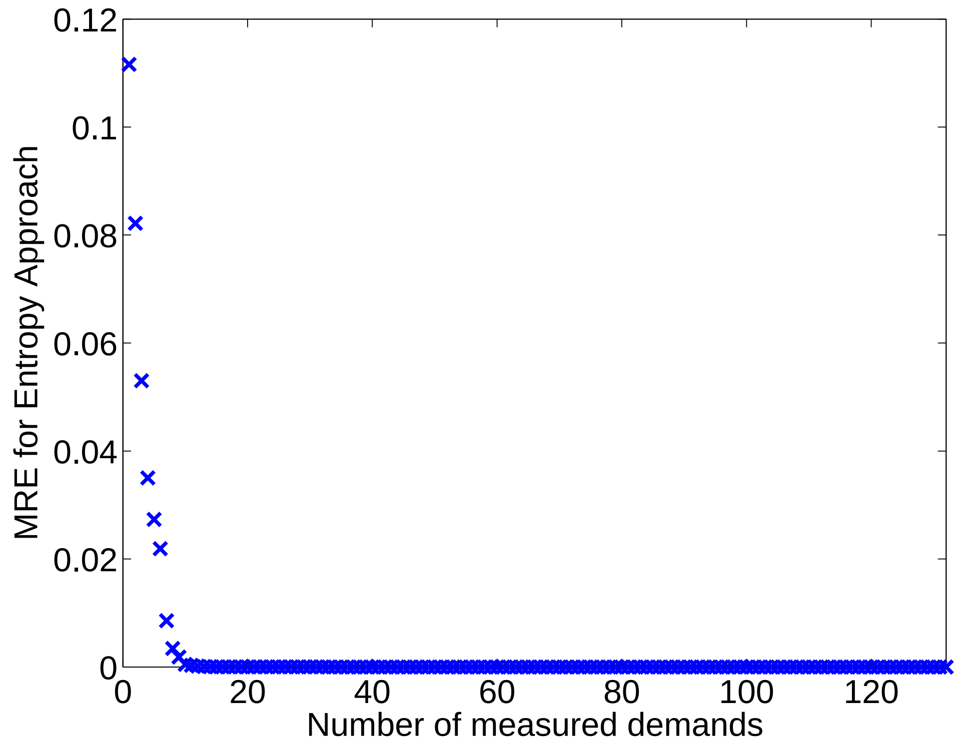
Demand Estimation Results

- Individual demands
  - Inaccurate estimates…
- Estimated worst-case link utilizations
  - Accurate!
- Explanation
  - Multiple demands on the same path indistinguishable, but their sum is known
  - If these demands fail-over to the same alternative path, the resulting link utilizations will be correct

Estimation with Measurements

- Estimation techniques can be used in combination with demand meadsurements
  - E.g. NetFlow or partial MPLS mesh

- This example: Greedy search to find demands which decreases MRE (Mean Relative Error) most.
  - A small number of measured demands account for a large drop in MRE



Data from [1]

Traffic Matrix Estimation
Case-Study

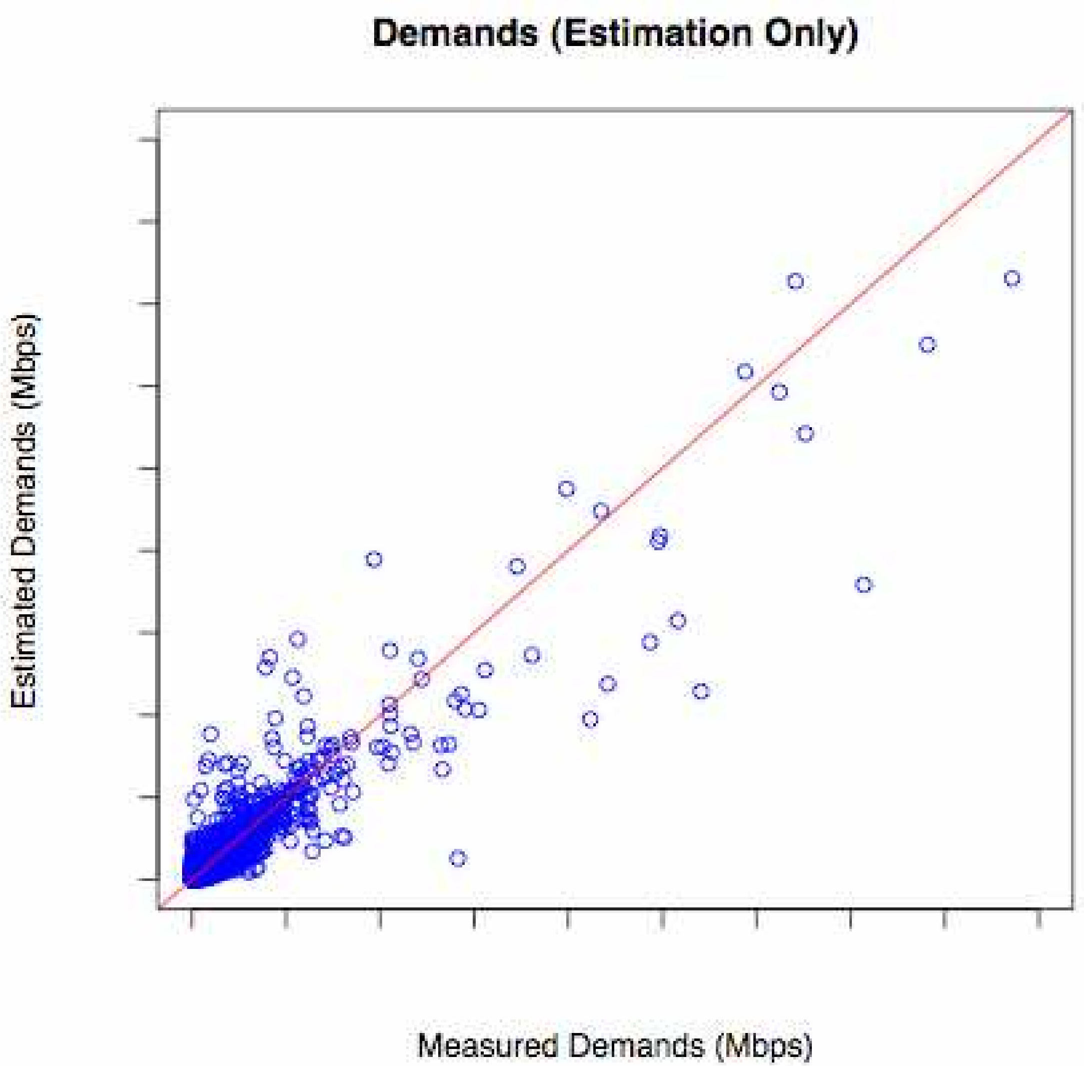
TM Estimation Deployment Case

- Large ISP network
  - about 80 Routers and 200 Circuits
  - 2550 TM entries
    - not all routers source/sink traffic (e.g. core)
- Known Traffic Matrix
  - Direct MPLS measurement
- Case-study will evaluate:
  - How does estimated TM compare to known TM?
  - How well does the estimated TM predict worst-case link utilizations?
  - How well do tools that require a TM work when given the estimated TM?
  - How much can the estimated TM be improved by adding point-to-point measurements?

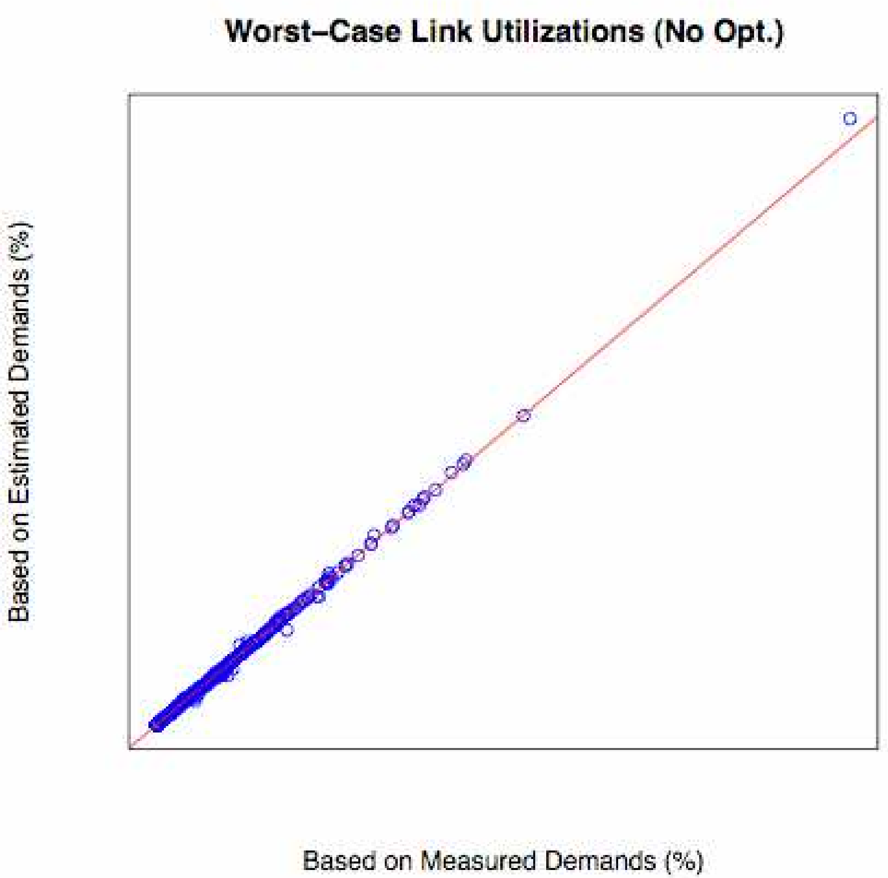
Procedure

- TM estimation using Cariden MATE Software
  - Demand Deduction tool
- Start with current network and known TM
  - save as "PlanA" (with TM "Known")
- IGP Simulation for non-failure
- Save Link Utilizations and Node In/Out traffic
- Estimate Traffic Matrix
  - New TM: "Estimated", Save as "PlanB"
- Do an IGP *Metric Optimization* on both networks
  - Using known TM in planA, estimated TM in PlanB
- Simulate IGP routing on both optimized networks
  - using *known* Traffic matrix for both
- Compare Results!

Estimated Demands

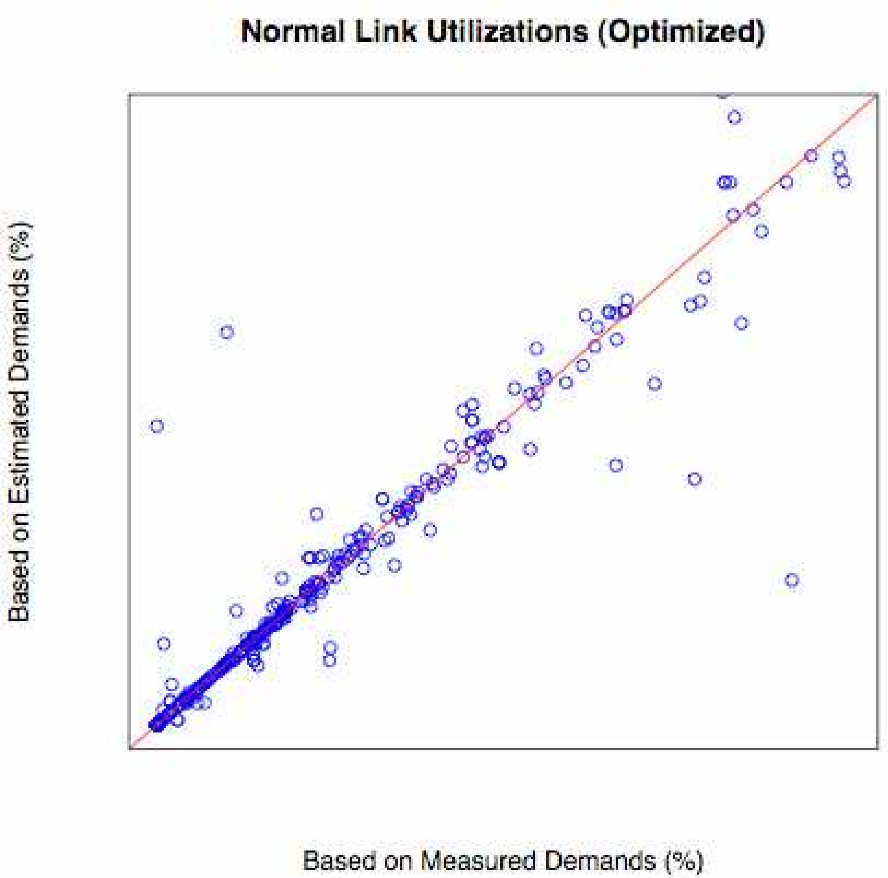


Worst-Case Link Util. (No. Opt)



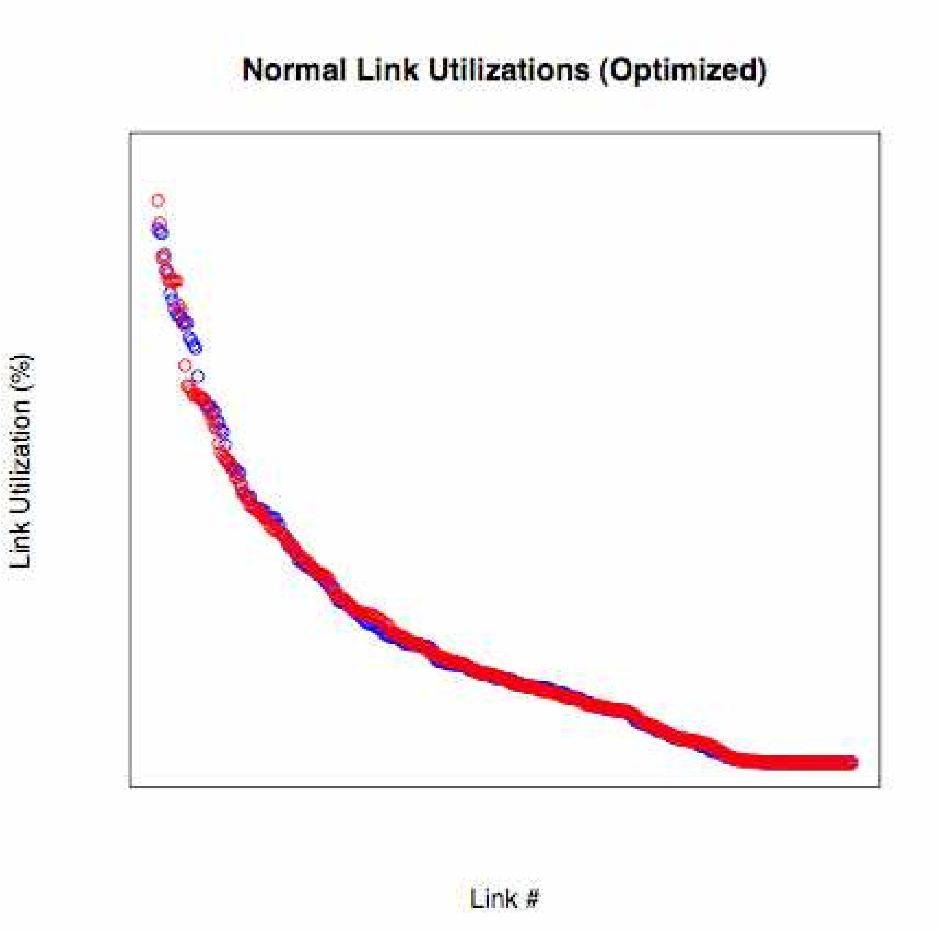
- No Metric Optimization
- PlanA Traffic Matrix:
  - Known
- PlanB Traffic Matrix:
  - Estimated
- IGP Simulation
  - Circuit + SRLG failures
- Compare Worst-Case Link Utilizations (in %)

Normal Link Utilizations (Opt.)



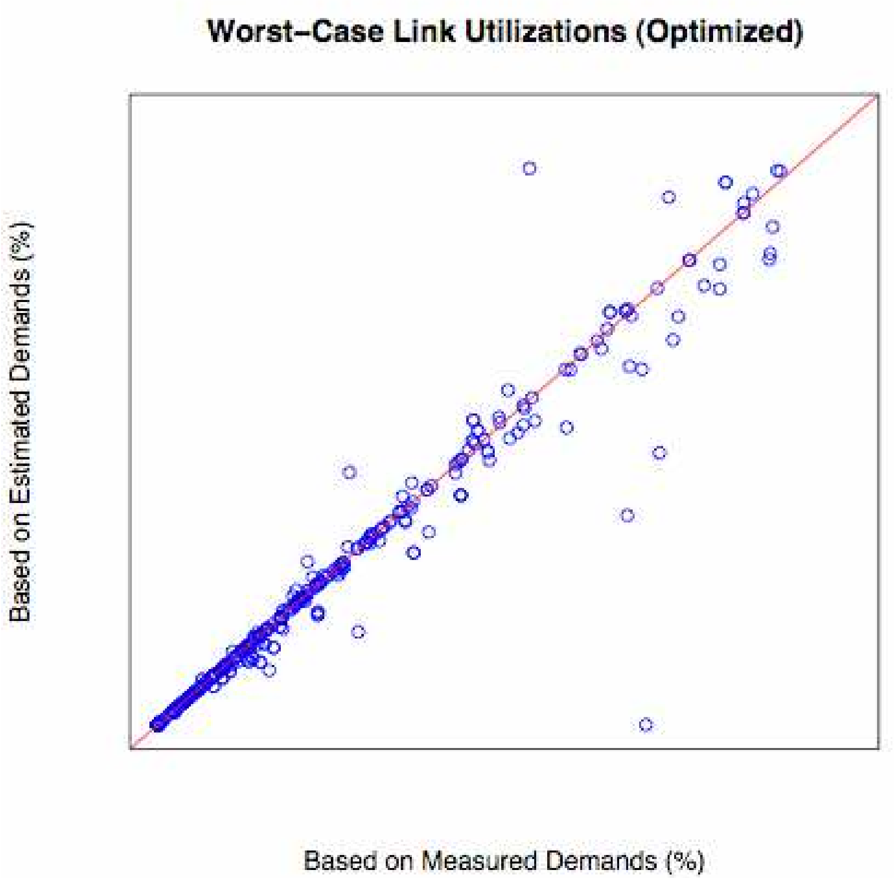
- IGP Metric Optimization
  - PlanA Traffic Matrix:
    - Known
  - PlanB bandwidth level:
    - Estimated
- IGP Simulation
  - PlanA Traffic Matrix:
    - Known
  - PlanB bandwidth level:
    - Original
- Compare Base Link Utilizations (in %)
  - non-failure

Normal Link Utilizations (Opt.)



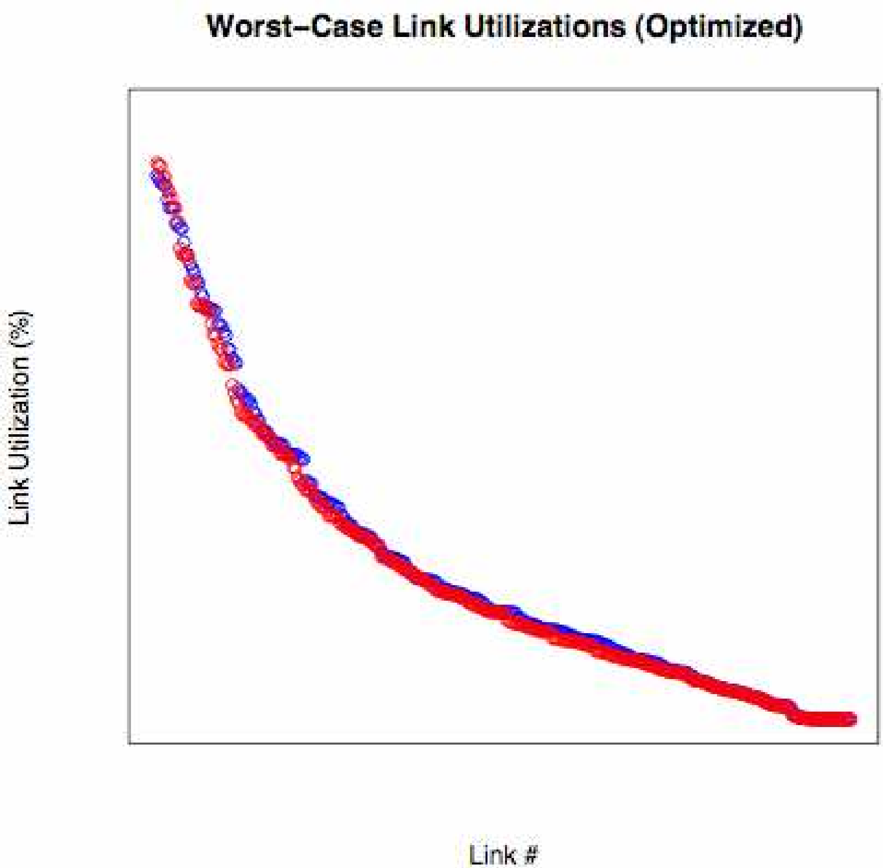
- Scenario: same as previous slide
- Compare *Sorted* Link Utilizations
  - non-failure
- Colors:
  - based on measured demands: BLUE
  - based on estimated demands: RED

Worst-Case Link Utilizations (Opt)



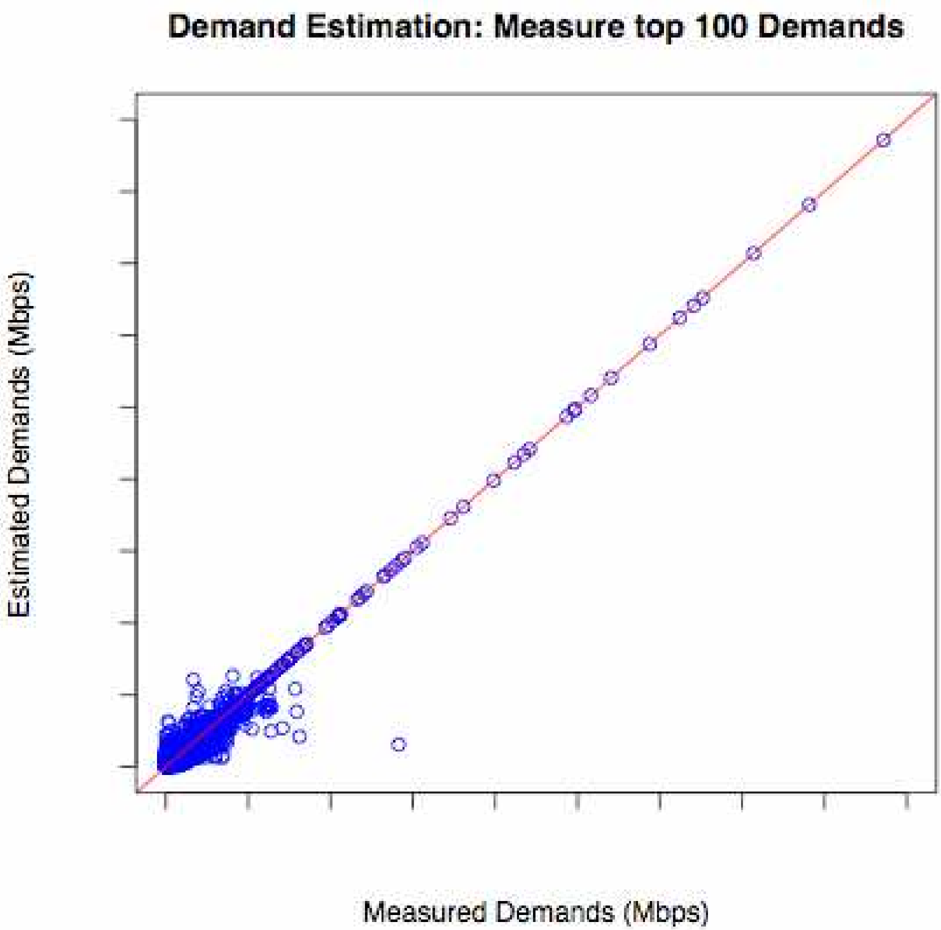
- Scenario: same
- Compare Worst-Case Link Utilizations (in %)
  - Circuits + SRLG failures

Worst-Case Link Utilizations (Opt)



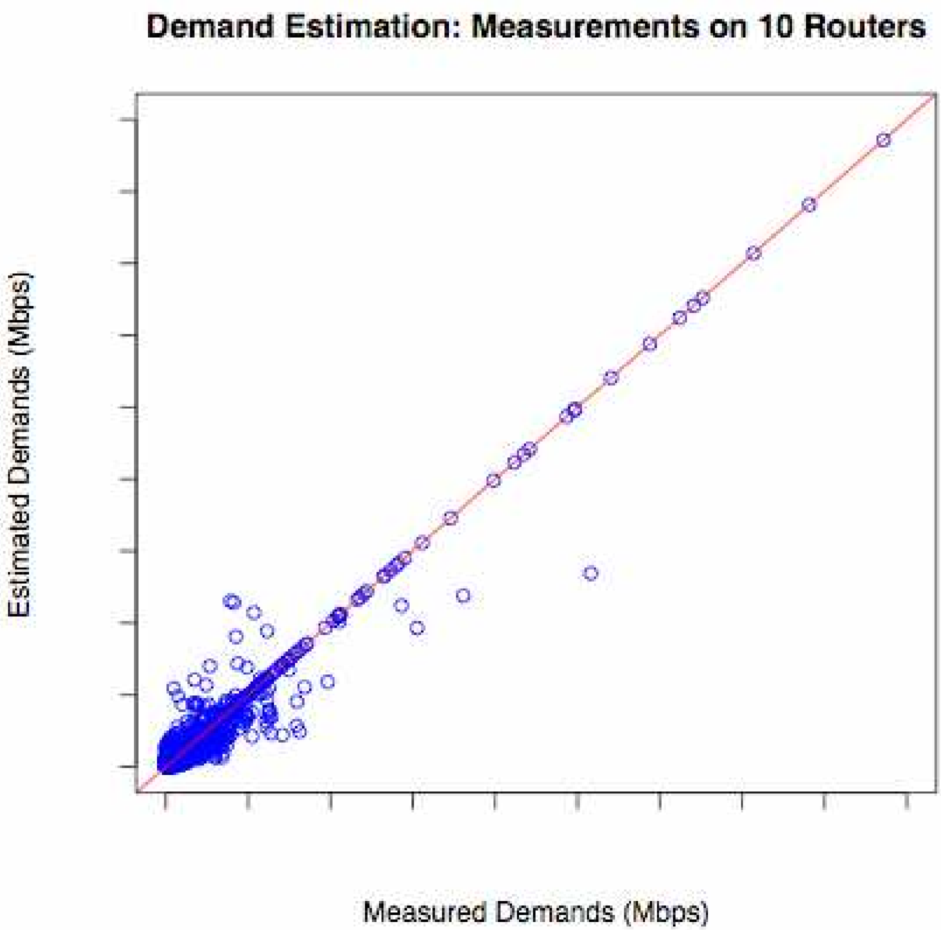
- Scenario: same
- Compare *Sorted* Worst-Case Link Utilizations (in %)
  - Circuits + SRLG failures
- Colors:
  - based on measured demands: BLUE
  - based on estimated demands: RED

Add Measurements (1)



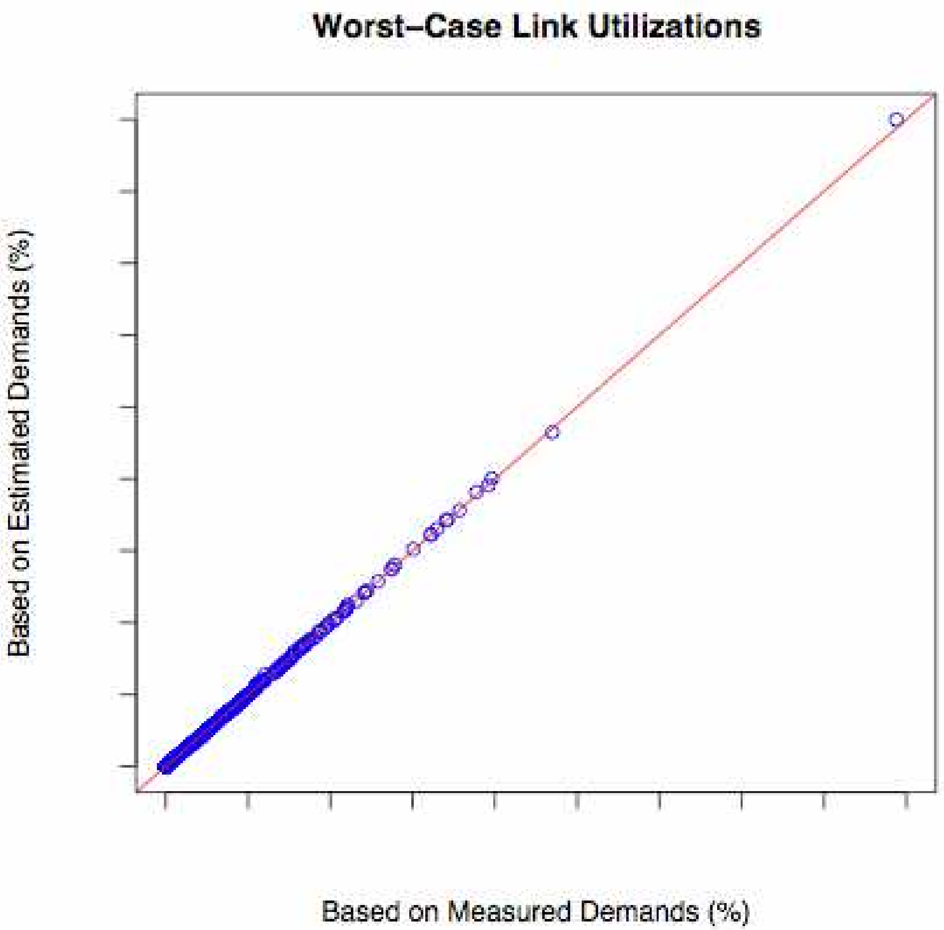
- Select the top 100 demands from the estimated traffic matrix
- Setup Juniper DCU (or equivalent) to measure these demands
  - on 23 routers
  - 38% of total traffic
- Add measured data to the TM estimation process
- (FYI: 990 demands represent 90% of total traffic)

Add Measurements (2)



- Select the top 10 routers from the measured in/out traffic
- Select the top 16 demands on each of these routers (estimated)
- Setup Juniper DCU to measure these demands
  - 160 demands
  - 10 routers
  - 41% of total traffic
- Add measured data to the TM estimation process

Worst-Case Link Utilization (2)



- Revisit the worst-case link utilizations, now with more accurate TM
- Similar results as before
- Hardly any room for improvement!

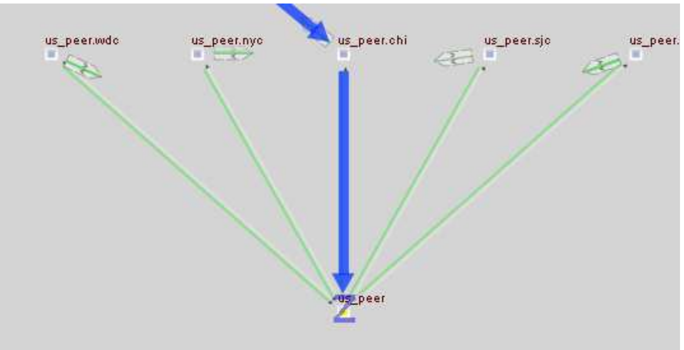
TM Estimation Case-Study

- Works very well on this ISP topology/traffic!
  - Also on AT&T, and all other networks we tried
- Even more accurate if used in combination with demand measurements
  - E.g. from NetFlow, DCU or MPLS

External/Inter-AS TM

- Traffic Matrix on a network will change due to core failures (closest-exit), or peering link failures

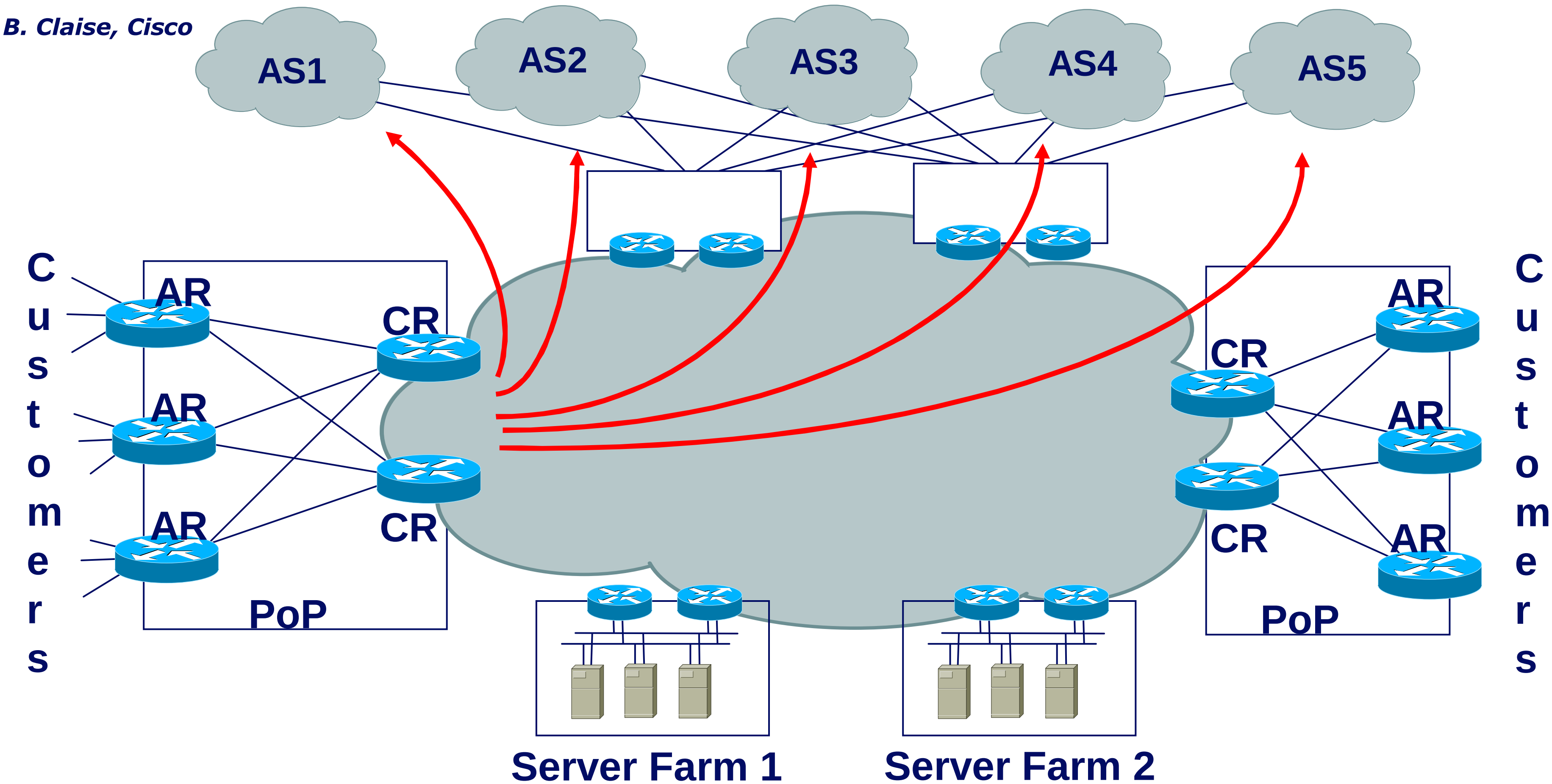
- Create *router-to-peer* TM
- Estimation procedure is similar
- Routing is different
  - policy restrictions:
    e.g. no traffic from peer to peer
  - Virtual model of remote AS



- Estimation can make use of a known core TM

External Traffic Matrix

B. Claise, Cisco



From "Router to BGP AS", the router being the **AR** or **CR**

The external traffic matrix can influence the internal one

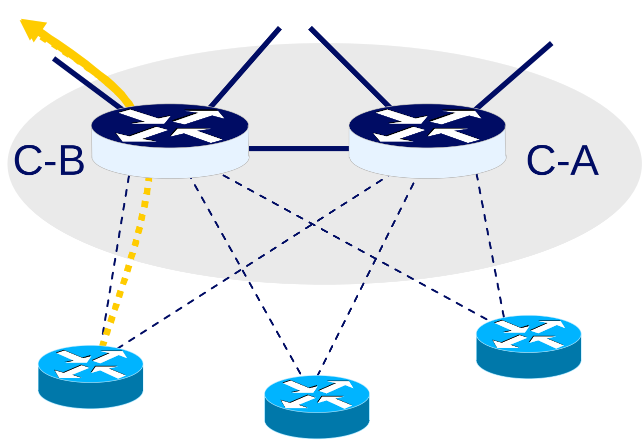
TM Estimation Summary

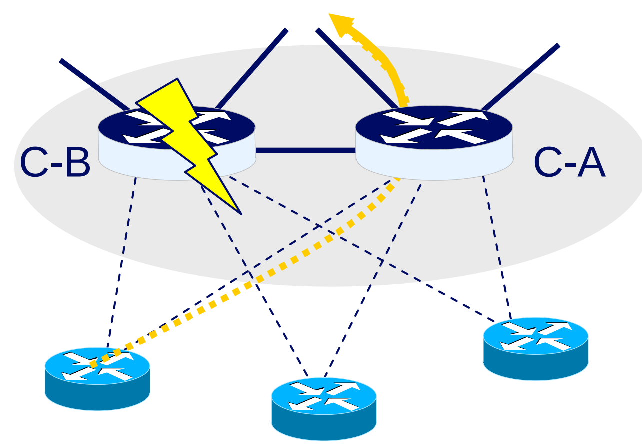
- Algorithms have been published
  - Implement yourself (e.g. IPF procedure)
  - Commercial tools are available
- Can be used in multiple scenarios:
  - Fully estimate Traffic Matrix
  - Combine with NetFlow/DCU/etc.
    - Measure large demands, estimate small ones
  - Estimate unknown demands in a network with partial MPLS mesh (LDP or RSVP)
  - Estimate Peering traffic when Core Traffic Matrix is known
- Also see AT&T work
  - E.g. Nanog29: *How to Compute Accurate Traffic Matrices for Your Network in Seconds* [2]

Traffic Matrices in Partial Topologies

Traffic Matrices in Partial Topologies

- In larger networks, it is often important to have a TM for a partial topology (not based on every router)
- Example: TM for core network (planning and TE)
- Problem: TM changes in failure simulations
- Demand moves to another router since actual demand starts outside the considered topology (red):



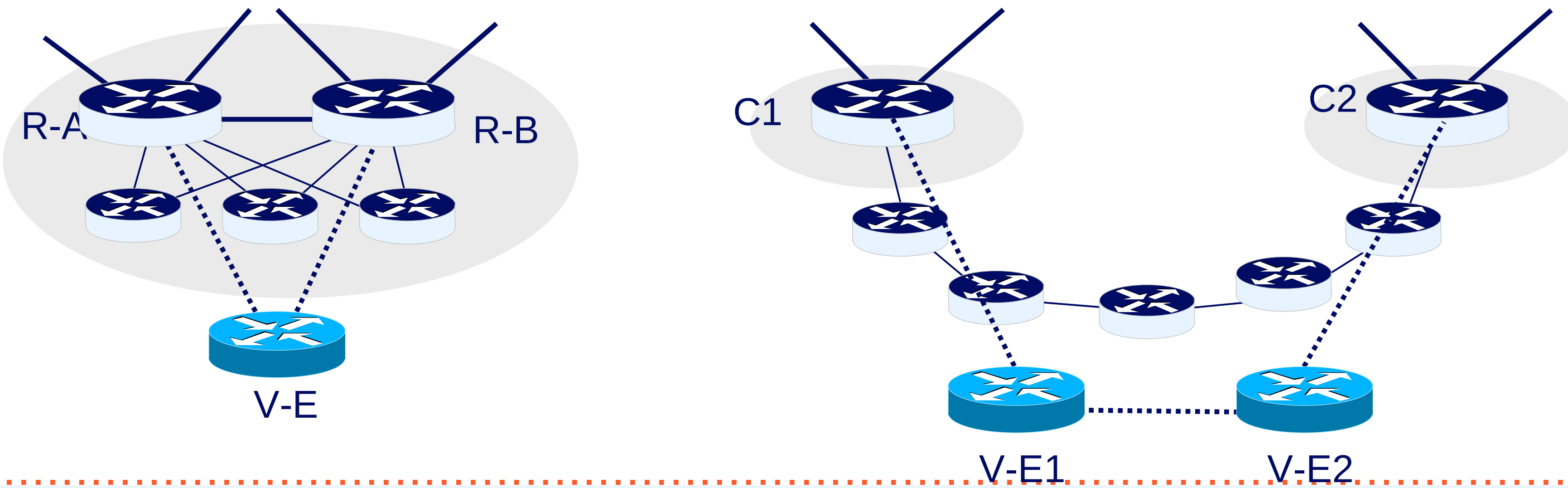


Traffic Matrices in Partial Topologies

- The same problem arises with link failures
- Results in inaccurate failure simulations on the reduced topology
- Metric changes can introduce demand shifts in partial topologies, too.
- But accurate (failure) simulations are essential for planning and traffic engineering tasks

Traffic Matrices in Partial Topologies

- Introduce virtual edge devices as new start-/endpoints for demands
- Map real demands to virtual edge devices
- Model depends on real topology
- Tradeoff between simulation accuracy and problem size.



Multicast

Multicast deployment

- Recent deployment of “IPTV-like” services
- Traffic becomes significant on backbone links
- Using SSM model
  - ‘streams’ are identified by multicast groups
- Unfortunately, no byte counters in the IF-MIB
  - only packets…
- IPMROUTE MIB provides (on every router):
  - Traffic per multicast group
  - Next-hops (outgoing interfaces)
- PIM MIB could be used to build topology
  - Neighbor discovery
- See GRNET Multicast Weathermap [9]

Summary & Conclusions

Overview

- “Traditional” NetFlow (Version 5)
  - Requires a lot of resources for collection and processing
  - Not trivial to convert to Traffic Matrix
- BGP NextHop Aggregation NetFlow provides almost direct measurement of the Traffic Matrix
  - Verion 9 export format
  - Only supported by Cisco in newer IOS versions
- BGP Policy Accounting and Juniper DCU are limited (only 64 or 16/126 classes) to build a full Traffic Matrix
  - But could be used as adjunct to TM Estimation

Overview

- MPLS networks provide easy access to the Traffic Matrix
  - Directly measure in RSVP TE networks
  - Derive from switching counters in LDP network
- Very convenient if you already have an MPLS network, but no reason to deploy MPLS just for the TM
- Estimation techniques can provide reliable Traffic Matrix data
  - Very useful in combination with partially know Traffic Matrix (e.g. NetFlow, DCU or MPLS)

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