Quantifying and Mitigating IGMP Filtering in Topology Discovery

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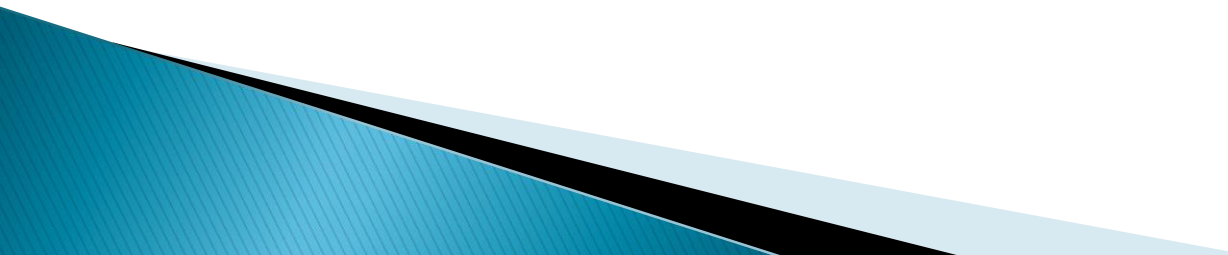III. University of Liege,   Belgium

Agenda

- Topology Discovery and IGMP probing

- IGMP filtering

- Quantifying the IGMP filtering impact

- Reassembling strategy

Topology Discovery

The Internet topology as a dynamic graph of

- IP Interfaces
  - Traceroute
- Routers
  - Traceroute & Alias Resolution, IGMP
- Point of Presence
- Autonomous Systems (AS)
  - IP-2-AS and Router-2-AS mapping

- Goals
  - IP network models & simulations
  - Ground truth input for topology generation
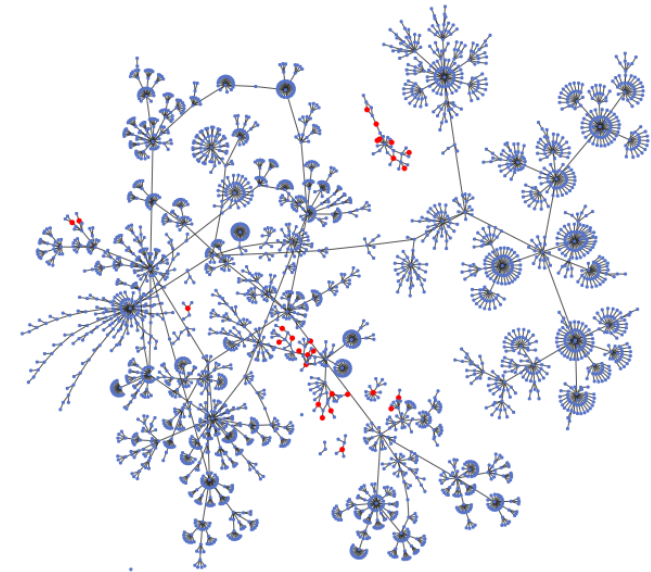
Sprint Network.
Router-level Map
MERLIN project. 2011

Topology Discovery

The Internet topology as a dynamic graph of

- IP Interfaces
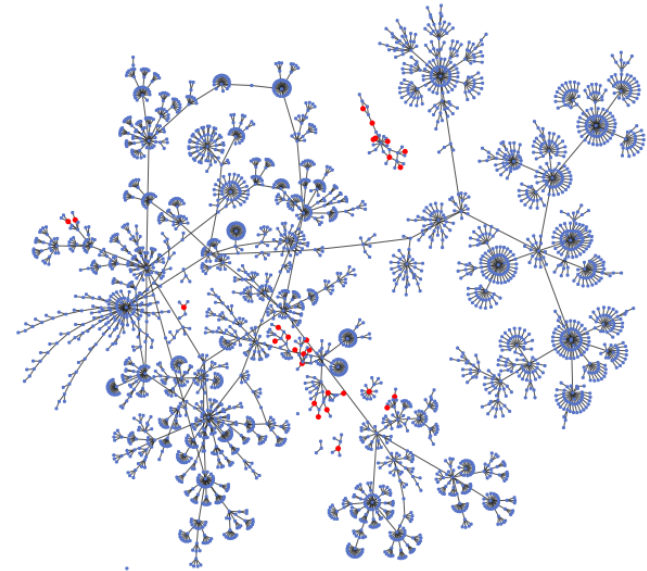 - Traceroute
- Routers
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- Goals
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Sprint Network.
Router-level Map
MERLIN project. 2011

IGMP Probing

- IGMP `ASK-FOR-NEIGHBORS` probes to elicit IGMP `NEIGHBORS-REPLY` messages.
- The targeted router provides information about its multicast enabled interfaces and the links involving those interfaces.
- The ME.R.L.IN project
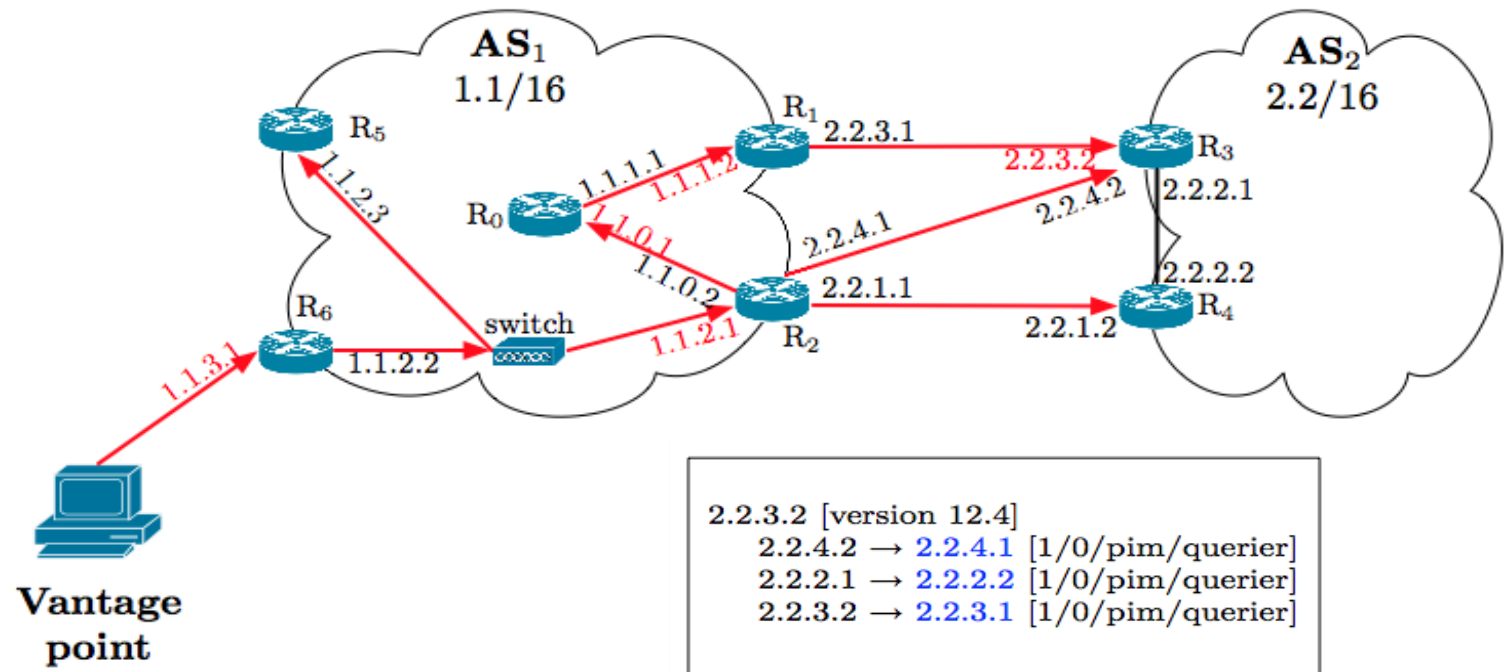
IGMP Probing: Advantages

- Natively discovering network at Router level
- Recursively exchange of `ASK-FOR-NEIGHBORS` and `NEIGHBORS-REPLY` messages

- Advantages
  - Highly accurate: no inference.
  - Alias Resolution: no need to gather IP interfaces.
  - Network friendly: 1 probe injected per router.
  - Forwarding independent: backup links reported.
  - Layer-2 infrastructure partially inferred.

IGMP Probing: Drawbacks

▸ Natively discovering network at Router level
▸ Recursively exchange of `ASK-FOR-NEIGHBORS` and `NEIGHBORS-REPLY` messages

▸ Drawbacks
  o Multicast scope
 o IGMP local and in-transit filtering

IGMP Probing: Drawbacks

- Natively discovering network at Router level
- Recursively exchange of `ASK-FOR-NEIGHBORS` and `NEIGHBORS-REPLY` messages

- Drawbacks
  - Multicast scope
  - IGMP local and in-transit filtering

IGMP Filtering

- Local filtering
  - The targeted router silently discards the packet probe.

- In-transit filtering
  - The IGMP probe or its reply are dropped along the path.

Even a single not responding router may induce a great fragmentation!

CMP A

CMP B

unresponsive router
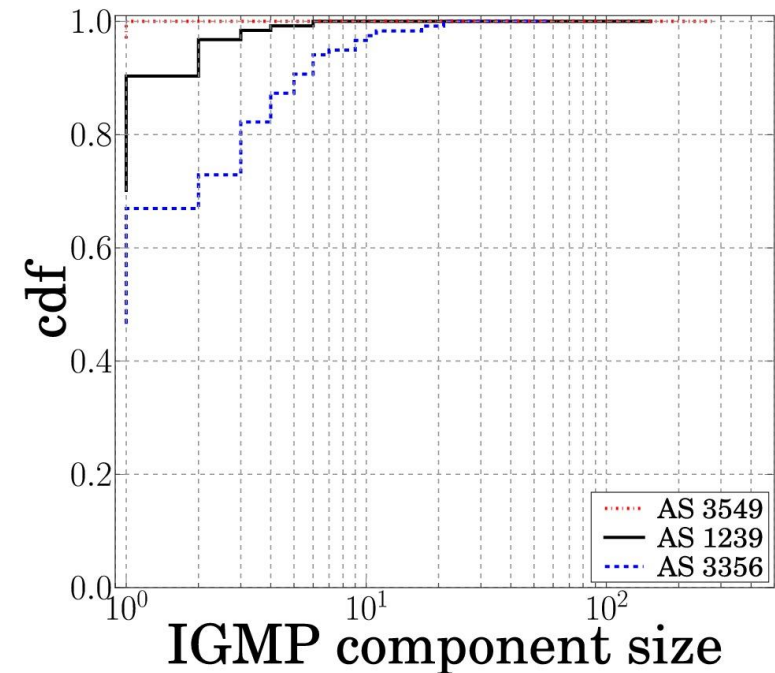
CMP C
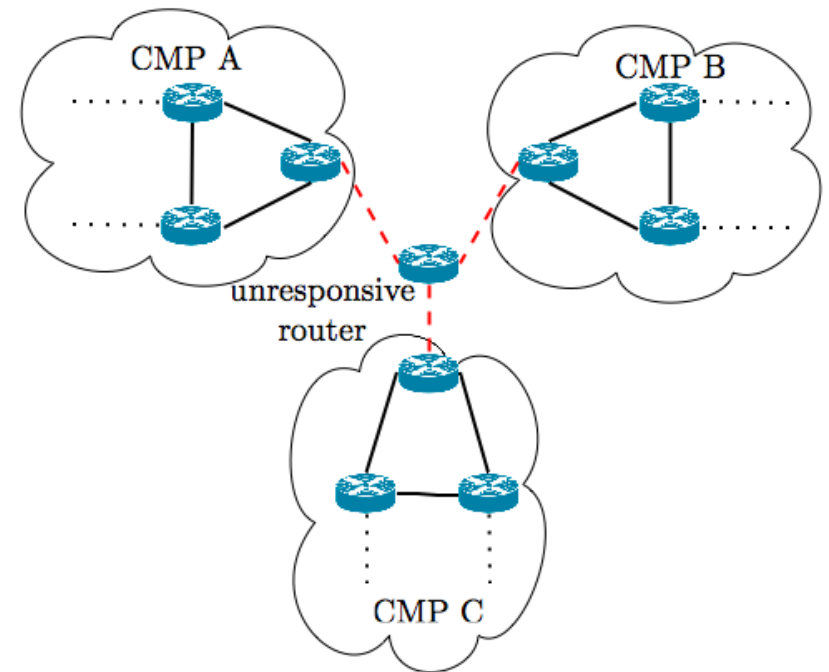
Quantifying the IGMP filtering impact

Quantifying the IGMP filtering impact

- MERLIN-based experimental campaign toward Sprint, Level3, Global Crossing.
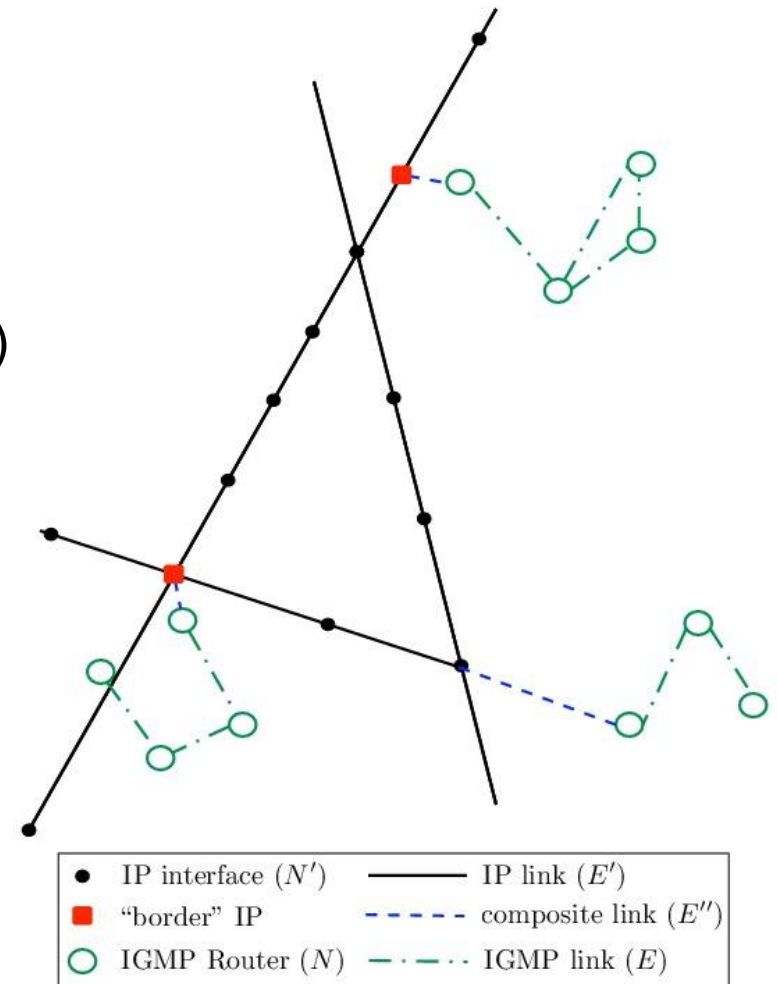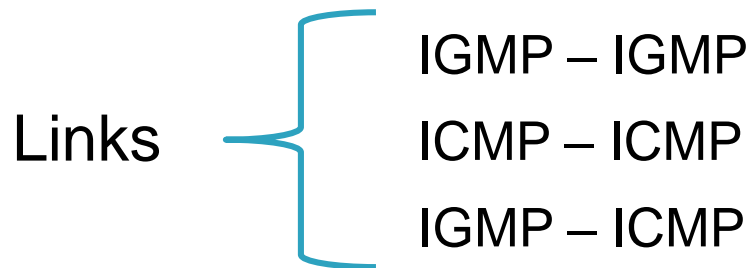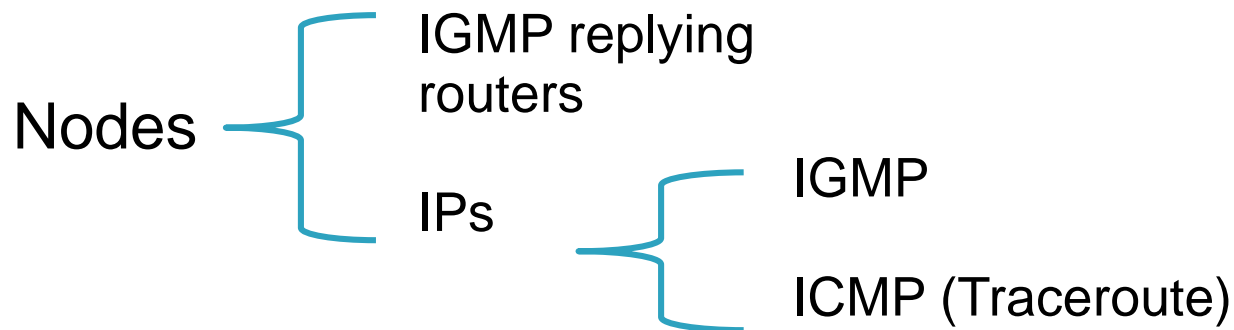

- MERLIN monitor
- MERLIN server

1. Few large connected components
2. Most isolated replying routers

Quantifying the IGMP filtering impact

▸ Analyzing the hybrid graph (IGMP + Traceroute)

Nodes
- IGMP replying routers
- IPs
  - IGMP
  - ICMP (Traceroute)

Links
- IGMP – IGMP
- ICMP – ICMP
- IGMP – ICMP

• IP interface (N')	—— IP link (E')
■ "border" IP	– – – composite link (E'')
○ IGMP Router (N)	–·–··– IGMP link (E)

Quantifying the IGMP filtering impact

▶ Graph reduction

1. Collapse connected IGMP routers in a single node (IGMP connected component – c.c.)

2. Set the weight of each link to 1

3. Identify IP nodes with a degree>=3

●	IP interface (N')	———	IP link (E')
■	"border" IP	– – – –	composite link (E'')
○	IGMP Router (N)	–·–·–	IGMP link (E)

Quantifying the IGMP filtering impact
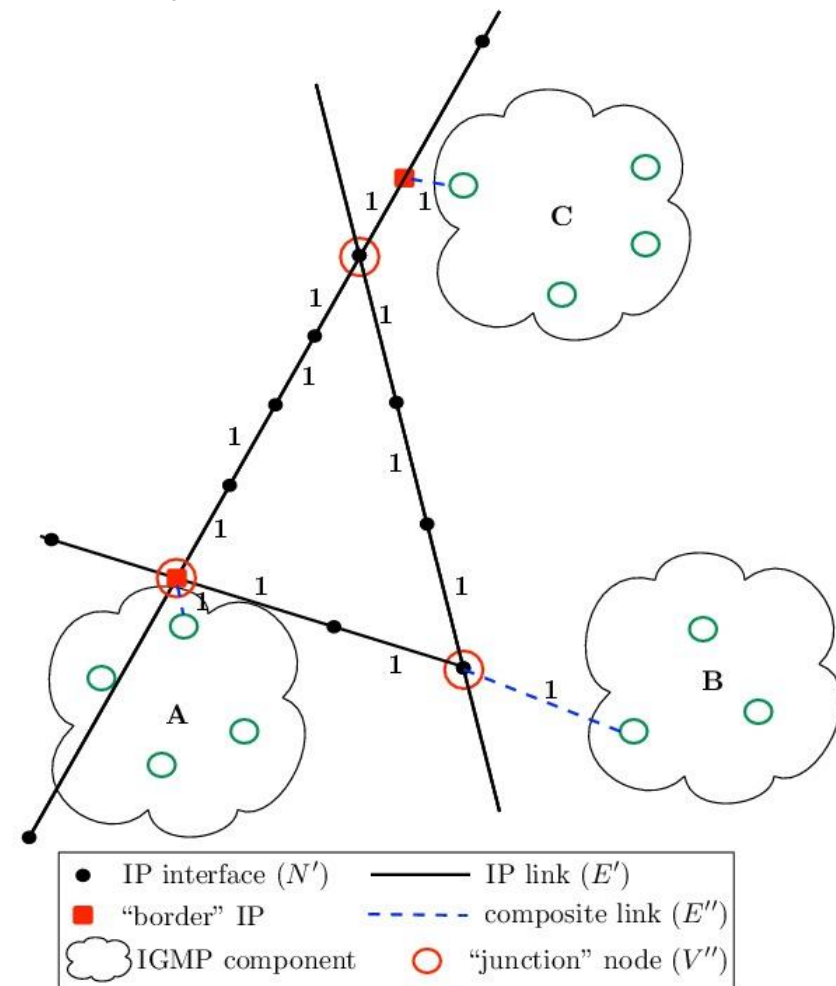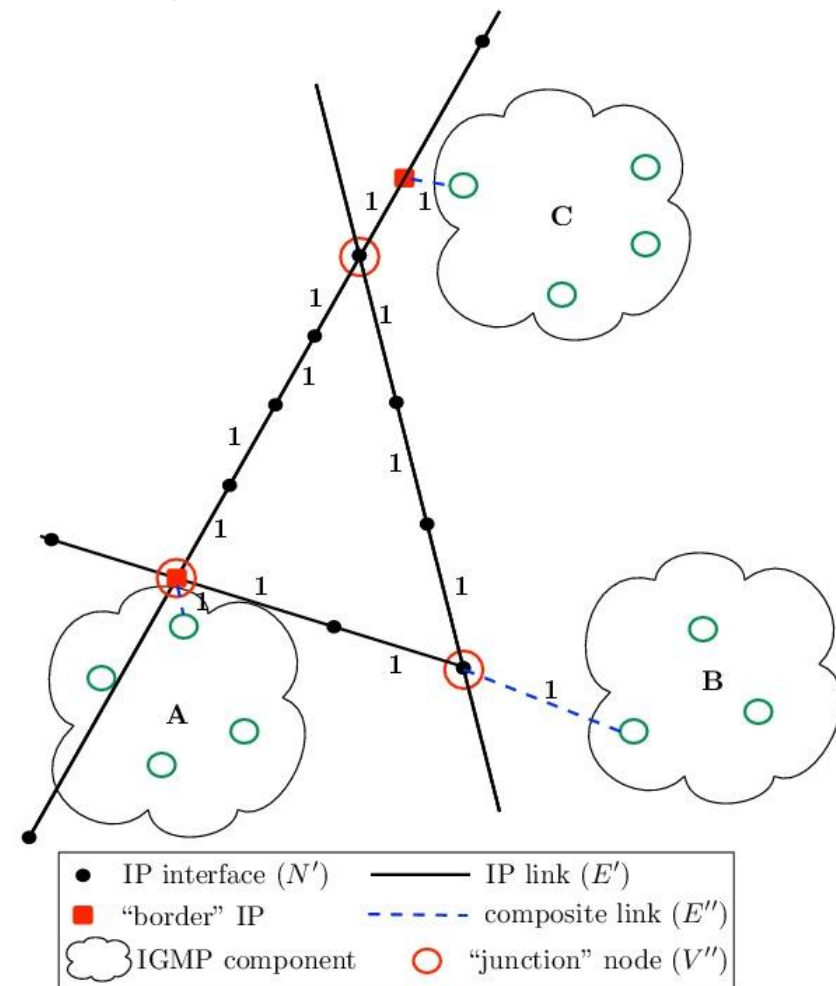
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● IP interface (N')	—— IP link (E')
■ "border" IP	- - - - composite link (E'')
☁ IGMP component	○ "junction" node (V'')

Quantifying the IGMP filtering impact
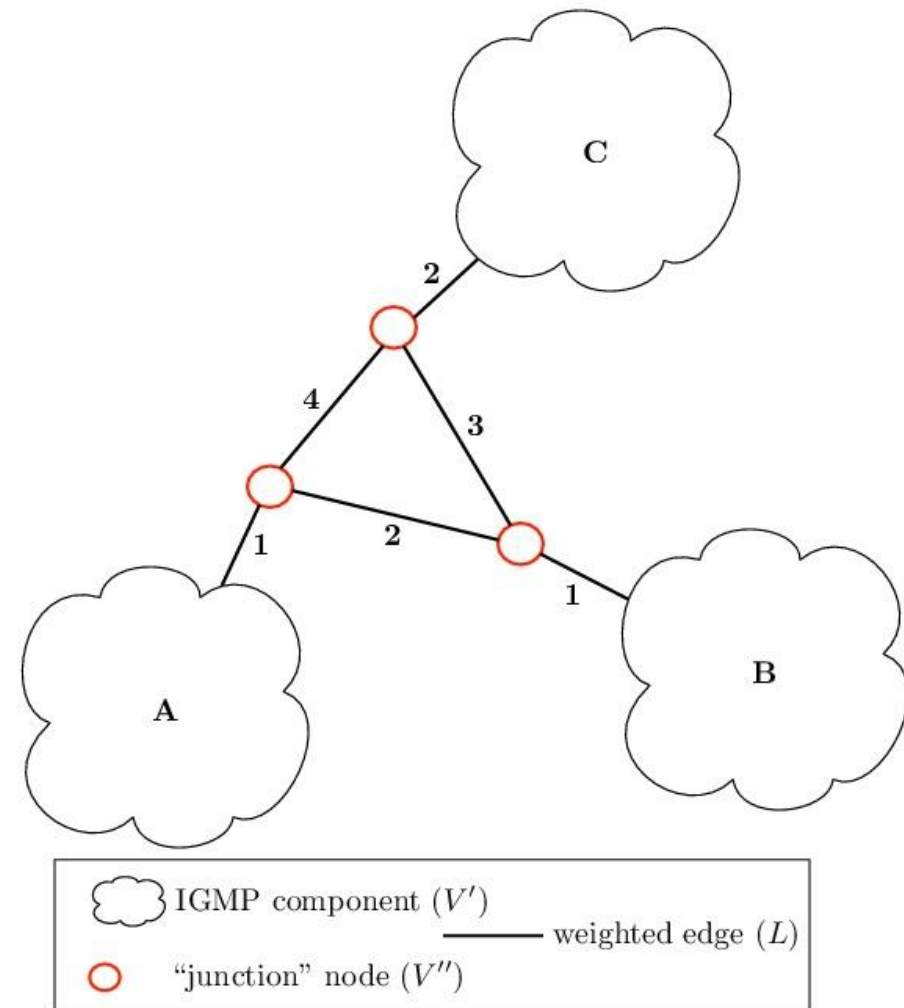
▸ Graph reduction

1. Collapse connected IGMP routers in a single node (IGMP connected component – c.c.)

2. Set the weight of each link to 1

3. Identify IP nodes with a degree>=3

4. Remove IP nodes with degree of 2

5. Keep track of the original distances with new weights

Quantifying the IGMP filtering impact

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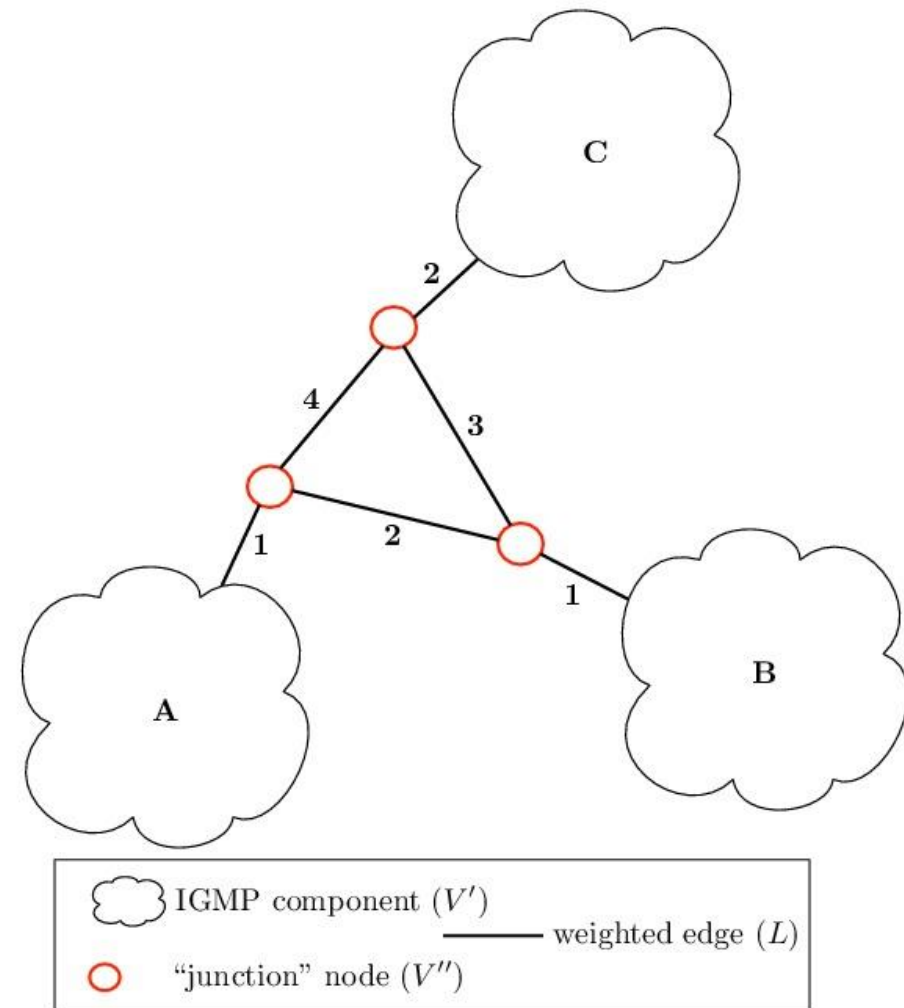5. Keep track of the original distances with new weights

Quantifying the IGMP filtering impact
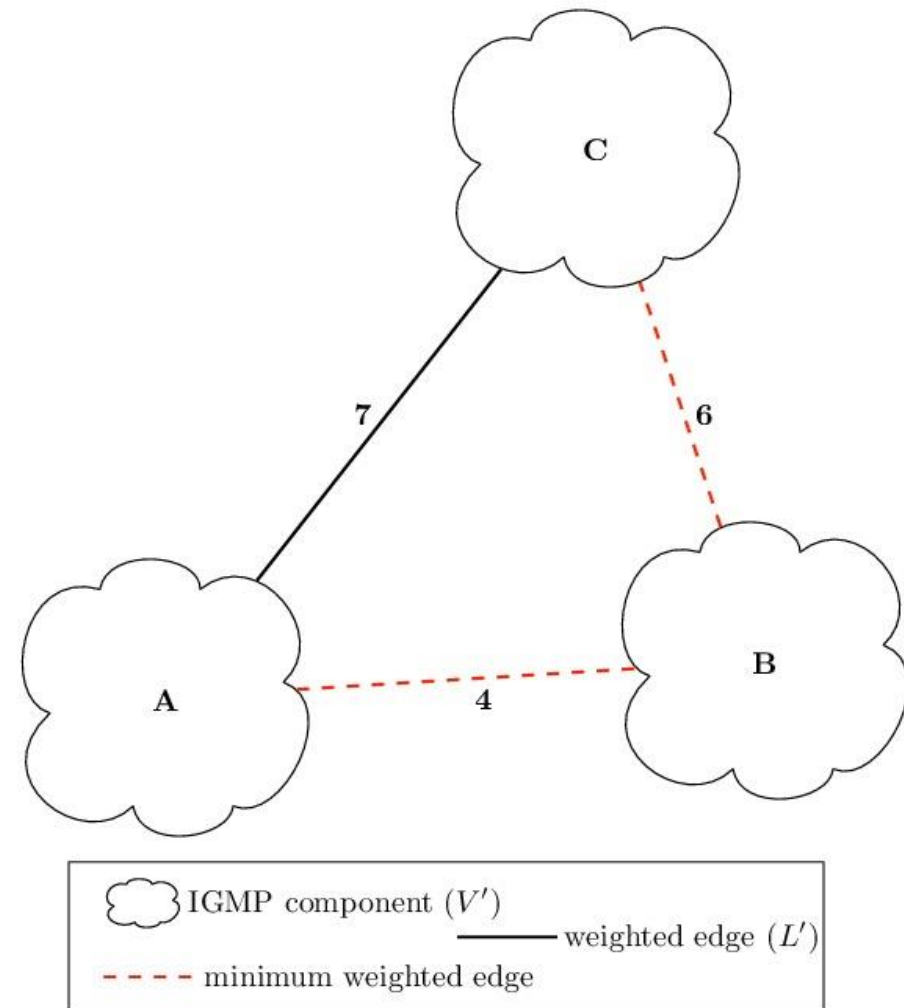
▸ **Graph reduction**

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6. Compute the shortest path for each pair of IGMP c.c. (Dijkstra)

7. Compute the minimal weighted tree (Kruskal) ({A,B,C} {A-B, B-C})

IGMP component (V') —— weighted edge (L)

○ "junction" node (V'')

Quantifying the IGMP filtering impact

▶ Graph reduction

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C

7   6

A   4   B

⬭ IGMP component (V')
——— weighted edge (L')
- - - - minimum weighted edge

Quantifying the IGMP filtering impact

How far are the IGMP components from each other?

Before applying Kruskal
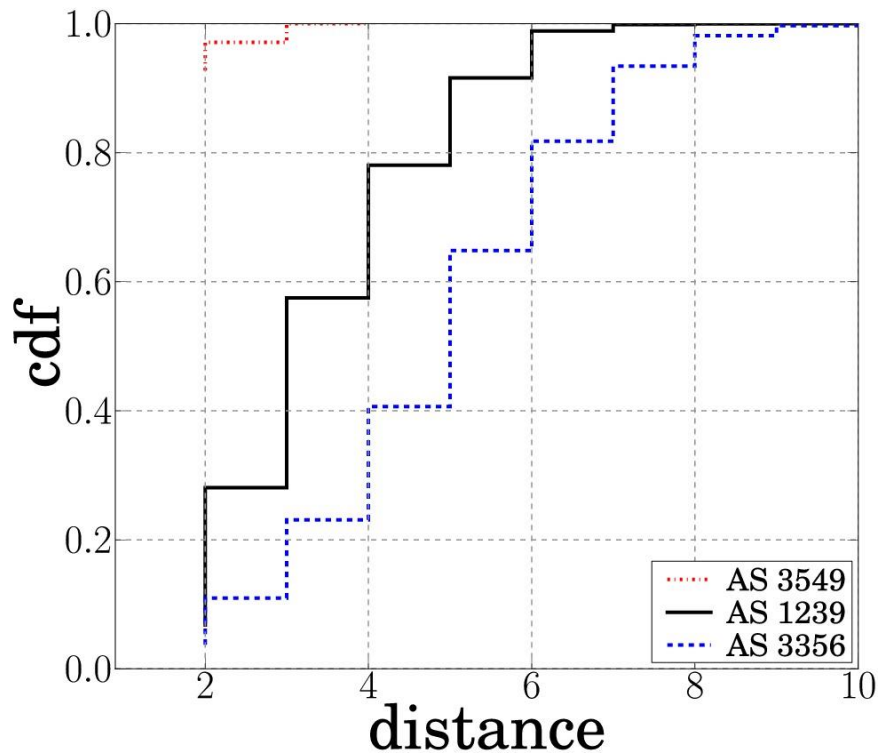
After applying Kruskal

All the links in the minimal weighted tree have a weight of 2!

3. There exists at least one path between most pairs of IGMP c.c.

**4. Each IGMP component is not located farther than 2 hops from its closest component**

Reconnection Strategy

Reconnection Strategy

▸ How to obtain a full connected router-level topology of the network?

▸ *Alias resolution technique* to transform the hybrid graph in a full router level topology.

▸ However
   ◦ Alias resolution techniques are intrusive, time costing, and error-prone;
   ◦ IGMP pure topology is highly accurate.

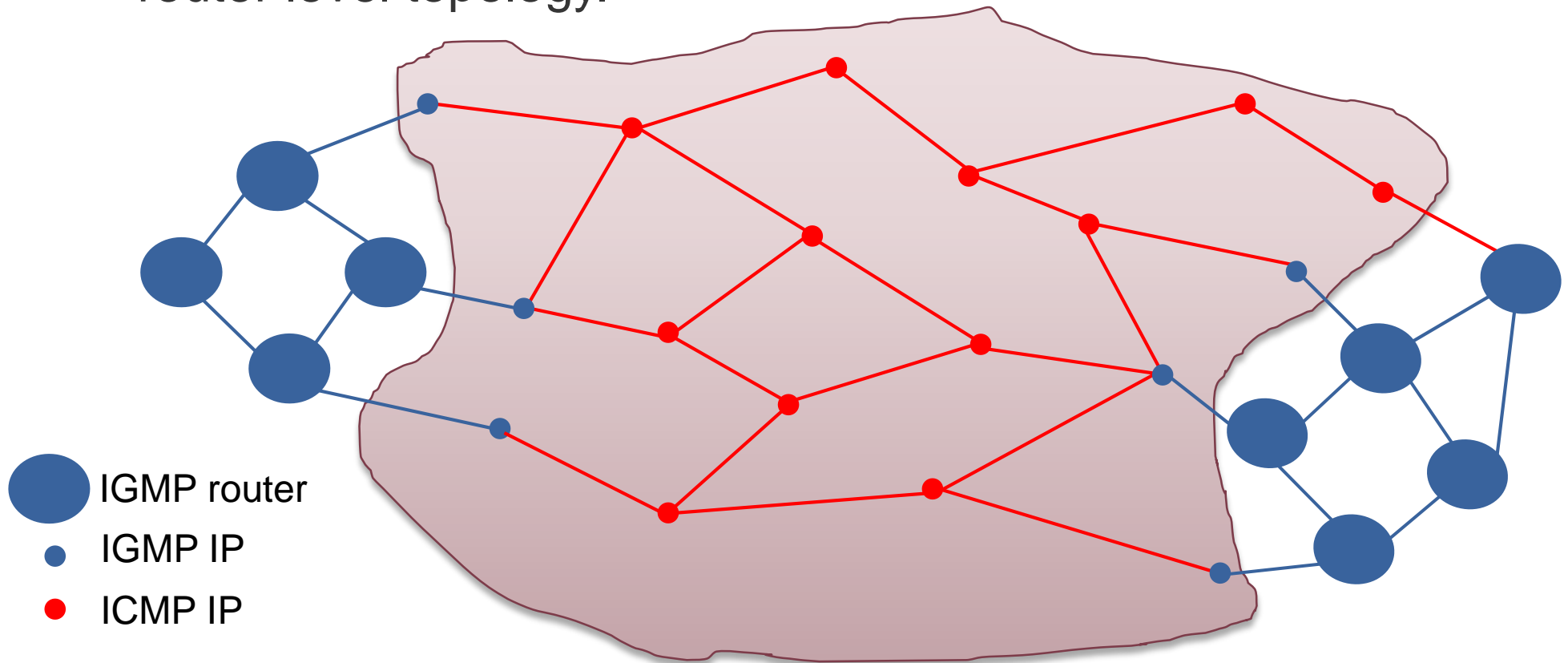> ▸ How to preserve the IGMP accuracy providing a full connected router level graph?

Reconnection Strategy

Apply *Alias Resolution* (Ally) to transform the hybrid graph in a router level topology.

- ● IGMP router
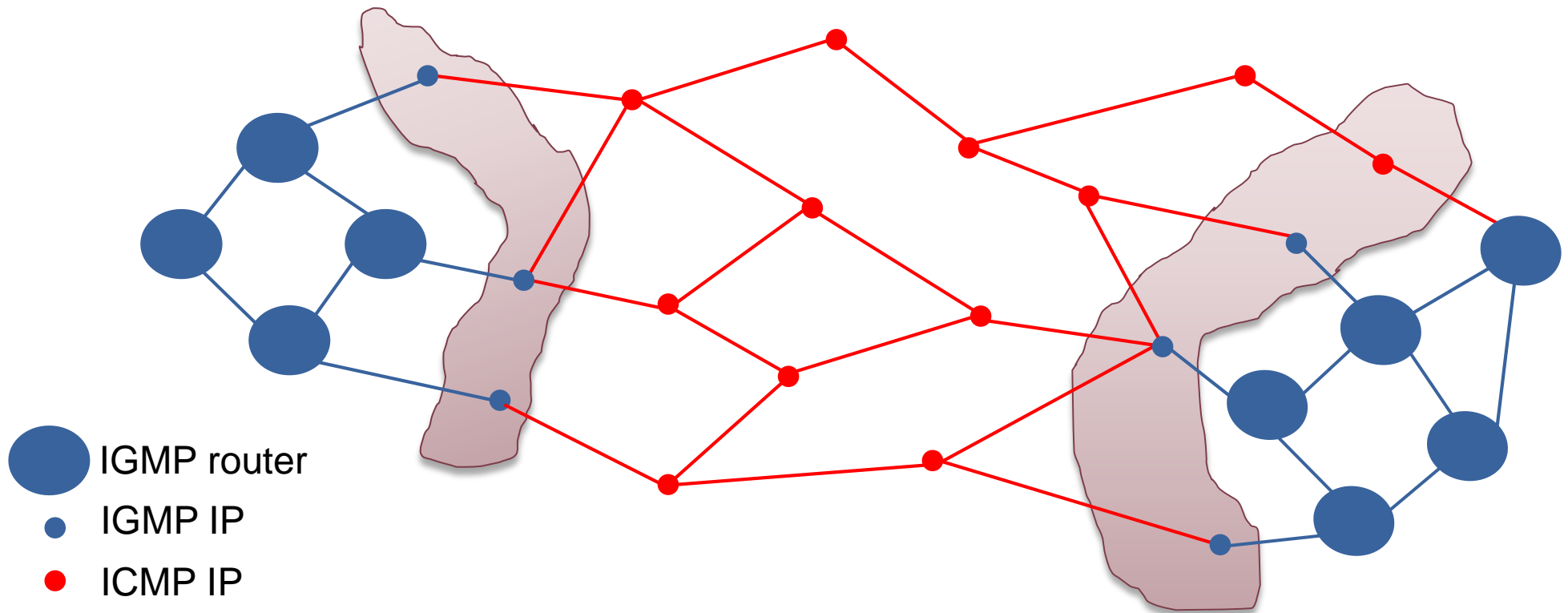- ● IGMP IP
- ● ICMP IP

Reconnection Strategy

Apply *Alias Resolution* (Ally) to transform the hybrid graph in a router level topology.

IGMP router

IGMP IP

ICMP IP
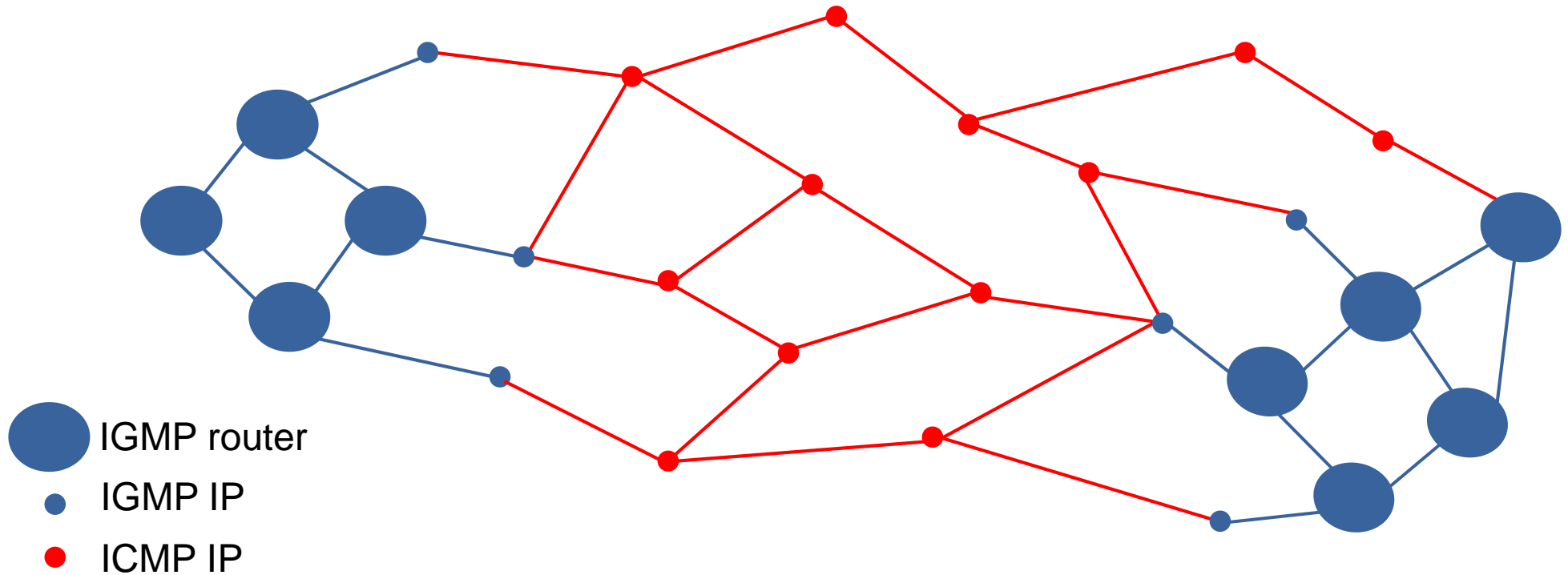
Applying alias resolution on the entire IP level portion of the topology is extremely time-costing and error-prone!

Reconnection Strategy

Key Idea: consider only the IPs located *close* to the routers in the current router level topology.
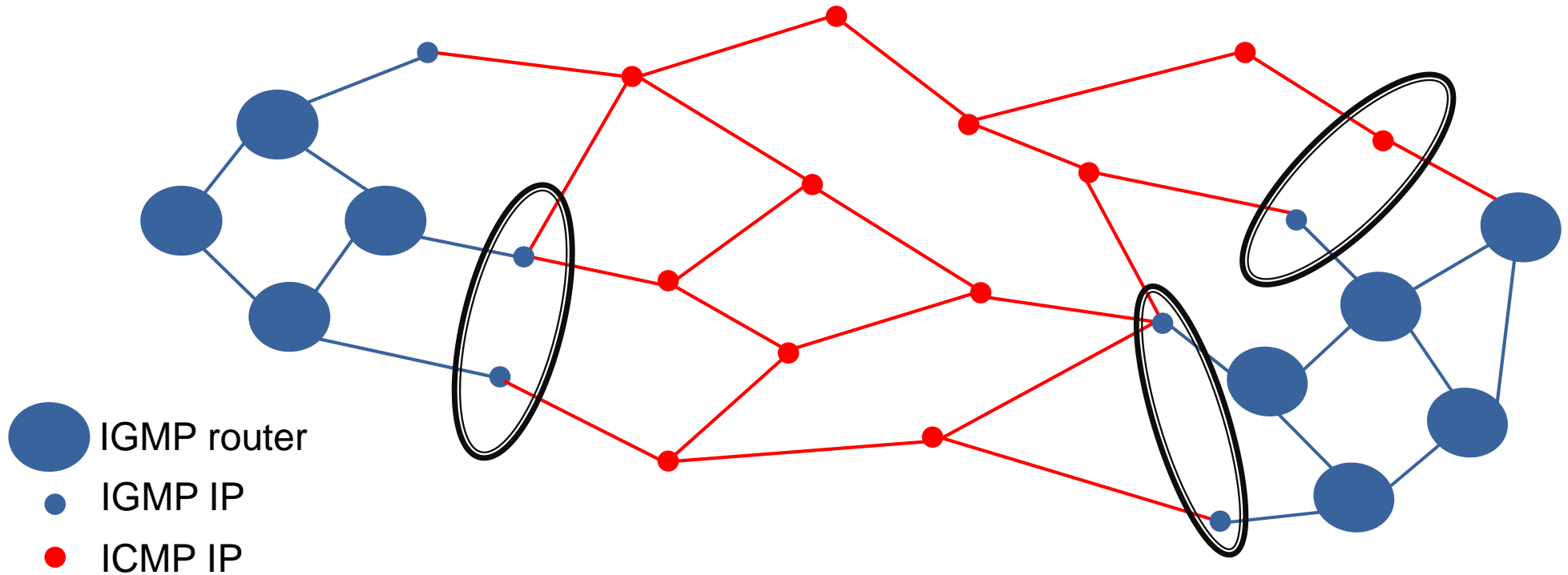

IGMP router
IGMP IP
ICMP IP

Apply alias resolution on the IP level *neighborhood* of current router level topology.

Reconnection Strategy

Key Idea: consider only the IPs located *close* to the routers in the current router level topology.

- ⬤ IGMP router
- • IGMP IP
- • ICMP IP

Apply alias resolution on the IP level *neighborhood* of current router level topology.

Reconnection Strategy

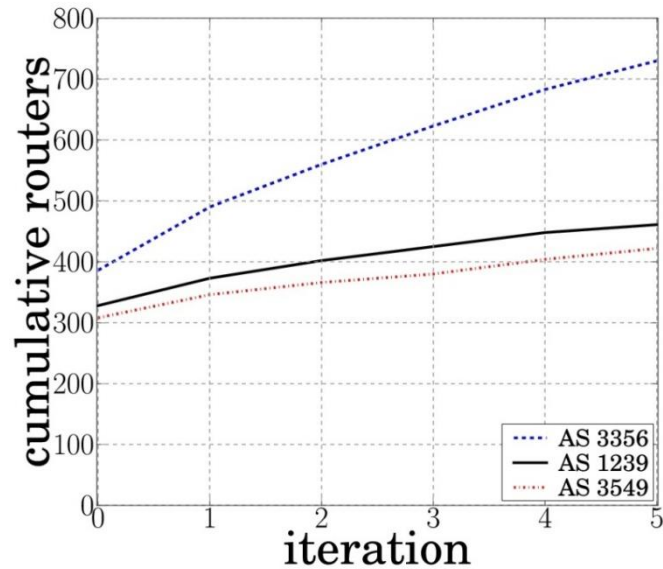Key Idea: consider only the IPs located *close* to the routers in the current router level topology.
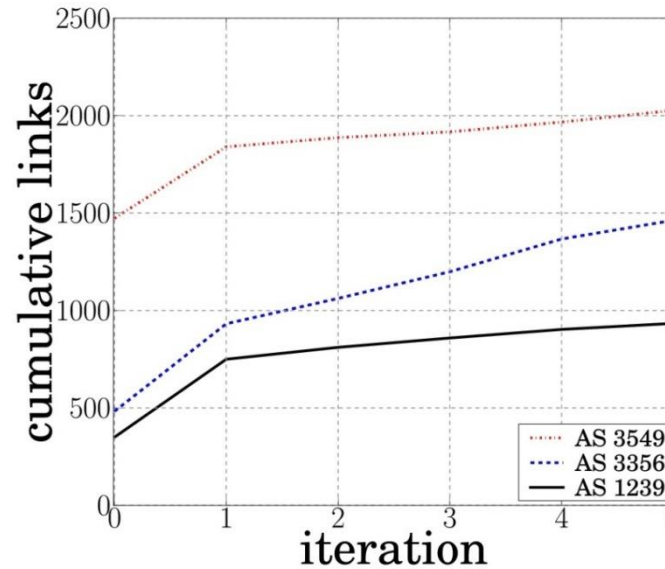

- 🔵 IGMP router
- 🔵 IGMP IP
- 🔴 ICMP IP
- 🔴 Aliased router
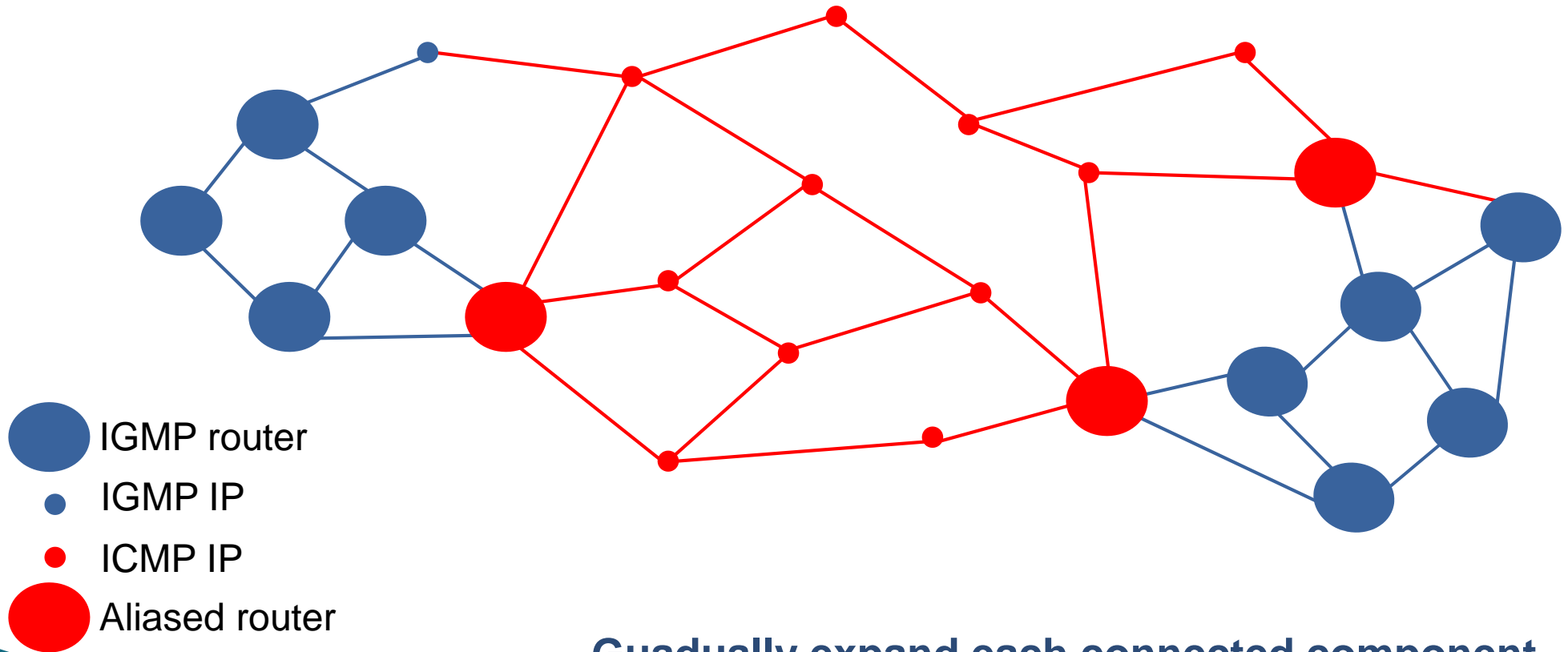
Guadually expand each connected component
iteration by iteration
until the router level graph is full connected.
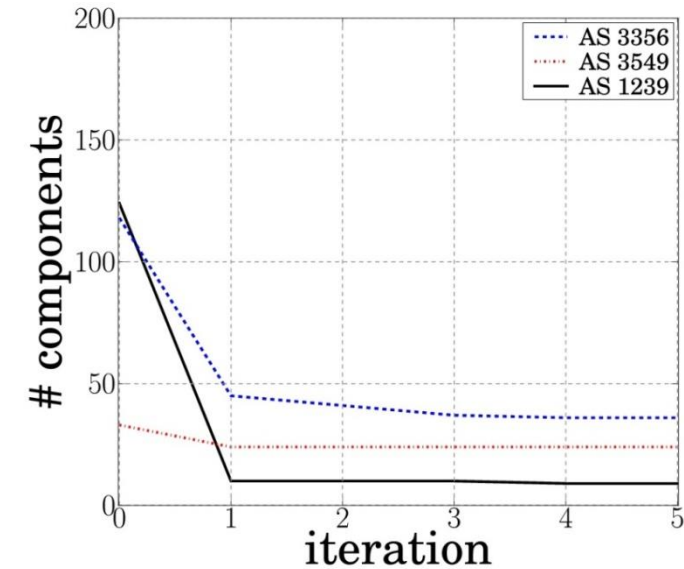
Reconnection strategy

Nodes Evolution

Links Evolution

Disjoint Components evolution

After 2 iterations

5. Strong components reduction

6. Largest components strongly grow (Sprint 393 nodes)

7. Strong reduction of the aliasing space exploration (-95%)

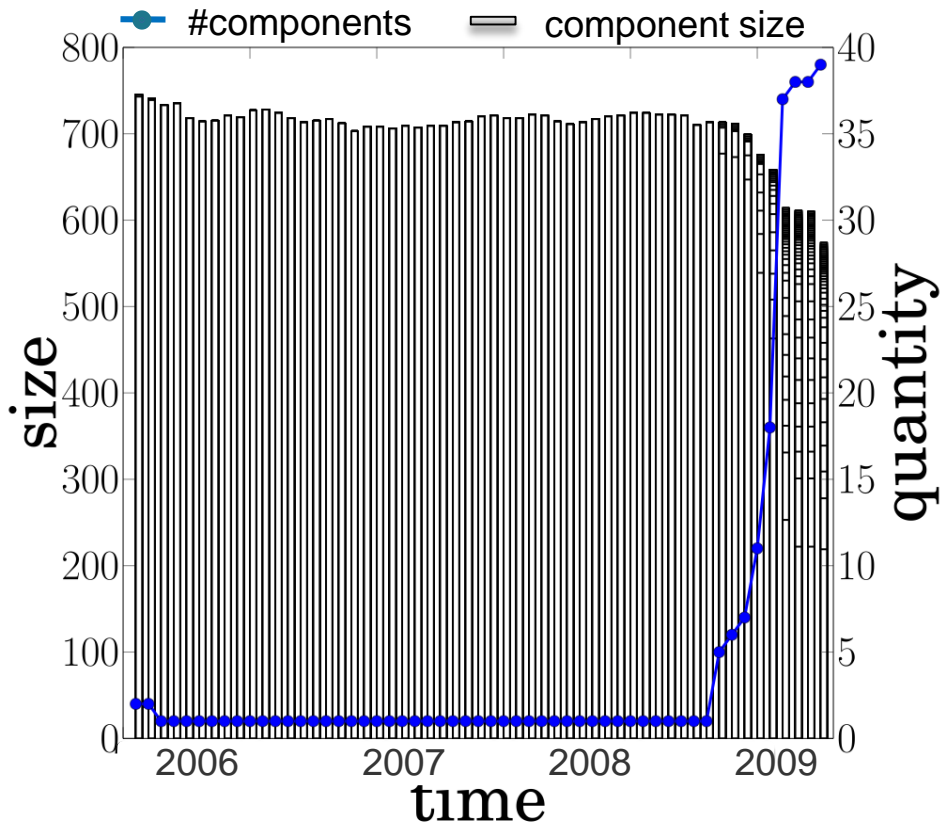| AS	#Components
Sprint	- 91%
Global Crox.	- 38%
Level3	- 62%

Conclusion

▸ IGMP filtering causes the collected topologies to be disconnected.

▸ We proposed
  ◦ A hybrid graph reduction method to investigate and characterize the phenomenon;
  ◦ An efficient reassembling strategy able to strongly reduce the number of components.

▸ For the first time in literature, we jointly exploited IGMP probing, Traceroute and Alias resolution in Topology Discovery.

▸ Our topologies are freely available at

http://svnet.u-strasbg.fr/merlin

Thank you!

IGMP Filtering over time

Sprint Network.

IGMP filtering is getting worse and worse!

- Multiple vantage points allow to deal with the in-transit filtering

- Local filtering is still challenging.

The final IGMP topologies consist of several disjoint components!