IGen: Generation of Router-level Internet Topologies Using Network Design Heuristics

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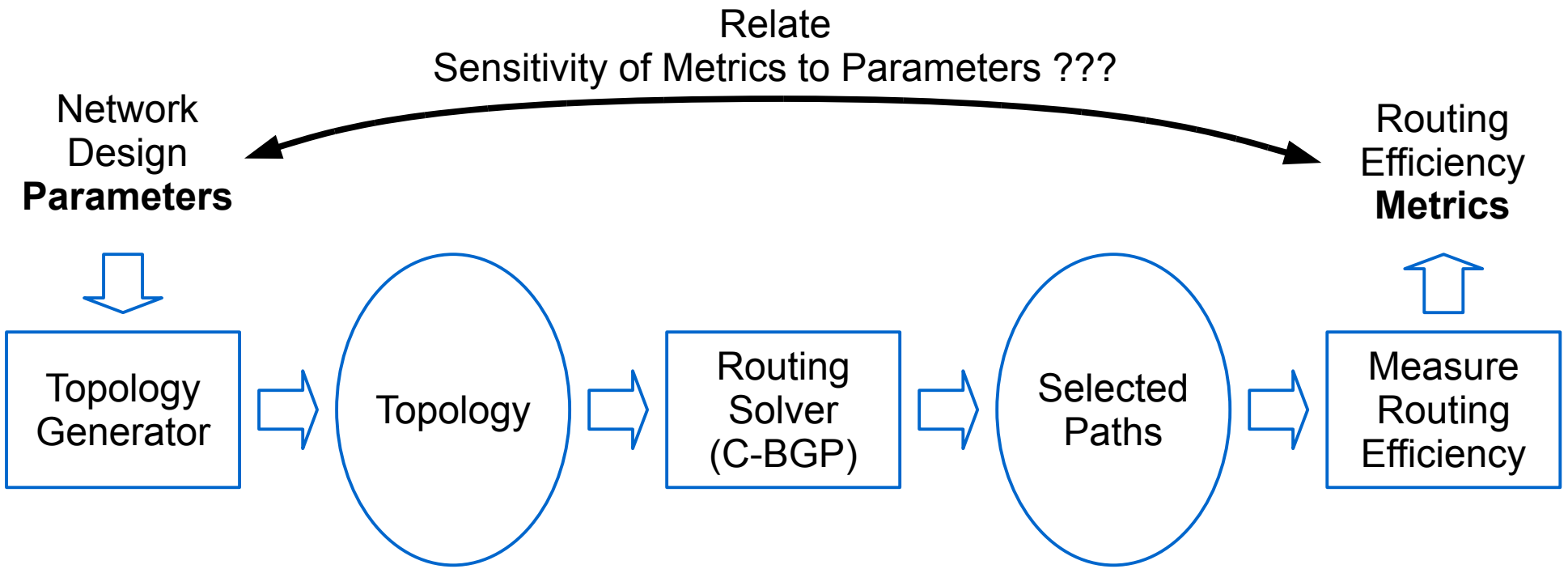
Motivations

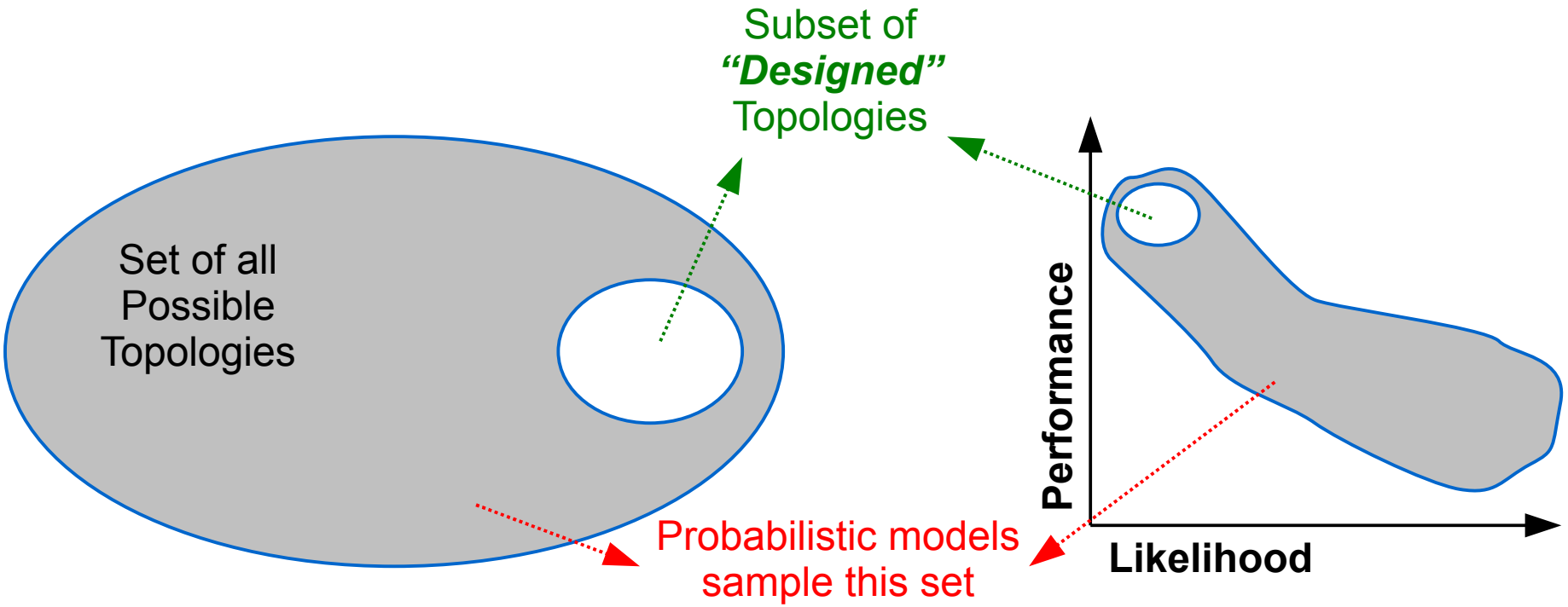
- **Routing Sensitivity Analysis**
  - Study sensitivity of (BGP) routing to several *"topological"* parameters



http://inl.info.ucl.ac.be/softwares/c-bgp

Generating Topologies...

- **Issue 1**
  - *"[...] a careful design process [...] can yield high performance topologies, but these are extremely rare from a probabilistic graph point of view."*
    [Lun Li et al, ACM SIGCOMM'04]



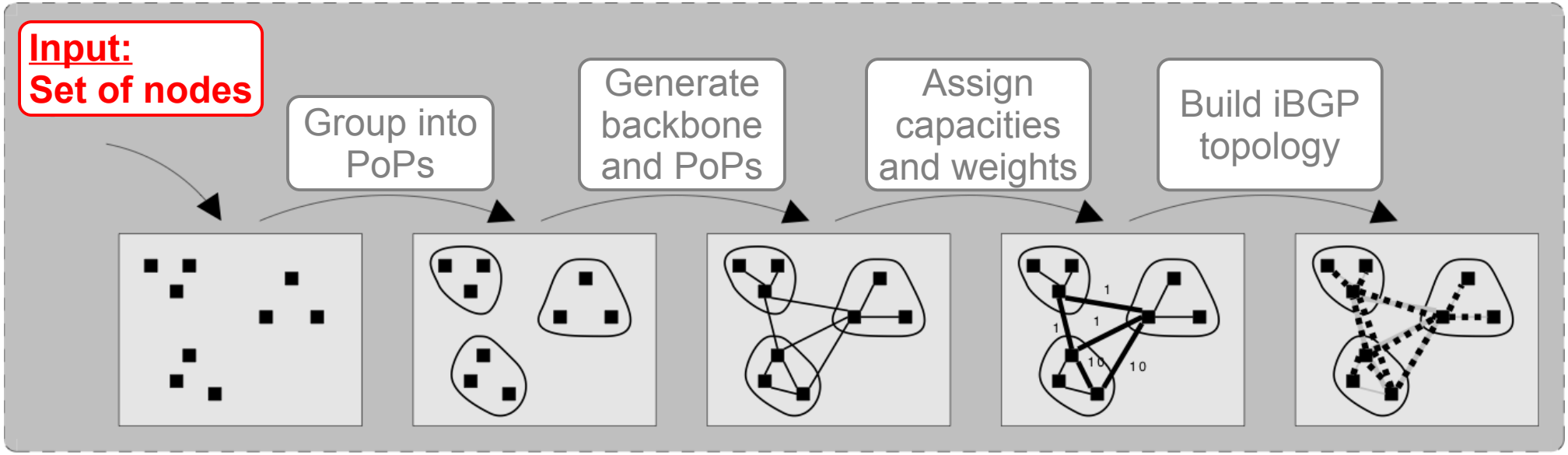
Generating Topologies...

- **Issue 2**
  - Well-known topology generator: *Waxman*

$$P(u,v) = \alpha . e^{\frac{-d(u,v)}{\beta . L}}$$

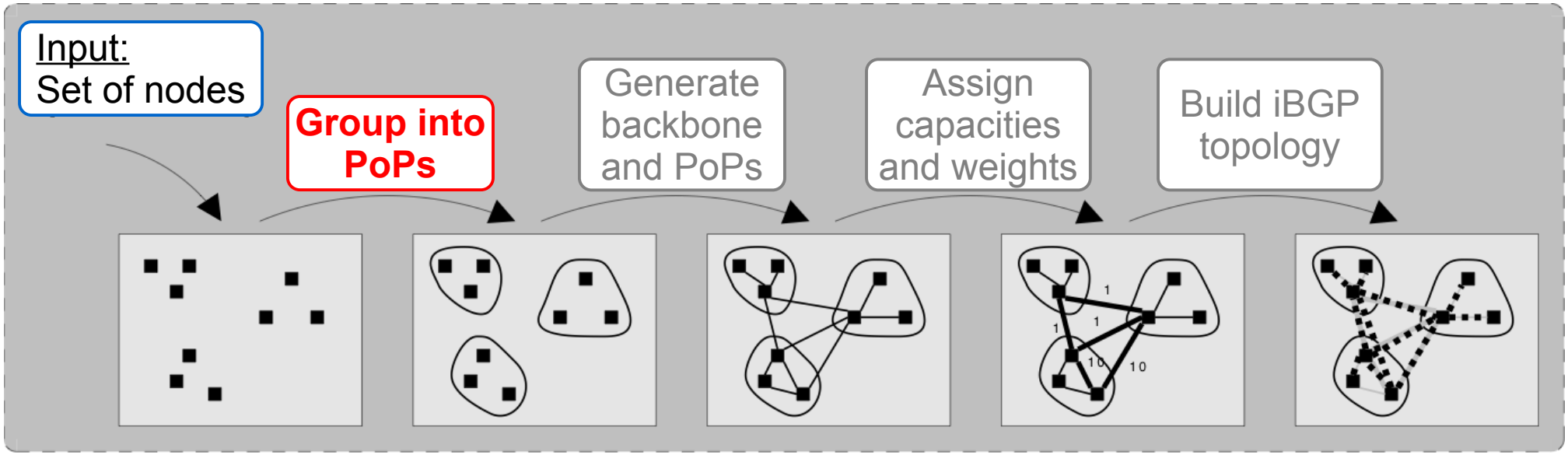
  - How to set (α, β) to achieve realistic network design objectives ?
    - minimize delay
    - maximize bandwidth
    - ensure robustness
    - limit financial cost
    - match equipment / technology constraints
    - ...

Methodology (1)



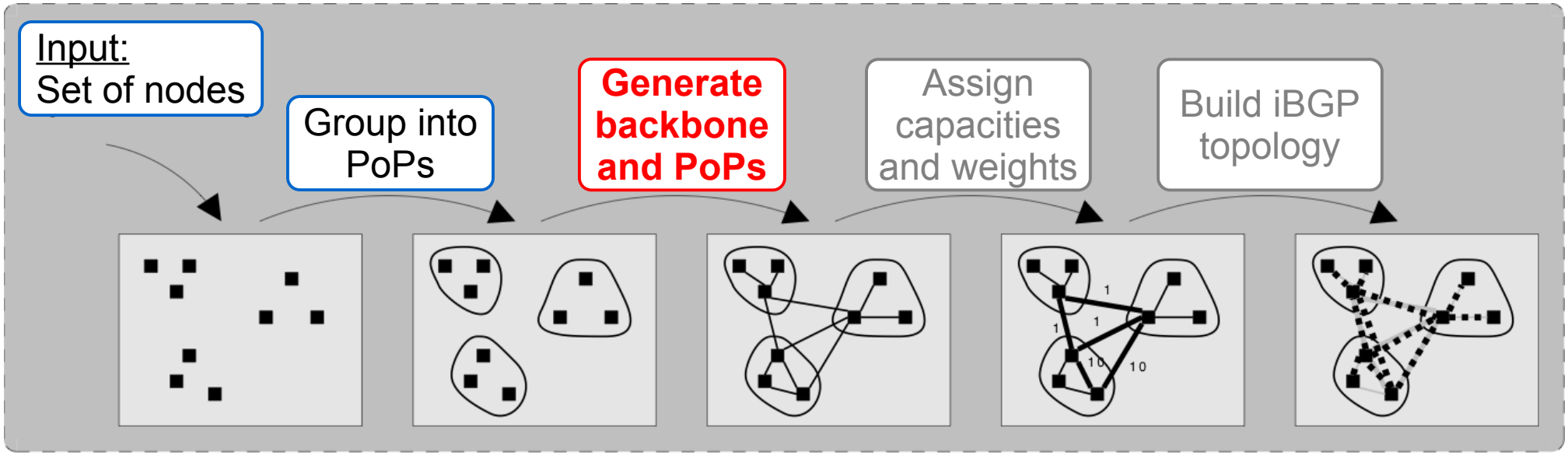
- **Import existing set of nodes**
  - with coordinates (e.g. from existing network or geoloc DB)
- **Generate set of nodes**
  - (X,Y): X~Uniform, Y~Uniform
  - optional constraints: (x,y) falls into set of polygons

Methodology (2)



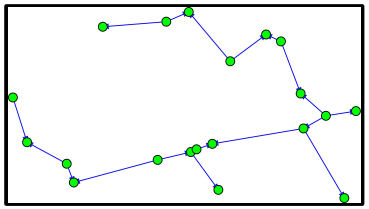
- **Clustering methods**
  - based on distance (euclidian or geodesic)
  - k-medoid (targets *k* PoPs) or hierarchical (target *k* PoPs but bounds intra-PoP variance)

Methodology (3)

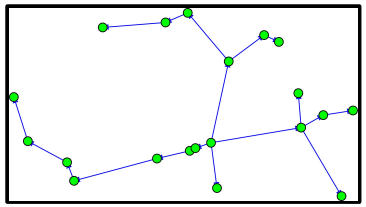


- **Mesh synthesis methods**
  - trees, union of disjoint trees, rings, union of rings, triangulation
  - loose control on graph density and connectedness
  - specific layout for PoPs (e.g. Sprint-like)

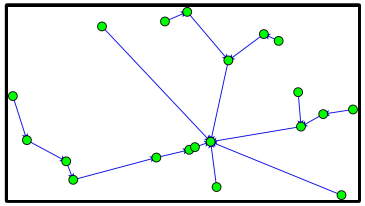
Backbone Generation Methods



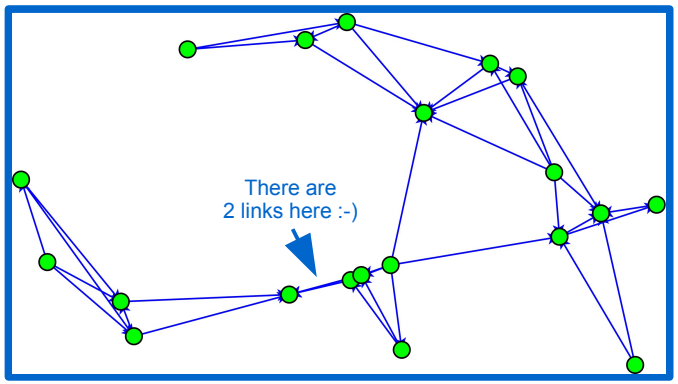
MST



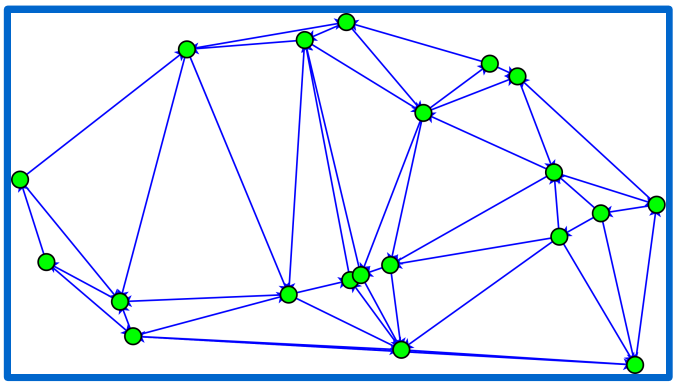
Hybrid MST / SPT
MENTOR (0.3)



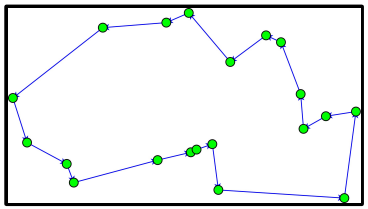
Hybrid MST / SPT
MENTOR (0.7)



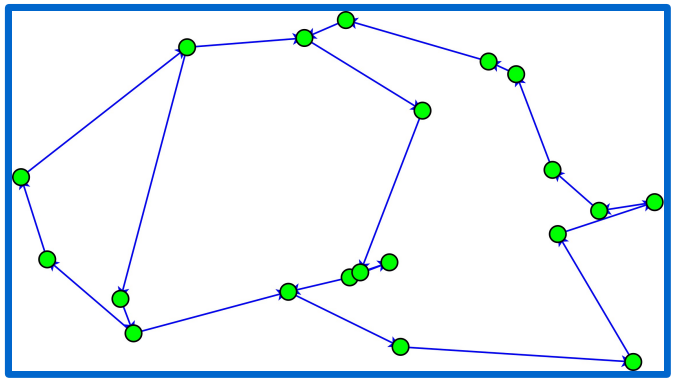
Union of
2 disjoint trees
(MSTs in example)



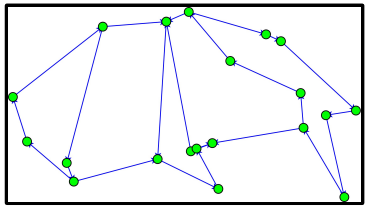
Delaunay
triangulation



Minimum cost
cycle



Union of 2 rings

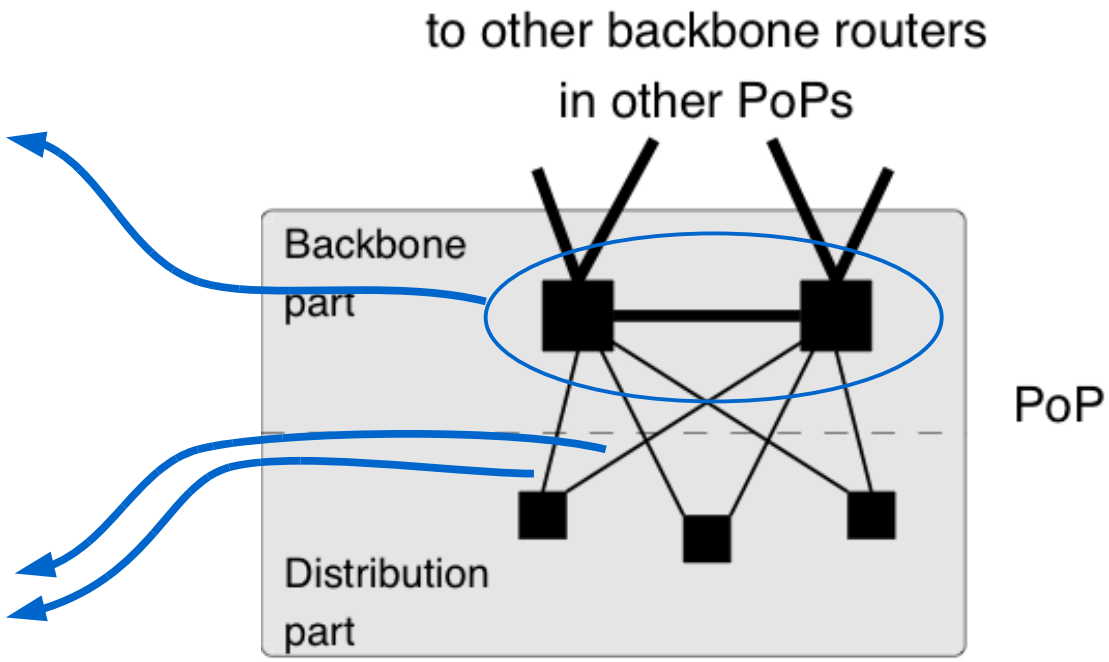


Union of 3 rings

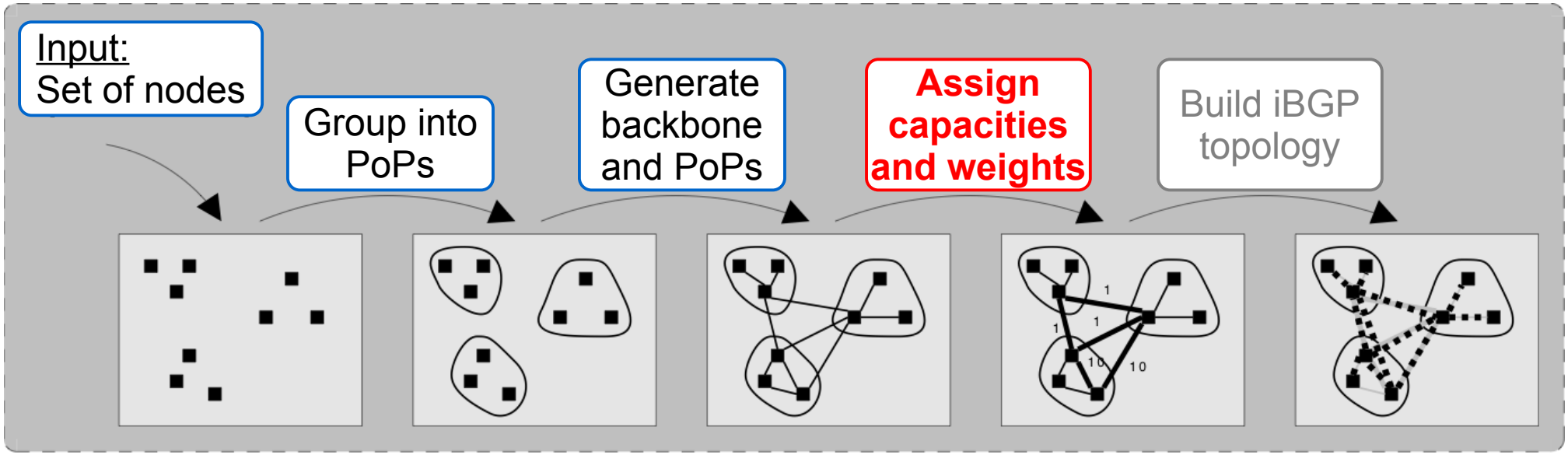
PoP Layout (Sprint-like)

1st param:
number of backbone routers in PoP (default: 2)

2nd param:
number of links from access routers to backbone routers

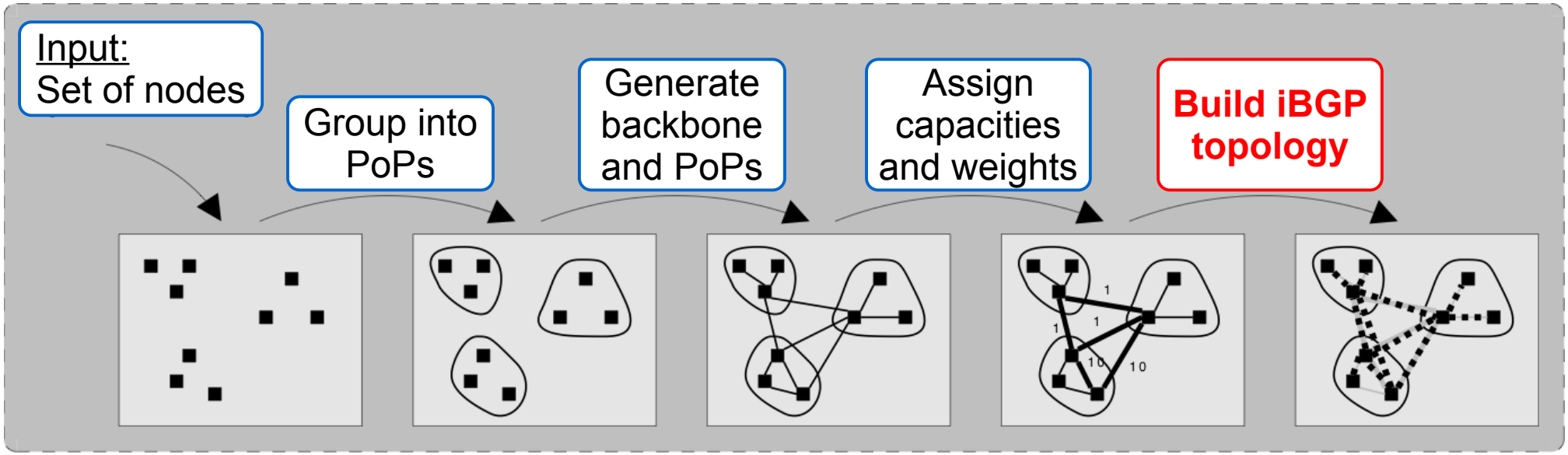


Methodology (4)



- **Capacities**
  - Based on traffic matrix (computes APSP and forward)
  - 2-levels. Example core=1GB / access=155MB
- **IGP weights**
  - Based on distance / inverse of capacity

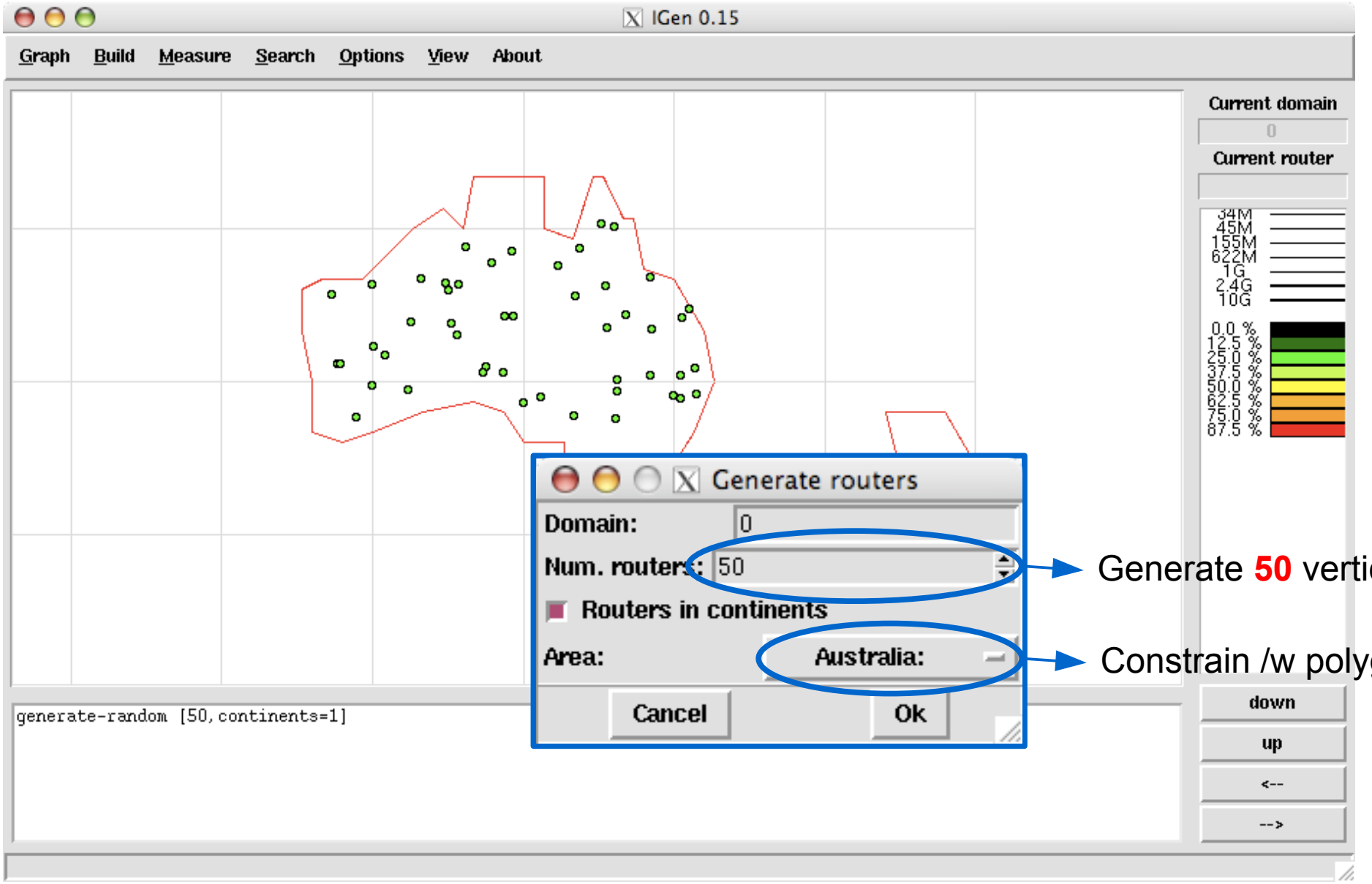
Methodology (5)



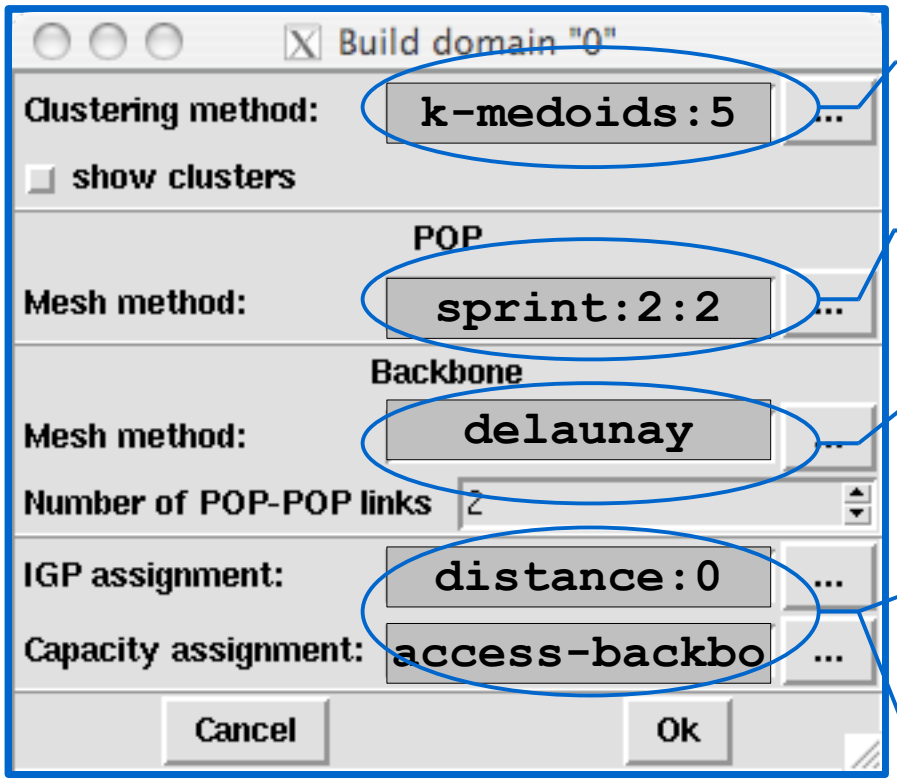
- **iBGP topology**
  - full-mesh
  - iBGP hierarchy (2 levels), route-reflectors chosen among backbone routers, access routers are clients of route-reflectors in their PoP

Example (1)

http://inl.info.ucl.ac.be/softwares/igen



Example (2)



1). Build **5 clusters** based on distance

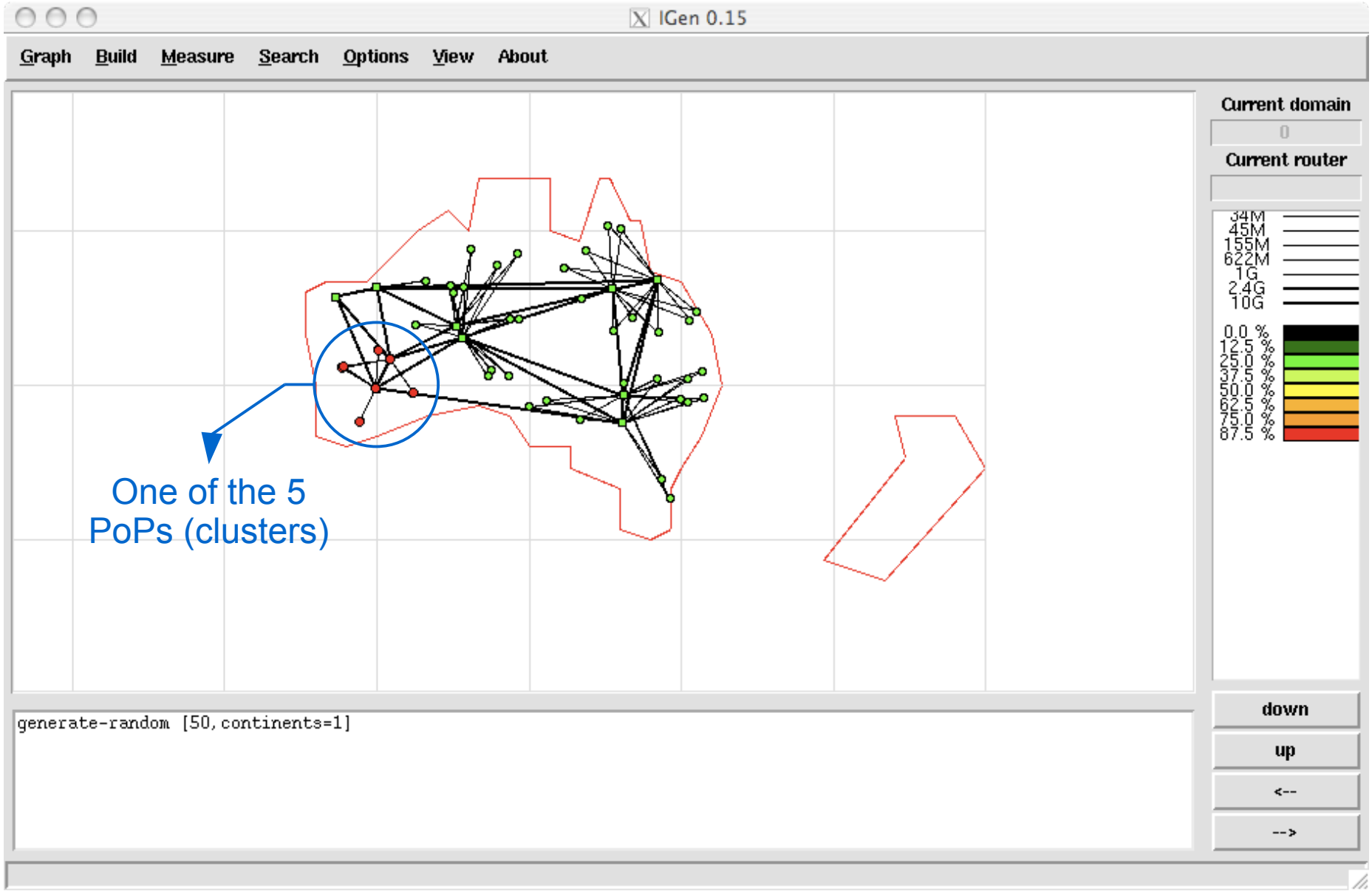
2). Build PoPs using **"Sprint" layout**

3). Build backbone using **triangulation**

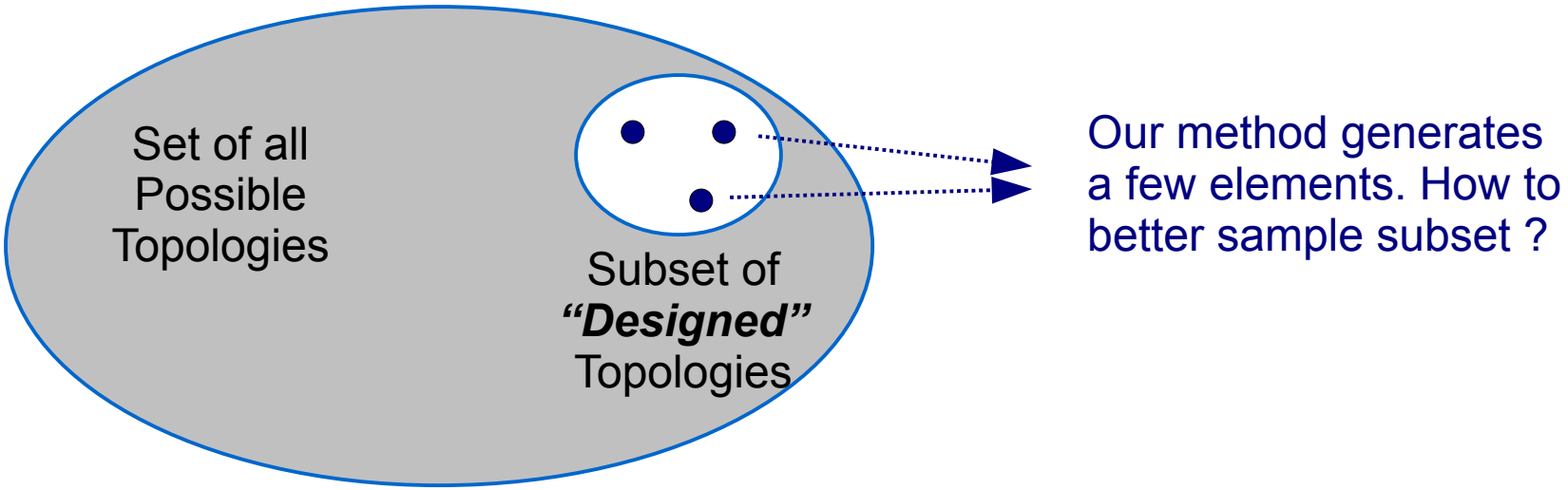
4). Assign IGP weights based on **link mileage**

5). Assign **155M/1G** to access/backbone links resp.

Example (3)


IGen 0.15
Graph
Build
Measure
Search
Options
View
About
Current domain
0
Current router
34M
45M
155M
622M
1G
2.4G
10G
0.0 %
12.5 %
25.0 %
37.5 %
50.0 %
62.5 %
75.0 %
87.5 %
One of the 5
PoPs (clusters)
generate-random [50,continents=1]
down
up
<--
-->

Conclusion



- **Further work**
  - Finer control on graph density
  - More than 2-tiers
  - Other typical PoP designs
  - Other node placement strategies
  - Synthesis of Internet-wide topologies (in progress)

Questions

???