Subnet Based Internet Topology Generation

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ISMA 2011

Workshop on Active Internet Measurements

Outline

- Introduction
- Related Work
- Methodology
  - Algortihm
- Results
- Future Work

Introduction

- Performance of network protocols are dependent on the underlying topology
  - network researchers use synthetic topologies in simulations

- Researchers need realistic synthetic network topologies
  - which imitates the characteristics of the Internet

Literature Review

- Before 1999
  – Strong belief that “Internet is hierarchical”
- 1999-2001
  – Discovery of Internet’s degree distribution to be power law
- 2001-
  – The degree distribution characteristics is not sufficient

GT-ITM [Zagura-96]

- Two types of hierarchical graphs(n-level, TS)
  – Transit-stub reproduces the hierarchical structure of Internet

1. A connected random graph is generated
2. Each node is considered as a **transit domain**
   – each transit domain is expanded to form another connected random graph
3. A number of random graphs are generated as **stubs** and connected to transit nodes

BRITE [Medina01]

- Power law distribution due to
  - preferential connectivity and incremental growth
- Skewed node placement
  - area is divided into squares
  - nodes are distributed among squares
- Locality based preferential network connections
  - uses Waxman probabilistic function
- Node degree distribution is preserved

HOT [Mahadevan06]

- A systematic approach to analyze and synthesize *dK*-series graphs
- Increasing *k* better models the Internet, whereas increases computational complexity
- 1K graphs model degree distribution
  - is not sufficient
- 2K graphs match joint degree distribution

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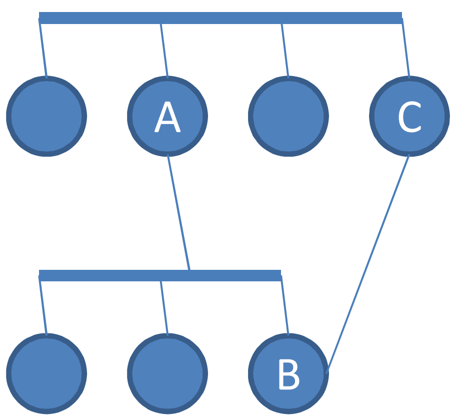
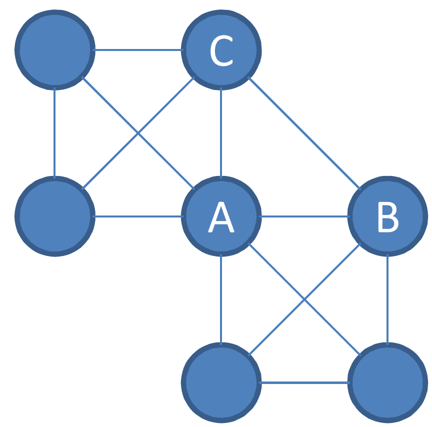
Motivation

- Subnetworks are the bricks of the Internet
  – connected nodes form cliques
- Ignoring subnets during generation misses important characteristics
  – topologies are composed of point to point links
    - misrepresent the Internet
- We emphasizes the distinction between
  – the observed degree distribution and
  – the real degree distribution (i.e., interfaces)

Observed Degree vs. Alias

- Ignoring subnets results in a network of point-to-point links only.





Network Topology Generation

- Objectives
  - Subnet Distribution
  - Observed Degree distribution
  - Alias Distribution

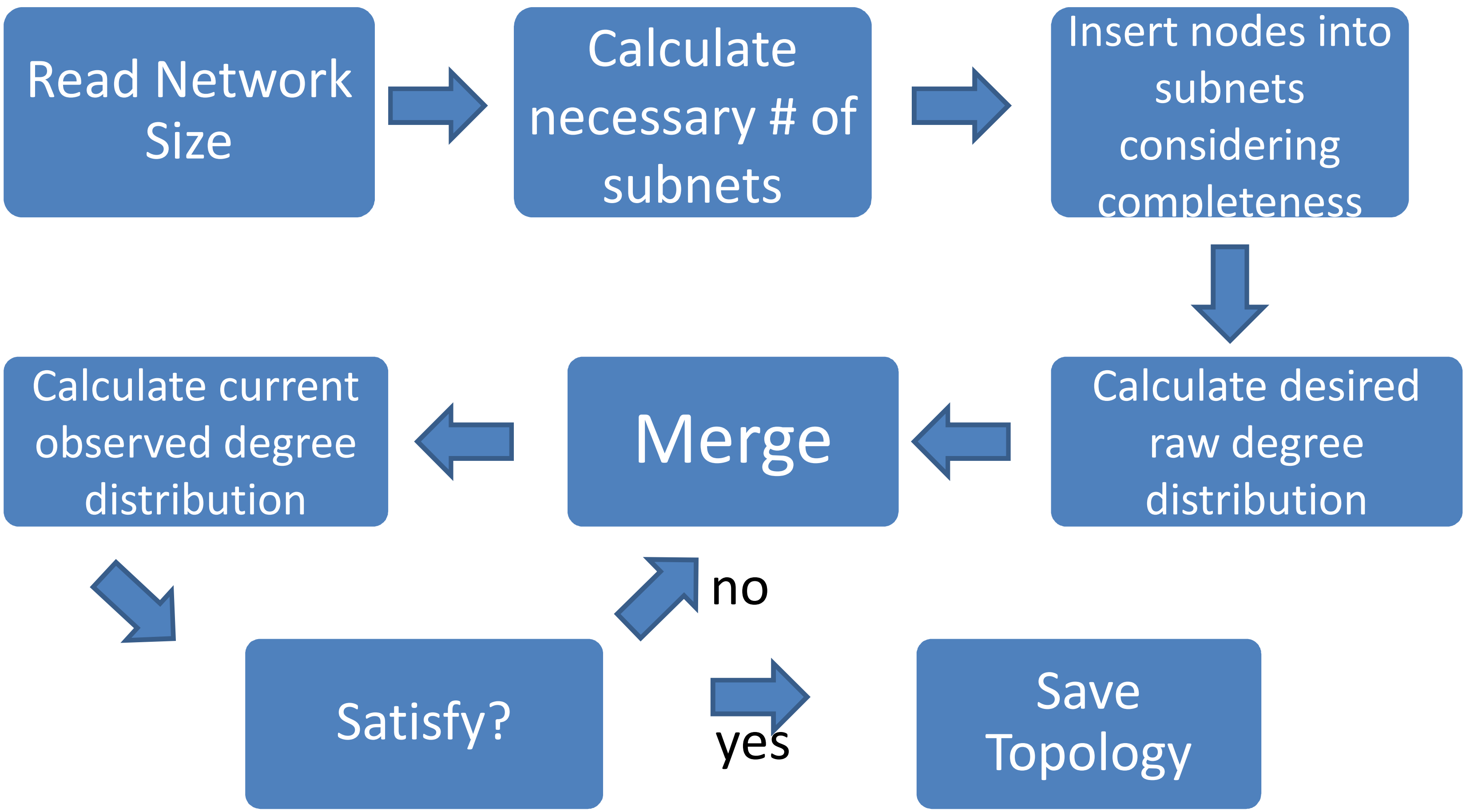
Subnet Centric Approach

- Number of nodes (n_{user})
- Subnet distribution for this many nodes
  - Scale the values of the distribution with

$$n_{user} \ / \ n_{reference}$$

  - Large subnets may disappear in small networks
    - distribute their ratio to closest subnet levels
- Create bins for each subnet
  - place nodes into bins considering occupancy rate

Algorithm

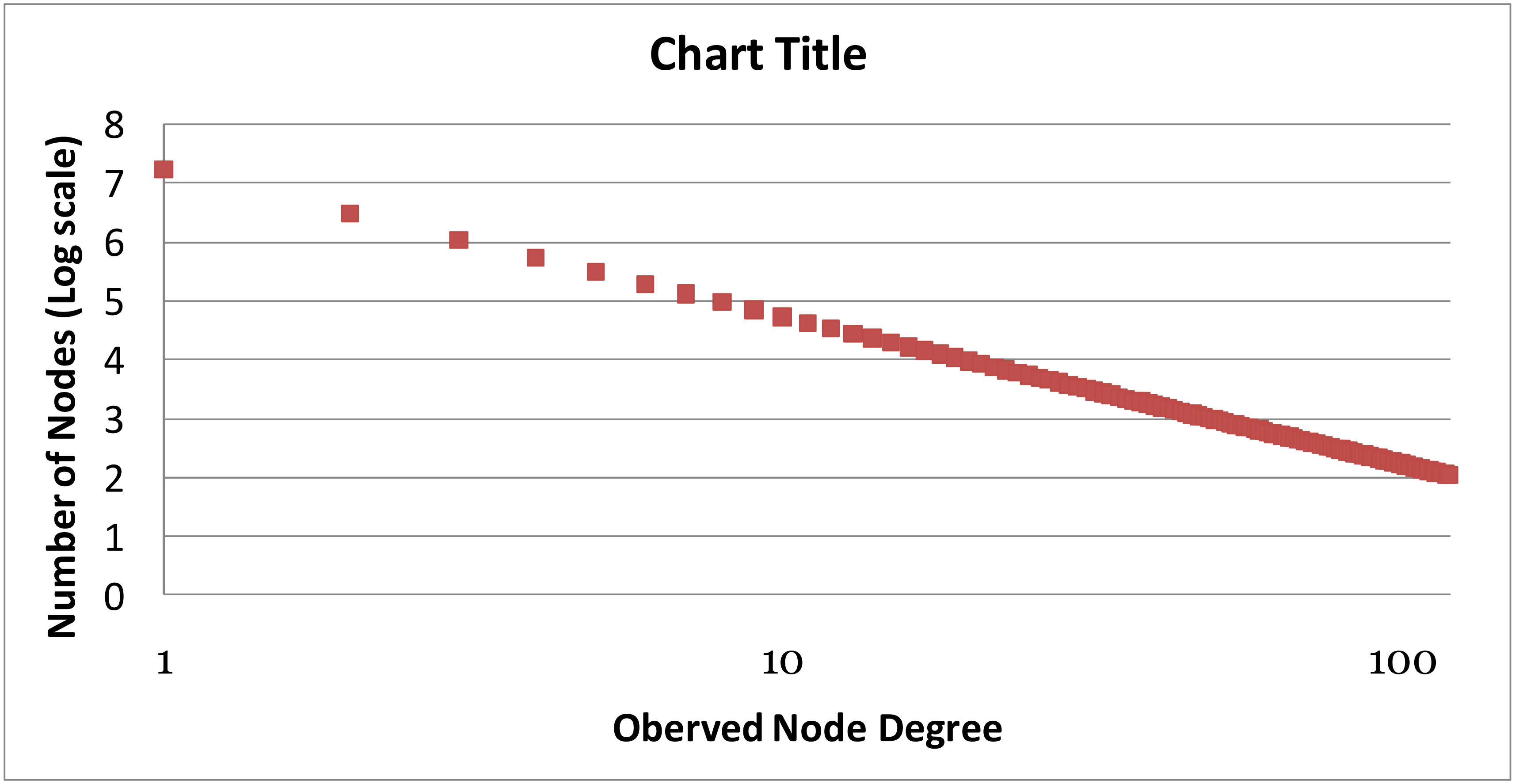

Read Network Size
Calculate necessary # of subnets
Insert nodes into subnets considering completeness
Calculate desired raw degree distribution
Merge
Calculate current observed degree distribution
Satisfy?
no
yes
Save Topology

Subnet Distribution

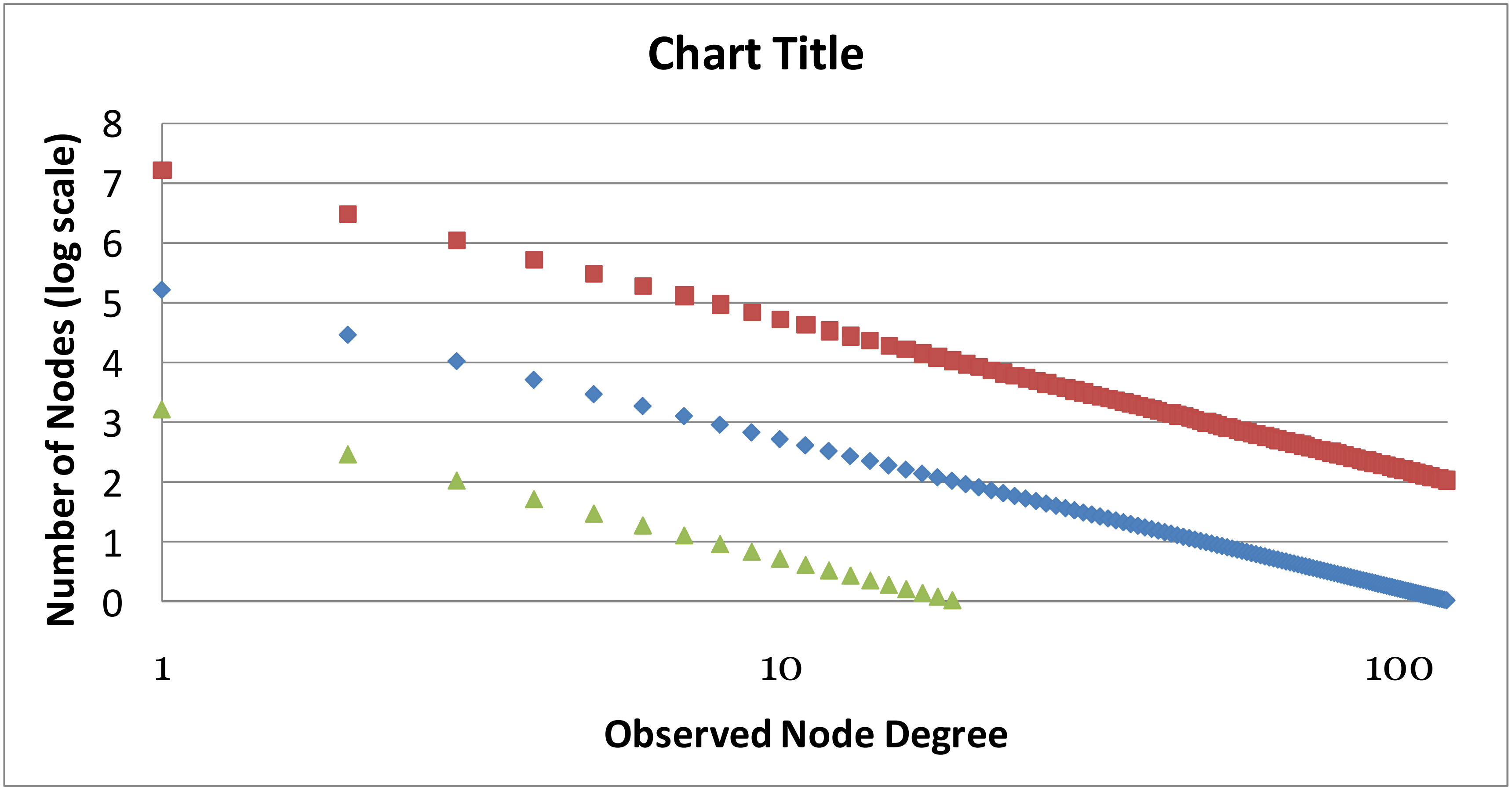
- Subnet distribution data is obtained from Cheleby project
- For an 147K node network ($\mathtt{n}_{\mathtt{reference}}$)
  - 385K IP addresses (interfaces)

	/24	/25	/26	/27	/28	/29	/3X
Number of Occurrence	4	36	184	1294	8836	93110	58011
Distribution (%)	0.002	0.022	0.11	0.80	5.47	57.66	35.92
Completeness (%)	26	30	28	27	27	39	100

Shifting Desired Degree Distribution



Shifting Desired Degree Distribution

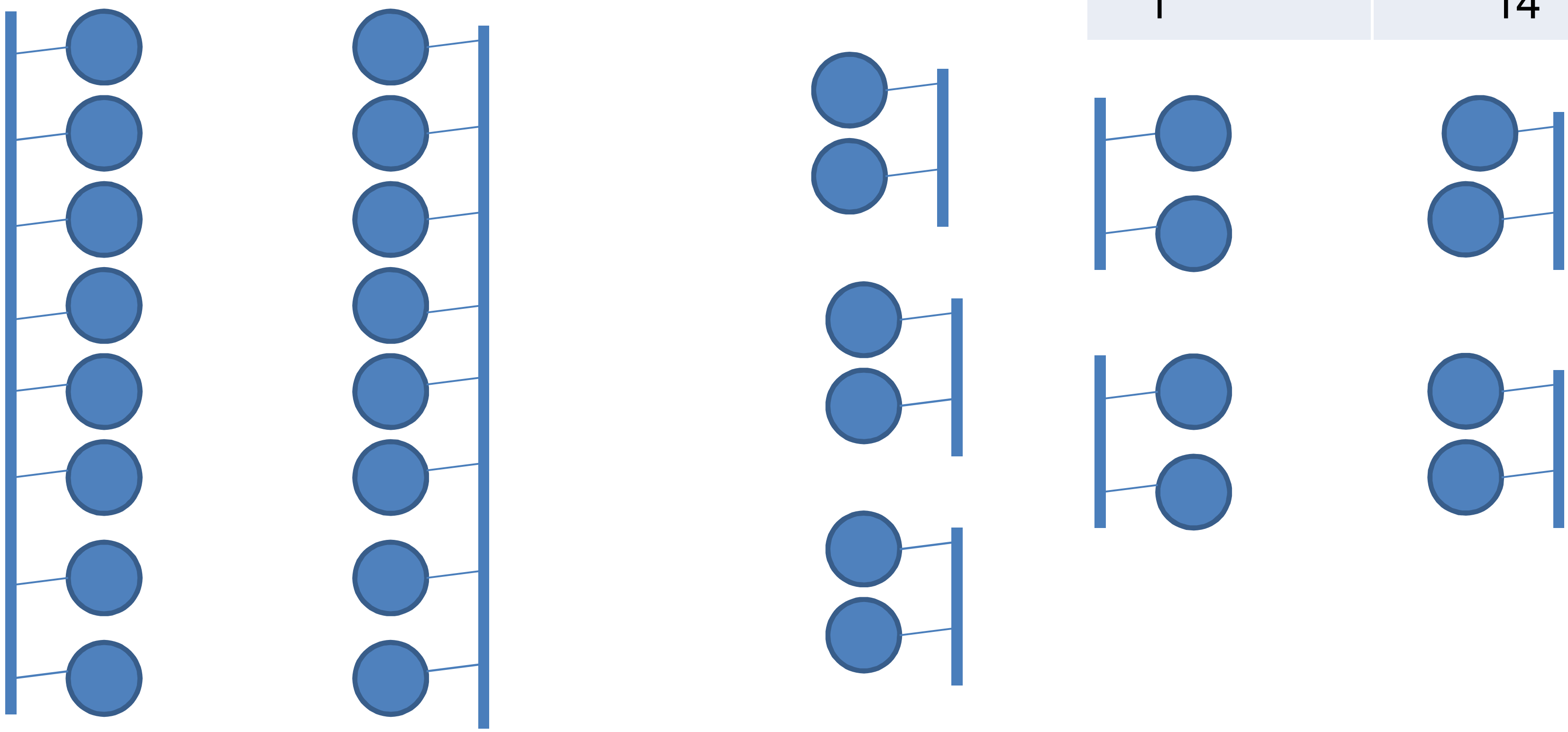


Example

n=10, /29=2, /30=3, /31=4

Assume occupancy rates to be 100%

Observed Degree Distribution	# of Nodes
7	16
1	14

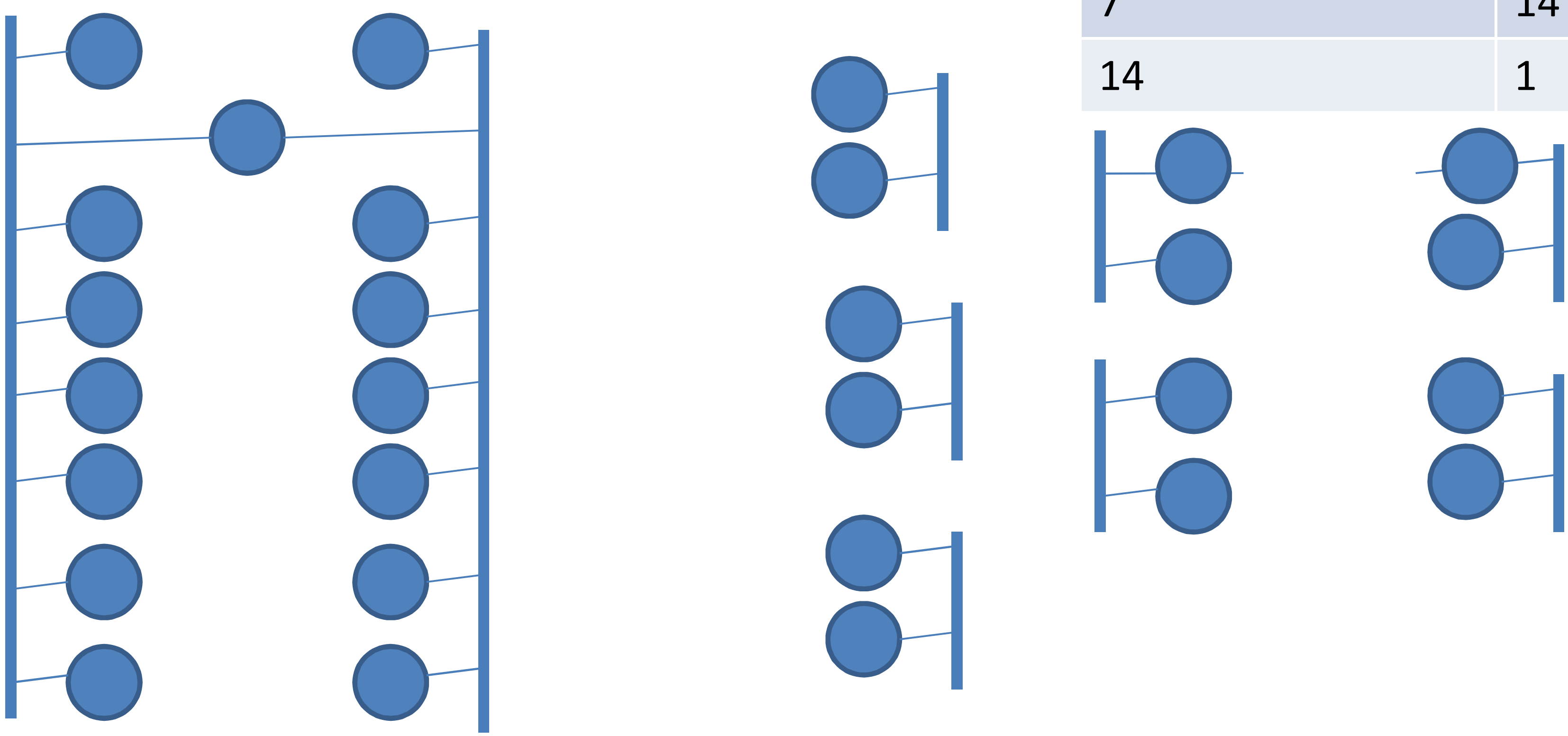


Example

Continue until n=10

Consider power law distribution

Raw Degree Distribution	
1	12
1	2
7	14
14	1



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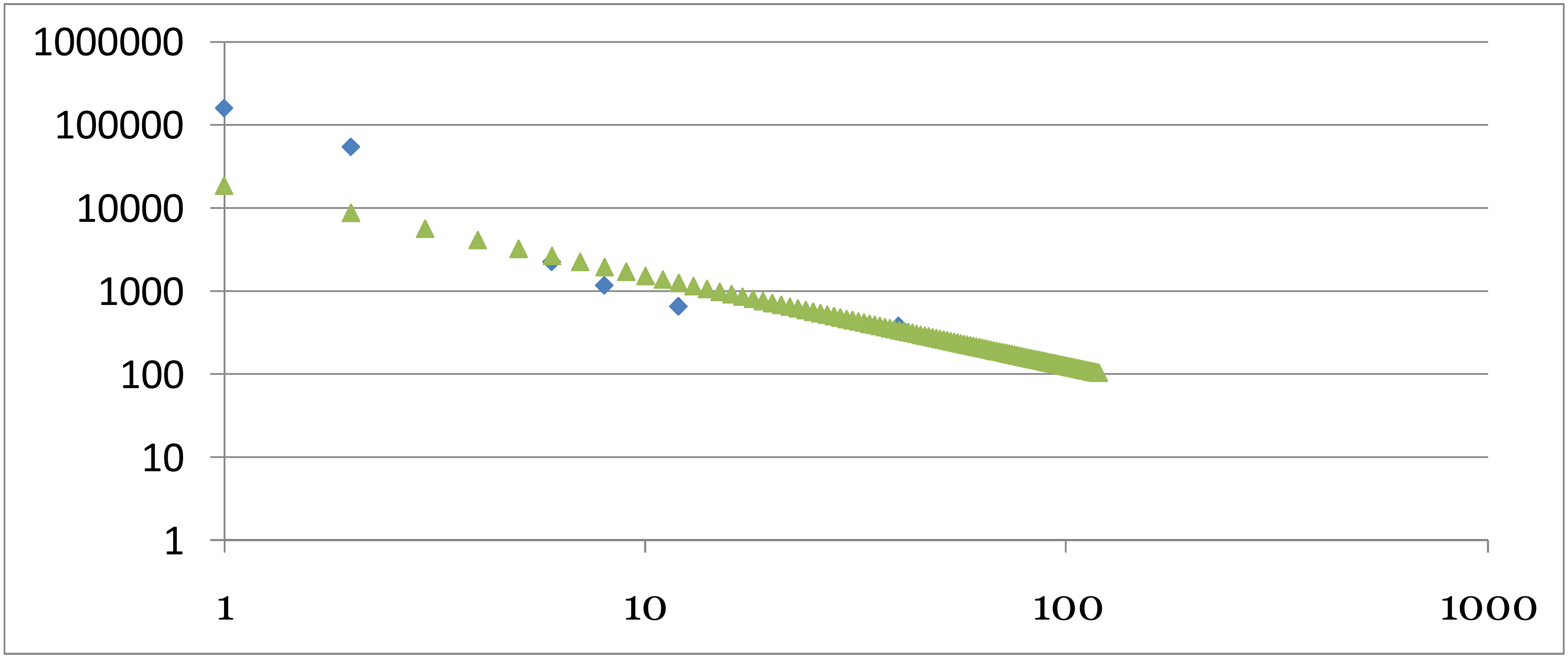
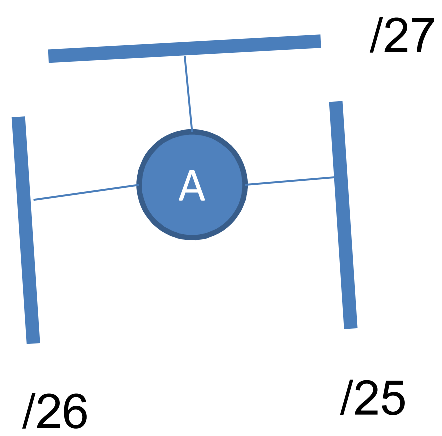
Degree Distribution before Merging

	/24	/25	/26	/27	/28	/29	/3x
Completeness	0	0.33	0.21	0.31	0.51	0.54	1
# of nodes per subnet	0	41	13	9	7	3	2



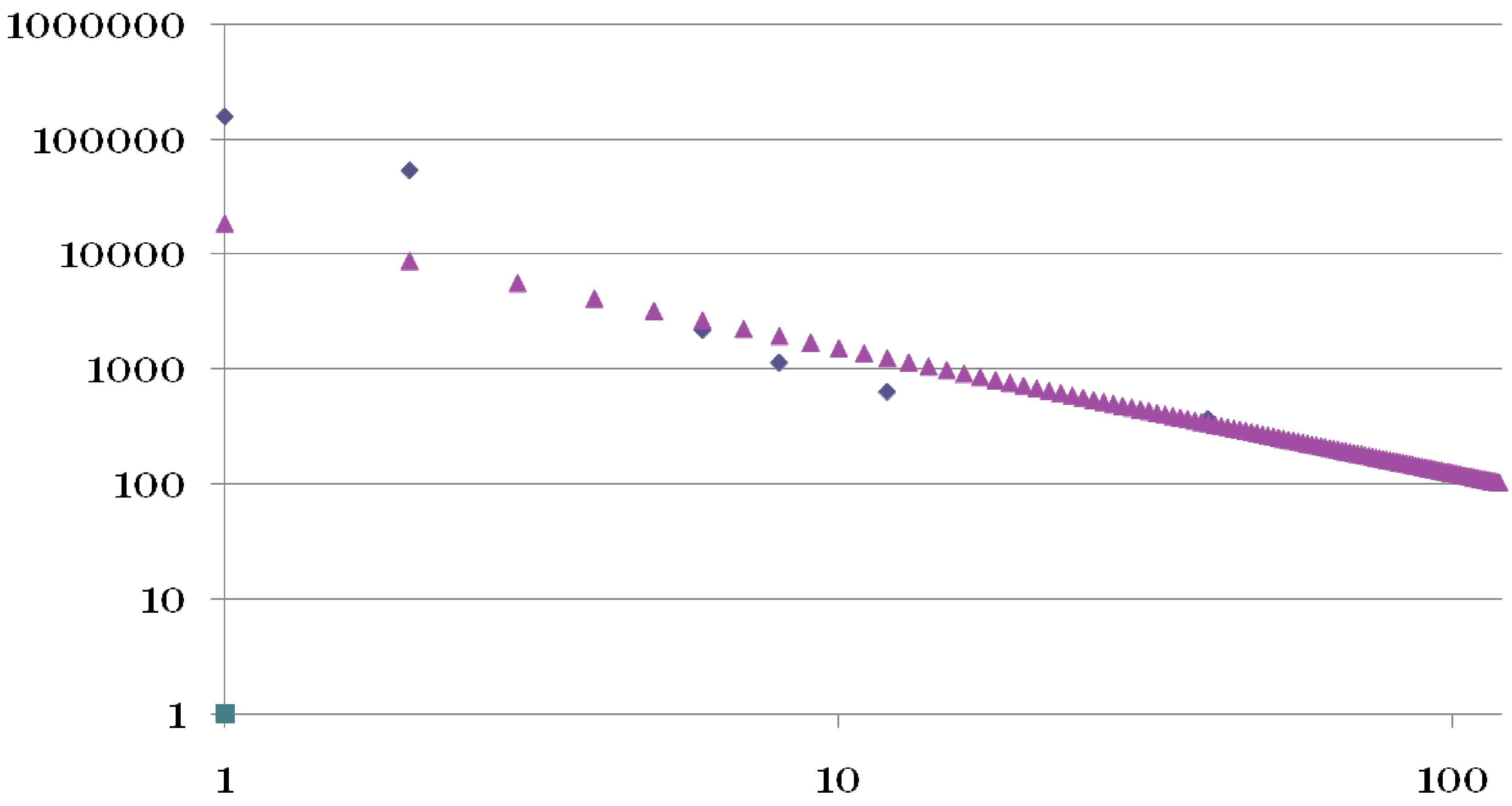
Merging

- By merging 3 nodes of /25 , /26 and /27 we can have a single node of degree:
  – Raw Degree = 41+13+9 = 63



! Merging can be performed between nodes of distinct subnets

Degree Distribution during Merging



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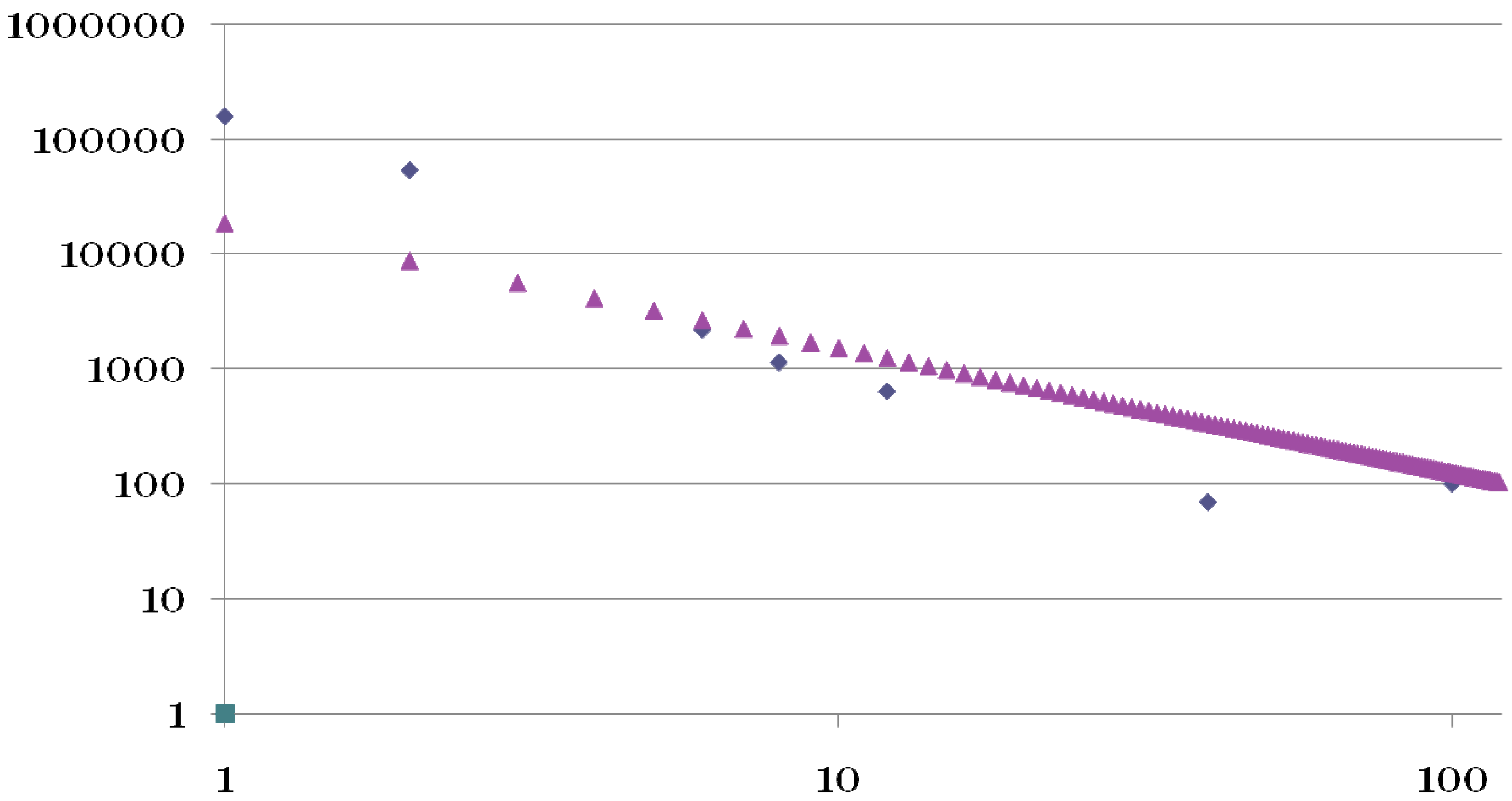

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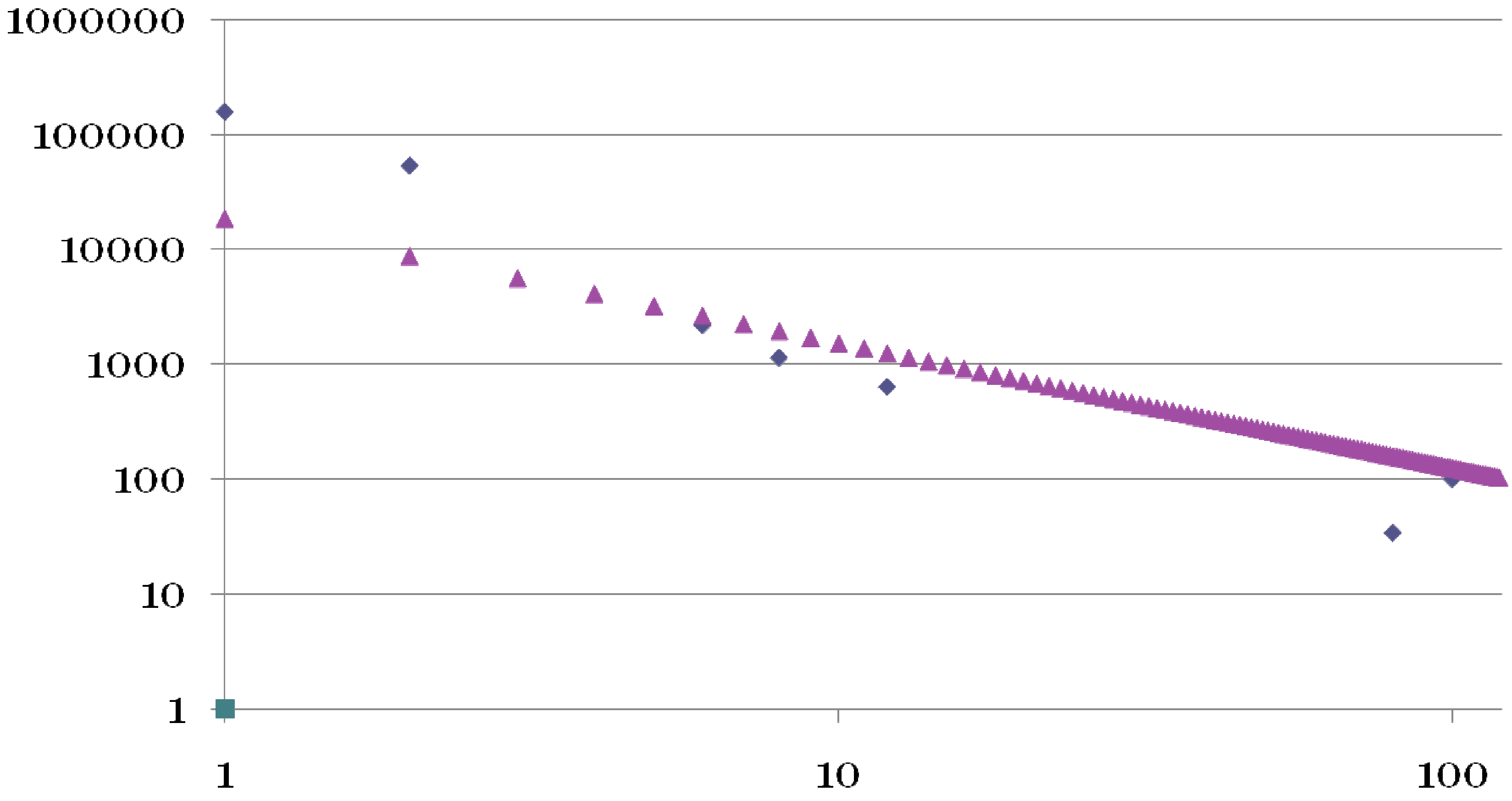

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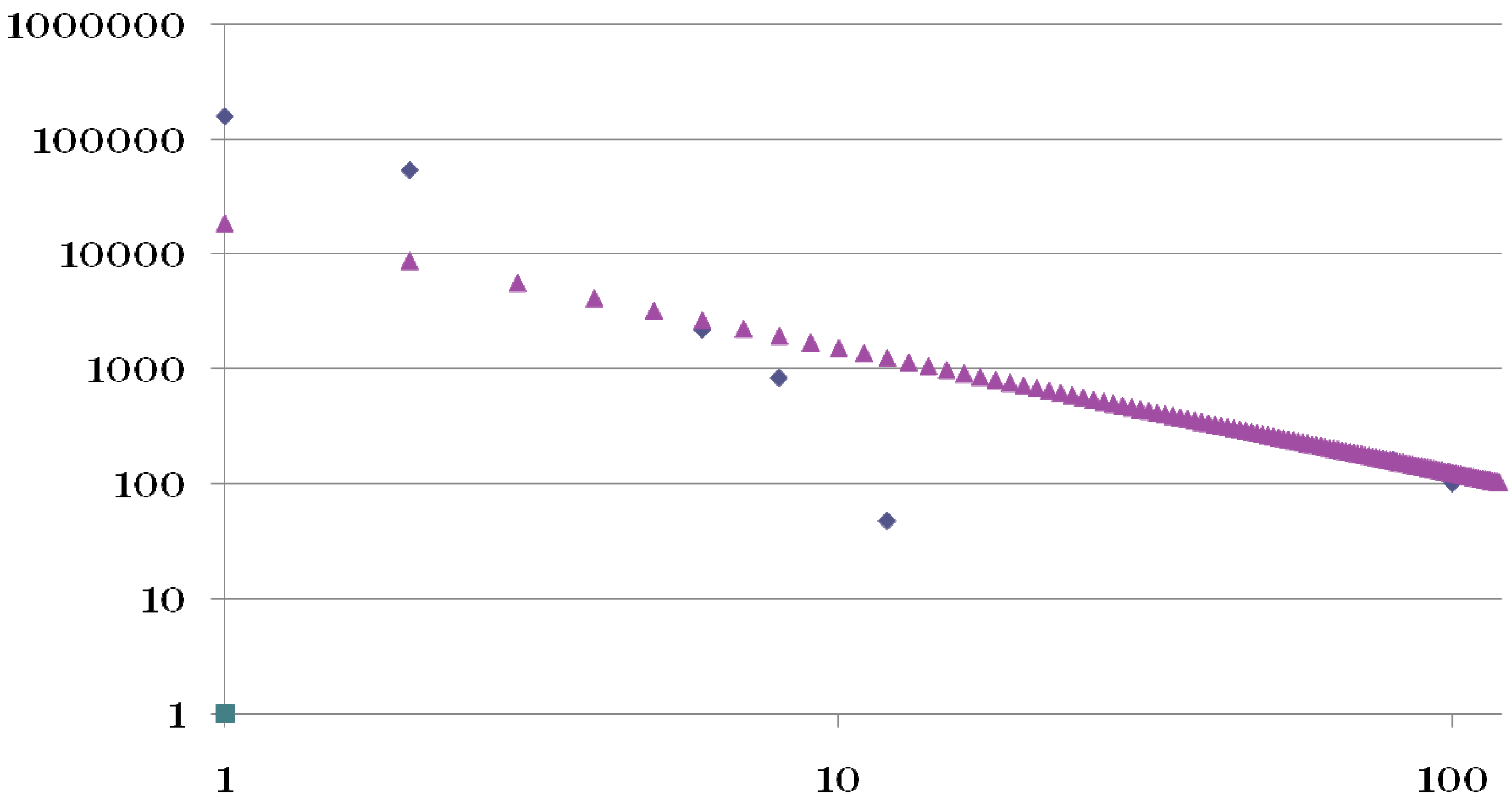

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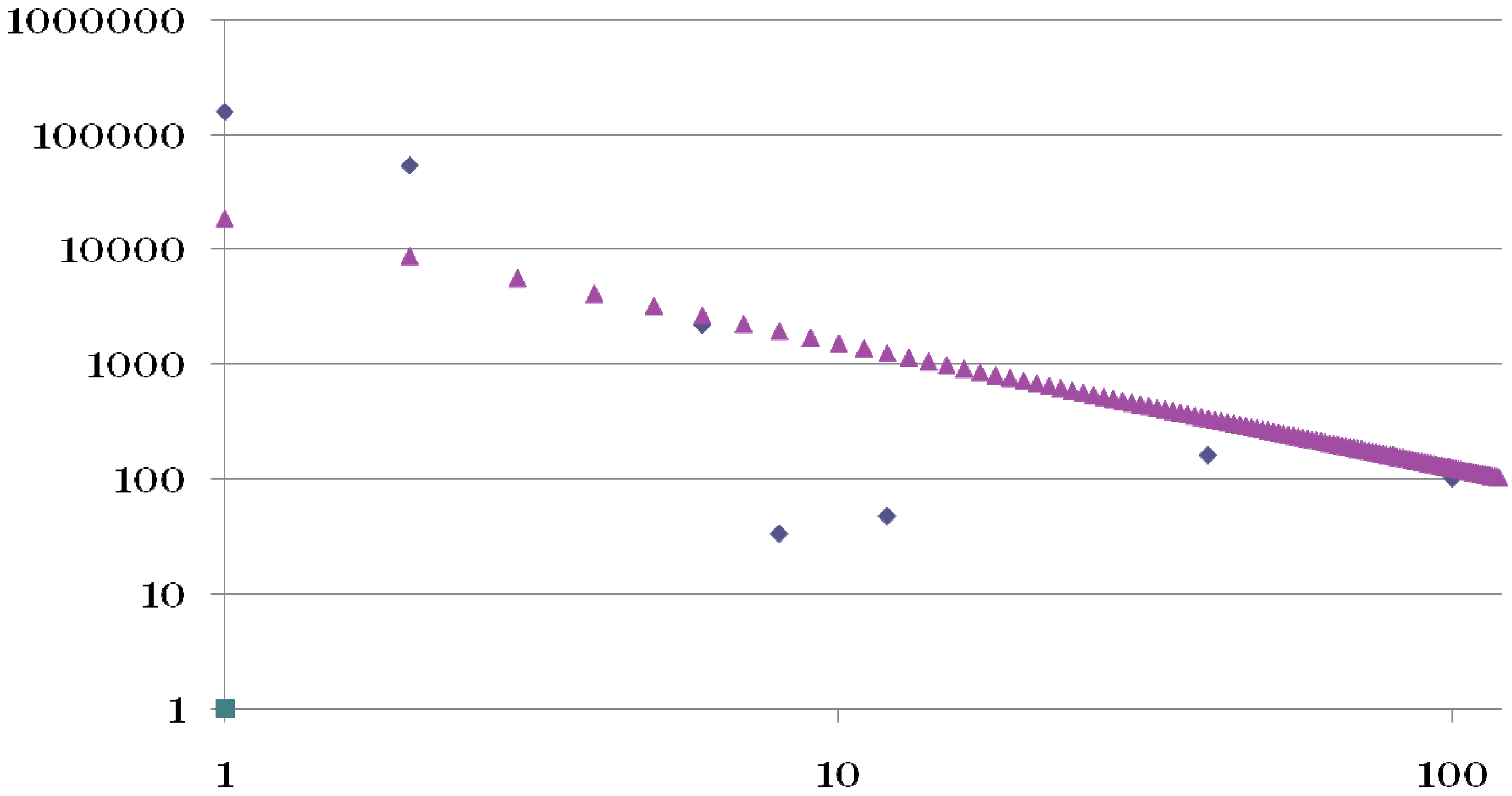

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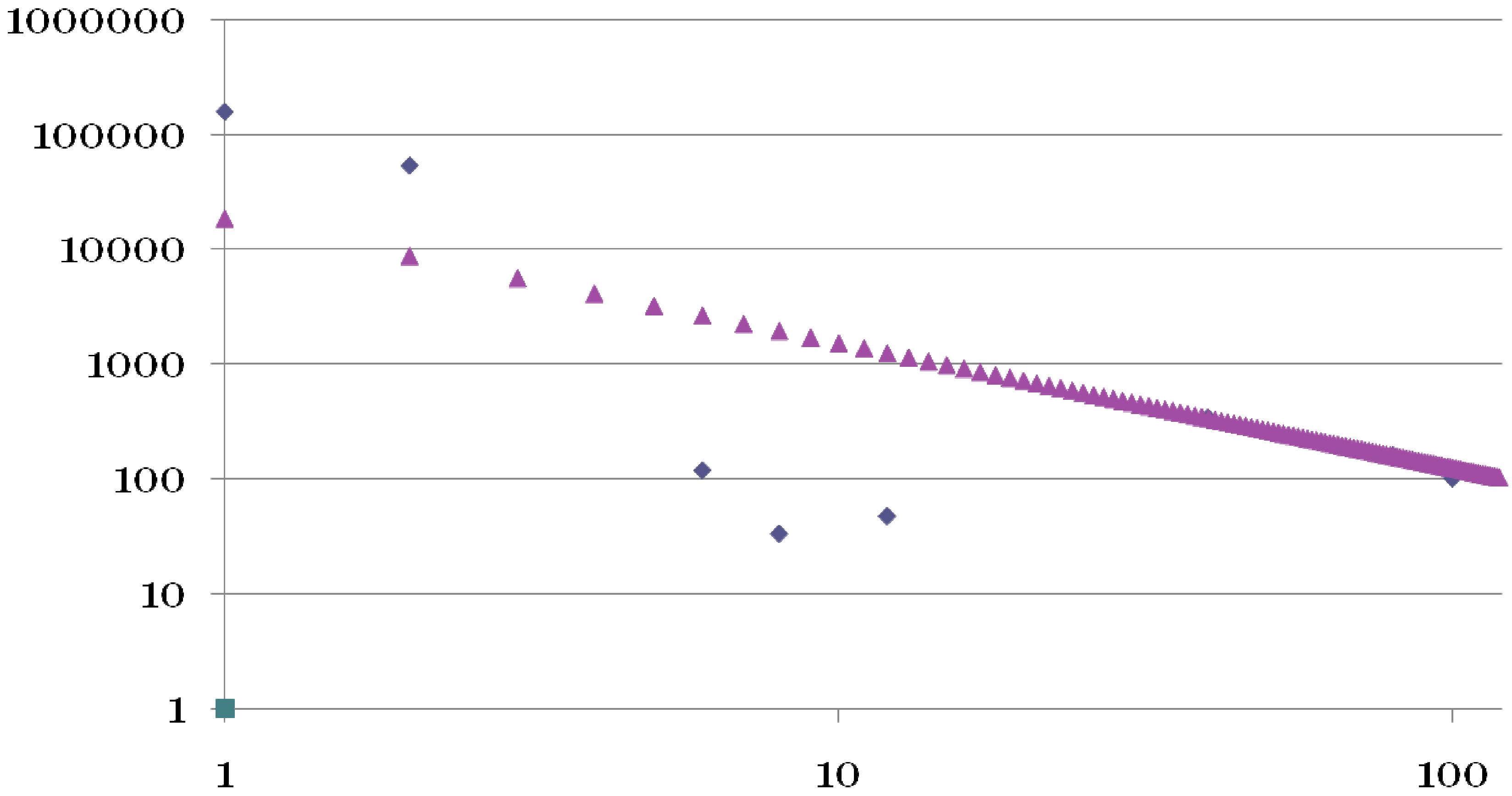

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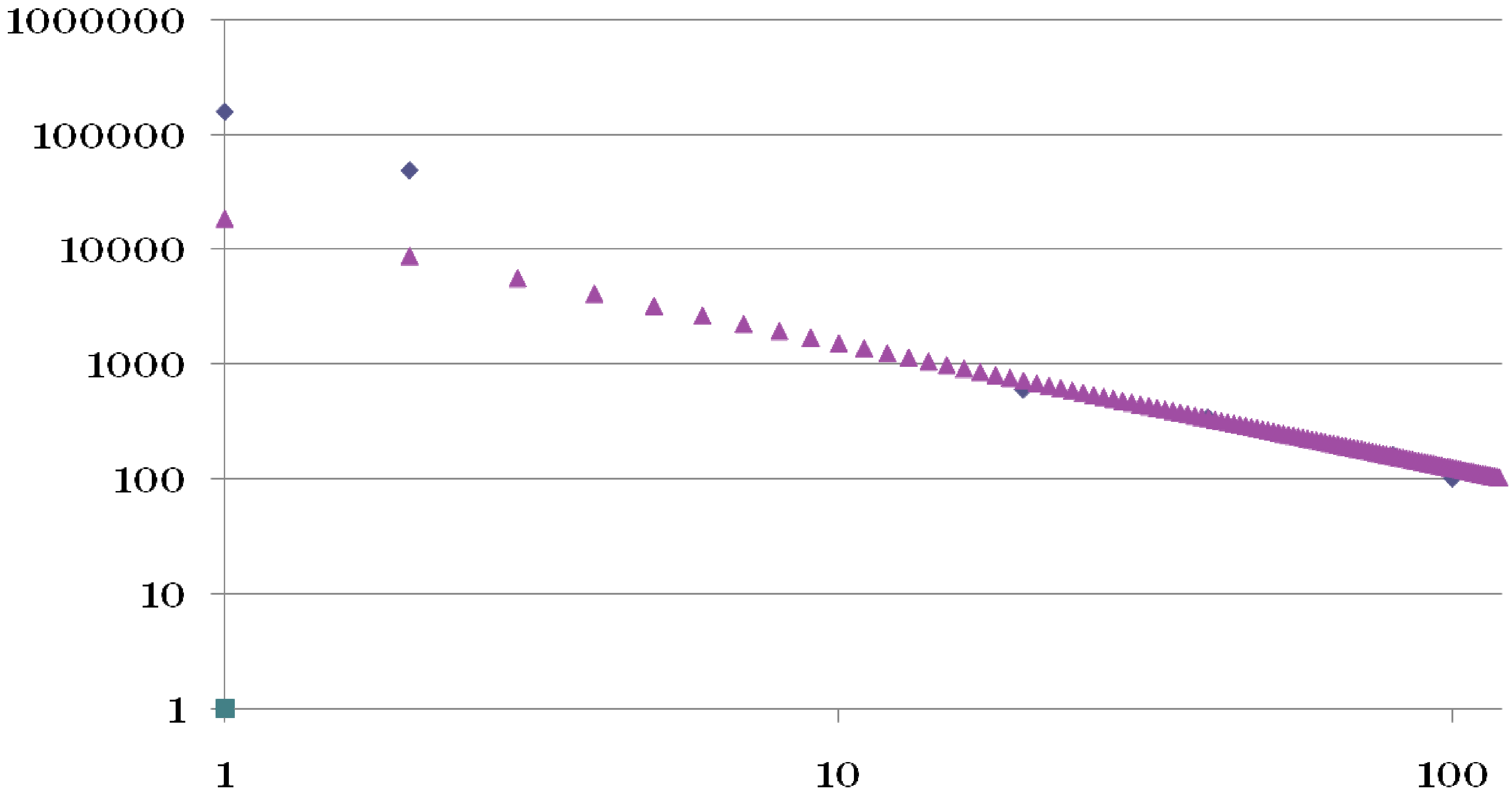
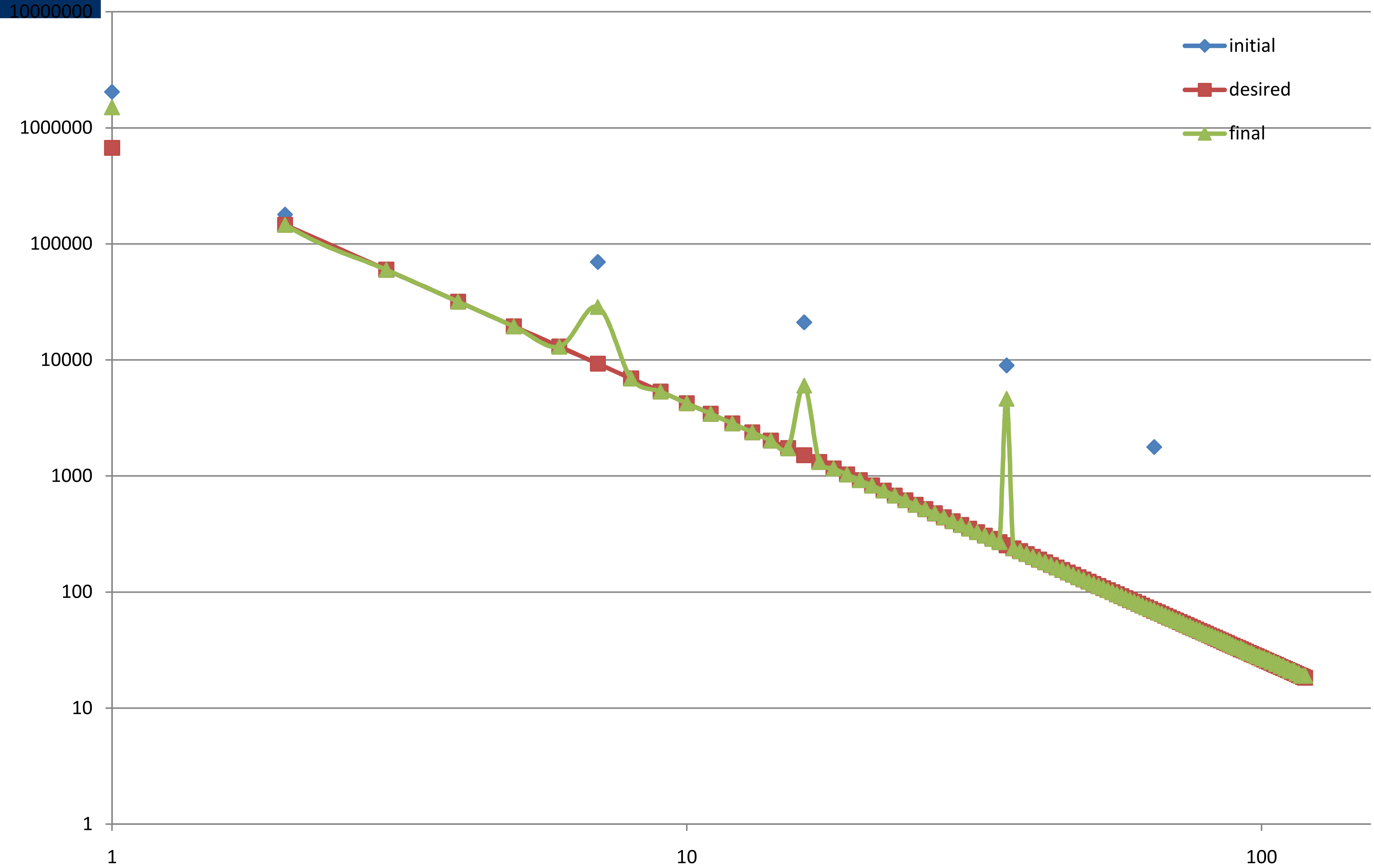


Subnet Distribution

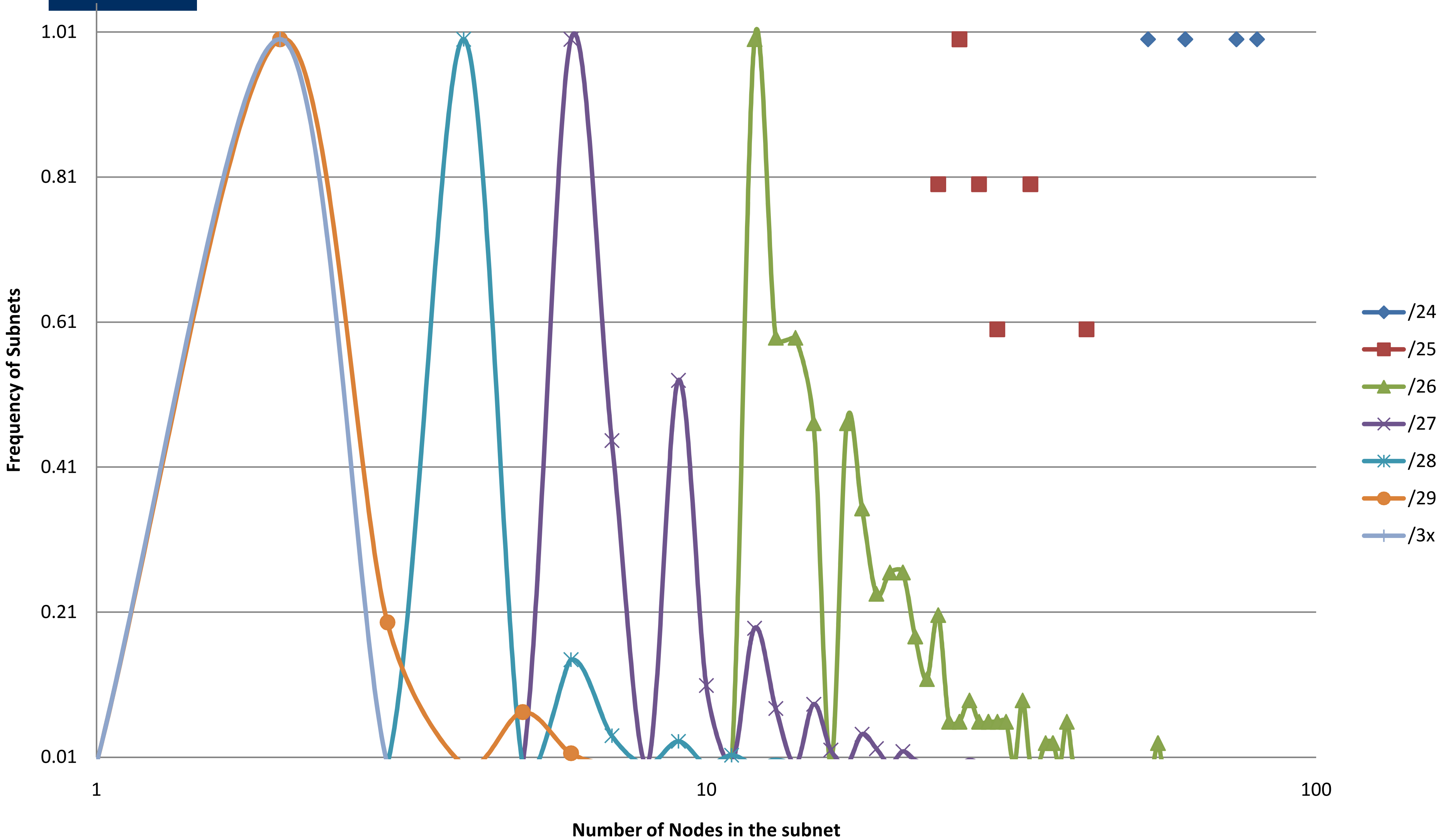
- Although many merge operations are done, subnet distribution is still satisfied.

	/24	/25	/26	/27	/28	/29	/3X
Number of Occurence	0	9	51	128	313	18062	79674
Distribution(%)	0	0.01	0.05	0.13	0.32	18.39	81.10
Completeness(%)	0	33	21	31	51	54	100

1M node topology



Size Distribution of Subnets



Results

- Both *subnet distribution* and *interface distribution* can be matched
  - generates more realistic topologies

- Our method requires measurement data
  - subnet distributions
  - interface distribution
  - exponent of observed degree distribution

Work in Progress

- Matching
  - Characteristic path length
    - rewring
  - Assortativity
    - subnet merging order
- Same approach will be applied to satisfy subnet and interface distributions
- Node centric approach

Thank you

Questions ?

Data Structure