Distributed Generation of Random Graphs Based on Social Network Models

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Outline

- About Spark
- Task definition
- RGG: graphs without a community structure
- CKB: graphs with a community structure
- Testing
- Conclusions

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What is Spark?

- Independent fast platform for distributed computing that supports the data processing by MapReduce model, Pregel and Graphx
  - ✓ Storing data in memory for fast processing of interactive inquiries
  - ✓ Can be 100 times faster than Hadoop
- Compatible with the Hadoop storage system (HDFS, Hbase, SequenceFiles etc)

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Spark programming model

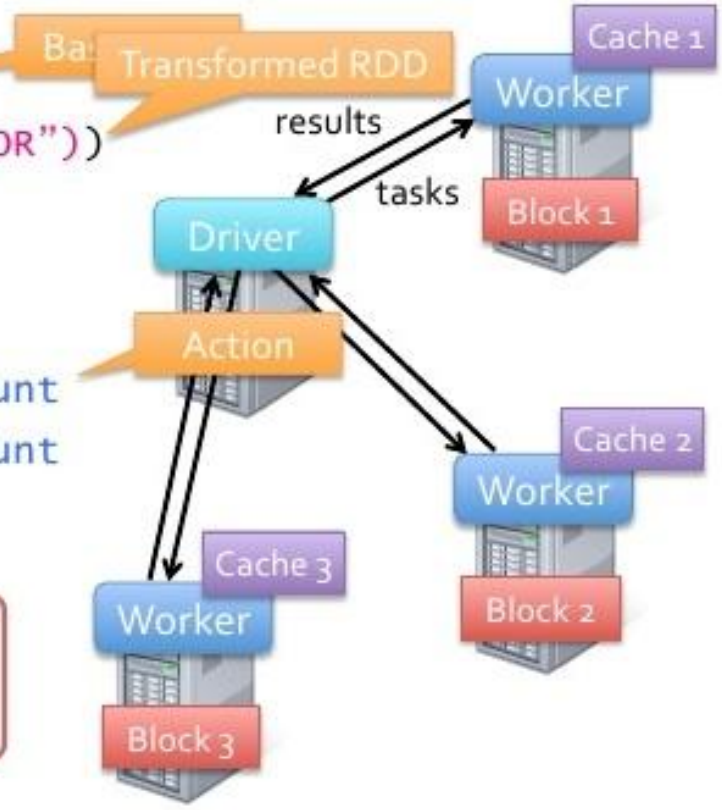
- The main idea: resilient distributed datasets (RDDs)
  - ✓ Distributed collection of objects that can be cached in the cluster nodes memory
  - ✓ One can manipulate using various parallel operations (such as map and reduce)
  - ✓ Automatically rebuild in case of failures
- Interface:
  - ✓ Elegant interface integrated into the Scala language
  - ✓ Can be used interactively from the Scala console

Example: logs analysis

1. Upload an error message in the memory
2. Interactive execute queries to them

```
lines = spark.textFile("hdfs://...")
errors = lines.filter(_.startsWith("ERROR"))
messages = errors.map(_.split('\t')(2))
cachedMsgs = messages.cache()

cachedMsgs.filter(_.contains("foo")).count
cachedMsgs.filter(_.contains("bar")).count
. . .
```



Result: scaled to 1 TB data in 5-7 sec
(vs 170 sec for on-disk data)

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Task definition

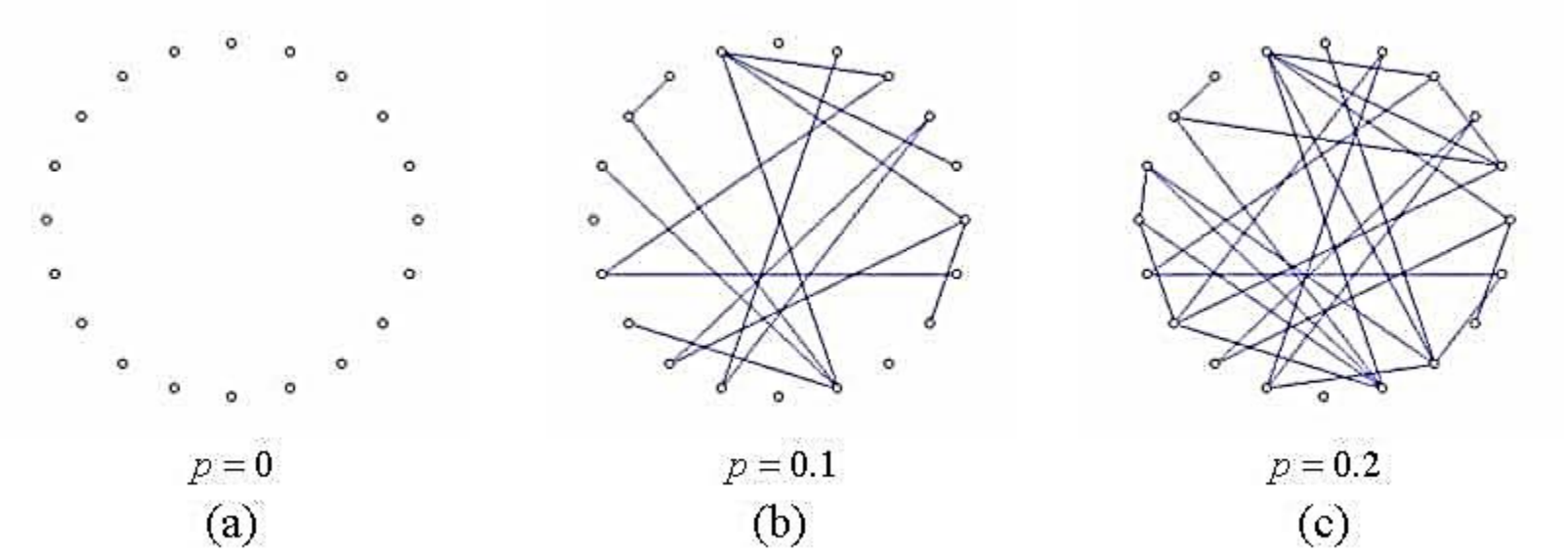
To generate random graph…

- …which will satisfy the basic properties of social networks;
- … in a reasonable time (even a billion vertices);

What is a random graph?

Erdős–Rényi graph

- N nodes
- Edge appears with a probability p



$p = 0$ (a)

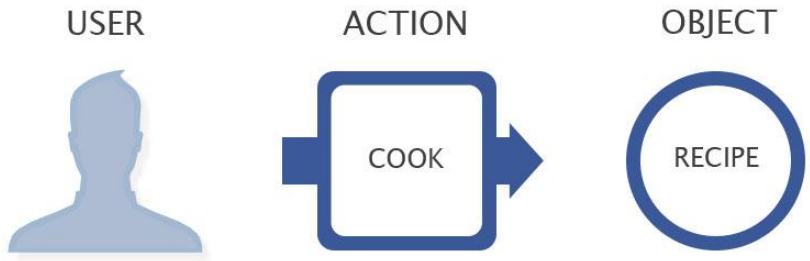
$p = 0.1$ (b)

$p = 0.2$ (c)

What is a social graph?

Type of nodes

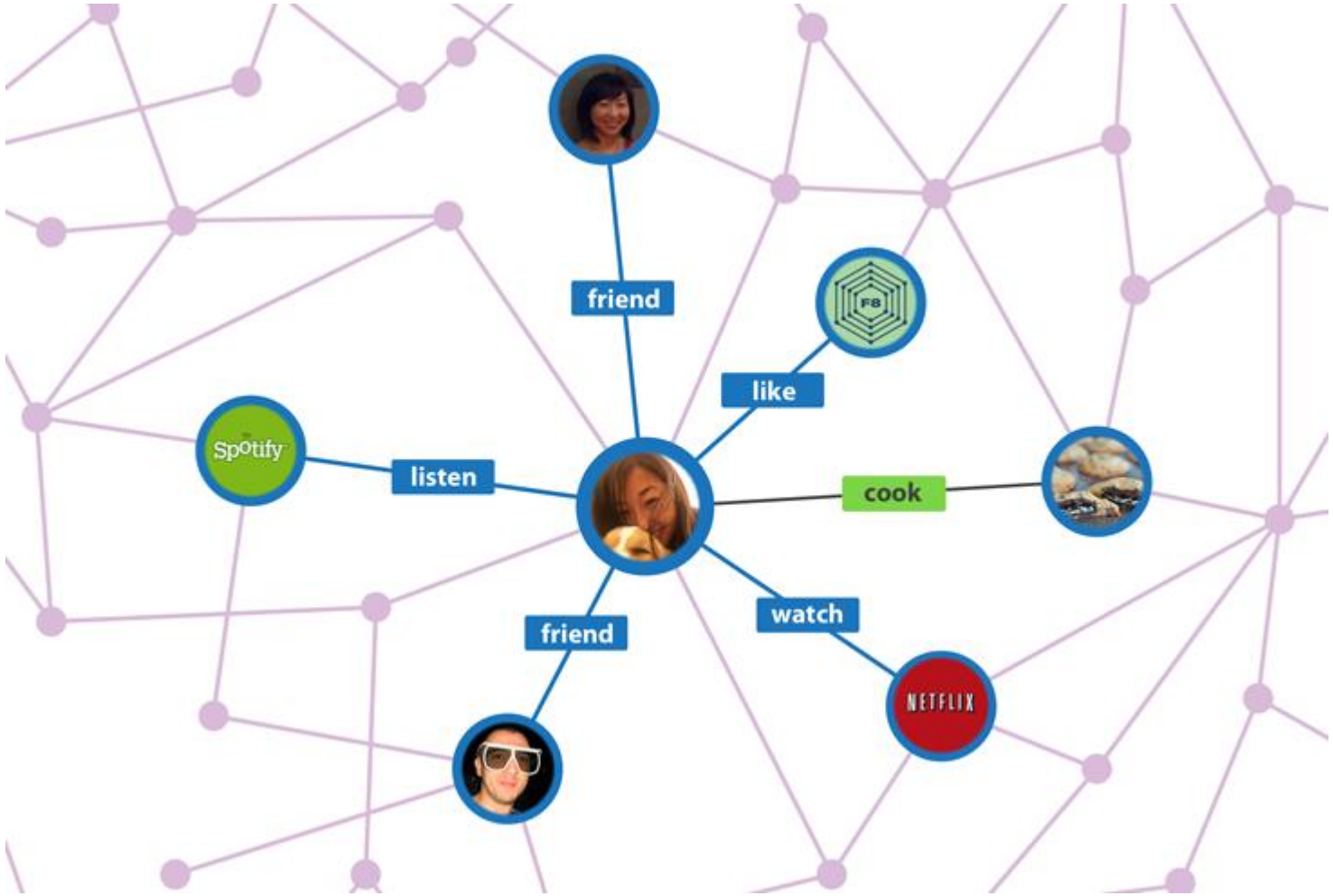
- Users: profiles field: attributes, interests, contacts
- Communities: lists, groups
- *Content*: messages, pictures, videos



Type of edges

- Social ties: friends, followers
- *Interacting with a content*: «likes», reposts, comments

What is a social graph?



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Social network properties

- Node degree distribution is a power law:

$$P(x) \propto x^{-\beta}$$

- Small effective diameter:

$$D \approx \frac{\ln(N)}{\ln(\ln(N))}$$

- Users are clustered in the overlapping communities

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Motivation

- The dimensions of modern social networks reach hundreds of millions vertices.
- It is required network analysis algorithms, whose effectiveness is proven on large graphs.
- Collecting real data is hindered due to the large time and resource costs.

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RGG: graphs without a community structure

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RGG: input

- ***N*** – number of nodes
- ***d*** – mean degree
- **β** – degree distribution power law exponent

RGG: main steps

- Natural numbers (node degrees) are generated by power law distribution
- Computing the number of edges to generate
- Choosing the pair of numbers (edges) (i, j) proportional to their degrees

RGG: extensions

- Directed version
- Bigraph generation
- Attributes, texts, «likes»
- Communities

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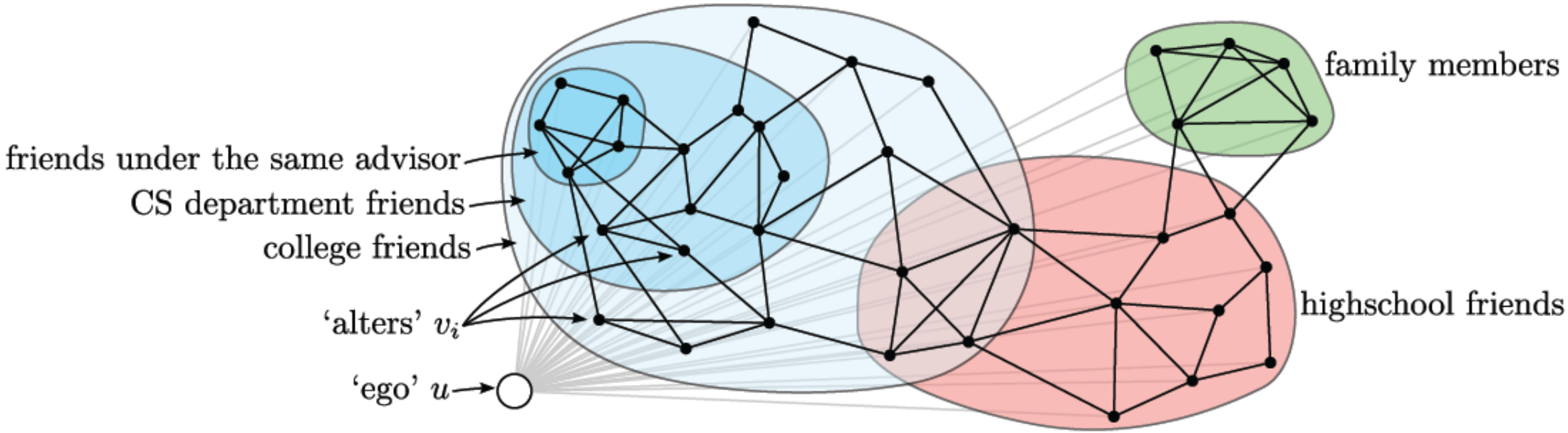
What is a community?

What is a community?



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CKB: graphs with a community structure

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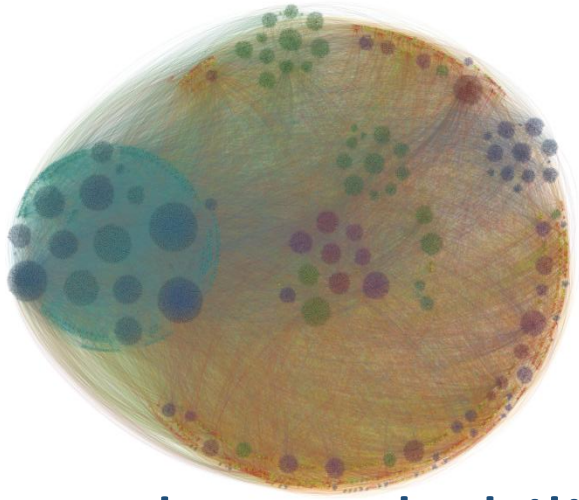
CKB: input



- N_1 – number of nodes
- d – mean degree
- Power law distribution parameters: max, min and exponent values
- α, γ – two constants that determine the edge probability
- ε – the edge probability between users regardless the community structure

CKB

Main steps:

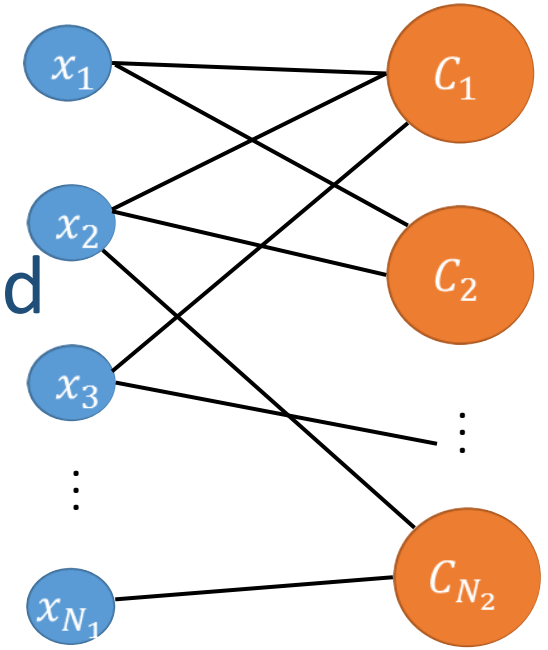
1. Bigraph node-community generation
2. Edges in communities are generated
3. Edges between users regardless the community structure are generated

CKB: node-community

1. Number of communities is computed from*

$$N_1 \cdot E[X_1] = N_2 \cdot E[X_2]$$

2. Memberships and community sizes are generated according to a power law with β_1 and β_2 exponents
3. Graph realization of these 2 degree sequences is created by random pairwise combinations of vertices from different parts



* $E[X_1]$ and $E[X_2]$ is the average values of membership and community size respectively

CKB: edges generation

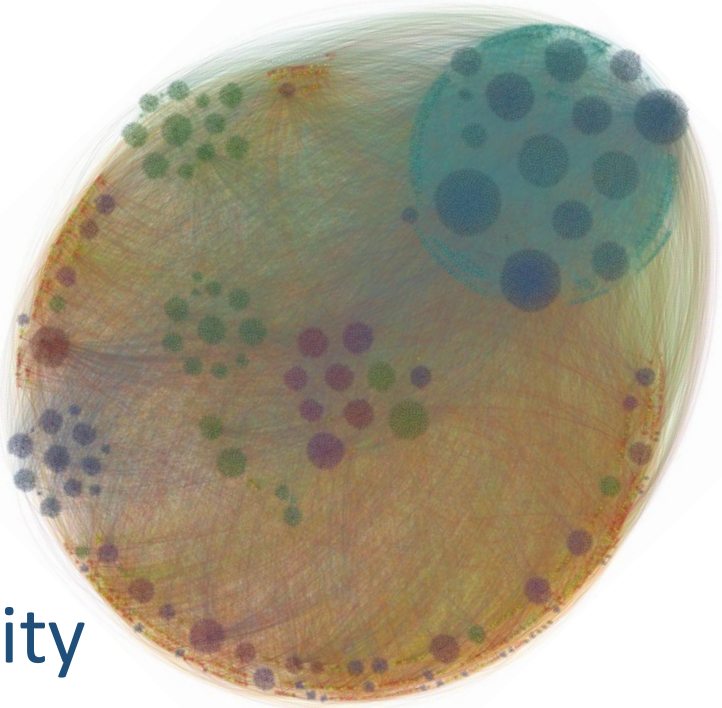
1. Edges in community are generated with probability*:

$$p = \frac{\alpha}{x_i^{\gamma}},$$

where x_i – size of i-th community

2. Edges between users regardless the community structure are generated with a probability:

$$p_{out} = \varepsilon$$



* Yang, J., and Leskovec, J. Structure and overlaps of communities in networks.
**Yang, J., and Leskovec, J. Community-affiliation graph model for overlapping network community detection.

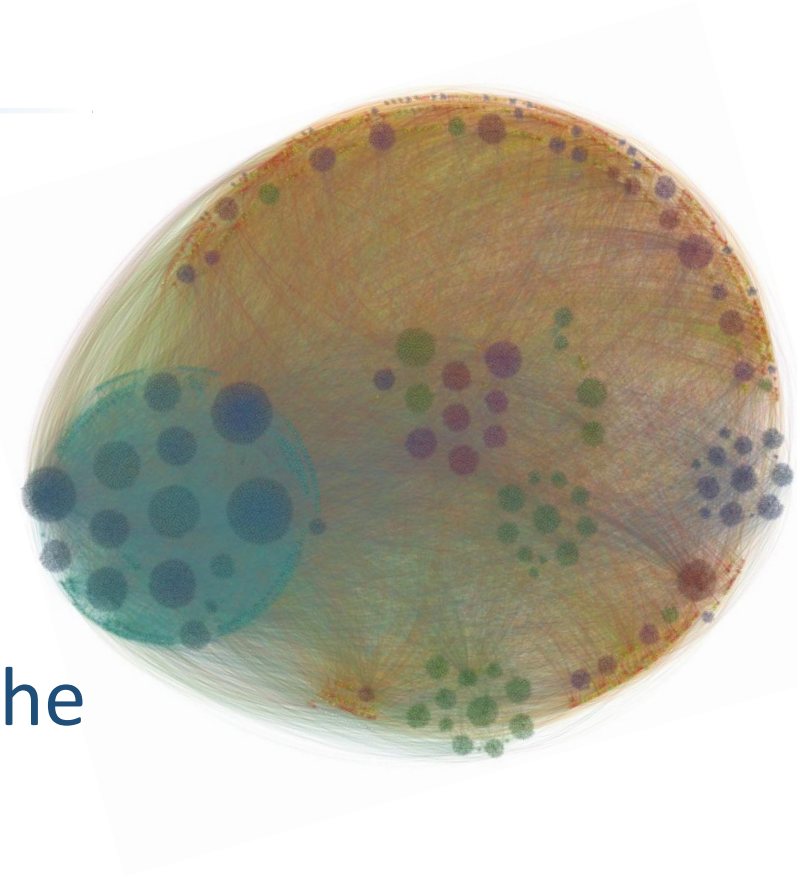
CKB: edges generation

1. Number of edges in a community is

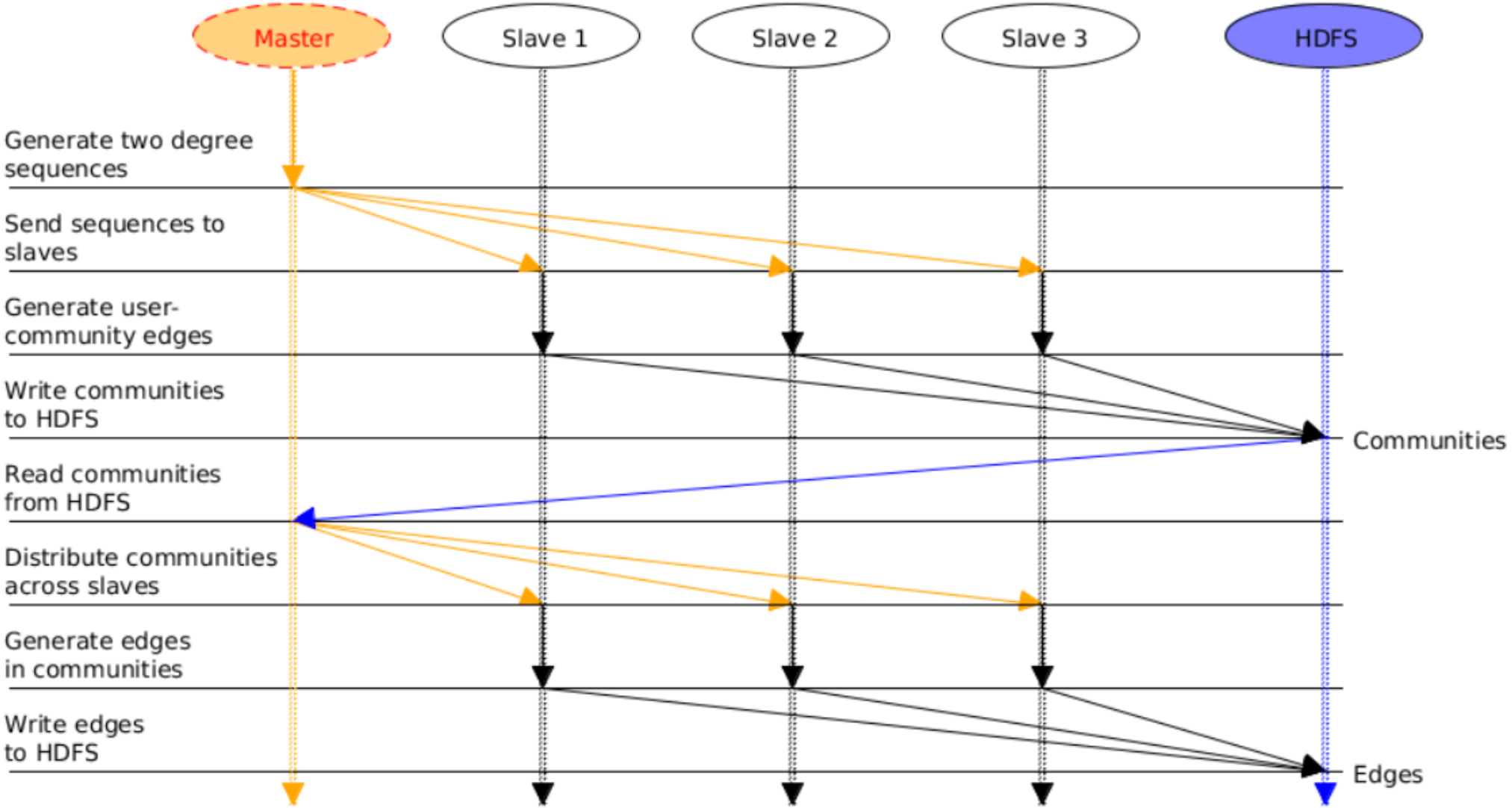
$$M_i \sim Bin\left(\frac{x_i(x_i-1)}{2}, \frac{\alpha}{x_i^{\gamma}}\right)$$

2. Number of edges between users regardless the community structure is:

$$M_i \sim Bin\left(\frac{N_1(N_1-1)}{2}, \varepsilon\right)$$



CKB: Apache Spark realization



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Comparing with a real data

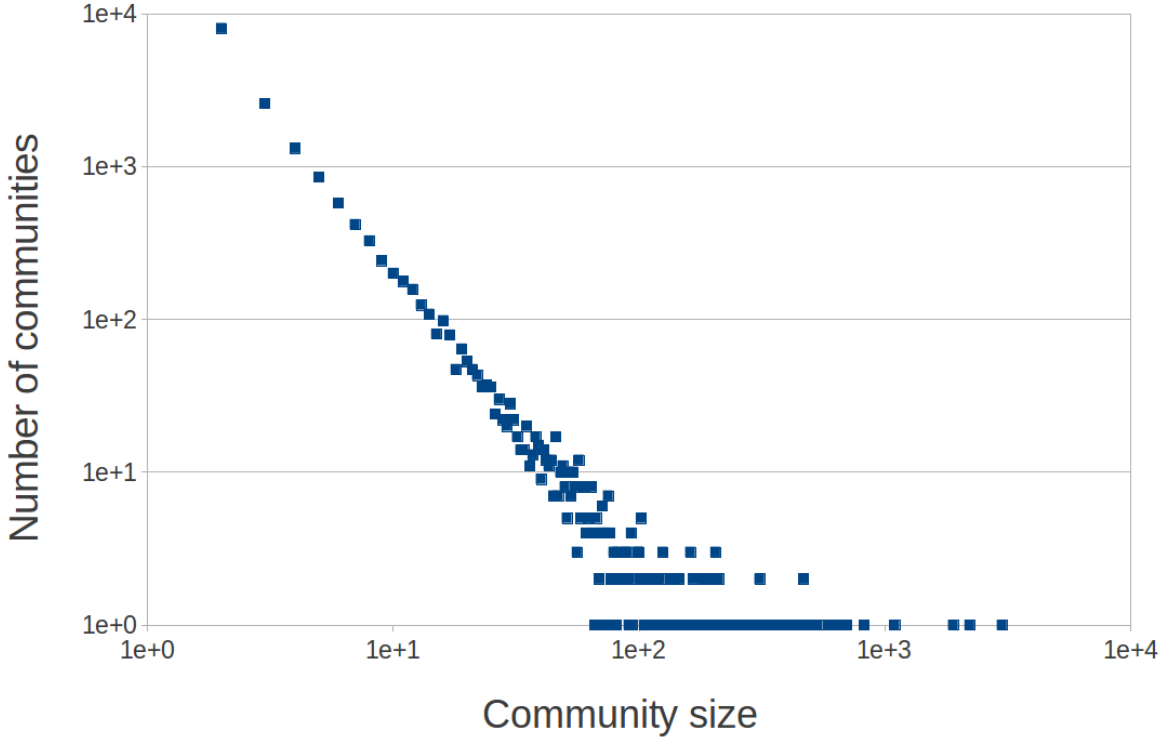
	LiveJournal	CKB
Number of nodes	$\approx 4 \cdot 10^6$	$\approx 4.2 \cdot 10^6$
Number of edges	$\approx 34.6 \cdot 10^6$	$\approx 38.2 \cdot 10^6$
Degree distribution exponent	2.14	2.15
Community size distribution exponent	2.22	2.26
Membership distribution exponent	2.15	2.15
Median of community size distribution	10	8
Median of membership distribution	2	2
Percentage of nodes with membership more than 1	63%	66%
Average clustering coefficient	0.3538	0.1034
Effective diameter	6.4	5.16

Comparing with a real data

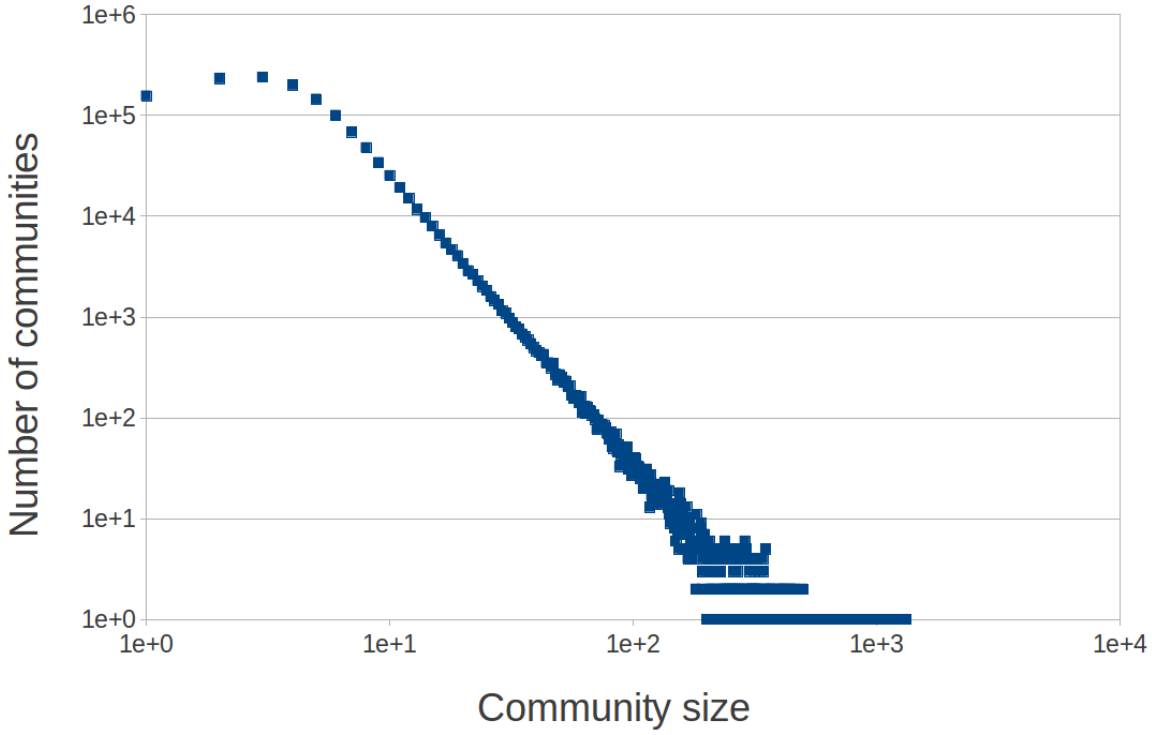
	YouTube	CKB
Number of nodes	$\approx 1.1 \cdot 10^6$	$\approx 1.1 \cdot 10^6$
Number of edges	$\approx 3 \cdot 10^6$	$\approx 3 \cdot 10^6$
Degree distribution exponent	2.36	2.41
Community size distribution exponent	2.83	2.95
Membership distribution exponent	2.53	2.45
Median of community size distribution	3	4
Median of membership distribution	2	2
Percentage of nodes with membership more than 1	38%	68%
Average clustering coefficient	0.1723	0.1066
Effective diameter	6.5	6.2

Comparing YouTube and CKB

YouTube

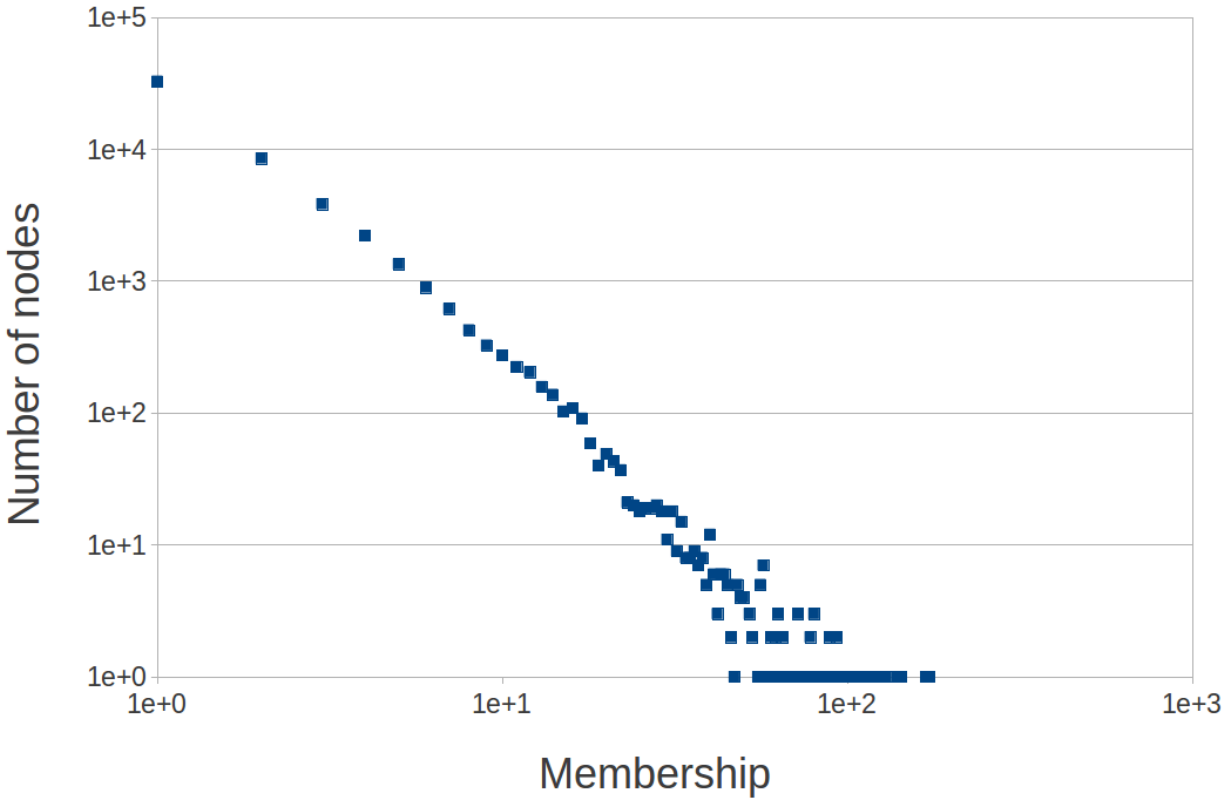


CKB

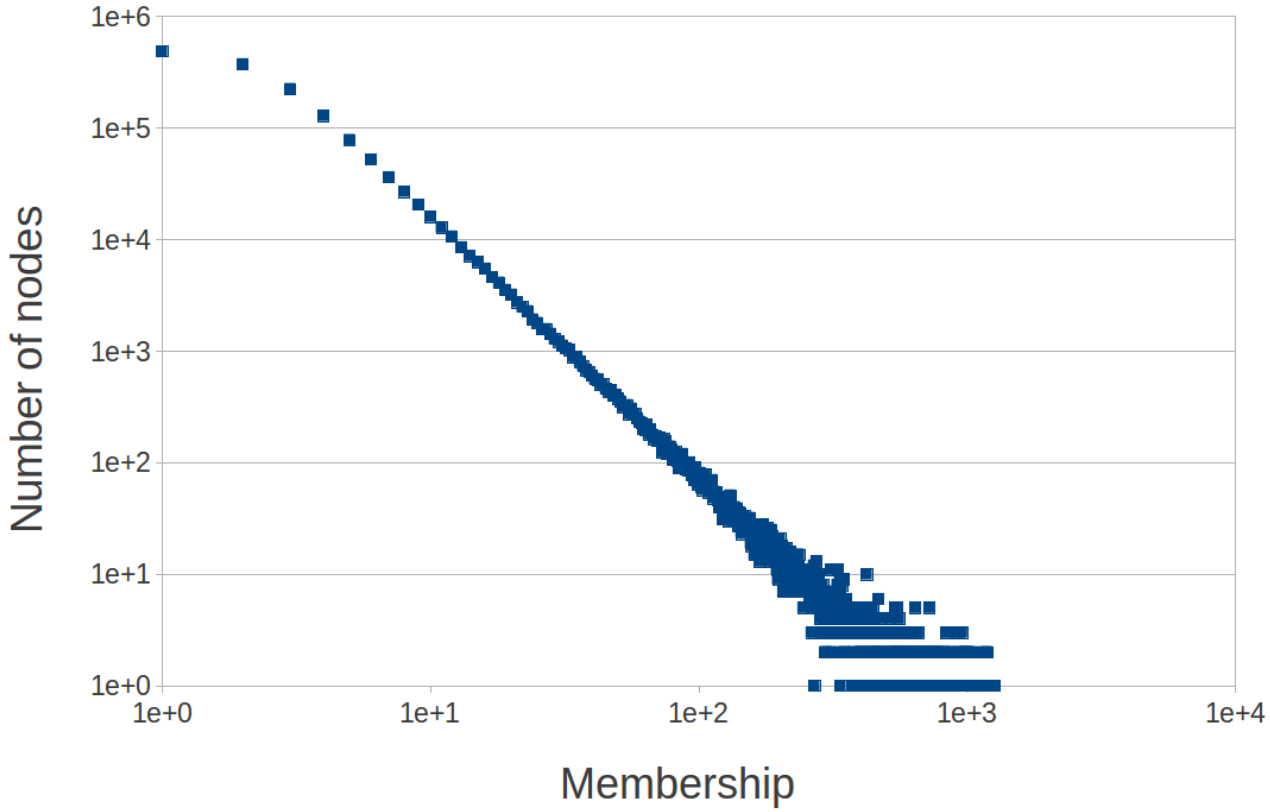


Comparing YouTube and CKB

YouTube



CKB



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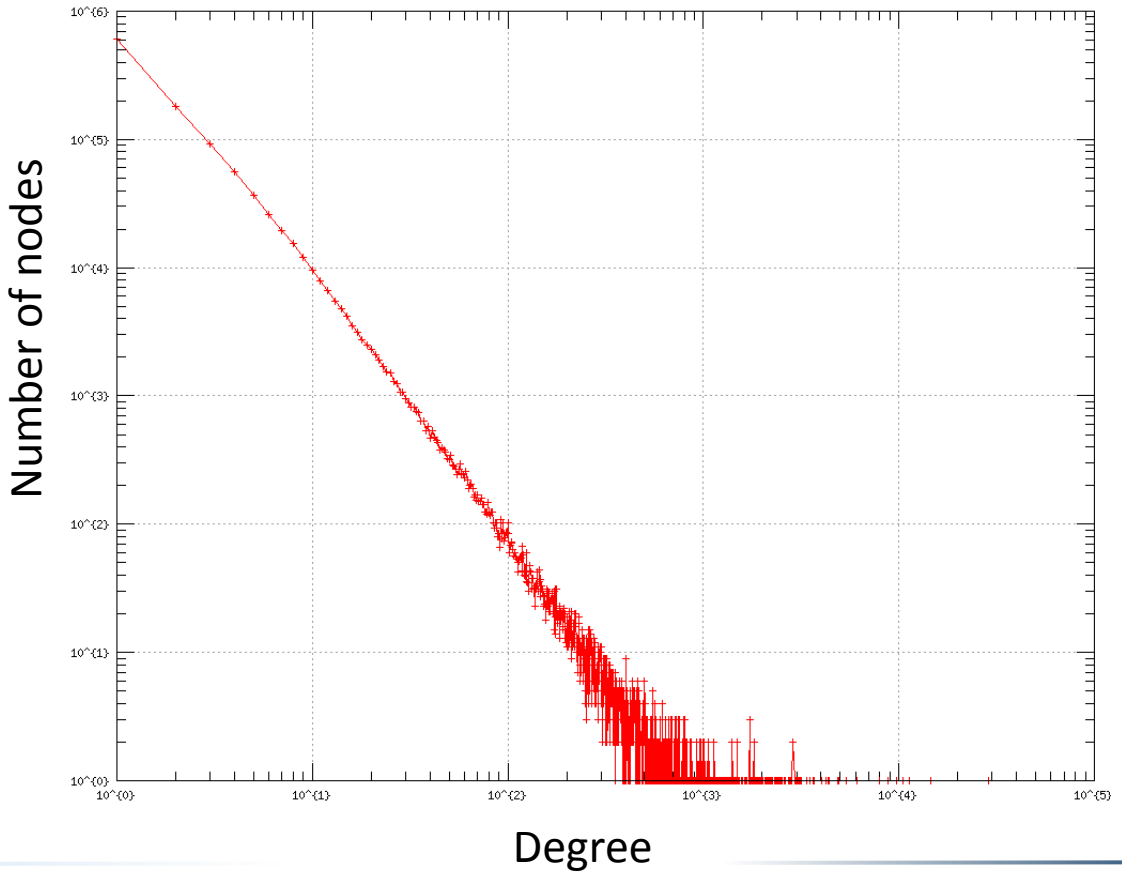
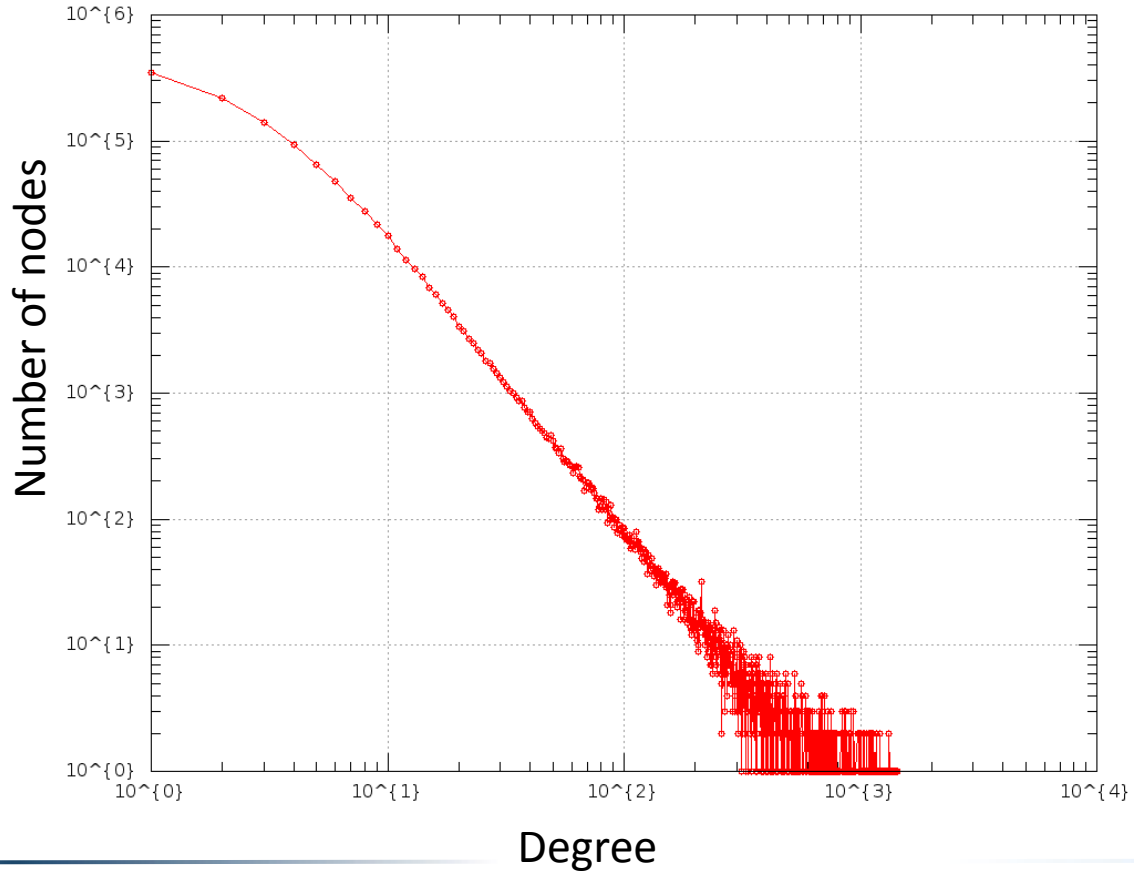
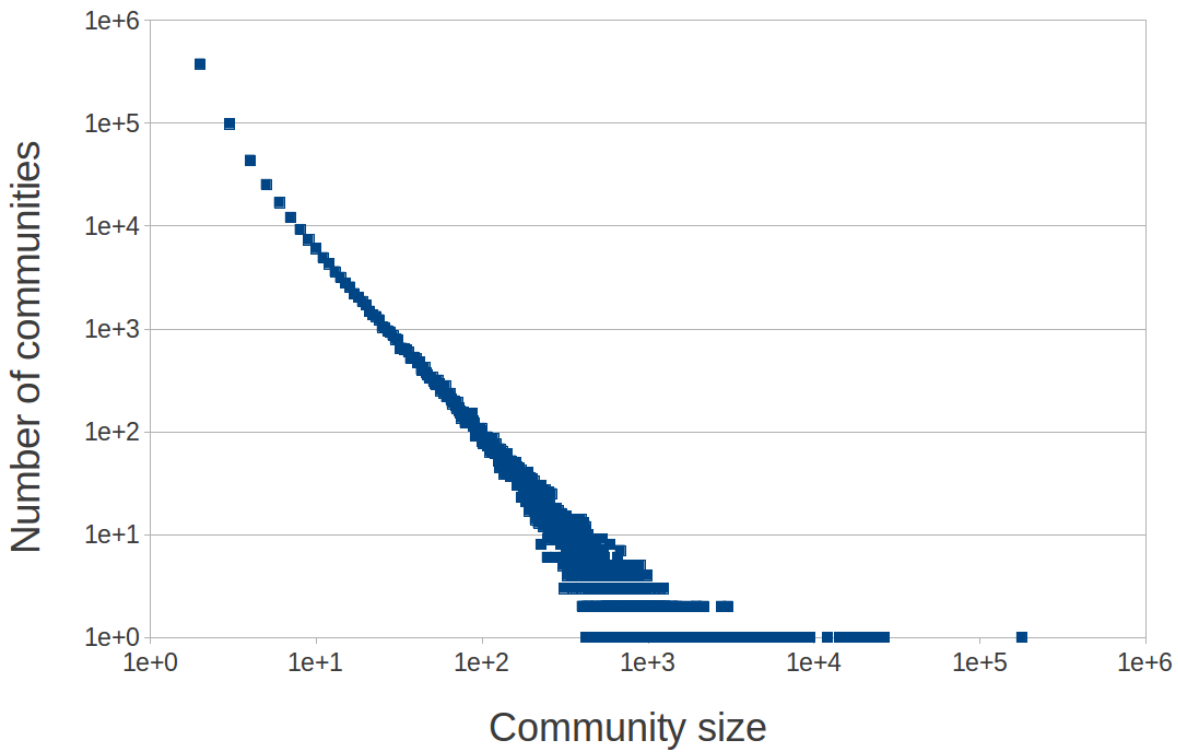


CKB

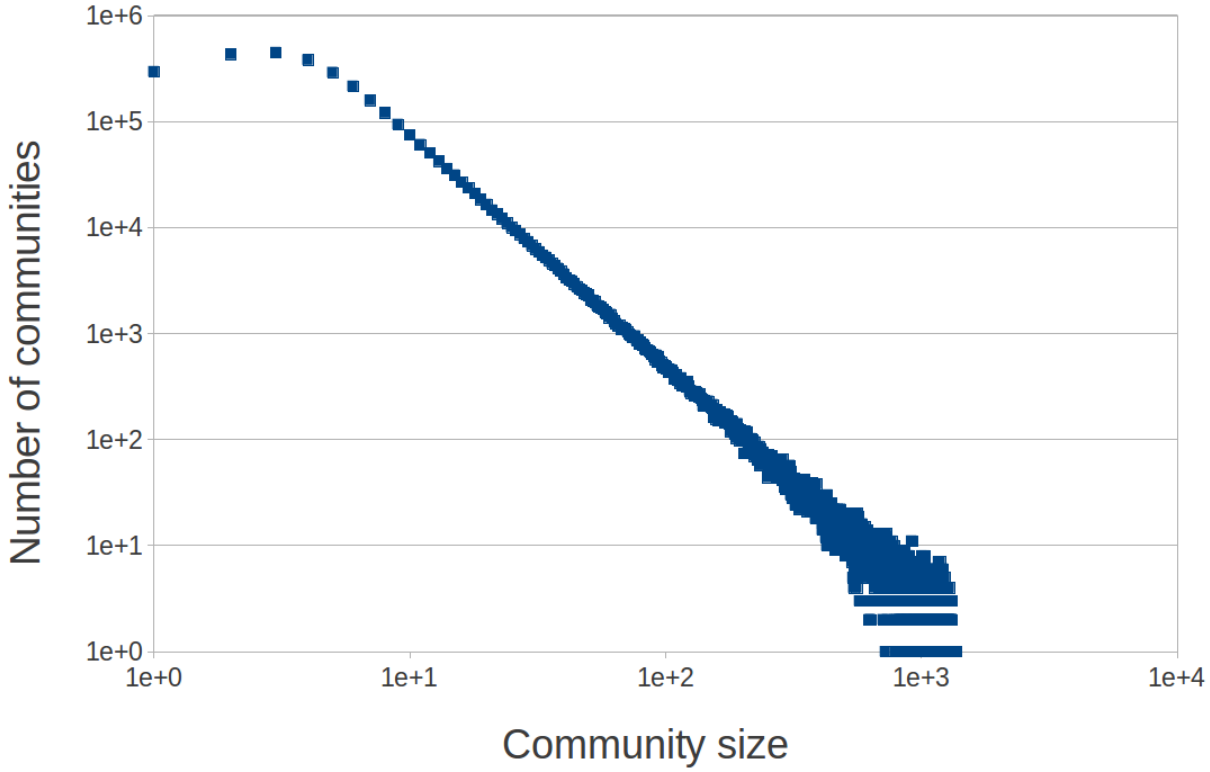


Comparing LiveJournal and CKB

LiveJournal



CKB



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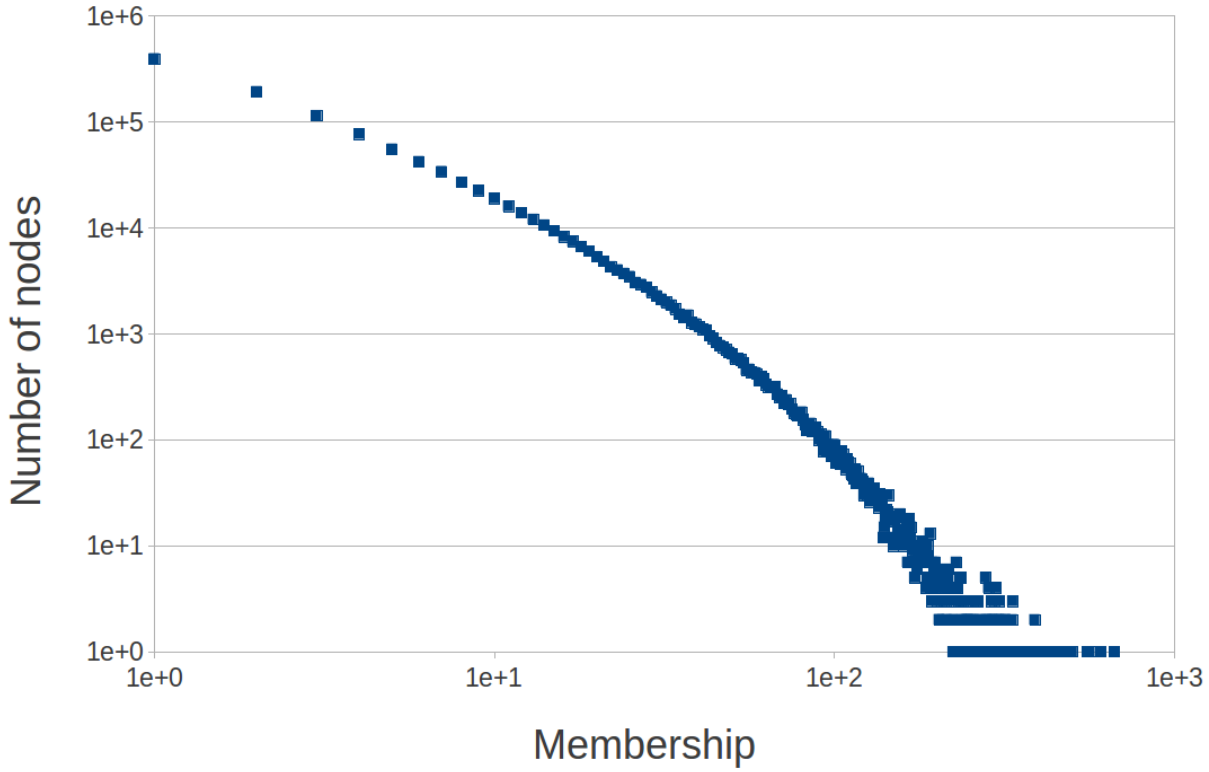
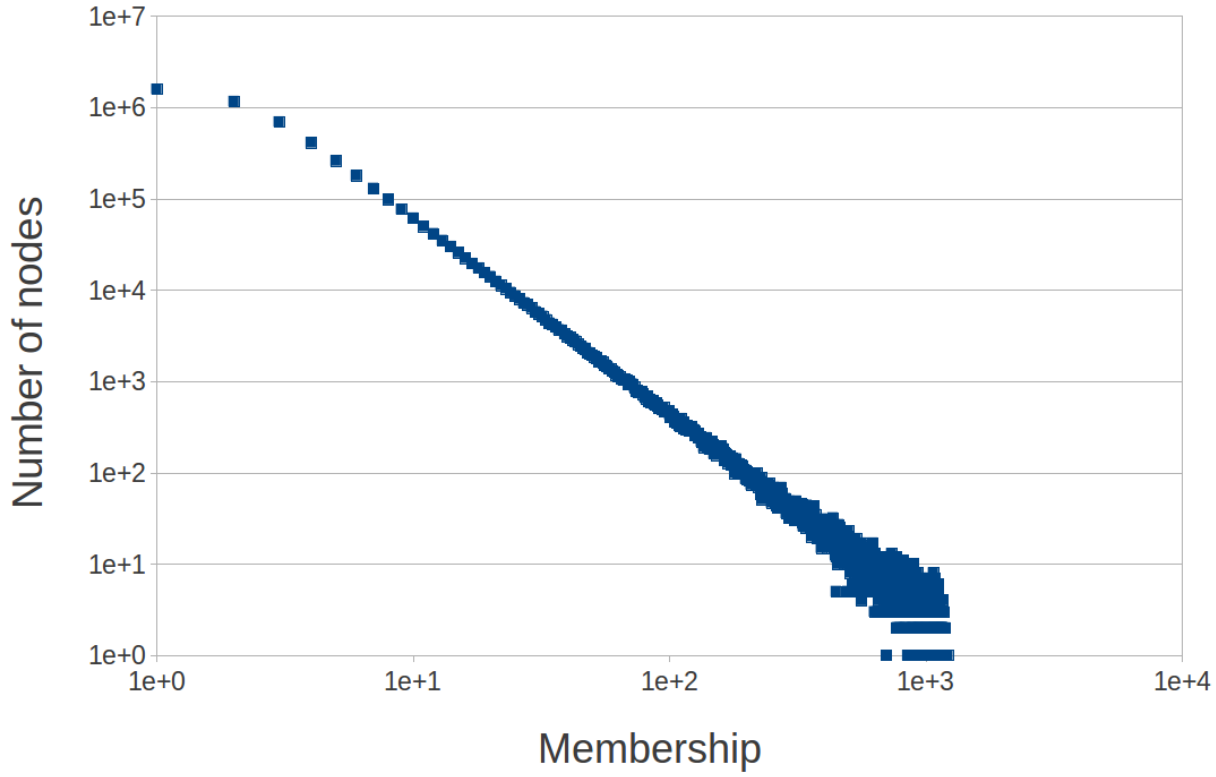


CKB



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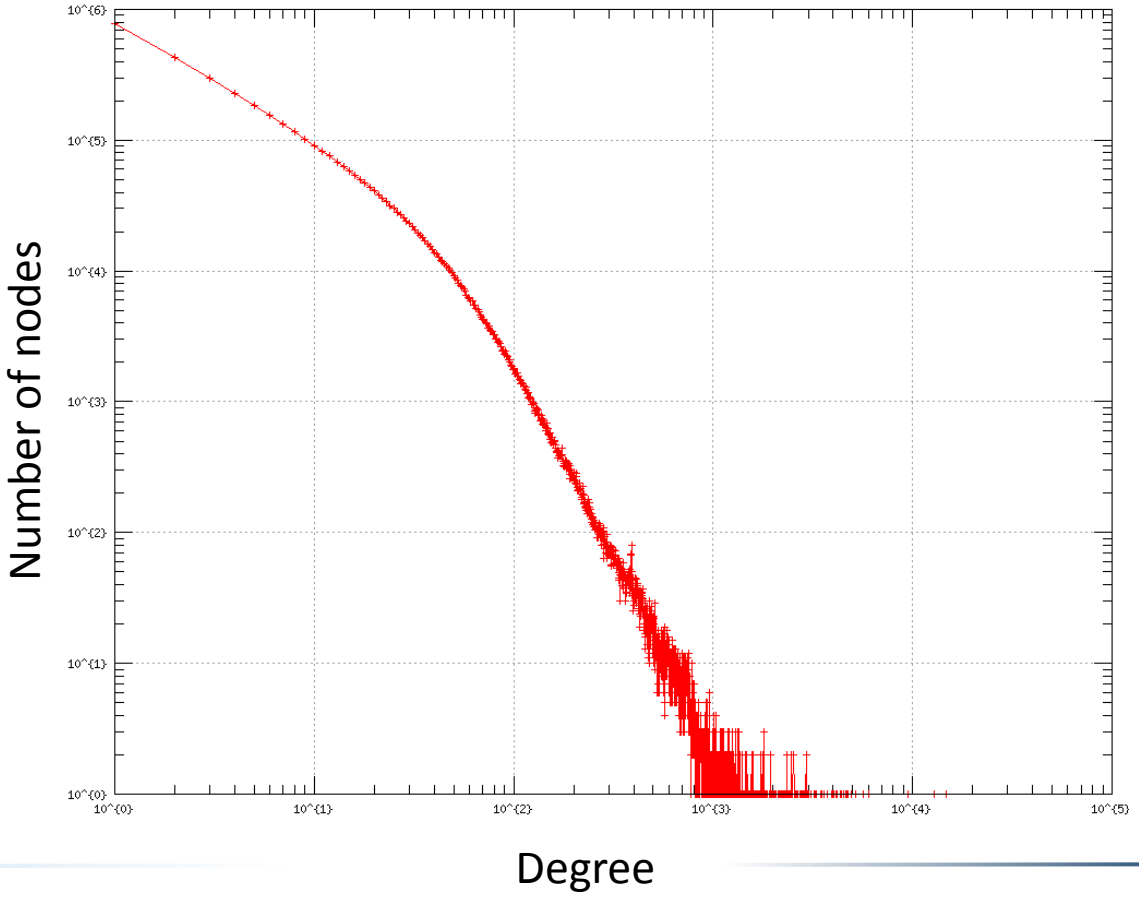
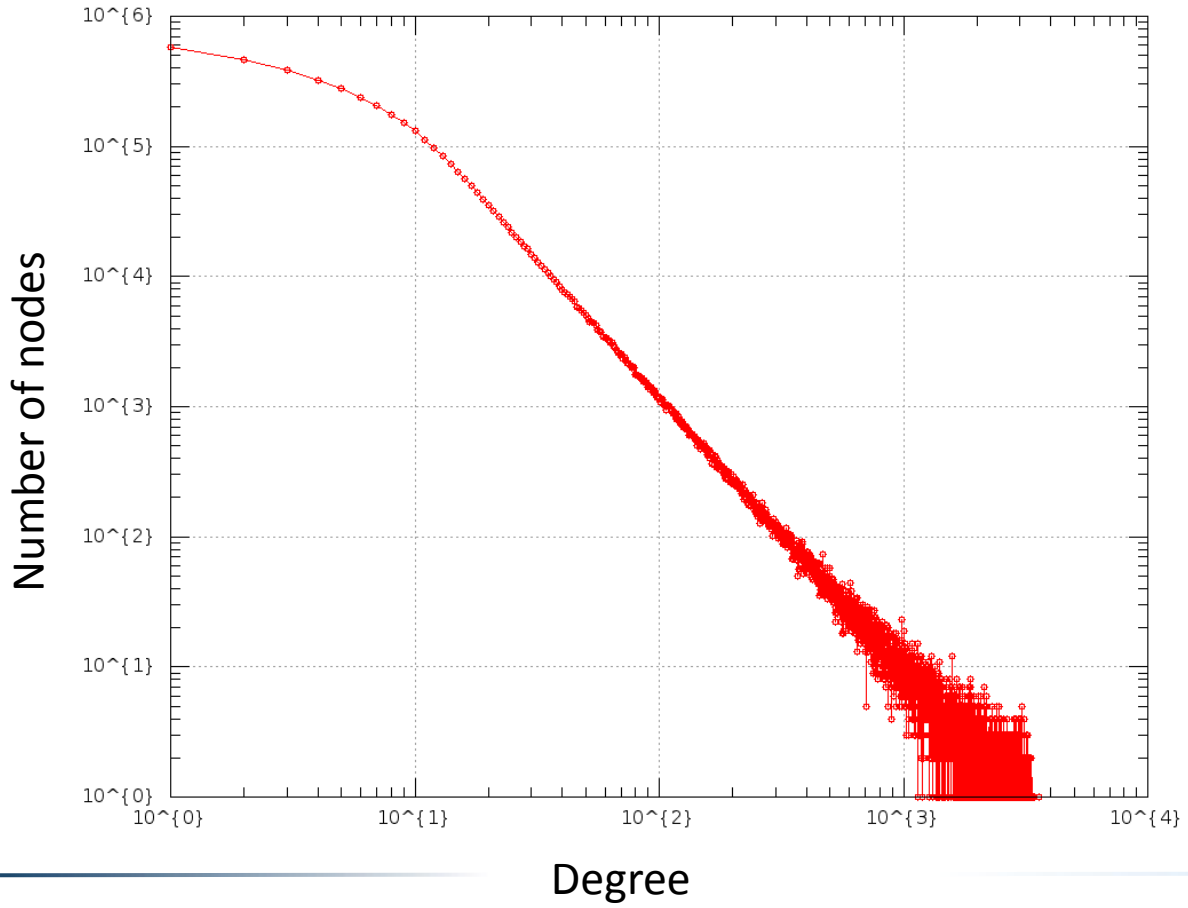
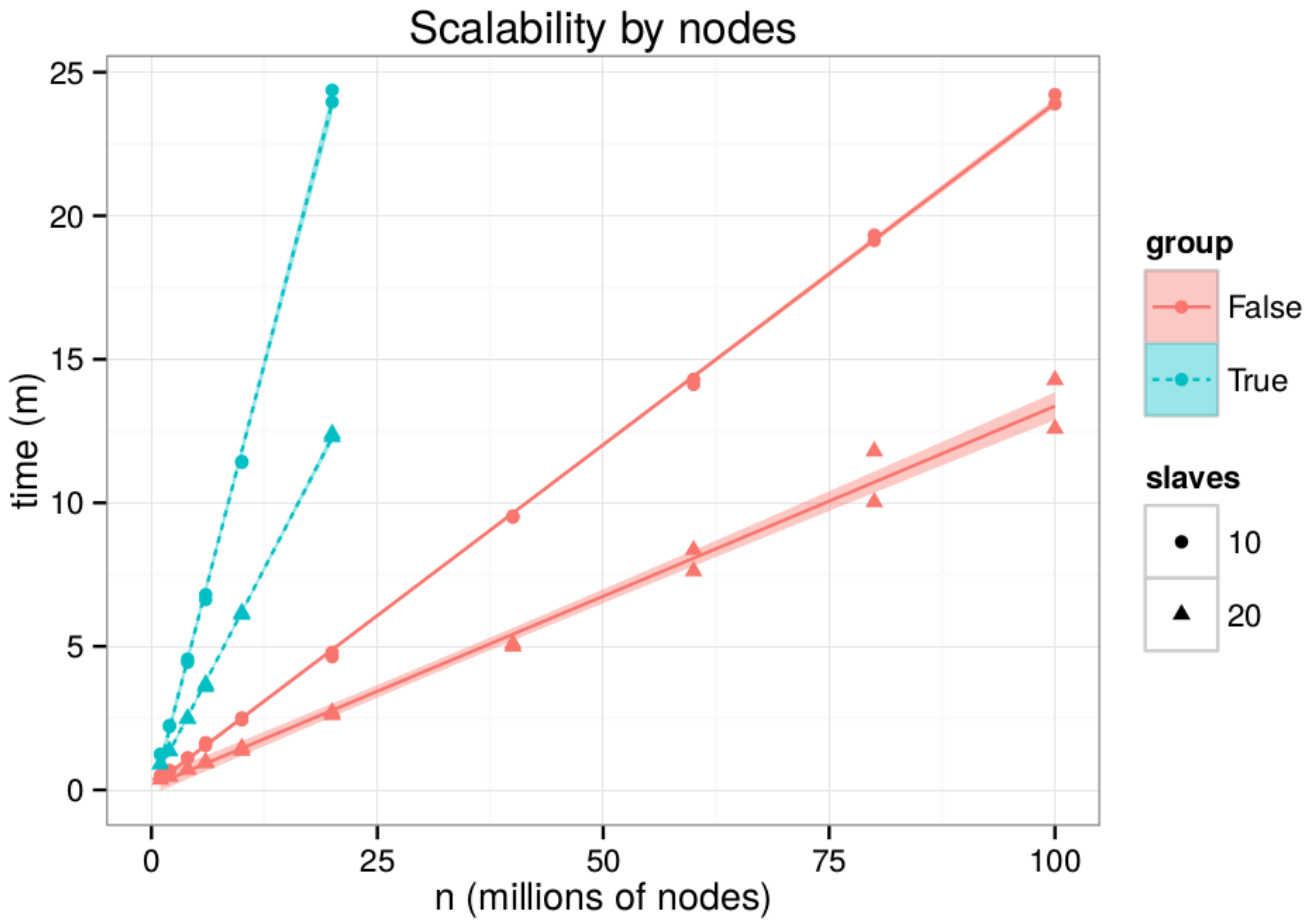


CKB



Scalability: RGG



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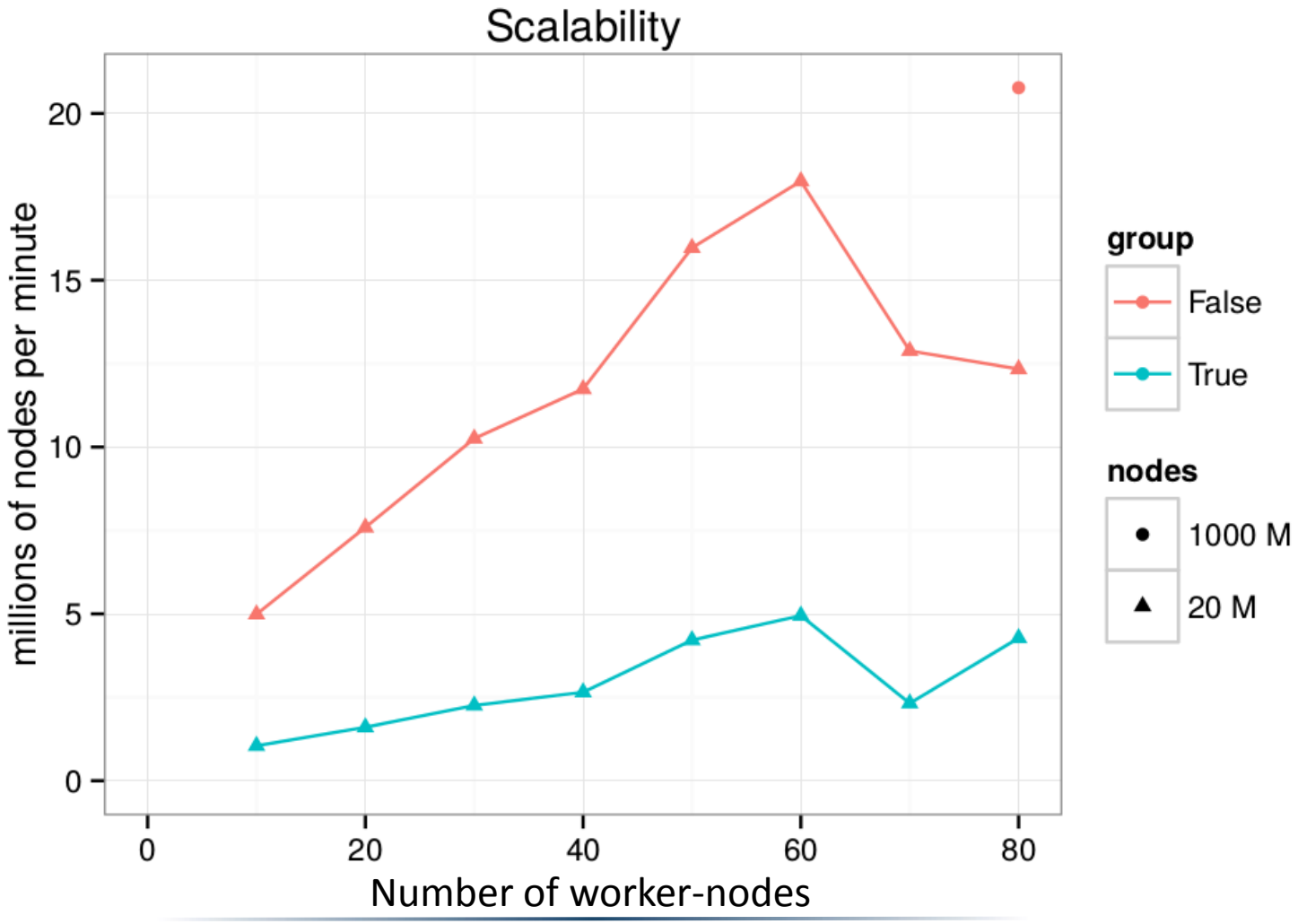
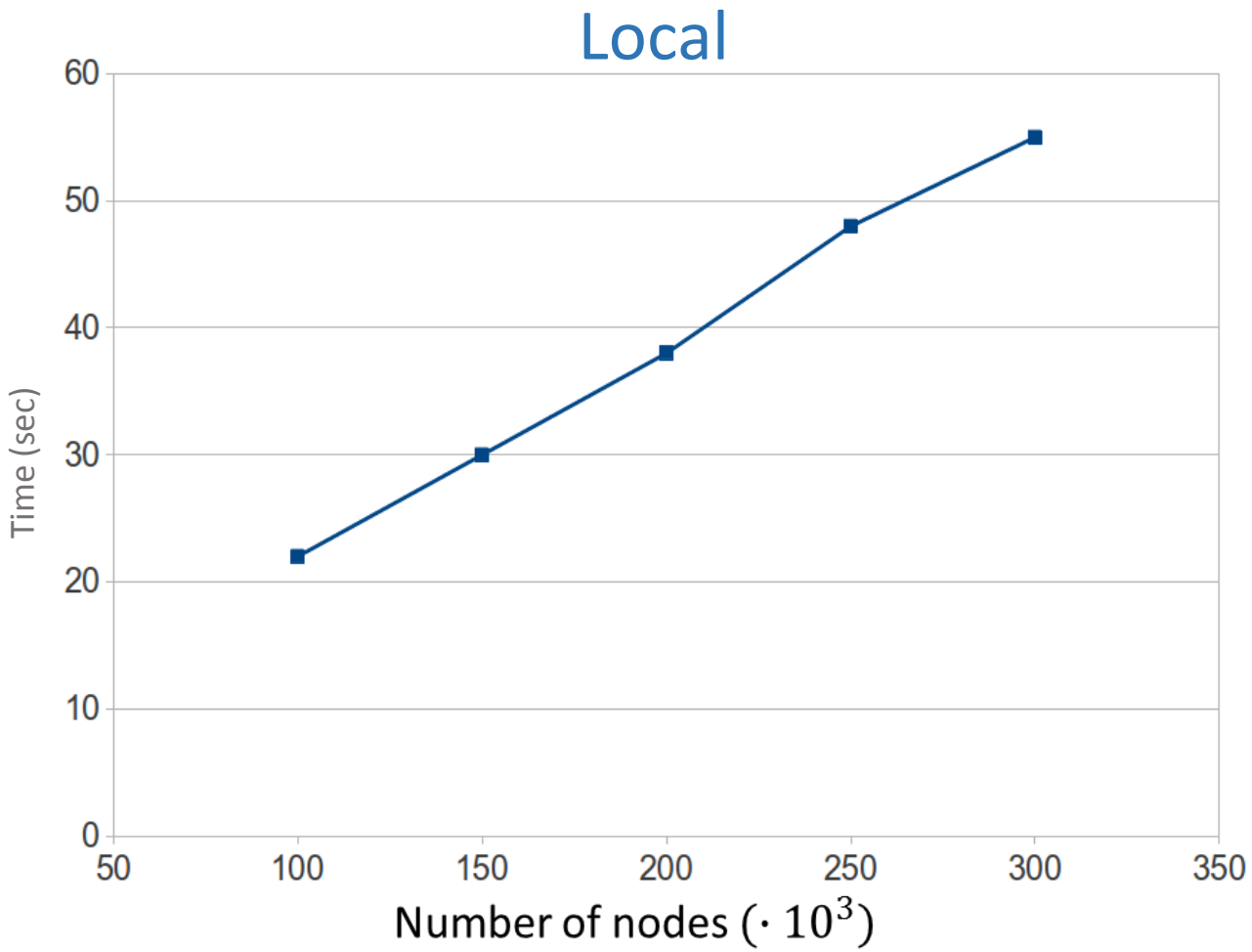


Scalability: CKB

Parameters of generation for scalability testing:

- $\beta_1=\beta_2=2.5$
- $\alpha=4$, $\gamma=0.5$
- $\min(m_i)=1$
- $\min(c_i)=2$
- $\max(m_i)=\max(c_i)=10{,}000$



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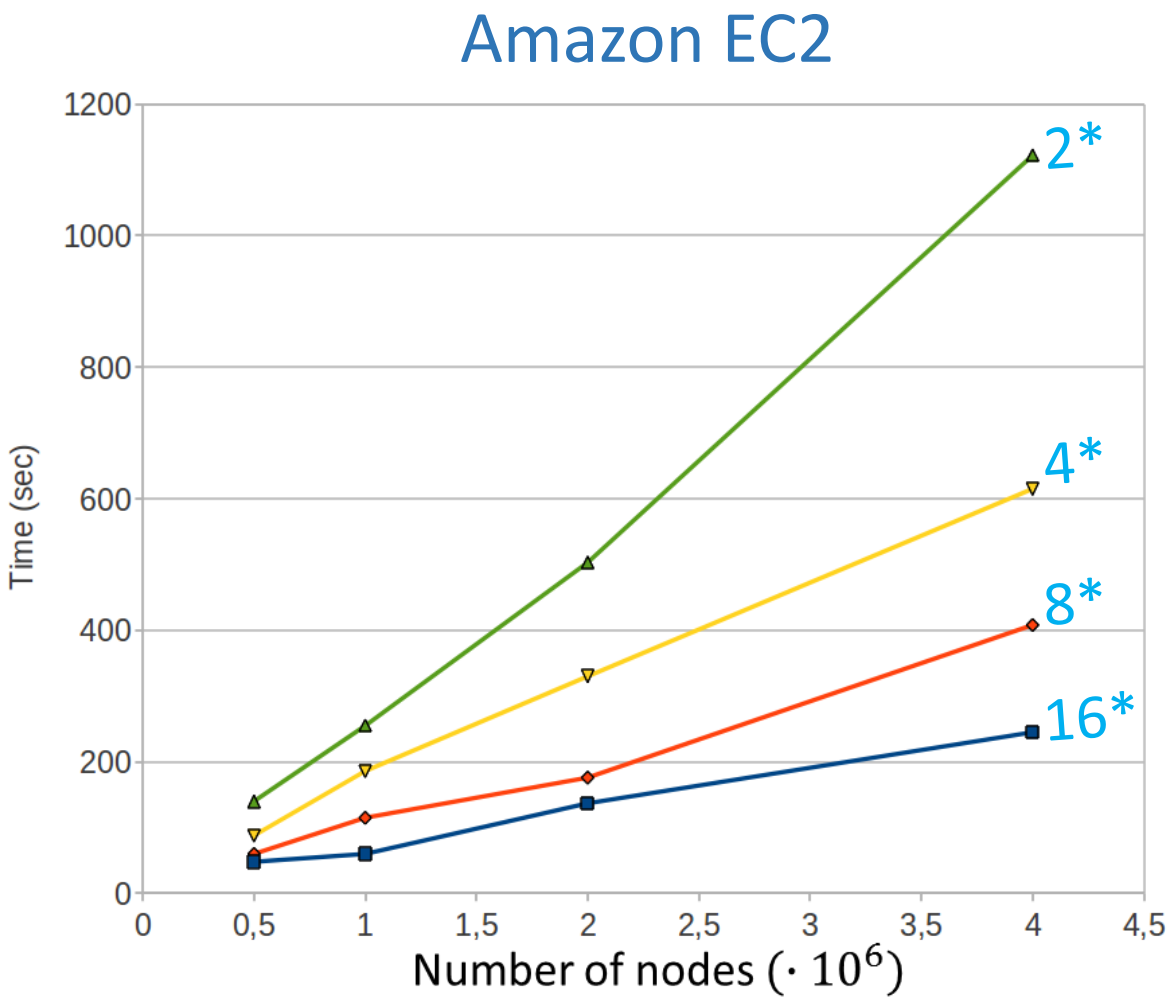

*The numbers at the end of lines indicate the number of machines m1.large** in cluster which was used for generation

**m1.large – type of the machine on Amazon EC2 cluster (2 vCPU, 7.5 GiB memory, 2x420GB instance storage).

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Conclusions

Described tools create real network and have a number of advantages:

- Graphs with social network properties
- Linear scalability
- A billion-node generation takes reasonable time (55 (150) minutes on 80 (150) machines for RGG (CKB))
- Flexibility of the models

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Open questions

- Testing of various community detection algorithms
- Support the variation of clustering coefficient
- Weighted and hierarchical versions
- Community generation based on attributes and content

The End

Questions?

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