Fusion of Content and Context in Human Language Technology

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National Security Agency
Fort Meade, Maryland

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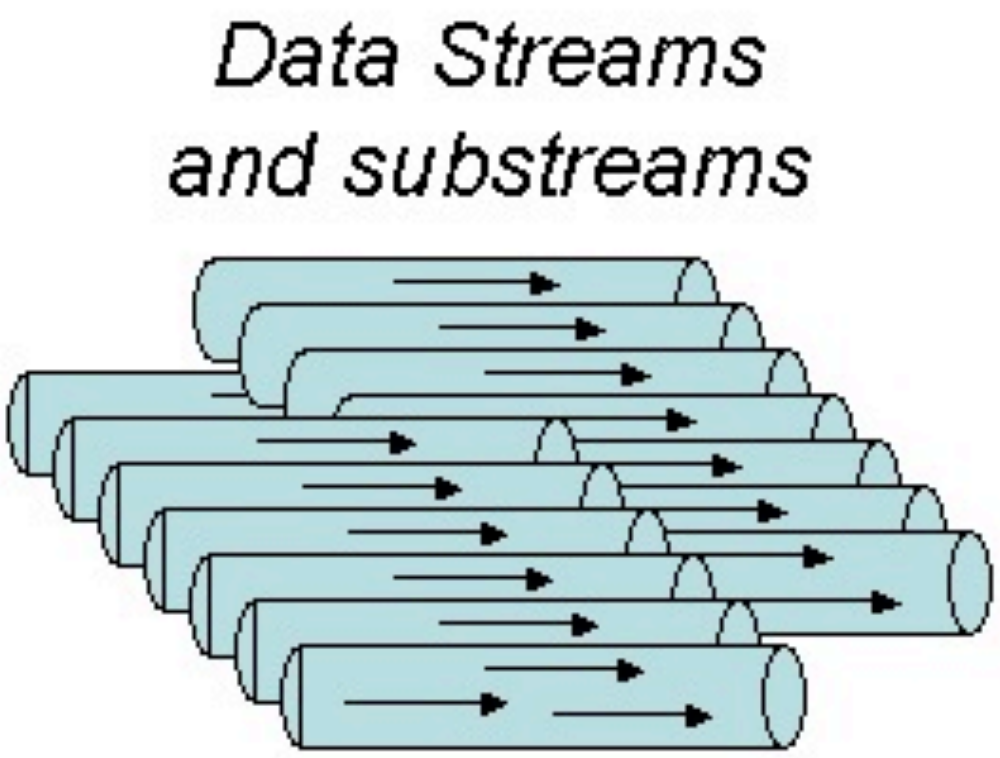
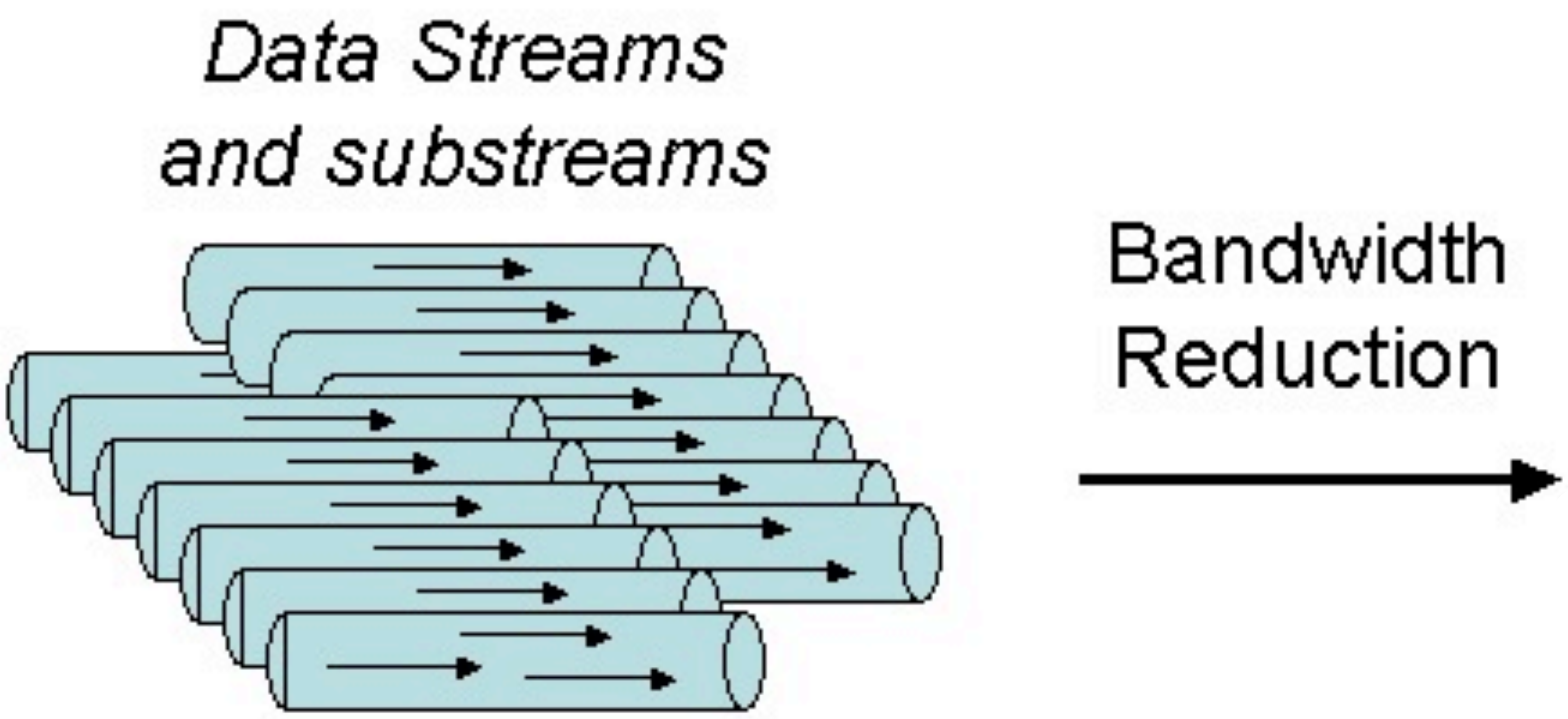
Outline

- Motivation: Coping with Information Overload
- Examples of Context and Content
- Random Attributed Graphs
- Three Tasks
  - Stream Characterization
  - *Vertex Nomination*
  - Dyadic Priors

Coping with Information Overload



Coping with Information Overload



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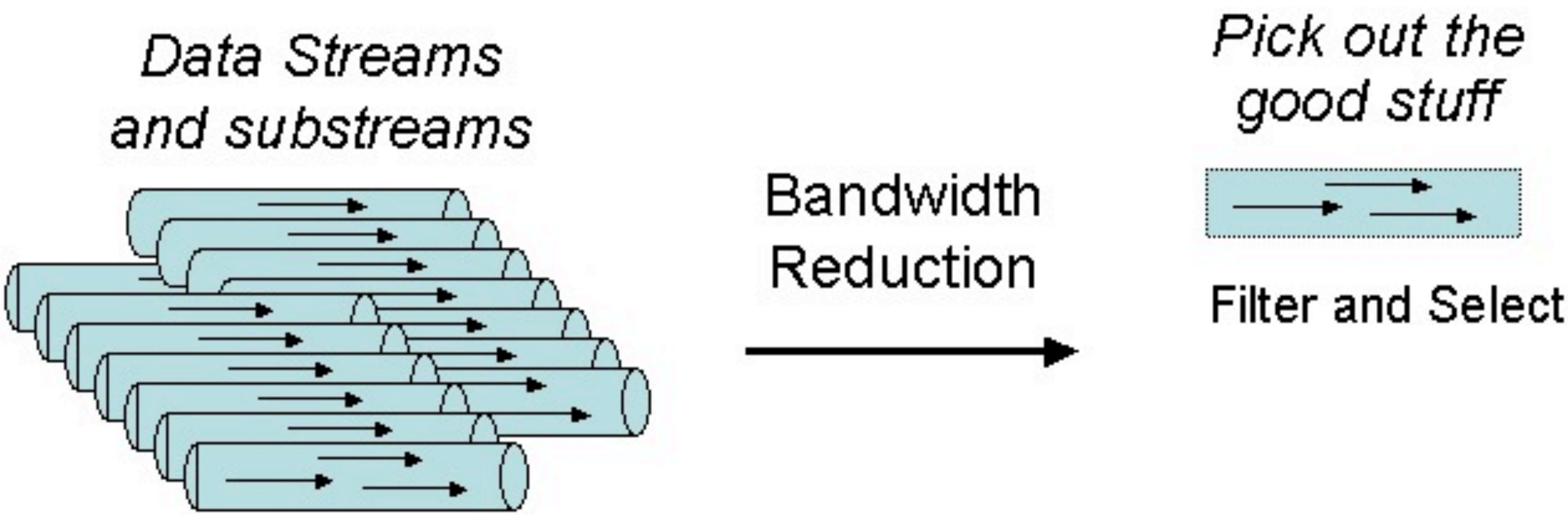

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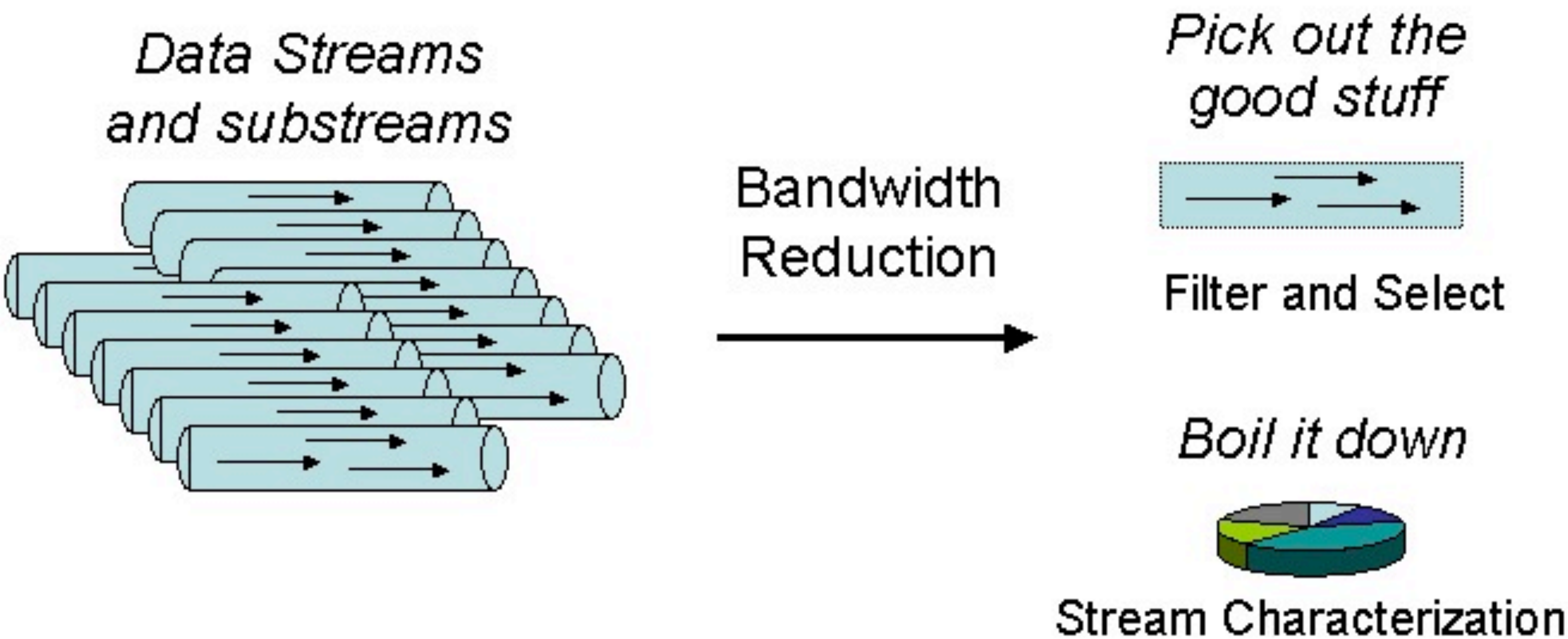

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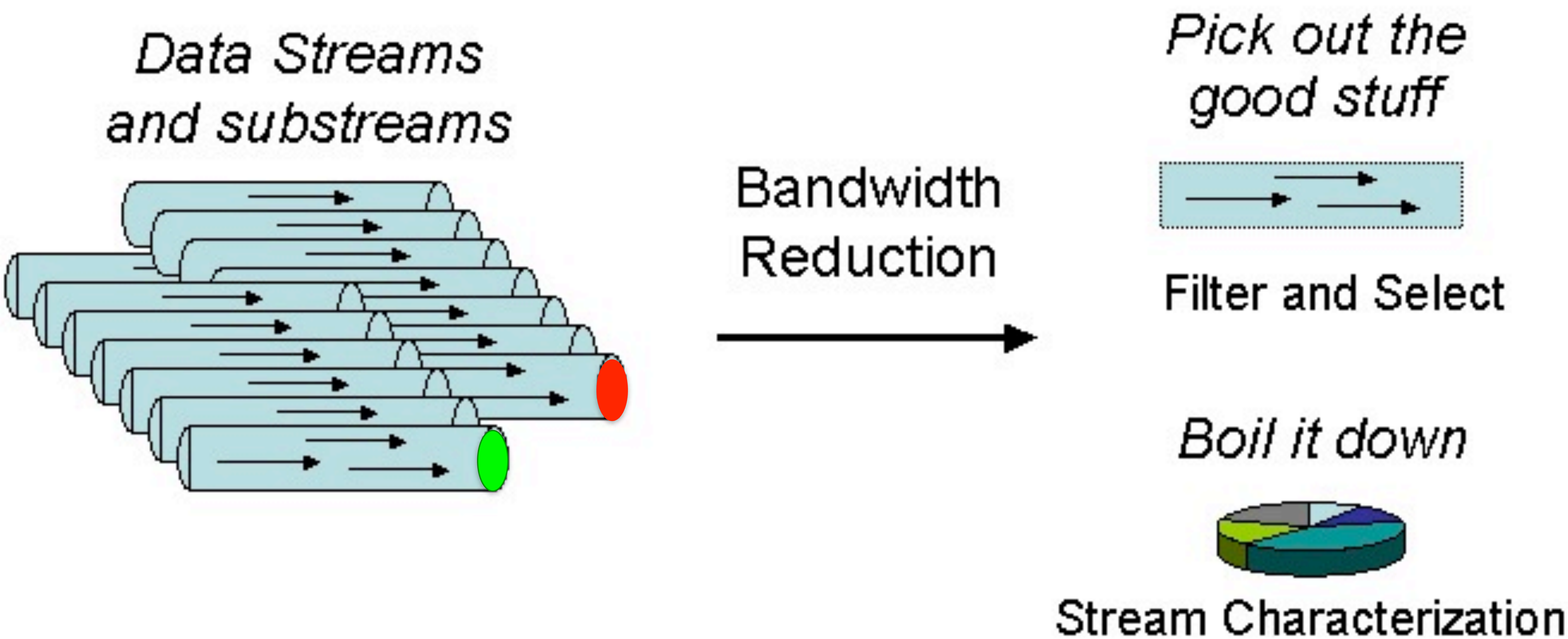

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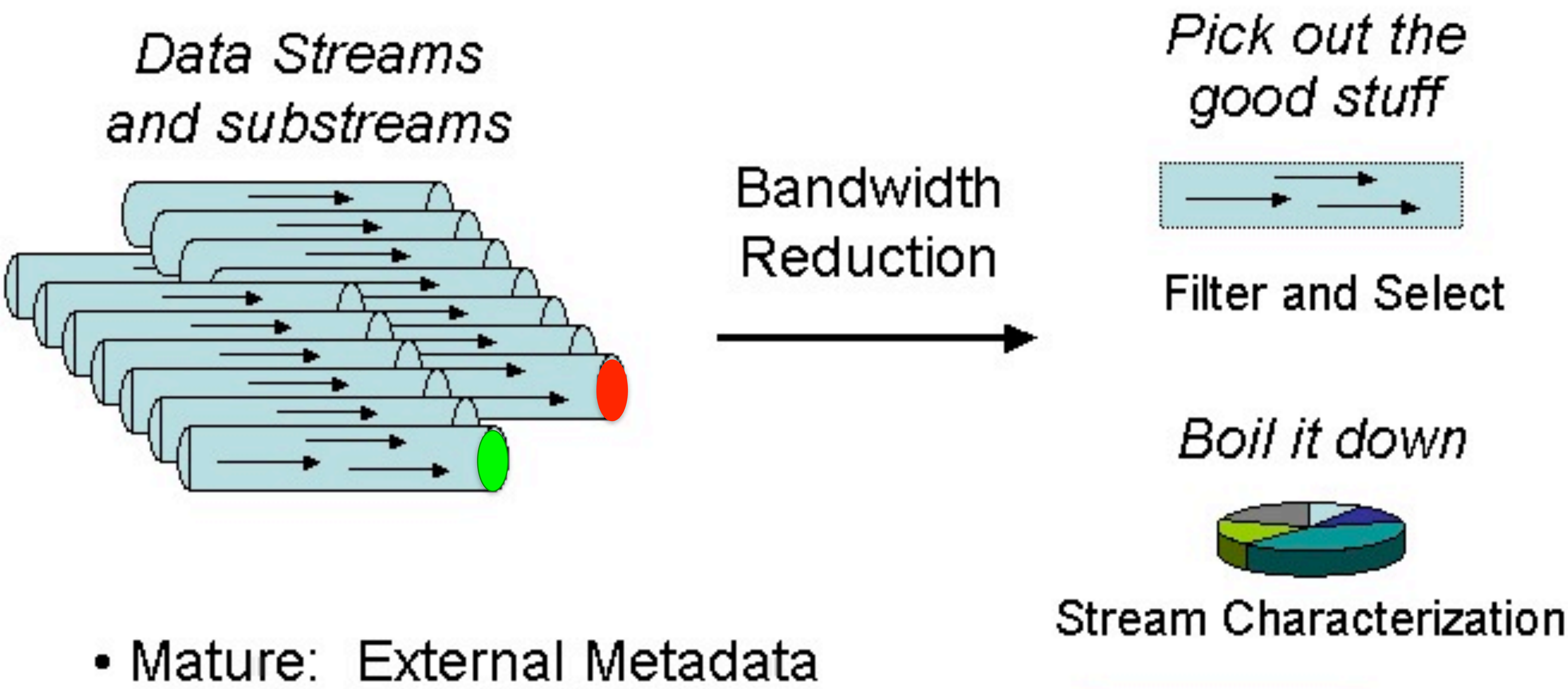
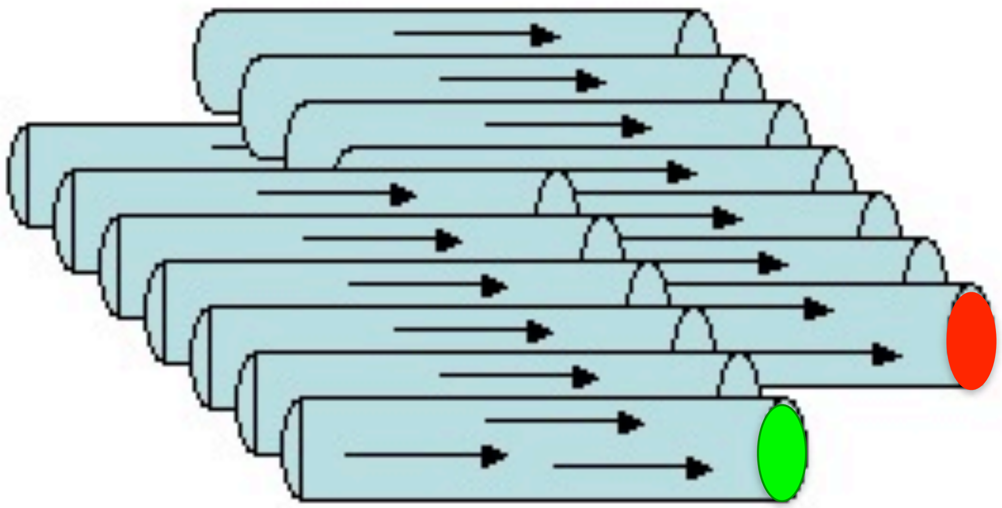


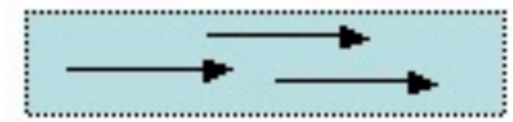
Coping with Information Overload

Data Streams and substreams



Bandwidth Reduction

Pick out the good stuff



Filter and Select

Boil it down

Stream Characterization

- Mature: External Metadata

- **Emerging: Metacontent**

Coping with Information Overload

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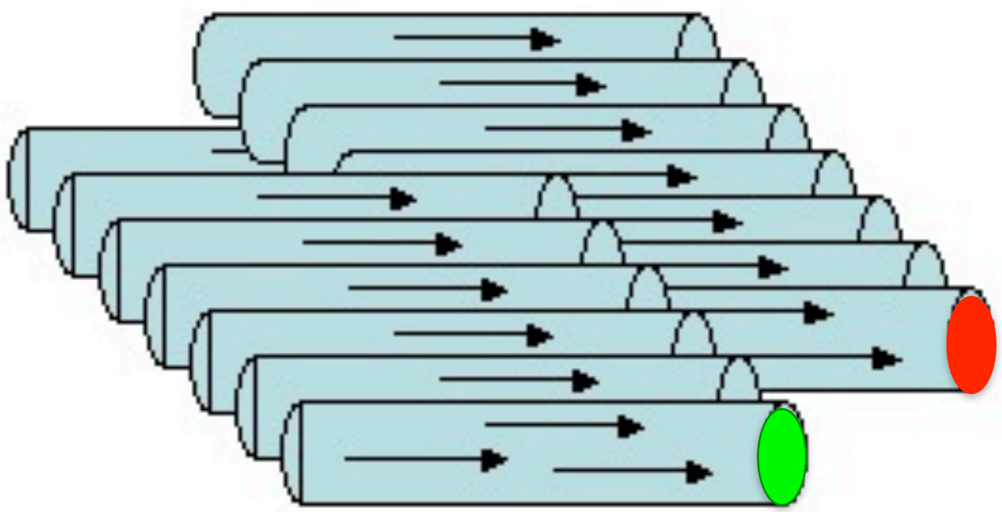

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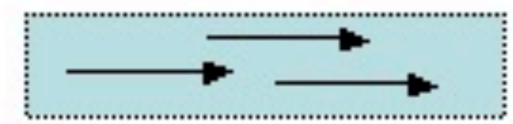

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Stream Characterization

- Mature: External Metadata

- **Emerging: Metacontent**

- *language*
- *speaker*
- *topic*

Content has associated meta-data
challenge: how to exploit?

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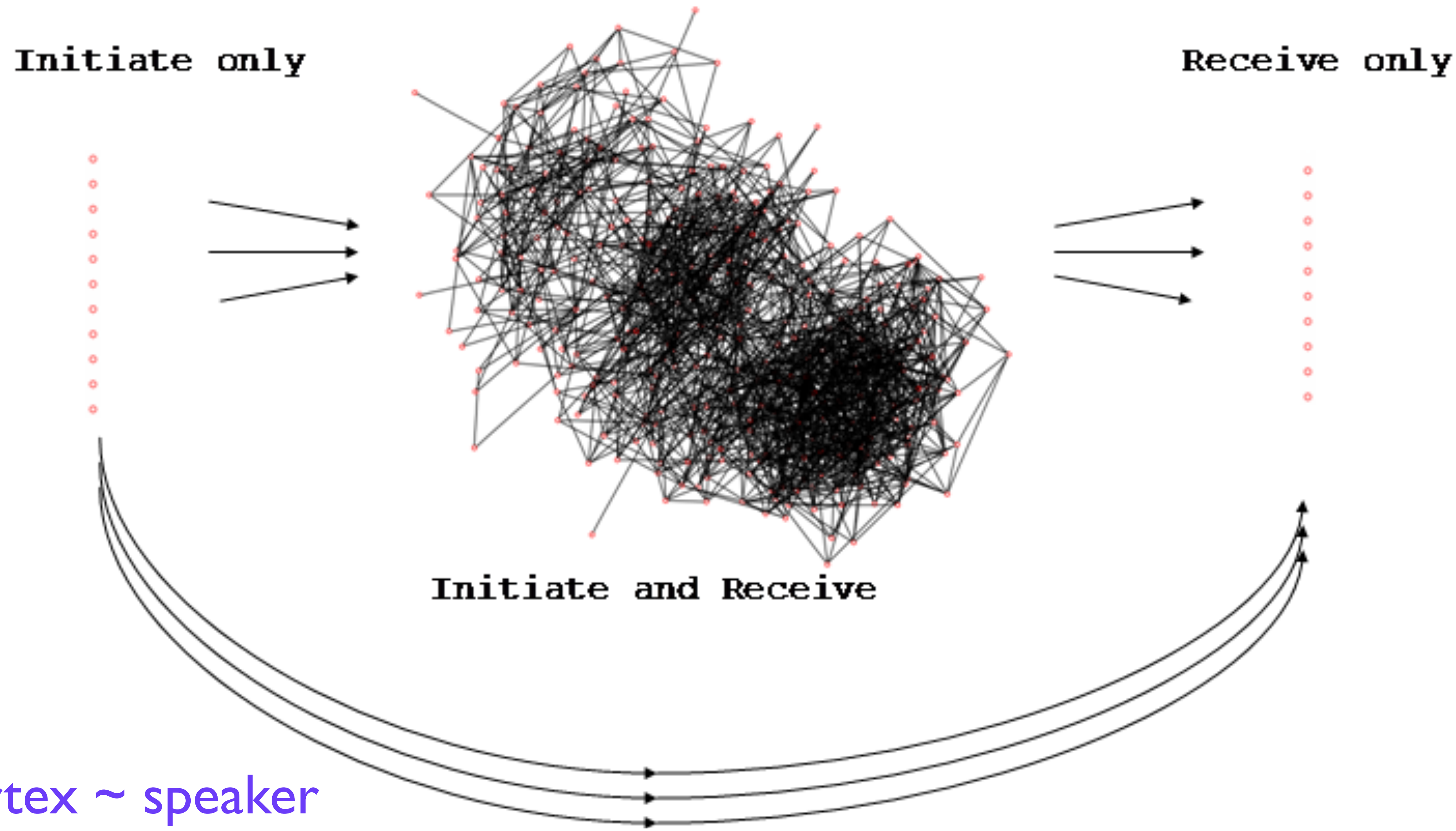
- Citeseer scientific articles have authors and citations

Communication Events from the Enron Corpus

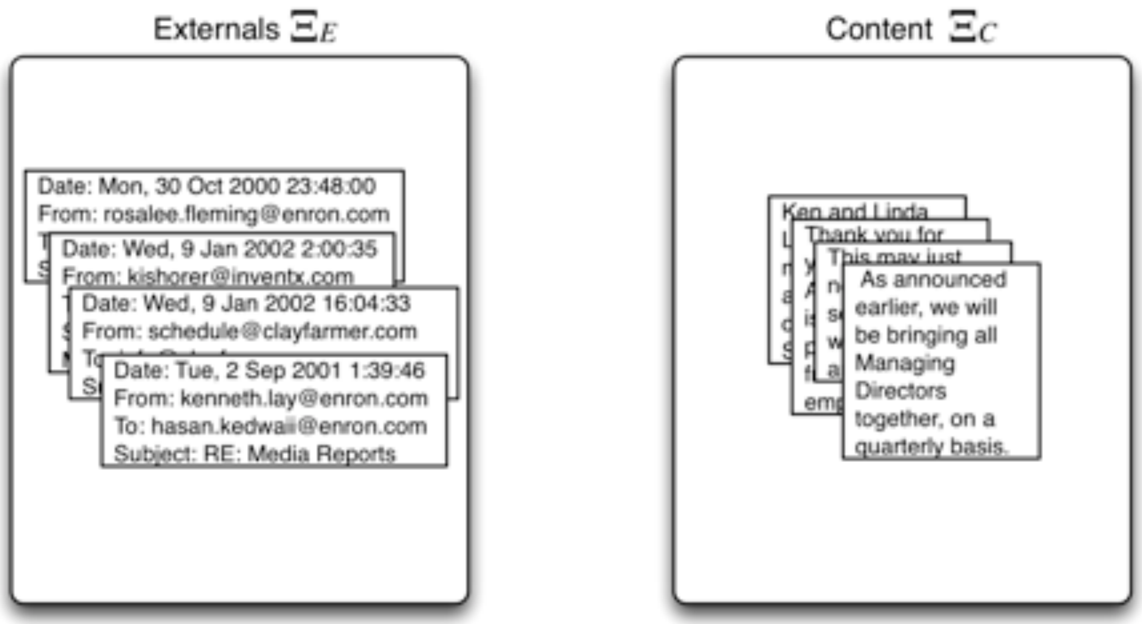
Date	Time	Sender	Receiver	Sender's Rank	Topic
2001-01-02	04:15:00	steven.k	jeff.d	Vice President	(1) California Analysis
2001-02-09	13:49:09	louise.k	andy.z	President	(9) Daily Business
2001-02-16	21:06:00	drew.f	jeff.d	Vice President	(5) California Enron
2001-02-26	22:30:00	james.s	john.l	Vice President	(14) Energy Newsfeed
2001-03-01	07:54:00	diana.s	kate.s	Trader	(5) California Enron
2001-04-06	05:15:00	mike.g	john.l	Manager	(7) Newsfeed California
2001-04-16	06:12:00	richard.s	steven.k	Vice President	(9) Daily Business
2001-05-11	16:02:00	andy.z	john.l	Vice President	(11) Enron Online
2001-06-27	17:44:24	s..s	geoff.s	Vice President	(9) Daily Business
2001-09-05	14:36:53	geoff.s	louise.k	Director	(12) Enrononline Daily
2001-09-15	20:51:20	m..p	louise.k	Vice President	(12) Enrononline Daily
2001-10-04	14:19:16	john.l	louise.k	CEO	(11) Enron Online
2001-10-05	18:49:05	j..k	richard.s	Vice President	(9) Daily Business
2001-10-08	17:50:19	shelley.c	darrell.s	Vice President	(1) California Analysis

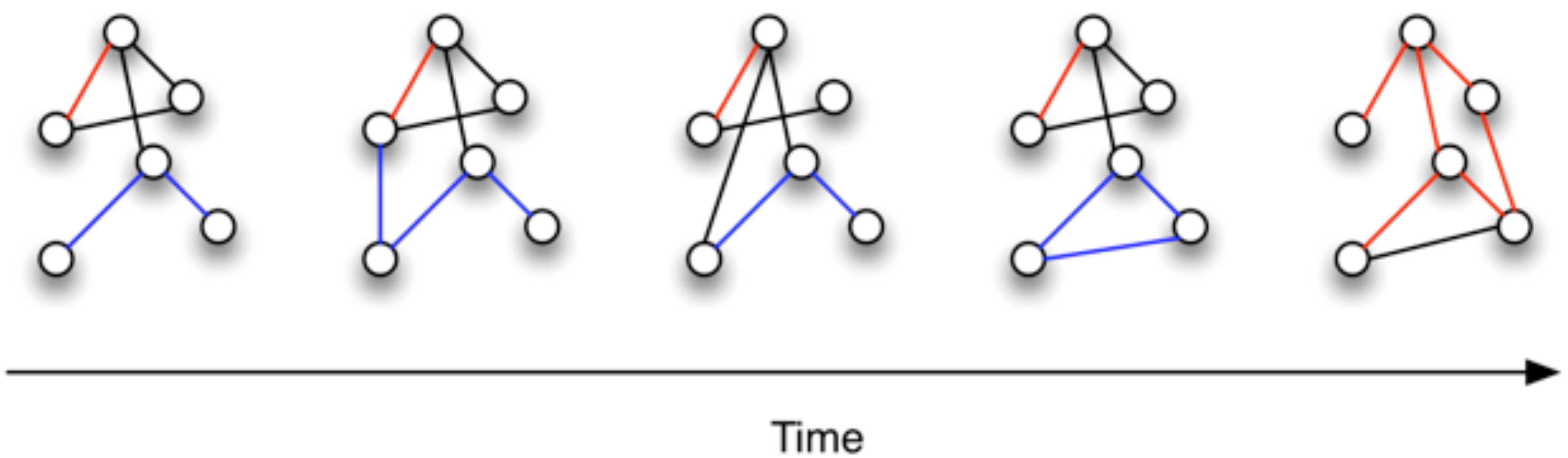
SwitchBoard Communications Graph



Vertex ~ speaker
Edge ~ dialog

Time Series of Attributed Graphs





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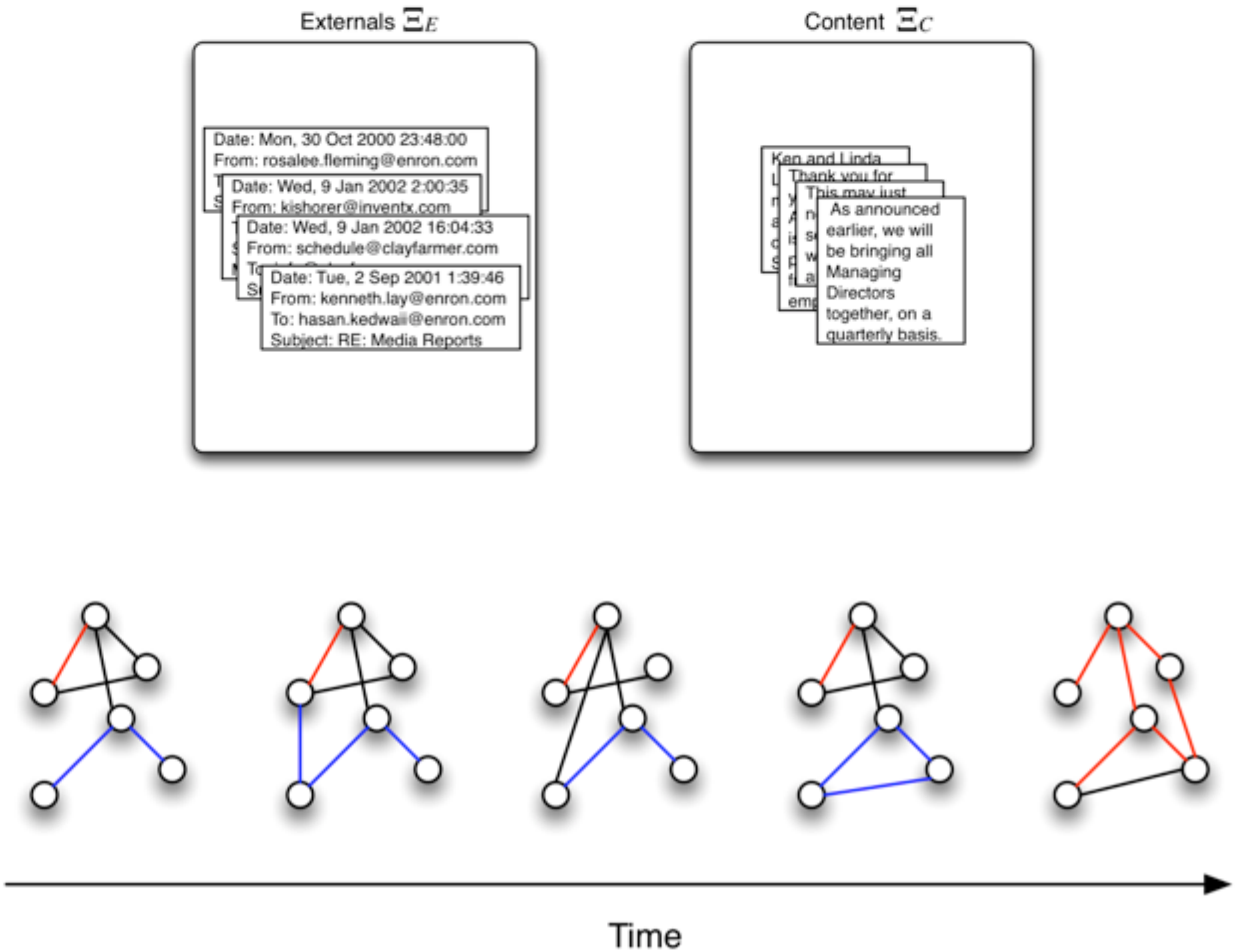

Generated by some random process $\mathbf{G}_t$?

Random Attributed Graphs (RAGs)

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- There is significant literature on stochastic models for language and documents streams, ignoring conte***x***t.
- There is a computer science literature on attributed graphs, e.g. as produced by entity and relations, ignoring stochastic modeling.
- Before this research effort, *no* literature that we know of addressing time series of random attributed graphs.

Generative Models for RAGs

- Build RAG models by extending random graph models
- Erdos-Renyi (binomial) graphs, where a pair of vertices is connected with *iid* probability *p*.
- Kidney/Egg models, Block models
- Latent Position and Random Dot Product Models where

$$p_{ij} = h(x_i , x_j)$$

- Construct from time series of communication events

$$M = \{ (t, u_t , v_t , s_t) \}_t$$

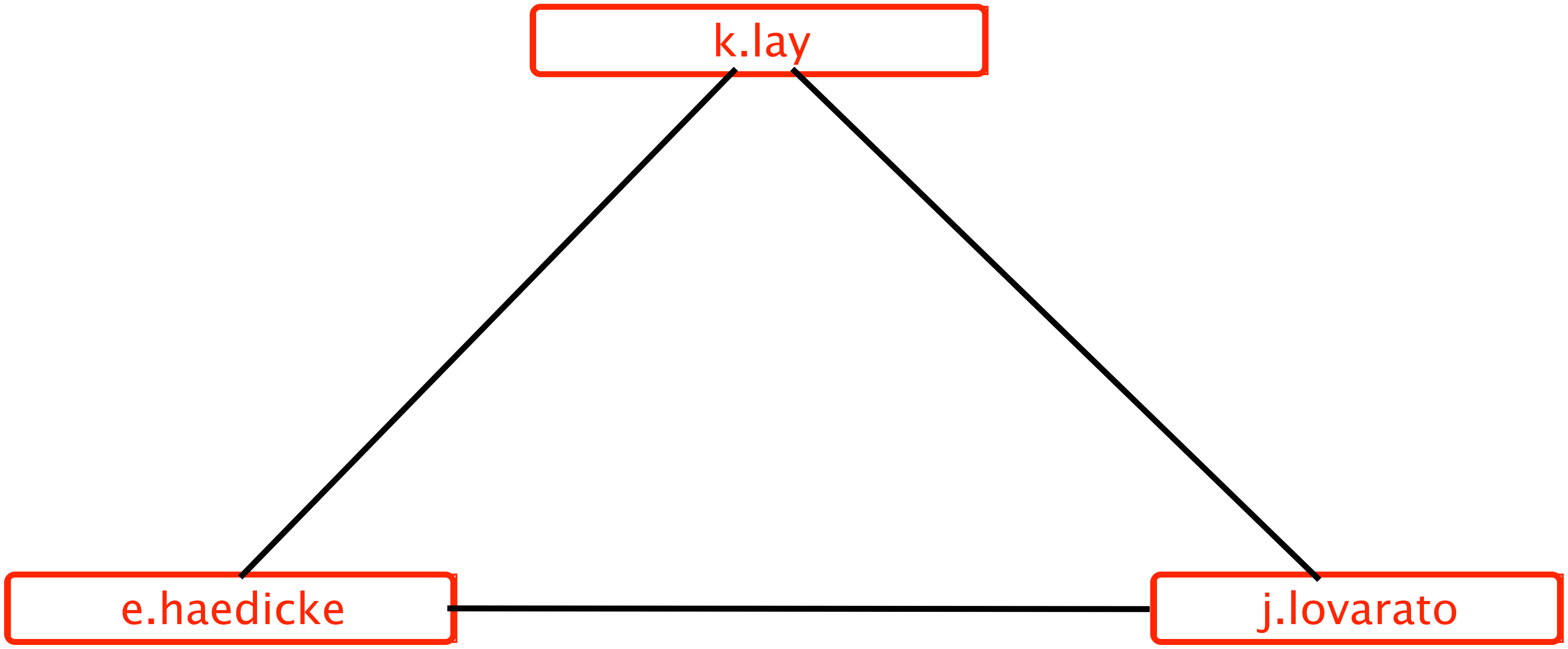
Vertex Nomination

- Cf. fraud and social network analysis
  - significant literature using graphs
- Intuition for fusion is clear
- Experimental evaluation on Enron email corpus
- Summer workshop
  - at JHU Human Language Technology COE
  - participants from all over the U.S.

Experimental Methodology

- Given a set of red vertices
- Occlude subset of red vertices
- Develop method for nominating vertices as red
- Evaluate on how well it discovers those occluded *red* vertices
  - versus false nominations

Enron Example: Red Vertices -> Red Documents



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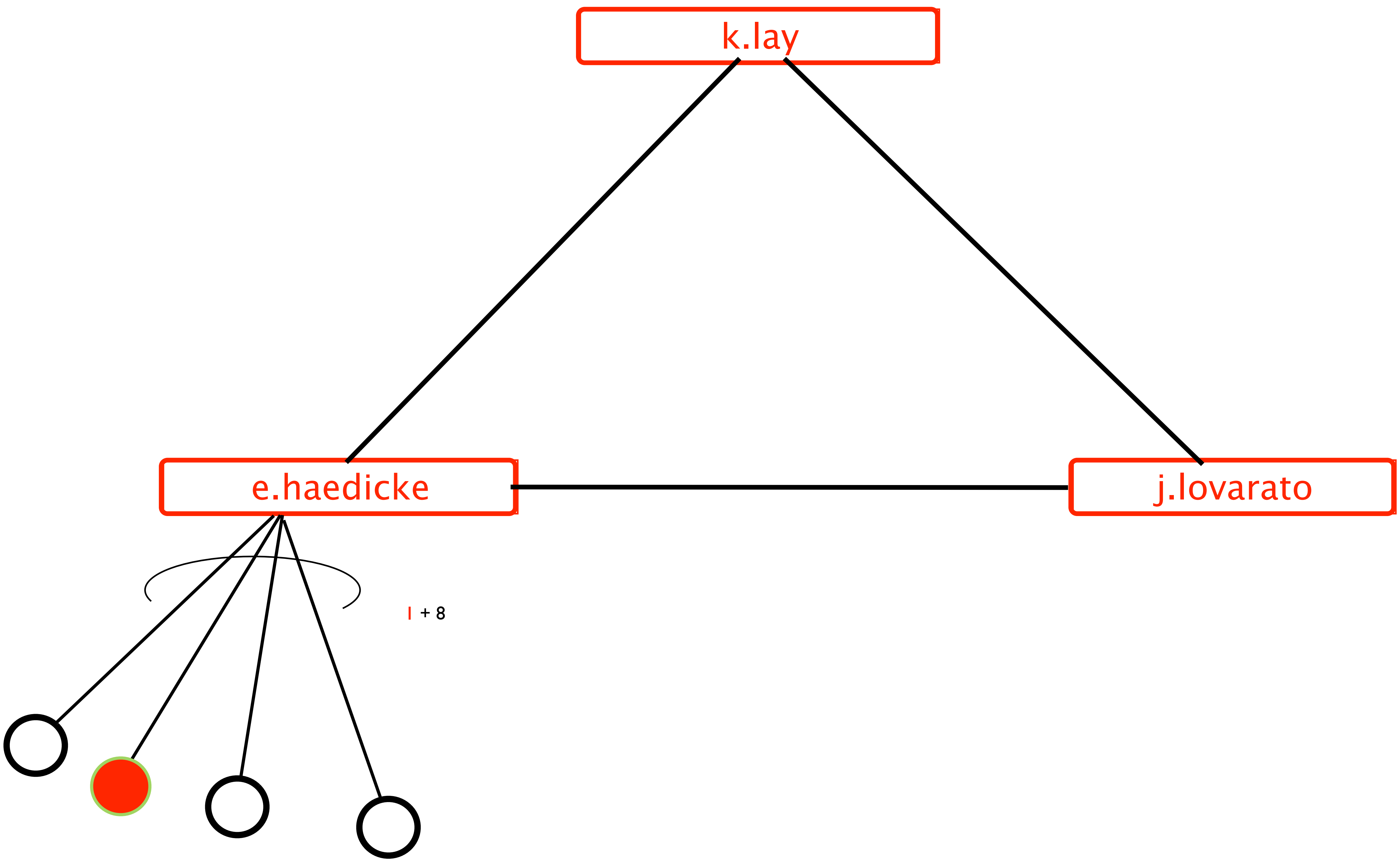

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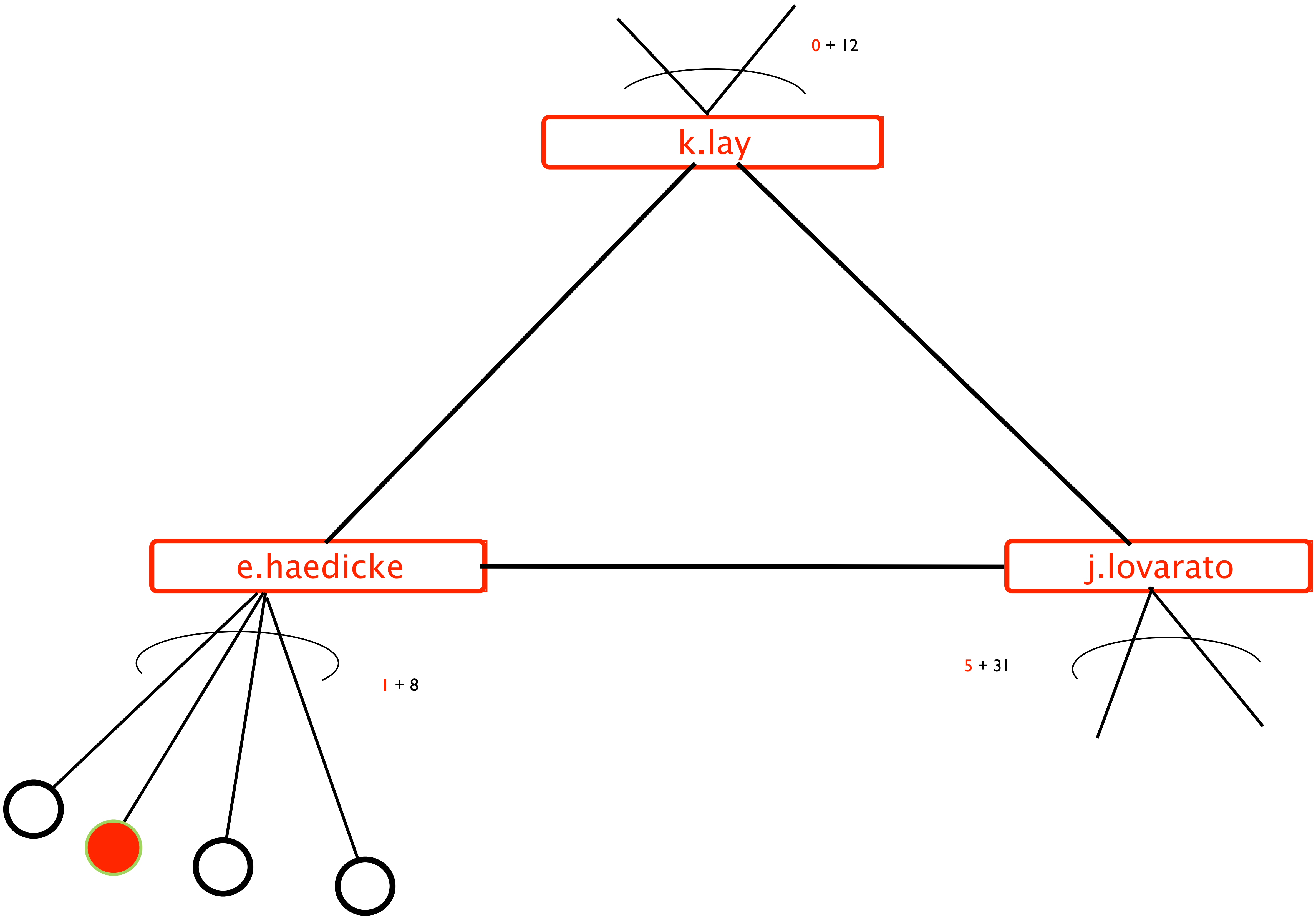

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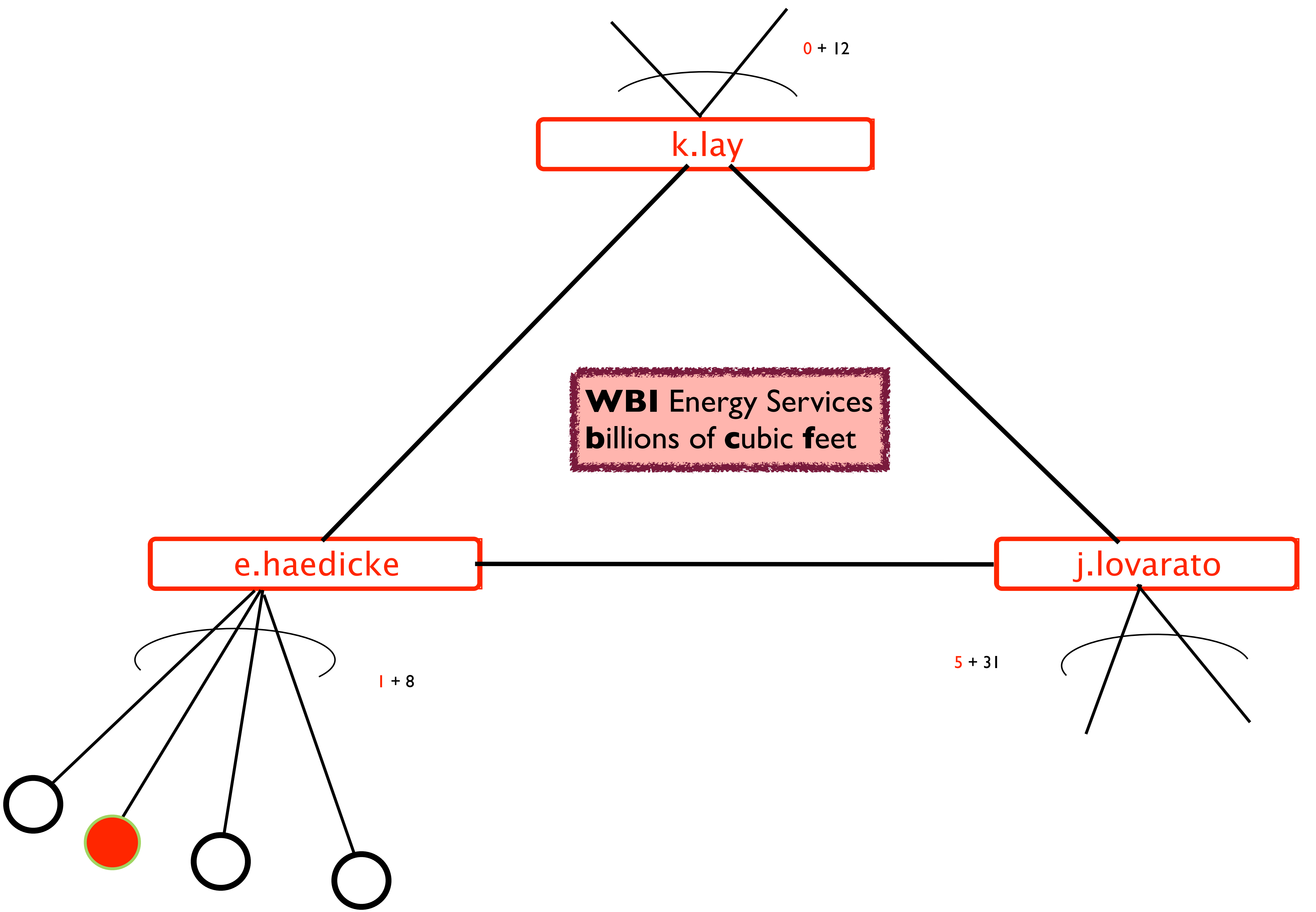

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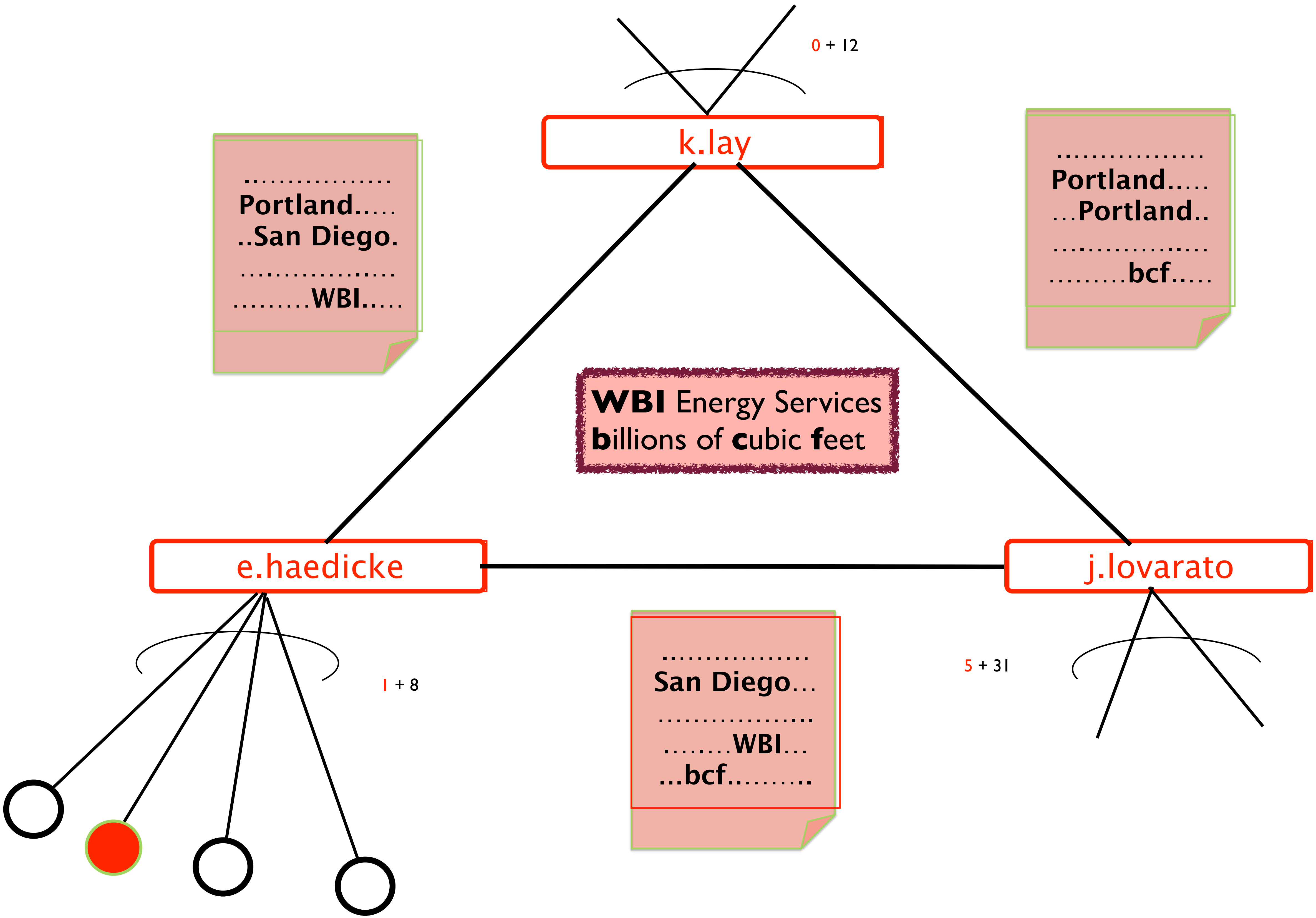

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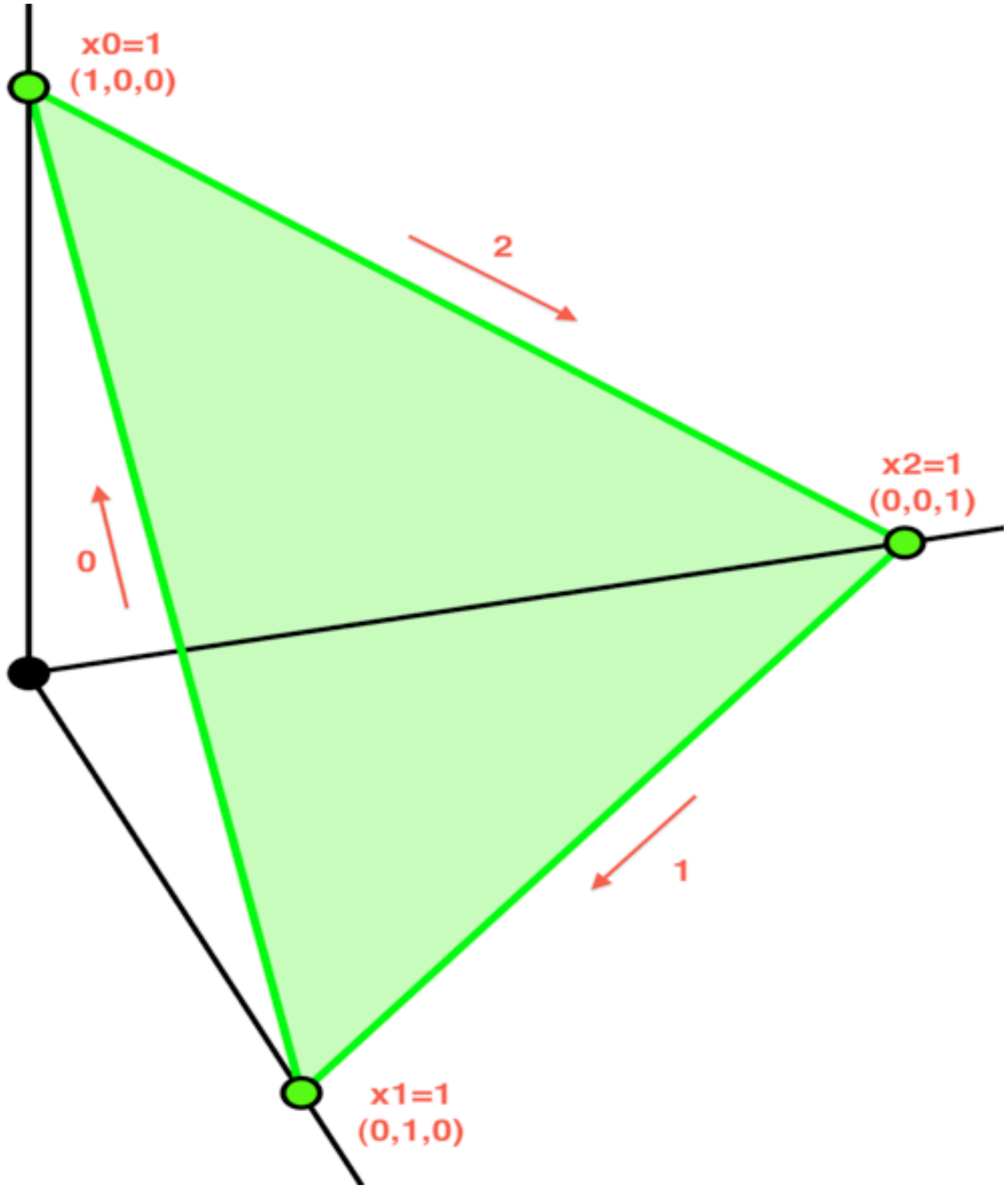
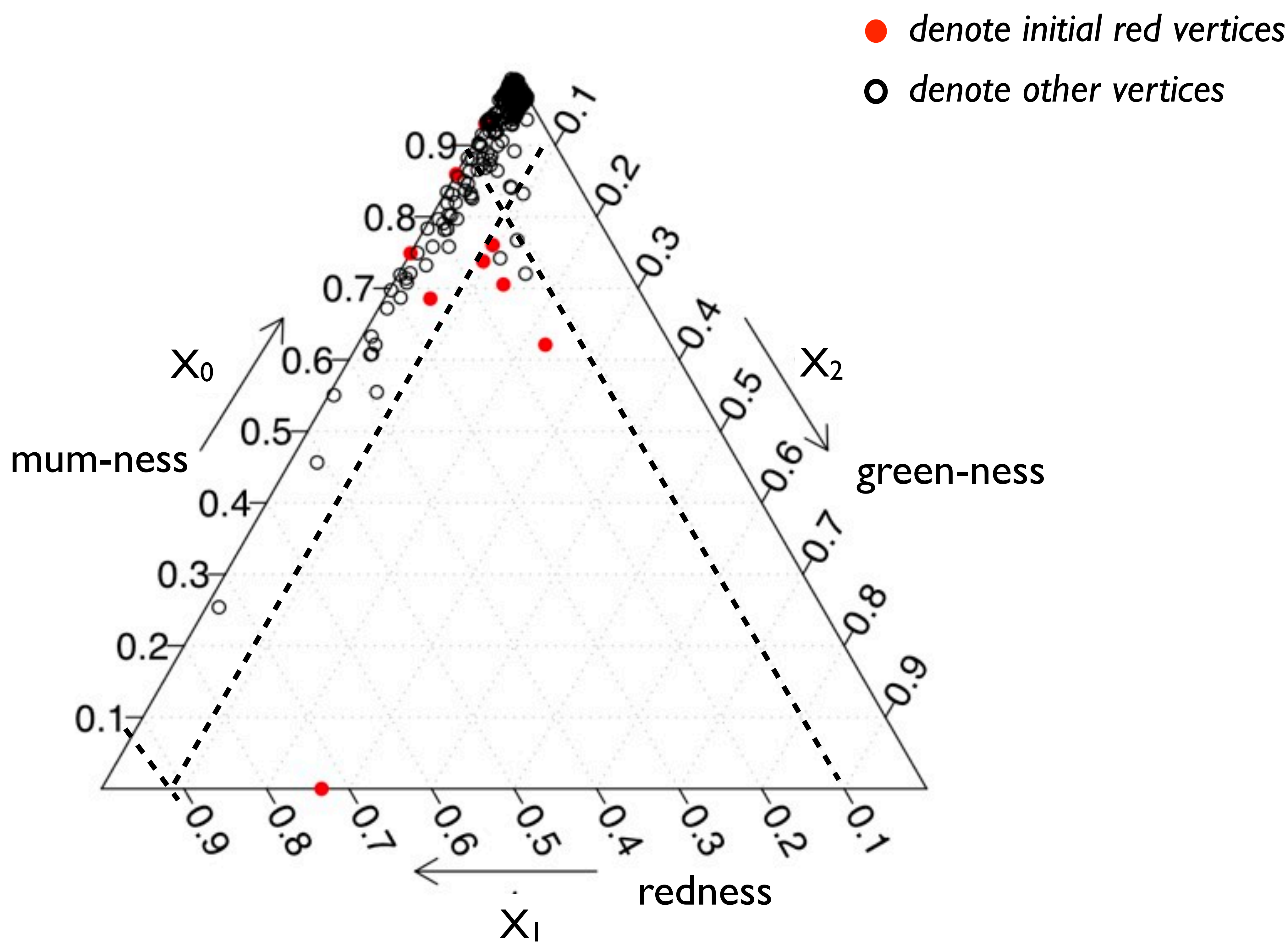
  - $\mathbf{x_0} = 1 - x_1 - x_2$ = non-edginess = tendency of the vertex to stay mum

Latent Vertex Attributes live in the 2D simplex



x0 ~ mum-ness
x1 ~ redness
x2 ~ greenness

Distribution of 184 Latent Vertex Attributes



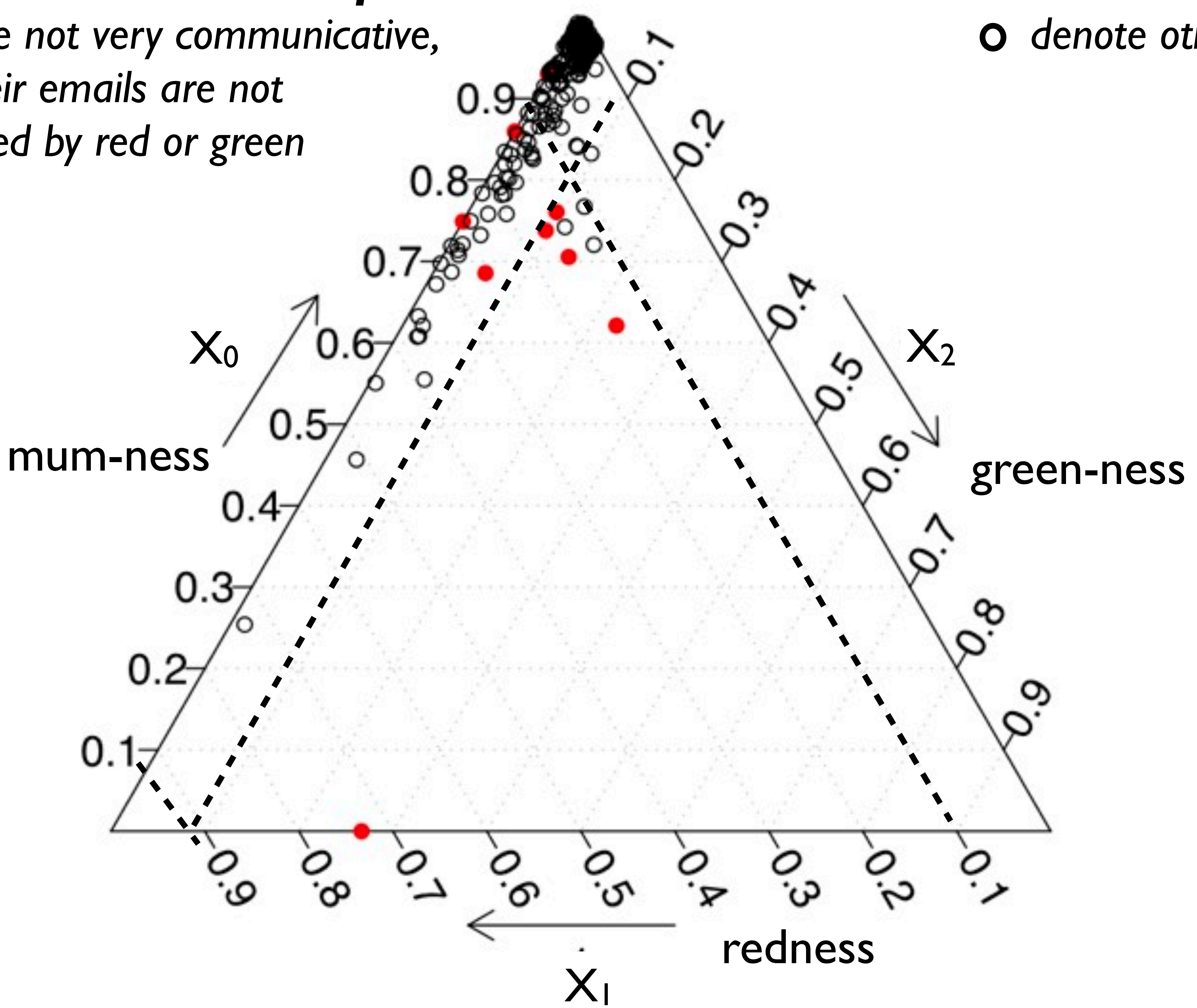
Distribution of 184 Latent Vertex Attributes

Sparse Communication Graph

most vertices are not very communicative, and their emails are not dominated by red or green

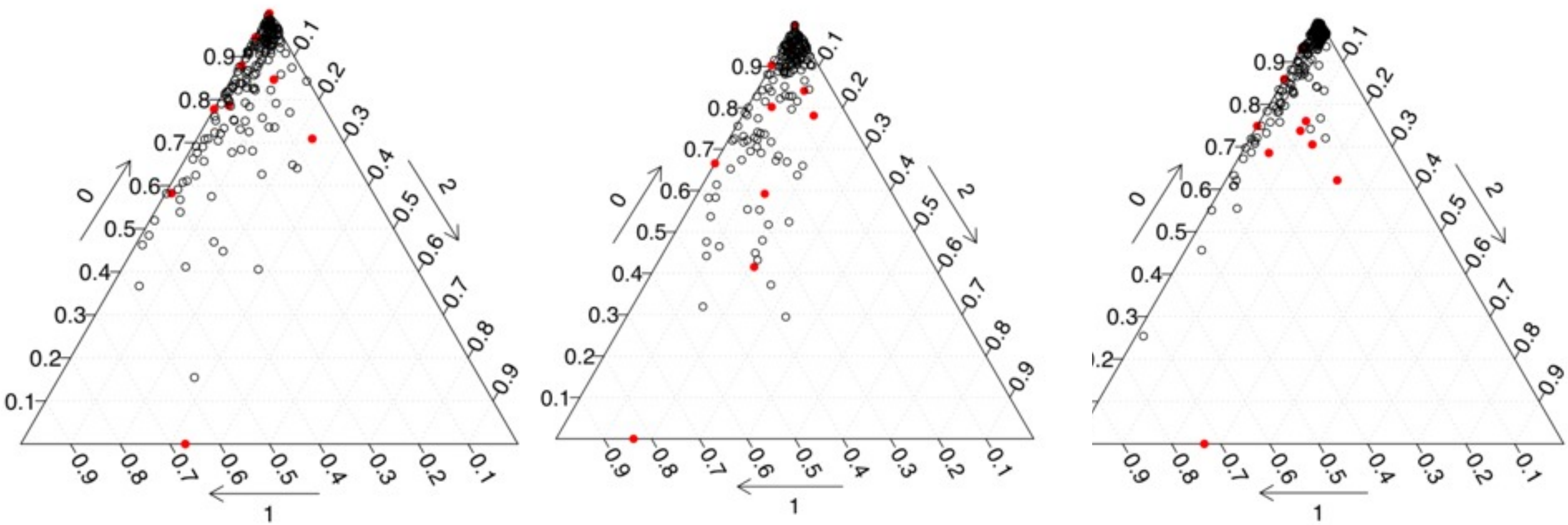
denote initial red vertices

denote other vertices



Anomalous Chatter Group in Enron Time Series

Induced Egg



Egg?	p>0.99	p~ 0.7	**p < 0.01**
Time	Weeks 18-37	Weeks 38-57	Weeks 58-77

Conclusions

- New Methods for Fusion of Conte***x***t and Conte***n***t
- Pioneered at JHU Human Language Technology COE
- Theory, Algorithms and Experimental Evaluation
- Tasks
  - Stream Characterization
  - Vertex Nomination
  - Dyadic Priors
- Experimentally evaluated on
  - Enron email corpus
  - Switchboard speech corpus
  - other data

Some References

- ***Statistical Inference on Random Graphs: Fusion of Graph Features and Content,*** Grothendieck, Priebe, and Gorin, Computational Statistics and Data Analysis (2010)
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