CSE 6242 A / CS 4803 DVA

Mar 7, 2013

Scaling Up

HBase, Hive, Pegasus

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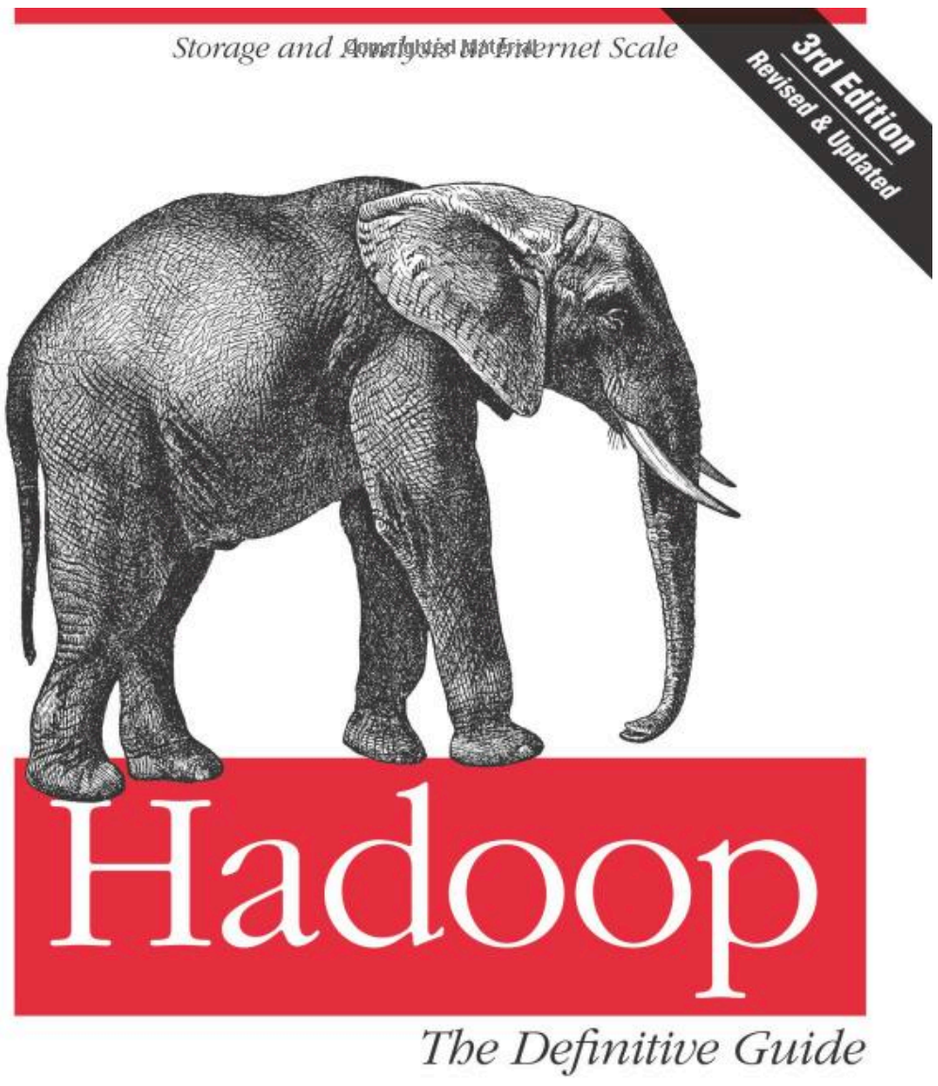
Some lectures are partly based on materials by
Professors Guy Lebanon, Jeffrey Heer, John Stasko, Christos Faloutsos, Le Song

Lecture based on these two books.



http://goo.gl/YNCWN

http://goo.gl/svzTV

Last Time...

APACHE HBASE

Introduction to **Pig**

Showed you a simple example run using **Grunt** (interactive shell)

- *Find maximum temperature by year*
- Easy to program, understand and maintain
  - You write a few lines of **Pig Latin**, Pig turns them into MapReduce jobs
  - **Illustrate** command creates sample dataset (from your full data)
    - Helps you debug your Pig Latin

Started with **HBase**

http://hbase.apache.org

Built on top of HDFS

Supports real-time read/write random access

Scale to very large datasets, many machines

Not relational, does NOT support SQL
("NoSQL" = "not only SQL")

Supports billions of rows, millions of columns

Written in Java; can work with many languages

Where does HBase come from?

HBase's "history"

Not designed for random access

Hadoop & **HDFS** based on...

- 2003 *Google File System* (GFS) paper
- 2004 Google *MapReduce* paper

HBase based on ...

- 2006 Google *Bigtable* paper

This "fixes" that

How does HBase work?

Column-oriented

Column is the most basic unit (instead of row)

- Columns form a row
- A column can have **multiple versions**, each version stored in a cell

Rows form a table

- **Row key** locates a row
- Rows **sorted** by row key lexicographically

Row key is unique

Think of row key as the “index” of the table

- You look up a row using its row key

Only one “index” per table (via row key)

HBase does not have built-in support for multiple indices; support enabled via extensions

Rows sorted lexicographically

(=alphabetically)

```
hbase(main):001:0> scan 'table1'
ROW       COLUMN+CELL
row-1     column=cf1:, timestamp=1297073325971 ...
row-10    column=cf1:, timestamp=1297073337383 ...
row-11    column=cf1:, timestamp=1297073340493 ...
row-2     column=cf1:, timestamp=1297073329851 ...
row-22    column=cf1:, timestamp=1297073344482 ...
row-3     column=cf1:, timestamp=1297073333504 ...
row-abc   column=cf1:, timestamp=1297073349875 ...
7 row(s) in 0.1100 seconds
```

"**row-10**" comes before "**row-2**".

How to fix?

Rows sorted lexicographically

(=alphabetically)

```
hbase(main):001:0> scan 'table1'
ROW       COLUMN+CELL
row-1     column=cf1:, timestamp=1297073325971 ...
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row-2     column=cf1:, timestamp=1297073329851 ...
row-22    column=cf1:, timestamp=1297073344482 ...
row-3     column=cf1:, timestamp=1297073333504 ...
row-abc   column=cf1:, timestamp=1297073349875 ...
7 row(s) in 0.1100 seconds
```

"**row-10**" comes before "**row-2**".

How to fix?

Pad "row-2" with a "0".

i.e., "row-02"

Columns grouped into **column families**

Column family is a new concept from HBase

- Why? Helps with organization, understanding, optimization, etc.
- In details...
  - Columns in the same family stored in same *file* called *HFile* (inspired by Google's SSTable = large map whose keys are sorted)
  - Apply compression on the whole family
  - ...

More on **column family, column**

Column family

- Each table only supports a **few** families (e.g., <10)
  - Due to shortcomings in implementation
- Family name must be **printable**
  - Should be defined when table is created
  - Shouldn't be changed often

Each **column** referenced as "**family:qualifier**"

- Can have **millions** of columns
- Values can be **anything** that's **arbitrarily long**

Cell Value

Timestamped

- Implicitly by system
- Or set explicitly by user

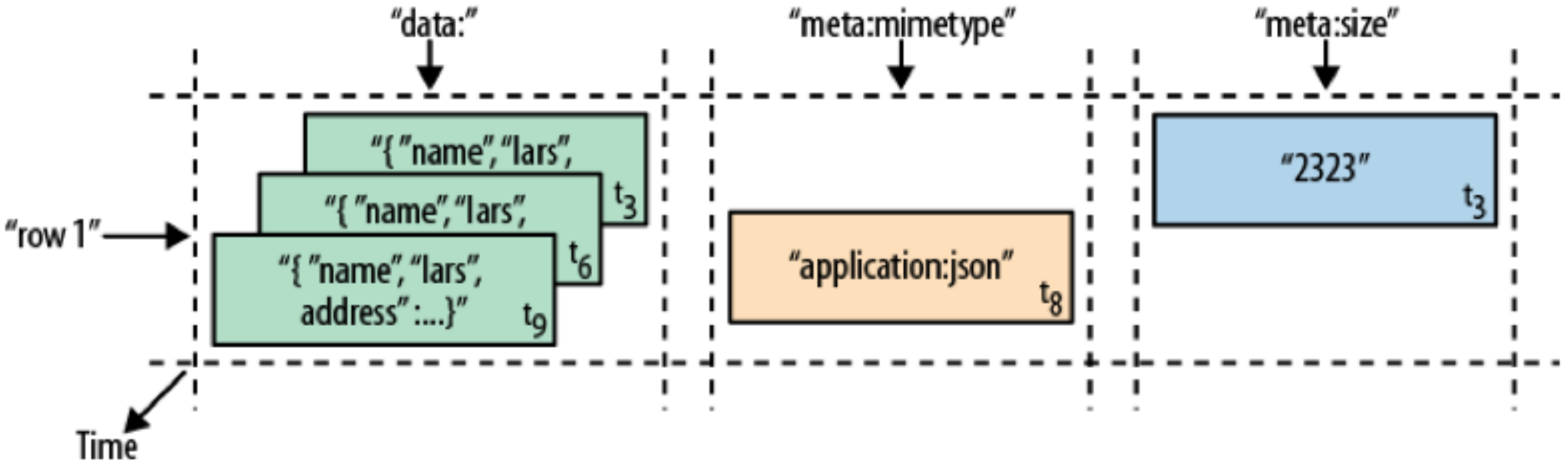
Let you store **multiple versions** of a value

- = values over time

Values stored in **decreasing** time order

- **Most recent value** can be read first

Time-oriented view of a row



Row Key	Time Stamp	Column "data:"	Column "meta:"	
			"mimetype"	"size"
"row1"	t_3	"{ "name" : "lars", "address" : ...}"		"2323"
	t_6	"{ "name" : "lars", "address" : ...}"		
	t_8		"application/json"	
	t_9	"{ "name" : "lars", "address" : ...}"		

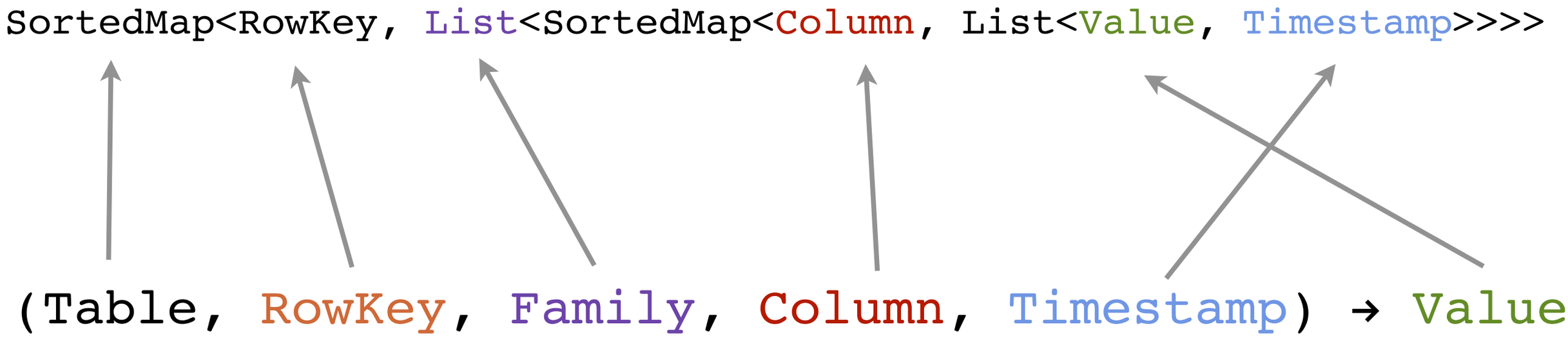
Concise way to describe all these?

HBase data model (= Bigtable's model)

- Sparse, distributed, persistent, **multidimensional map**
- Indexed by row key + column key + timestamp

```
(Table, RowKey, Family, Column, Timestamp) → Value
```

… and the geeky way



An exercise

How would you use HBase to create a *webtable* store **snapshots** of every **webpage** on the planet, **over time**?

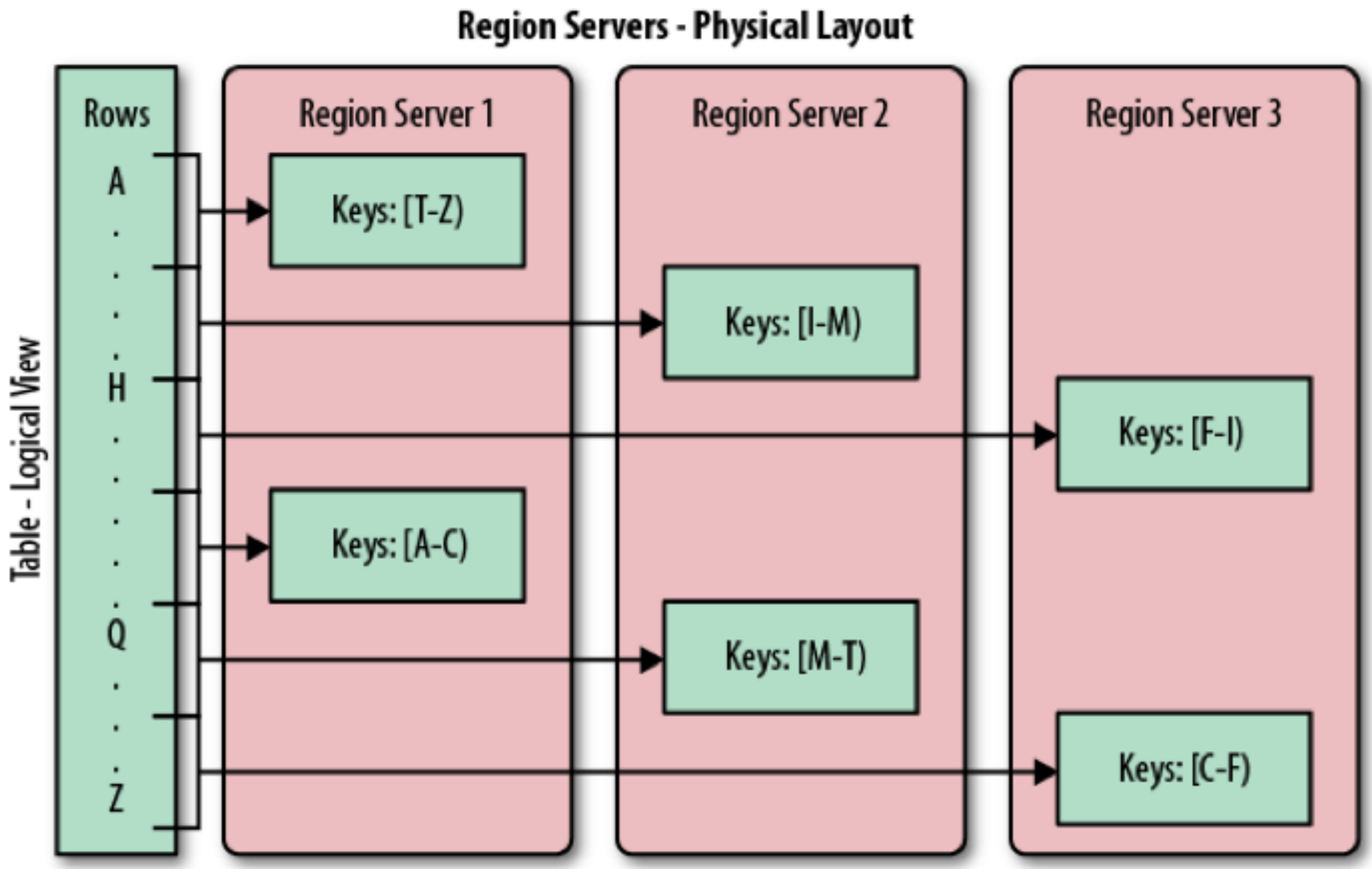
Also want to store each webpage's incoming and outgoing links, metadata (e.g., language), etc.

Details: How does HBase **scale up storage** & **balance load**?

Automatically divide contiguous ranges of rows into regions

Start with one region, split into two when getting too large

Details: How does HBase **scale up storage** & **balance load**?



How to use HBase

Interactive shell

- Will show you an example, locally (on your computer, without using HDFS)

Programmatically

- e.g., via Java, C++, Python, etc.

Example, using interactive shell

```
$ cd /usr/local/hbase-0.91.0-SNAPSHOT
$ bin/start-hbase.sh
starting master, logging to \
/usr/local/hbase-0.91.0-SNAPSHOT/bin/../logs/hbase-<username>-master-localhost.out
$ bin/hbase shell
HBase Shell; enter 'help<RETURN>' for list of supported commands.
Type "exit<RETURN>" to leave the HBase Shell
Version 0.91.0-SNAPSHOT, r1130916, Sat Jul 23 12:44:34 CEST 2011

hbase(main):001:0> status
1 servers, 0 dead, 2.0000 average load
```

Start HBase

Start Interactive Shell

Check HBase is running

Example: Create table, add values

```
hbase(main):002:0> create 'testtable', 'colfam1'
0 row(s) in 0.2930 seconds

      hbase(main):003:0> list 'testtable'
TABLE
testtable
1 row(s) in 0.0520 seconds

hbase(main):004:0> put 'testtable', 'myrow-1', 'colfam1:q1', 'value-1'
0 row(s) in 0.1020 seconds

hbase(main):005:0> put 'testtable', 'myrow-2', 'colfam1:q2', 'value-2'
0 row(s) in 0.0410 seconds

hbase(main):006:0> put 'testtable', 'myrow-2', 'colfam1:q3', 'value-3'
0 row(s) in 0.0380 seconds
```

Example: Scan (show all cell values)

```
hbase(main):007:0> scan 'testtable'
ROW                  COLUMN+CELL
 myrow-1             column=colfam1:q1, timestamp=1297345476469, value=value-1
 myrow-2             column=colfam1:q2, timestamp=1297345495663, value=value-2
 myrow-2             column=colfam1:q3, timestamp=1297345508999, value=value-3

2 row(s) in 0.1100 seconds
```

Example: Get (look up a row)

```
hbase(main):008:0> get 'testtable', 'myrow-1'
COLUMN                CELL
colfam1:q1            timestamp=1297345476469, value=value-1

1 row(s) in 0.0480 seconds
```

Can also look up a particular cell value, with a certain timestamp, etc.

Example: Delete a value

```
hbase(main):009:0> delete 'testtable', 'myrow-2', 'colfam1:q2'
0 row(s) in 0.0390 seconds

hbase(main):010:0> scan 'testtable'
ROW                  COLUMN+CELL
 myrow-1             column=colfam1:q1, timestamp=1297345476469, value=value-1
 myrow-2             column=colfam1:q3, timestamp=1297345508999, value=value-3

2 row(s) in 0.0620 seconds
```

Example: Disable & drop table

```
hbase(main):011:0> disable 'testtable'
0 row(s) in 2.1250 seconds
```

```
 hbase(main):012:0> drop 'testtable'
0 row(s) in 1.2780 seconds
```

RDBMS vs HBase

RDBMS (=Relational Database Management System)

- MySQL, Oracle, SQLite, Teradata, etc.
- Really great for many applications
- Ensure strong data consistency, integrity
- Supports transactions (ACID guarantees)
- ...

RDBMS vs HBase

How are they different?

- Hbase when you don’t know the structure/schema
- HBase supports sparse data (many columns, most values are not there)
- Use hbase if you only work with a small number of columns
- Relational databases good for getting “whole” rows
- HBase: Multiple versions of data
- RDBMS support multiple indices, minimize duplications
- Generally a lot cheaper to deploy HBase, for same size of data (petabytes)

Advanced topics to learn about

Other ways to get, put, delete... (e.g., **programmatically** via Java)

- Doing them in **batch**

Maintaining your cluster

- **Configurations**, **specs** for "master" and "slaves"?
- Administrating cluster
- Monitoring cluster's health

Key design

- **bad keys** can decrease performance

Integrating with MapReduce

More...

Hive

http://hive.apache.org

Use SQL to run queries on large datasets

Developed at Facebook

Similar to Pig, Hive runs on your computer

- You write **HiveQL** (Hive's query language), which gets converted into MapReduce jobs

Example: starting Hive

```
% hive
hive>
```

```
hive> SHOW TABLES;
OK
Time taken: 10.425 seconds
```

Example: create table, load data

```
CREATE TABLE records (year STRING, temperature INT,
quality INT)
ROW FORMAT DELIMITED
  FIELDS TERMINATED BY '\t';
```

Specify that data file is tab-separated

```
LOAD DATA LOCAL INPATH 'input/ncdc/micro-tab/sample.txt'
OVERWRITE INTO TABLE records;
```

Overwrite old file

This data file will be copied to Hive's internal **data directory**

Example: Query

```
hive> SELECT year, MAX(temperature)
    > FROM records
    > WHERE temperature != 9999
    >   AND (quality = 0 OR quality = 1 OR quality = 4 OR
quality = 5 OR quality = 9)
    > GROUP BY year;
1949    111
1950    22
```

So simple and boring! Or is it?

Same thing done with Pig

```
records = LOAD 'input/ ncdc/ micro-tab/ sample.txt'
  AS (year:chararray, temperature:int, quality:int);

filtered_records =
  FILTER records BY temperature != 9999
  AND (quality = = 0 OR quality = = 1 OR
       quality = = 4 OR quality = = 5 OR
       quality = = 9);

grouped_records = GROUP filtered_records BY year;

max_temp = FOREACH grouped_records GENERATE
  group, MAX( filtered_records.temperature);

DUMP max_temp;
```

Graph Mining using Hadoop

PROJECT PEGASUS

Carnegie Mellon University
SCHOOL OF COMPUTER SCIENCE

USING PEGASUS | DOWNLOAD | PUBLICATIONS | ABOUT

Pegasus *An award-winning, open-source, graph-mining system with massive scalability.*

Analyze petabytes of graph data with ease.

Pegasus 2.0
FREE DOWNLOAD

English, all platforms

We won the Open Source Software World Challenge, Silver Award

www.cs.cmu.edu/~pegasus/

Generalized Iterated Matrix Vector Multiplication (GIM-V)

PEGASUS: A Peta-Scale Graph Mining System - Implementation and Observations.

U Kang, Charalampos E. Tsourakakis, and Christos Faloutsos.

ICDM 2009, Miami, Florida, USA.
Best Application Paper (runner-up).

Generalized Iterated Matrix Vector Multiplication (GIMV)

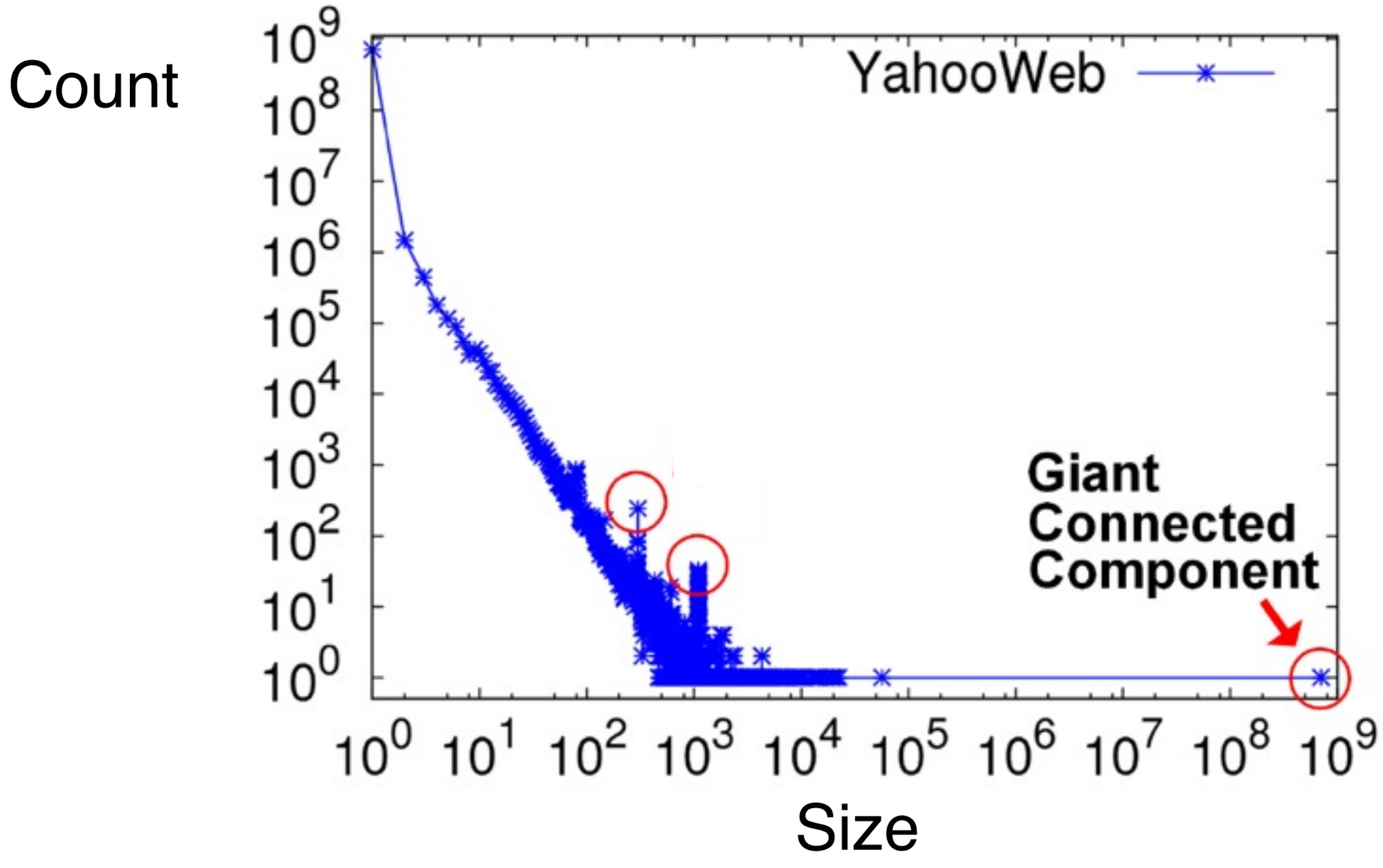
details

- PageRank
- proximity (RWR)
- Diameter
- Connected components
- (eigenvectors,
- Belief Prop.
- …)

Matrix – vector Multiplication (iterated)

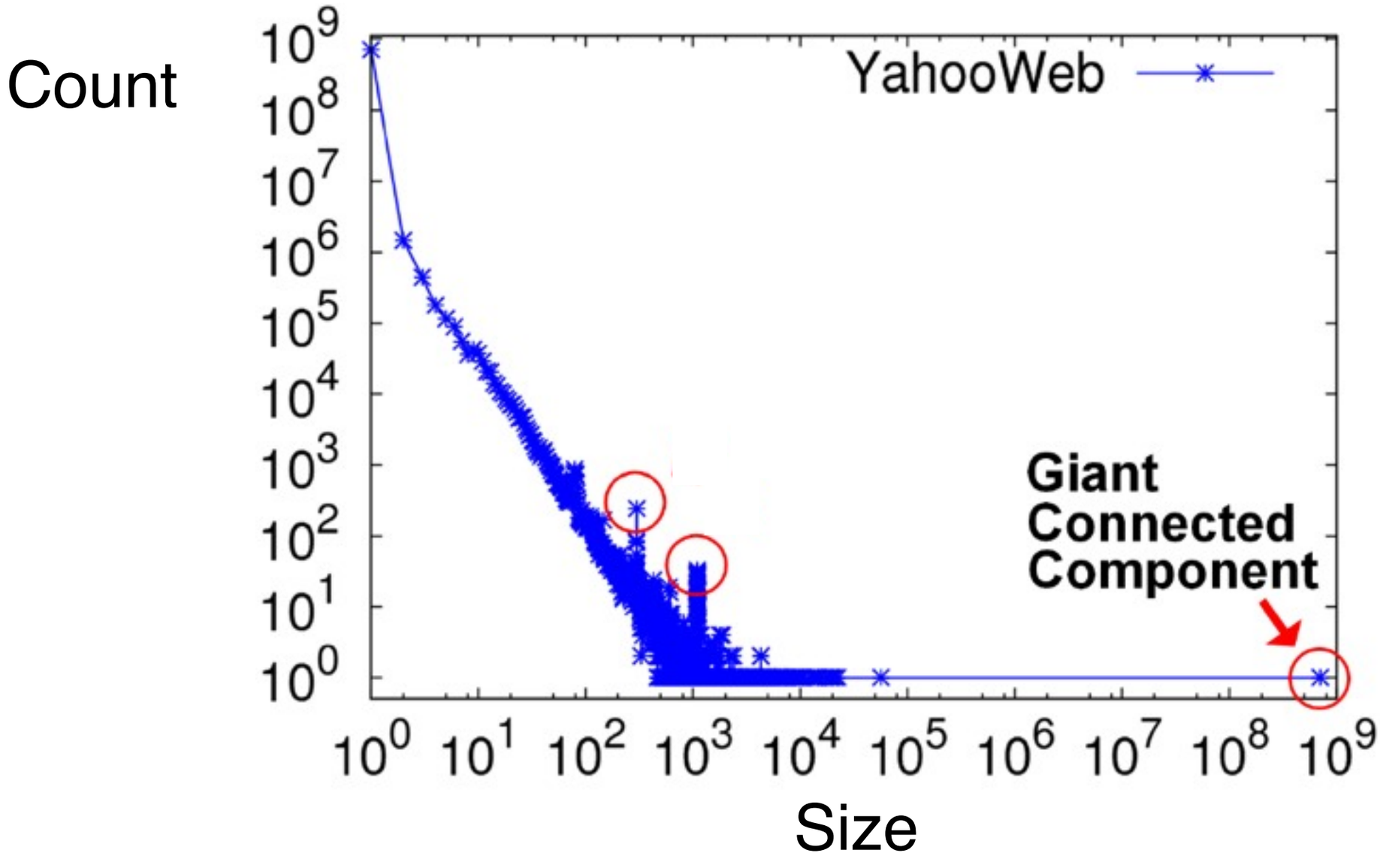
Example: GIM-V At Work

- Connected Components – 4 observations:



Example: GIM-V At Work

- Connected Components

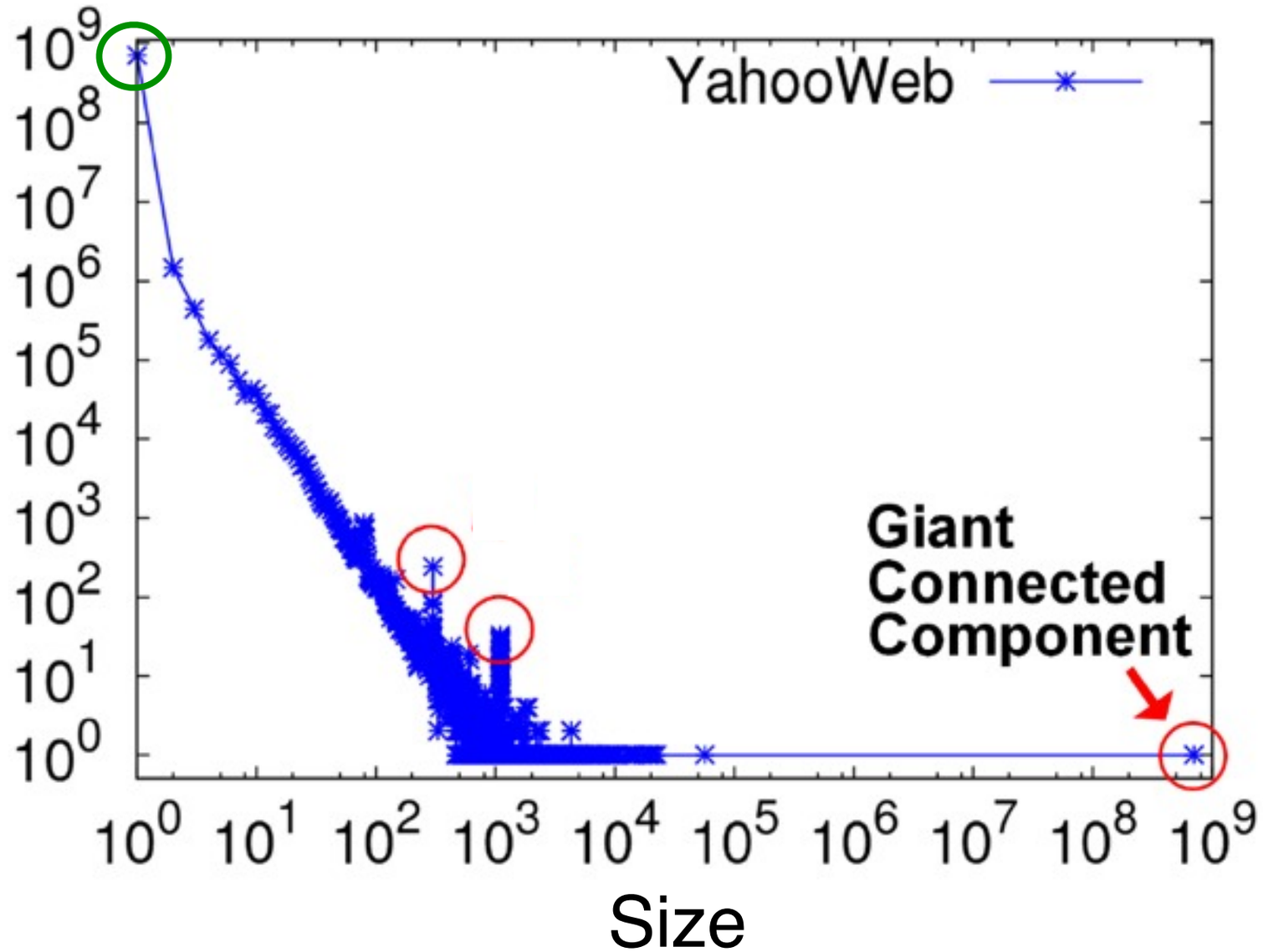


1) 10K x larger than next

Example: GIM-V At Work

- Connected Components

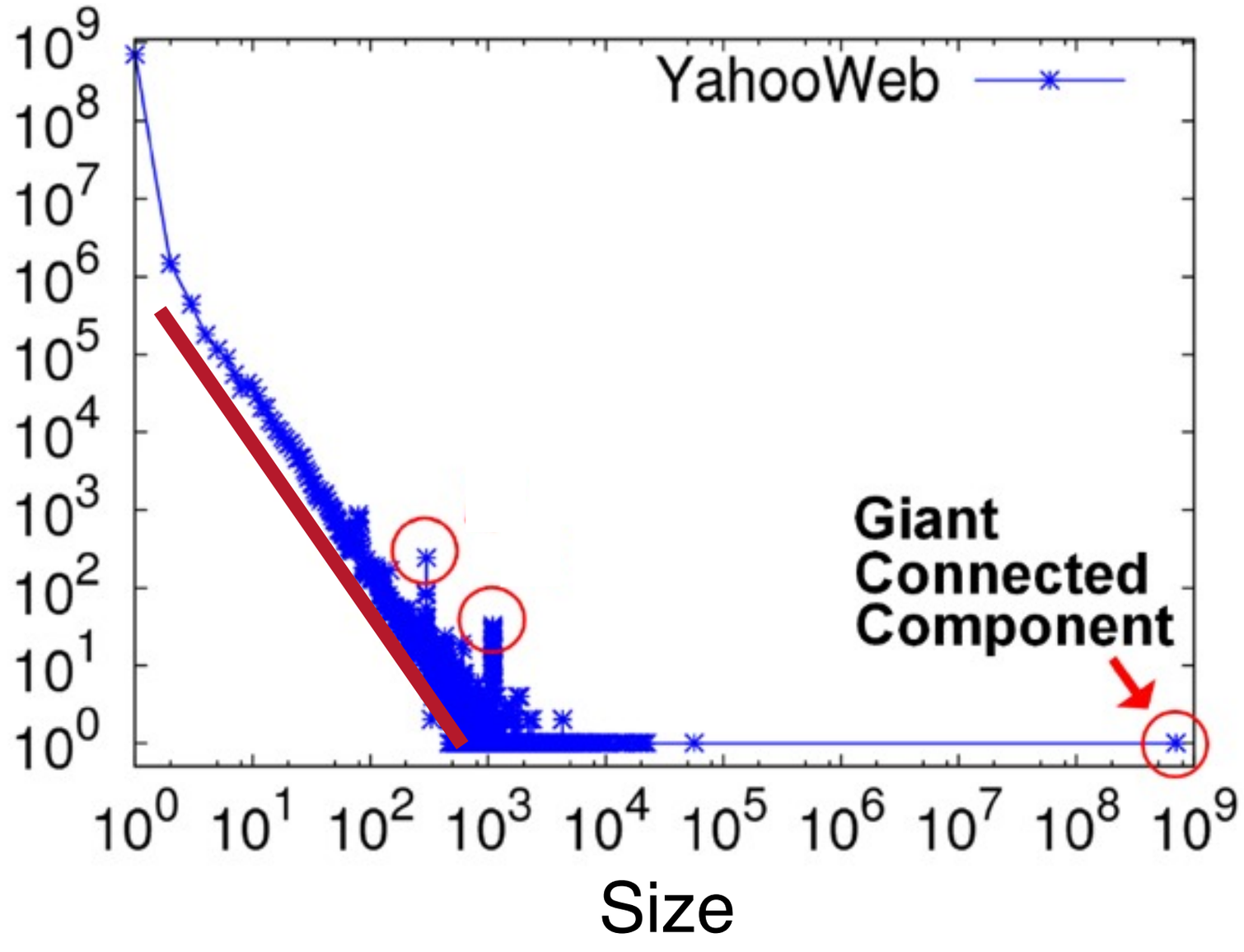
2) ~0.7B singleton nodes



Example: GIM-V At Work

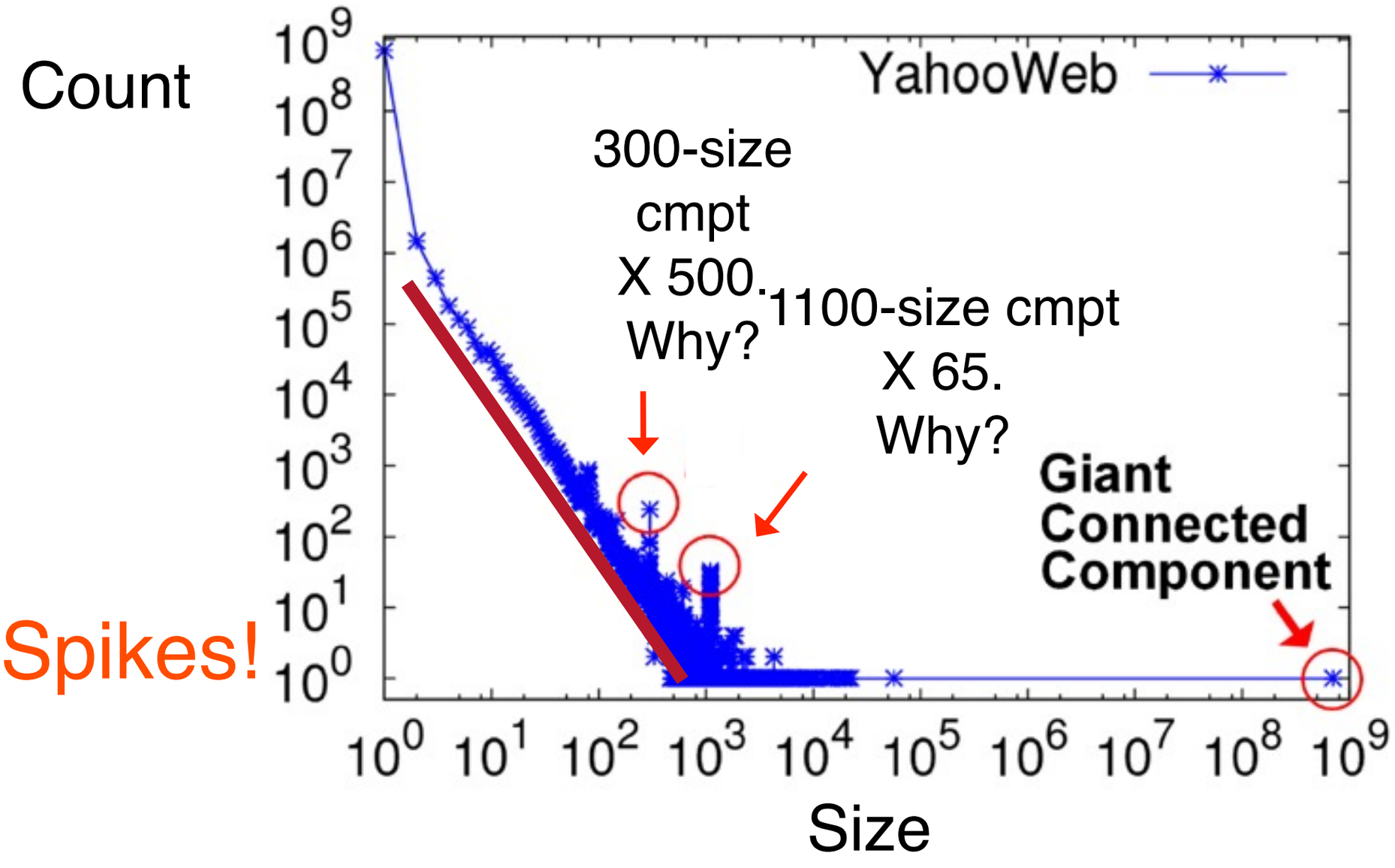
- Connected Components

3)
SLOPE!



Example: GIM-V At Work

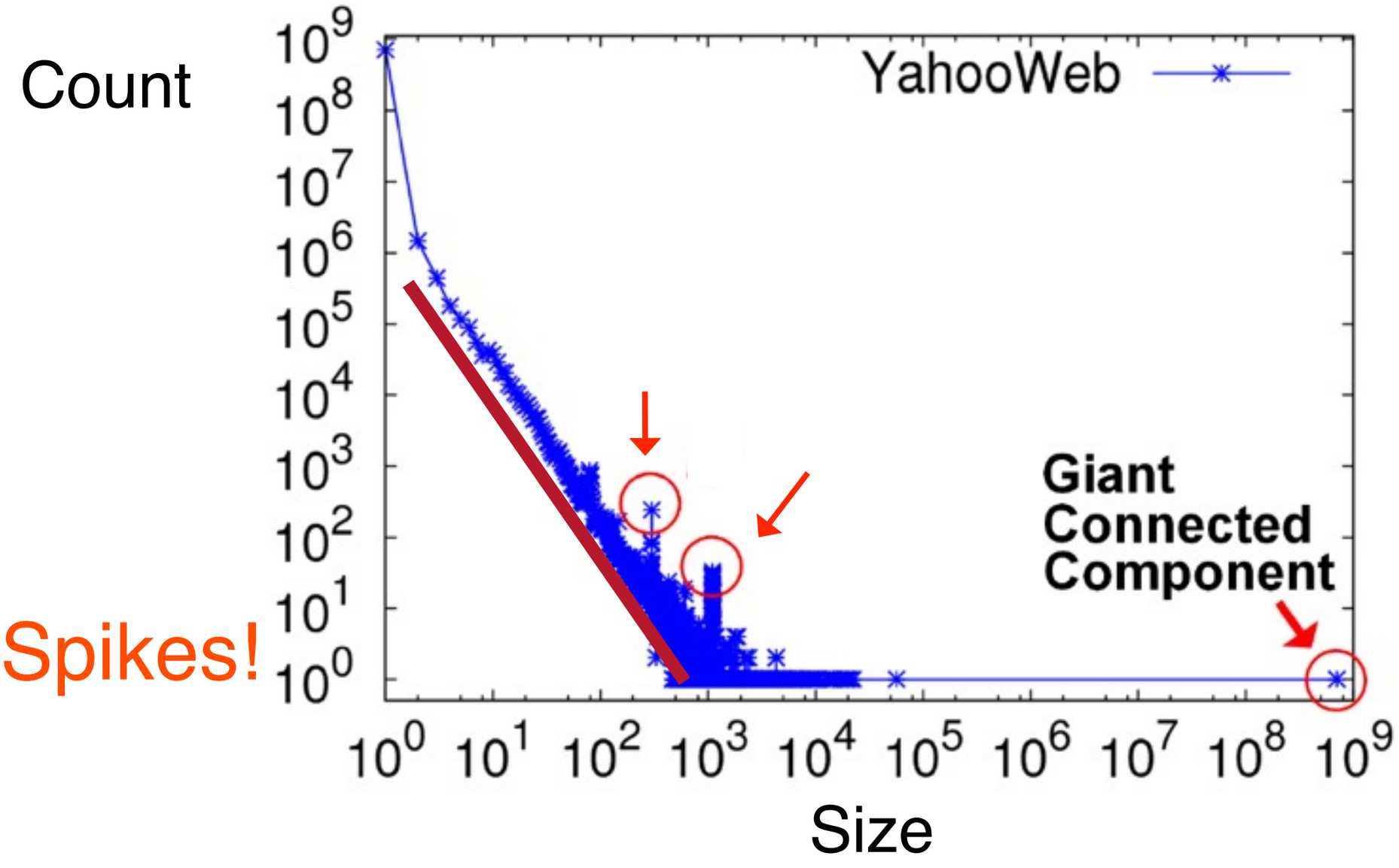
- Connected Components



4) Spikes!

Example: GIM-V At Work

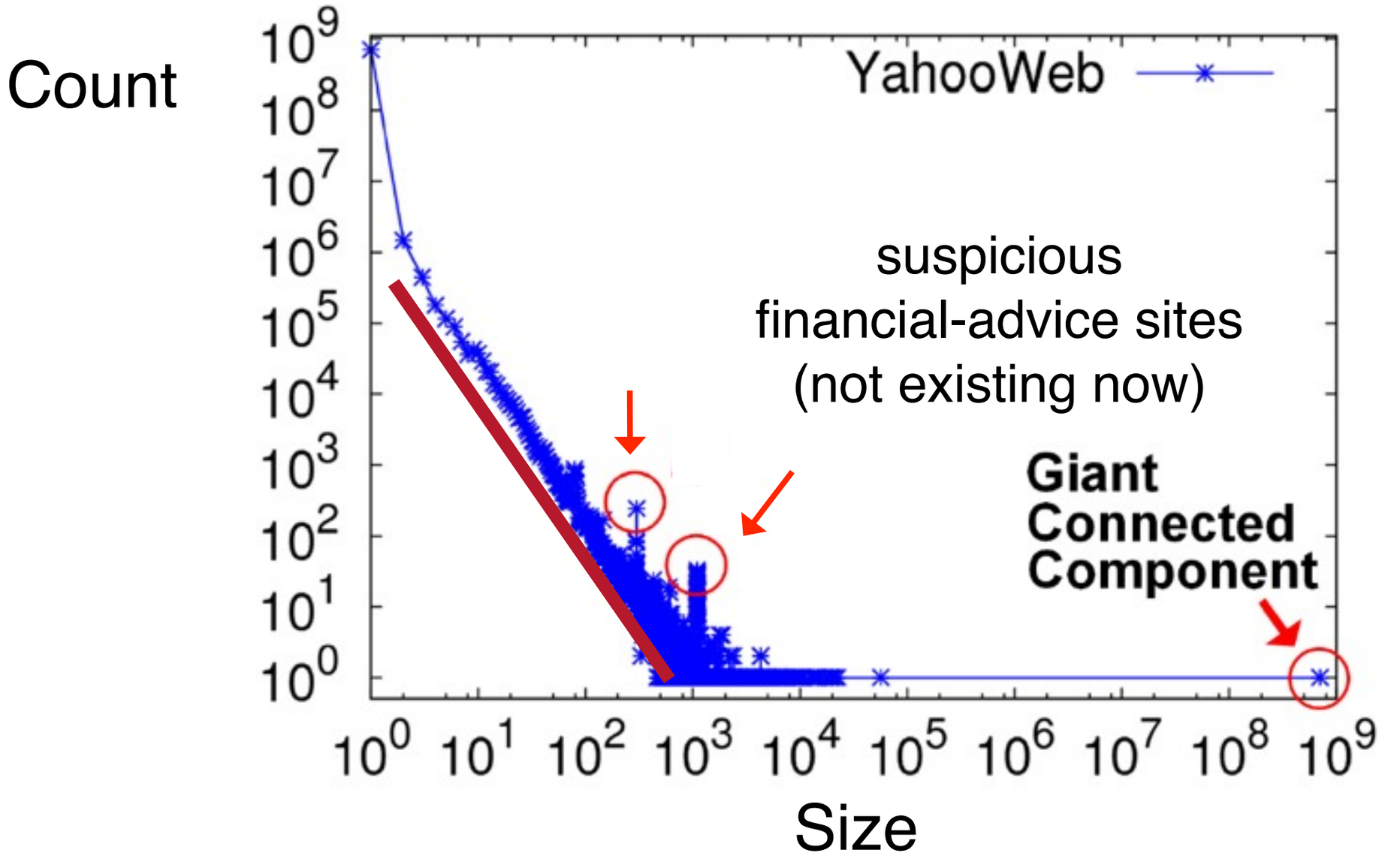
- Connected Components



4) Spikes!

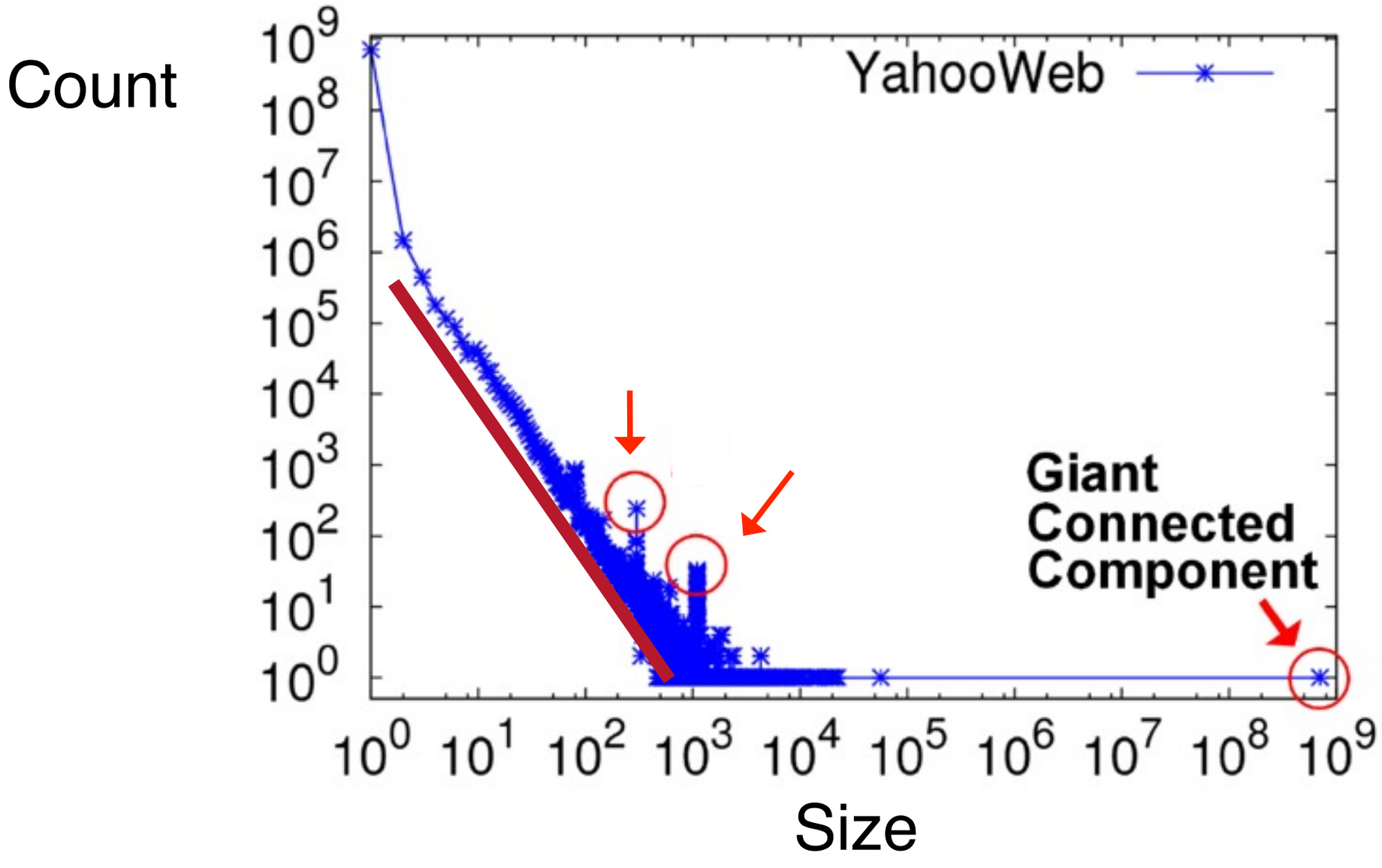
Example: GIM-V At Work

- Connected Components



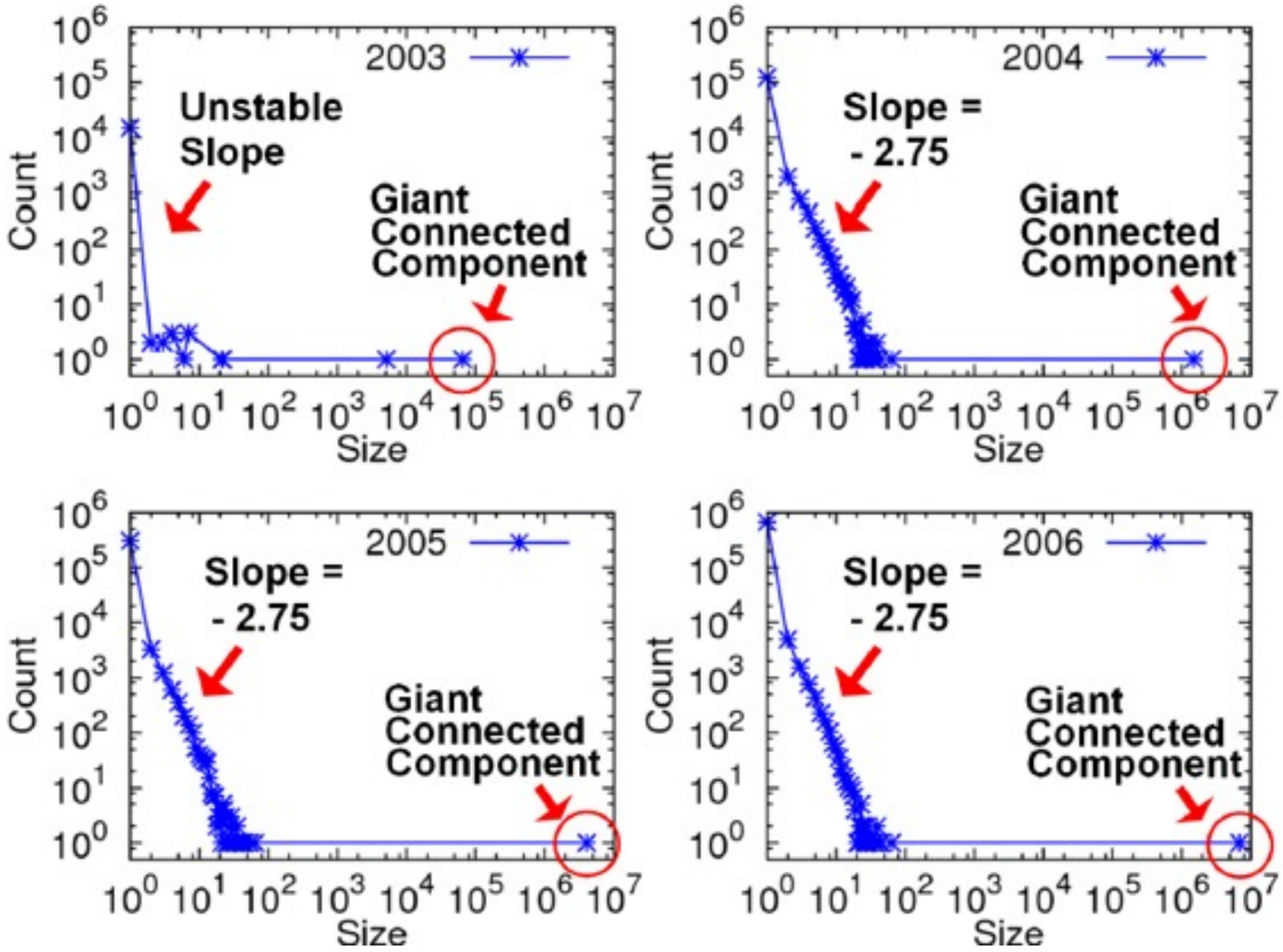
Example: GIM-V At Work

- Connected Components



GIM-V At Work

- Connected Components over Time
- **LinkedIn: 7.5M nodes and 58M edges**



Stable tail slope after the gelling point