
Using Graph Analysis and Fraud Detection in the Fintech Industry

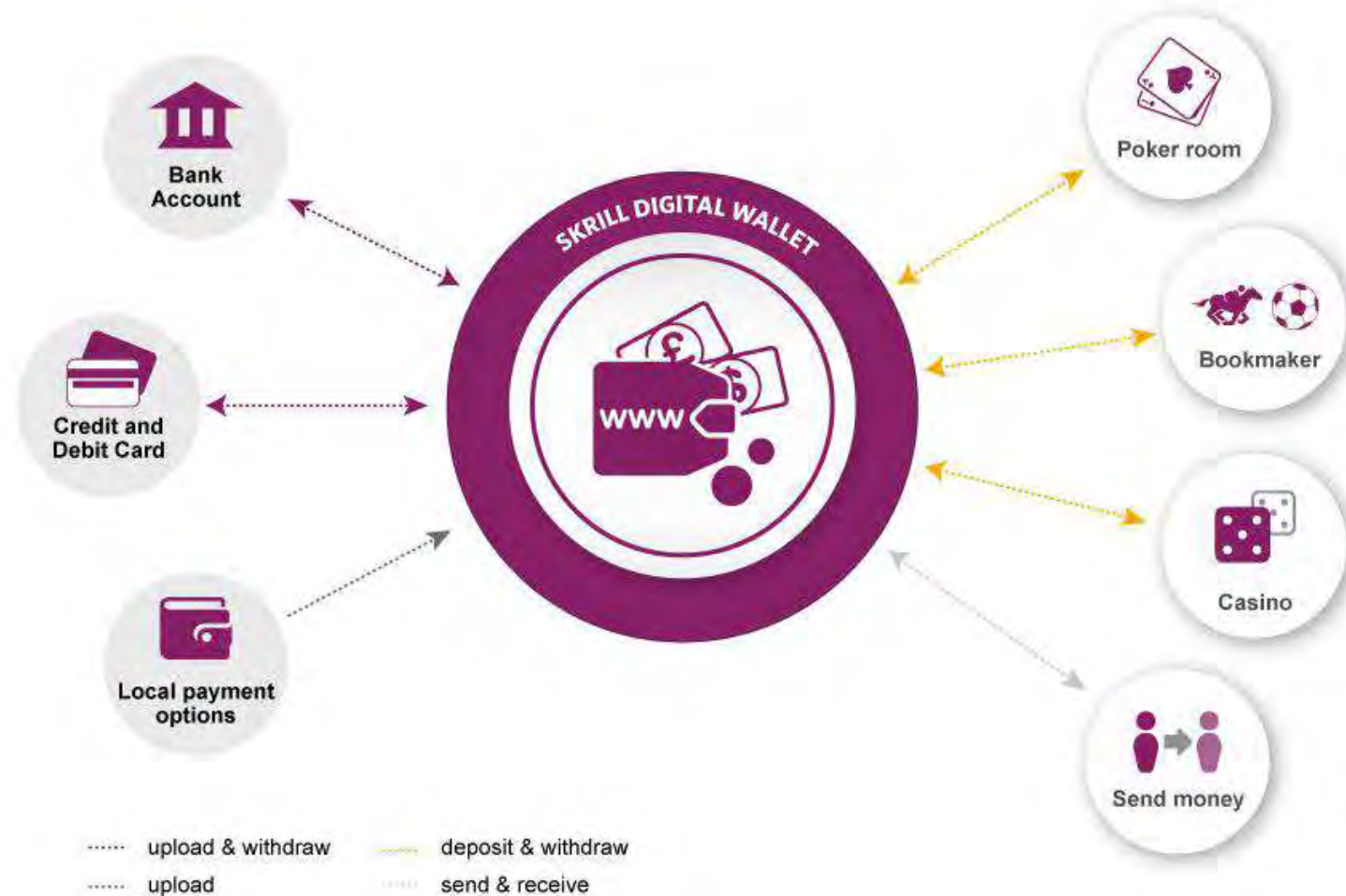
Stanka Dalekova Yavor I. Ivanov Dobroslav Hristov
@PlugIntoPaysafe

Who are Paysafe?

- Paysafe is leading specialized payments player in the world. We do the hard stuff better than our competition
- Global transactional volume of \$85bn in 2018.
- Real-time Payments
- Two e-wallet services

Neteller

Skrill



Use Case – Fast Fraud Analytics

- ~ 500 000 payments per day
- Fines on any fraud payment
- Balance between fraud protection and negative customer experience
- Fraudsters bury their patterns in lots of data.

Online Fraud Screening

To **PROCESS** or **NOT** to **PROCESS**?



or



or



Manual Review Metrics

- Fraud Benchmark Report by Cybersouce from 2016
 - 83 % of North Americans review 29% of the orders manually,
 - Fraud analysts can give insights about fraud patterns and customer behavior
 - After manual review, rule engines can be updated
 - Manual Review are costly and time-consuming
 - Decreasing customer experience by delaying the payment
- Fraud prevention industry [benchmark](#) by Kount.com from 2018
 - 93 percent of merchants perform manual reviews
 - nearly 30 percent have a manual review rate between 1 and 5 percent
 - 16 percent review between 5 and 10 percent
 - 20 percent review more than one-in-ten of their orders.

Data is our golden eggs, how to make it meaningful?



Breakthrough 😊

Q: A better way to analyze connected data?

**A: The payments in Paysafe are actually a
GRAPH!**

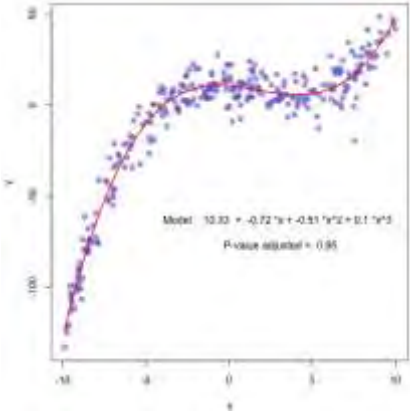
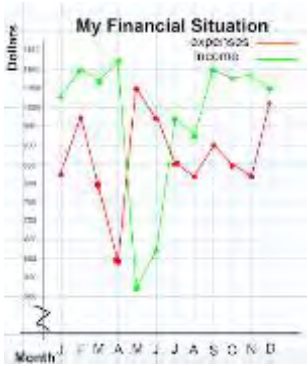
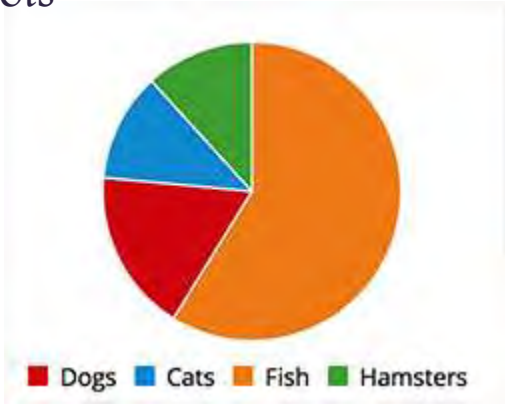
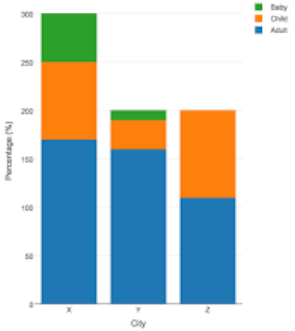
Graph Databases are invented to solve the performance problems of connected data.

Graph Theory

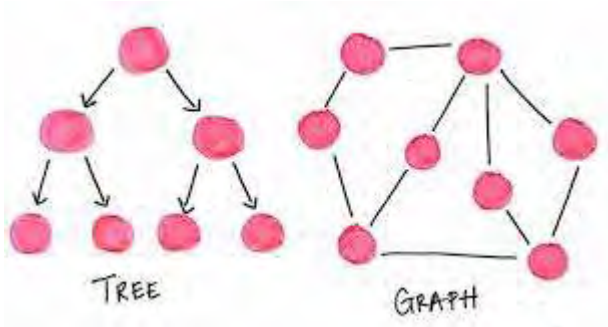
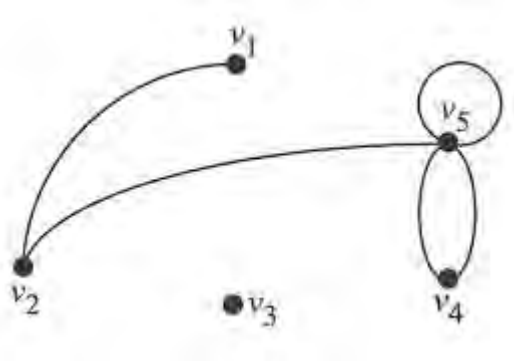
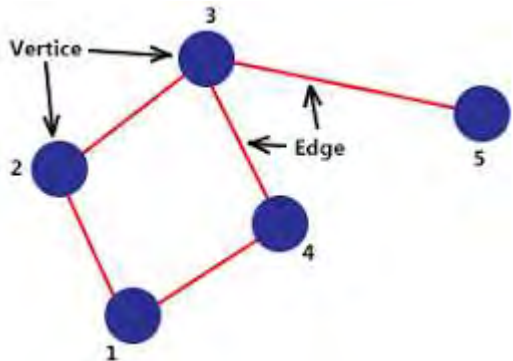
- Study on mathematical structures used to model pairwise relations between objects
- 250+ years of history – the paper written by Leonhard Euler on the Seven Bridges of Königsberg and published in 1736 is regarded as the first paper in the history of graph theory
- Graphs are used to model many types of relations and process
- Graphs solve many real-life problems – in computer science, social sciences, biology, etc.
- Hundreds of graph algorithms – strongly connected components, paths algorithms, nearest neighbor, page rank, edge weight algorithms, etc.

What exactly is a graph?

These are all plots

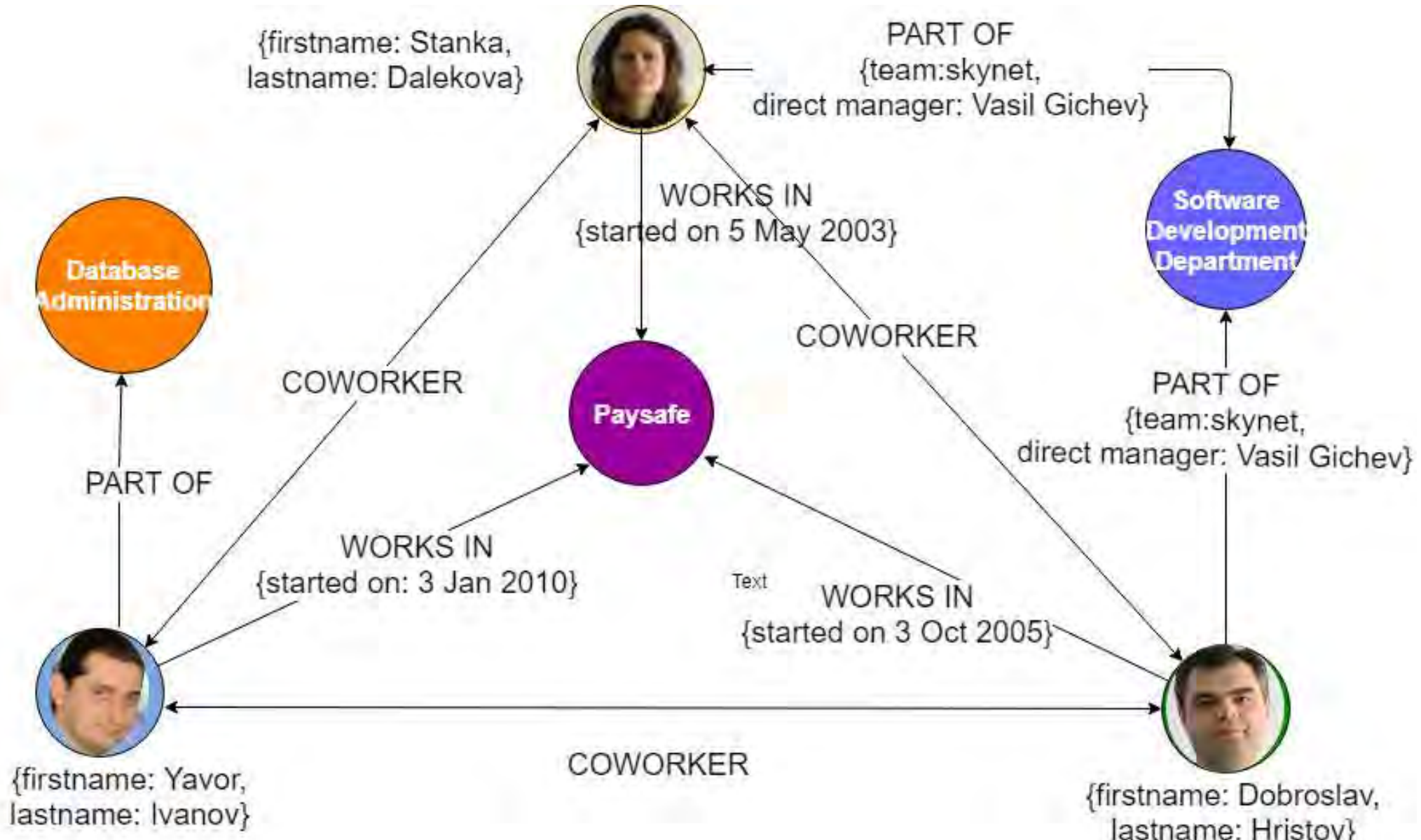


And these are all graphs



A **tree** is a minimally connected **graph** having only one path **between** any two vertices.

Property Graph



Graph Database

Graph databases store data in terms of

- **Entities (*nodes* or *vertices*)**
- **Relationships between entities (*edges* or *arrows*)**

A better way to explore connected data.

Graphs are eating the world

TIBCO® blog

Integration

API | BPM | Digital Transformation | MDM

Graph Databases: The Next Generation of Fraud Detection Technology

by [Iachia Vendetti](#) December 12, 2017 • Integration

Gartner

Who we serve | What we do | Conferences | Insights | Ab

Making Big Data Normal With Graph Analysis for the Masses

ARCHIVED Published: 27 July 2015 ID: G00278415

Analyst(s): Mark Beyer | Nick Heudecker

Are Graph Databases The Next Big Thing?
Published on July 8, 2017

Data News | Databases News | Insights

2018 is the year of graph databases. Here's why.

By [Amey Varangaonkar](#) - May 4, 2018 - 6:00 pm | 1060 | 0

Data Summit 2018 and the Rise of Graph Databases

by [George Andolina](#) | May 13, 2018 | 10:12 AM

The continuing rise of graph databases
Graph technology is well on its way from a fringe domain to going mainstream. We take a look at the state of the union in graph, featuring Neo4j's latest release and insights as well as data and opinions from Cloudera, DataStax, and IBM.

by [George Andolina](#) | May 13, 2018 | 10:12 AM | Topic: Innovation

Graphs are eating the world

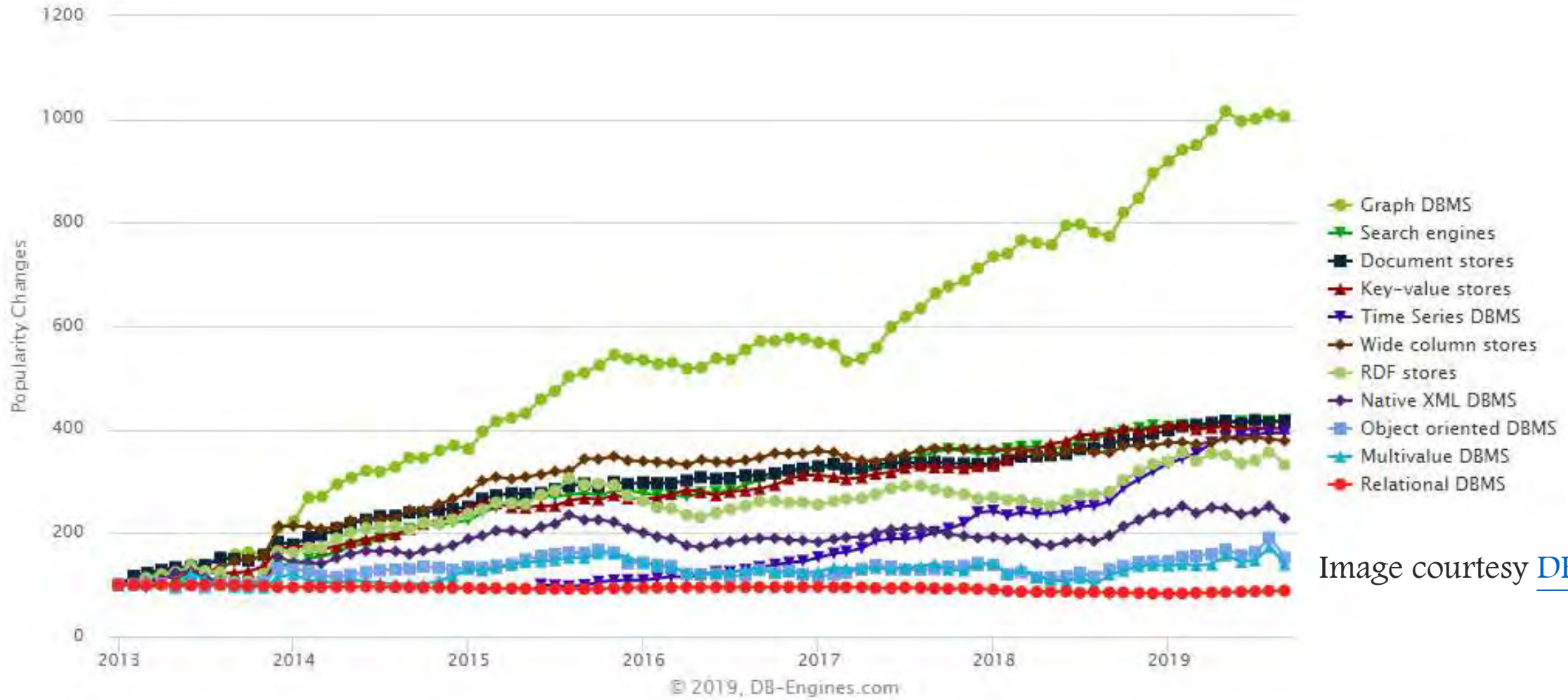


Image courtesy [DB-Engines](#)

Graph databases go mainstream

- Pioneer graph databases are several years old
 - Neo4j [Cypher]
 - IBM Graph [SPARQL and Gremlin]
 - JanusGraph [Gremlin] (renamed from TitanDB)
- Gaining more traction recently – new players
 - Oracle Spatial And Graph by Oracle (Property Graph 3+ years) [PGQL]
 - AWS Neptune by Amazon announced on 30 May 2018 [SPARQL and GREMLIN]
 - Azure Cosmos DB by Microsoft Graph API announced on 7 Feb 2018
 - Apache **Giraph** 4+ years
 - GraphX by Spark 3+ years
 - RedisGraph

SQL vs PGQL

- PGQL

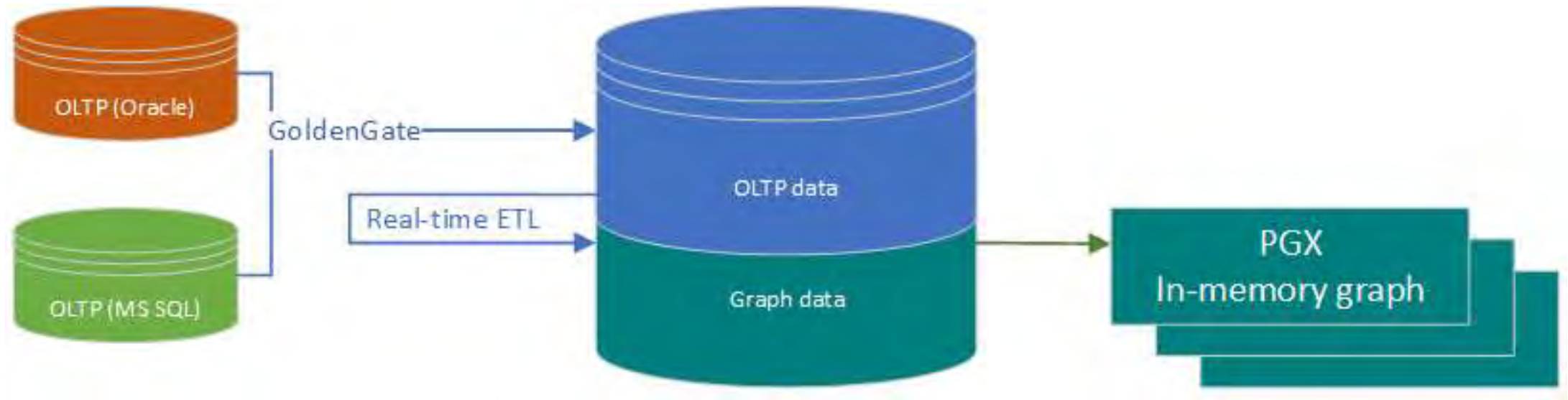
```
PATH knows_path := () -[:knows]-> ()
SELECT s1.fname, s2.fname
WHERE (s1) -/:knows_path*/-> (o) <-/:knows_path*/-(s2) ORDER BY s1,s2
```

Find the pairs of people who are connected to a common person through the “knows” relation

- SQL

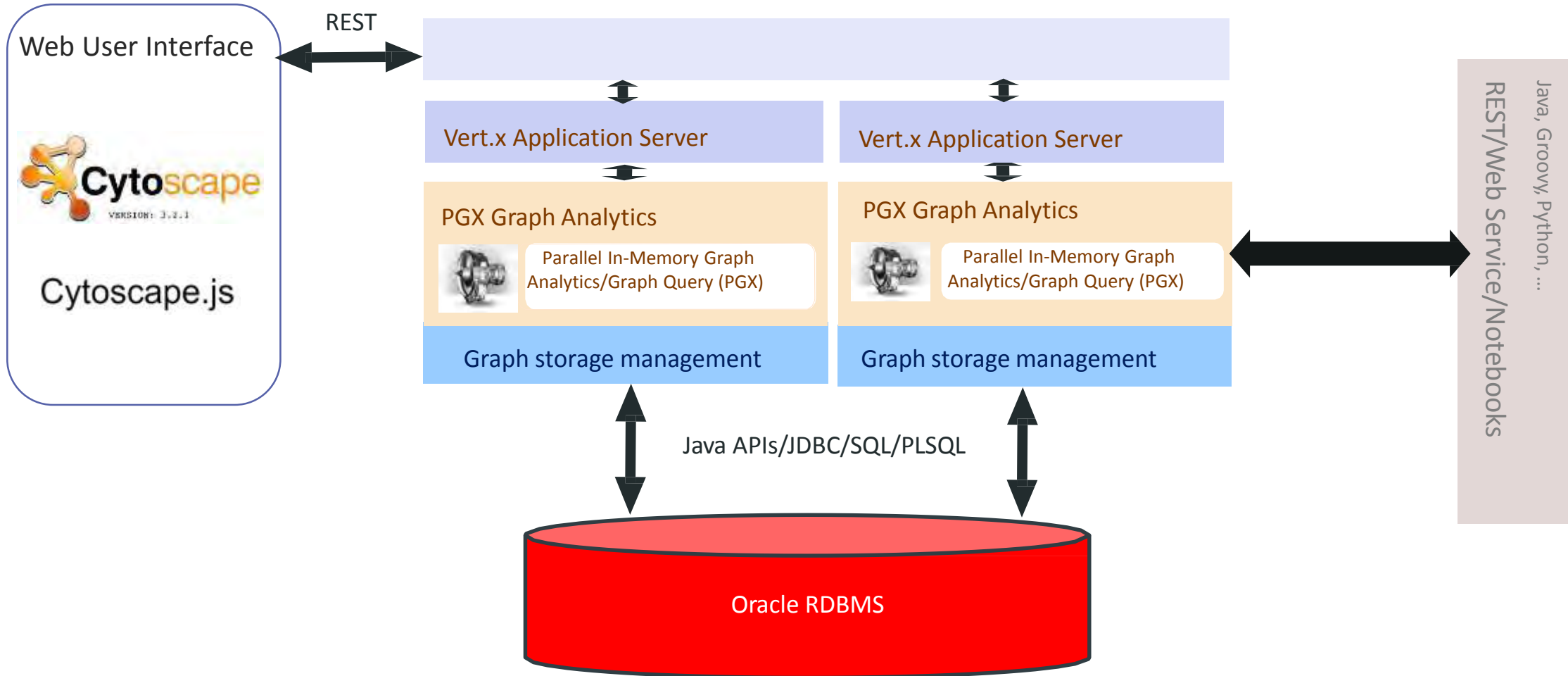
```
SELECT T2.T AS "s1.fname$T",T2.V AS "s1.fname$V",T2.VN AS "s1.fname$VN",T2.VT AS "s1.fname$VT",
       T3.T AS "s2.fname$T",T3.V AS "s2.fname$V",T3.VN AS "s2.fname$VN",T3.VT AS "s2.fname$VT"
FROM (/*Path[/SELECT DISTINCT SVID, DVID FROM ( SELECT VID AS SVID, VID AS DVID FROM "GRAPH1VT$" UNION
ALL SELECT SVID,DVID
      FROM (WITH RW (ROOT, SVID, DVID, LVL) AS ( SELECT ROOT, SVID, DVID, LVL FROM (SELECT SVID ROOT,
SVID, DVID, 1 LVL
      FROM (SELECT T0.SVID AS SVID, T0.DVID AS DVID FROM "GRAPH1GT$" T0 WHERE (T0.EL = n'knows'))
) UNION ALL SELECT DISTINCT RW.ROOT, R.SVID, R.DVID, RW.LVL+1 FROM (SELECT T1.SVID AS SVID,
      T1.DVID AS DVID FROM "GRAPH1GT$" T1 WHERE (T1.EL = n'knows')) R, RW WHERE RW.DVID = R.SVID )
      CYCLE SVID SET cycle_col TO 1 DEFAULT 0 SELECT ROOT SVID, DVID FROM RW ))/*]Path*/ ) T6,
/*Path[/SELECT DISTINCT SVID, DVID FROM ( SELECT VID AS SVID, VID AS DVID FROM "GRAPH1VT$" UNION
ALL SELECT SVID,DVID
      FROM (WITH RW (ROOT, SVID, DVID, LVL) AS ( SELECT ROOT, SVID, DVID, LVL FROM (SELECT SVID ROOT,
SVID, DVID, 1 LVL
      FROM (SELECT T4.SVID AS SVID, T4.DVID AS DVID FROM "GRAPH1GT$" T4 WHERE (T4.EL = n'knows'))
) UNION ALL SELECT DISTINCT RW.ROOT, R.SVID, R.DVID, RW.LVL+1 FROM (SELECT T5.SVID AS SVID,
      T5.DVID AS DVID FROM "GRAPH1GT$" T5 WHERE (T5.EL = n'knows')) R, RW WHERE RW.DVID = R.SVID )
      CYCLE SVID SET cycle_col TO 1 DEFAULT 0 SELECT ROOT SVID, DVID FROM RW ))/*]Path*/ ) T7,
"GRAPH1VT$" T2, "GRAPH1VT$" T3
WHERE T2.K=n'fname' AND T3.K=n'fname' AND T6.SVID=T2.VID AND T6.DVID=T7.DVID AND T7.SVID=T3.VID
ORDER BY T6.SVID ASC NULLS LAST, T7.SVID ASC NULLS LAST
```

Loading data into the graph



Parallel Graph AnalytiX(PGX) is a fast, parallel, in-memory graph analytic framework that allows users to load up their graph data, run analytic algorithms on them, and to browse or store the result.

PGX Architecture in Paysafe



Hardware requirements & sizing

- **PGX loads the *whole* graph and the properties needed for the analysis to be loaded into main memory**
- **Compressed sparse row (CSR) format**, a data structure which has minimal memory footprint while providing very fast read access.
- More info on graph memory consumption can be found [here](#)
 - **On heap memory only string properties**
 - **Off heap memory everything else** – graph topology(edges and vertices) and properties
- **Asynchronous Java API**

Graph Database Performance

Q: Is user "9" connected to user "1"?

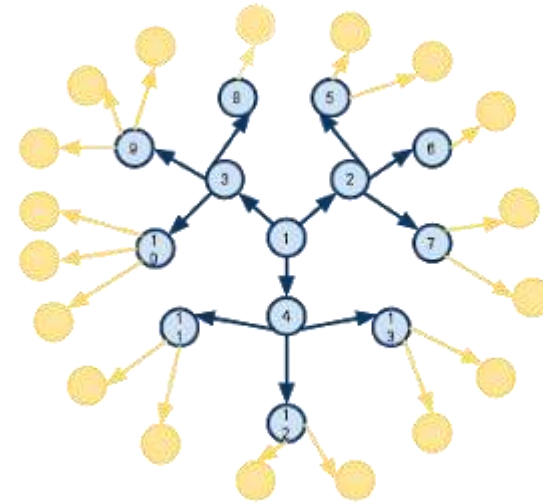
Relational Table

```
> SELECT * FROM friends;
```

user_id	friend_id
1	2
1	3
1	4
2	5
2	6
2	7
3	8
3	9
3	10

vs

Graph



If you double the number of rows in the table, you've doubled the amount of data to search, and thus doubled the amount of time it takes to find what you are looking for

You always walk the graph at most once. Conversely, a graph database looks only at records that are directly connected to other records. If it is given a limit on how many "hops" it is allowed to make, it can ignore everything more than that number of hops away.

Real-world example: is there a fraudster up to 4 hops away, on very active customer (worst case)?

- SQL created by Paysafe (32 lines)

- **1 day:** 50 min 20 sec
- **1 week:** *(cancelled after 4 hours)*
- **1 month:** *(did not even try)*

- SQL optimized by Oracle (62 lines)

- **1 day:** 20.3 sec
- **1 week:** 8 min 33 sec
- **1 month:** *(cancelled after 6 hours)*

- 4 PGQL queries (7 lines each)

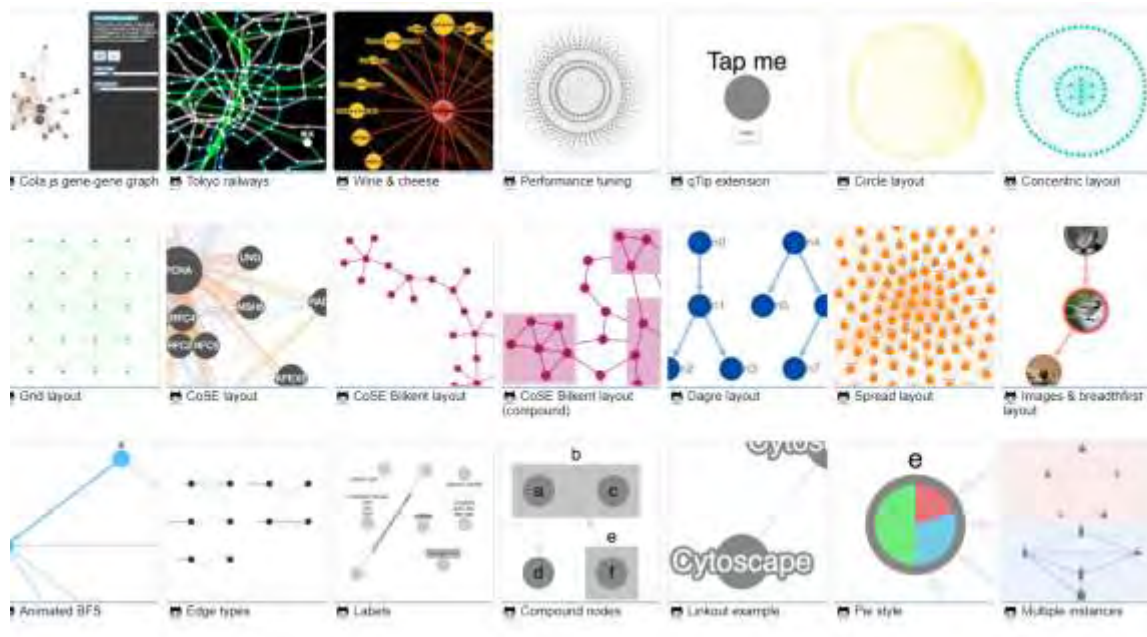
- **1 day:** 0.547 sec
- **1 week:** 0.588 sec
- **1 month:** 0.597 sec

```
SQL created by Paysafe (32 lines)
SQL optimized by Oracle (62 lines)
4 PGQL queries (7 lines each)
```

```
SELECT ...
MATCH (v0) -[e0_1:"pays to"]-> (v1)
WHERE (v1.isMerchant = false)
      AND (v0.customerId = ...)
      AND (e0_1.requestTime >= ...)
      AND (e0_1.requestTime <= ...)
LIMIT 20000
```

Payments Flow Visualization

- Cytoscape is an [open source](#) software platform for visualizing complex networks and integrating these with any type of attribute data.
- There is a JS library supporting many different layouts
- Make asynchronous call for any hop, display up to 10 hops in seconds



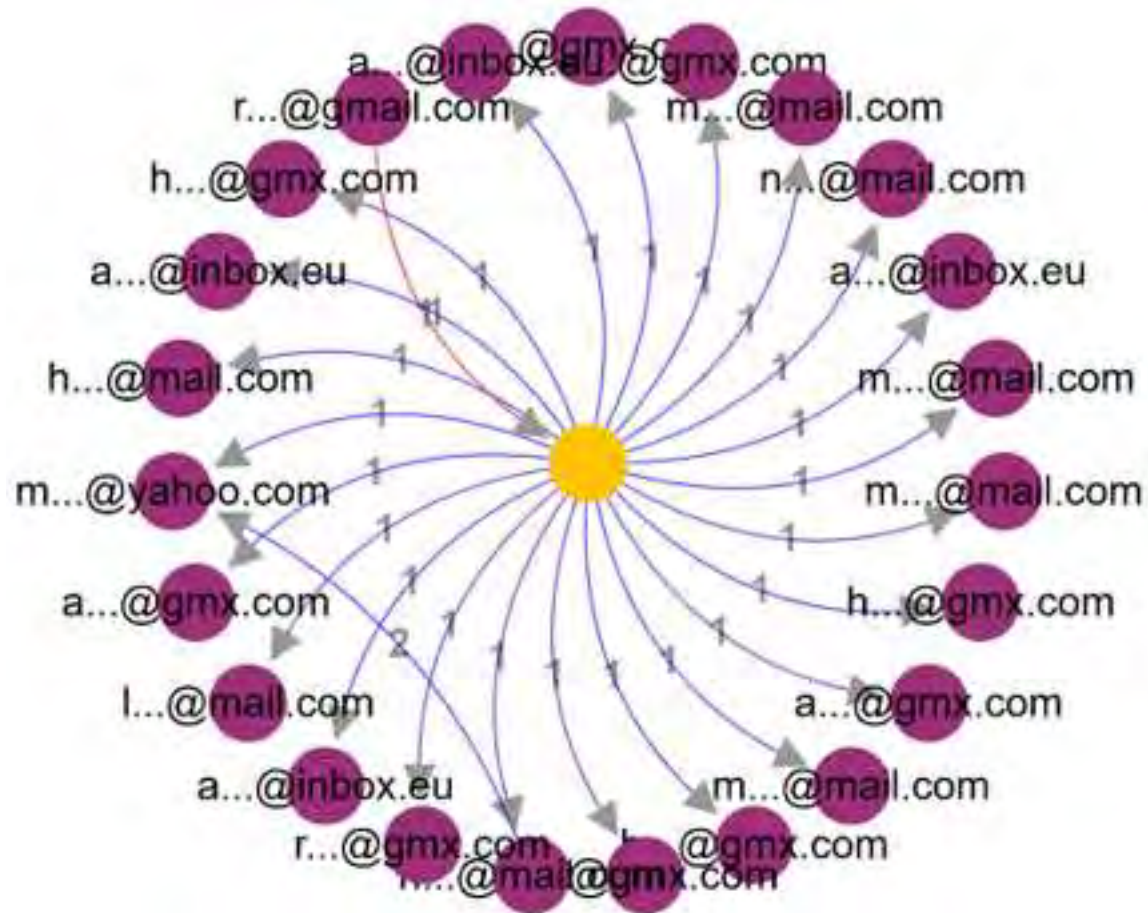
Typical customer behavior

Filter: From Date: 12/15/2018 To Date: 12/13/2018 Filter by: 100% Send Money Receive Money (Apply Filters) First on page: Customers at All times Customer ID: 45525075461 Company: Neteller Email: a...@gmail.com Legend: Green: Active Customer Purple: Suspended Customer Yellow: Inactive Customer

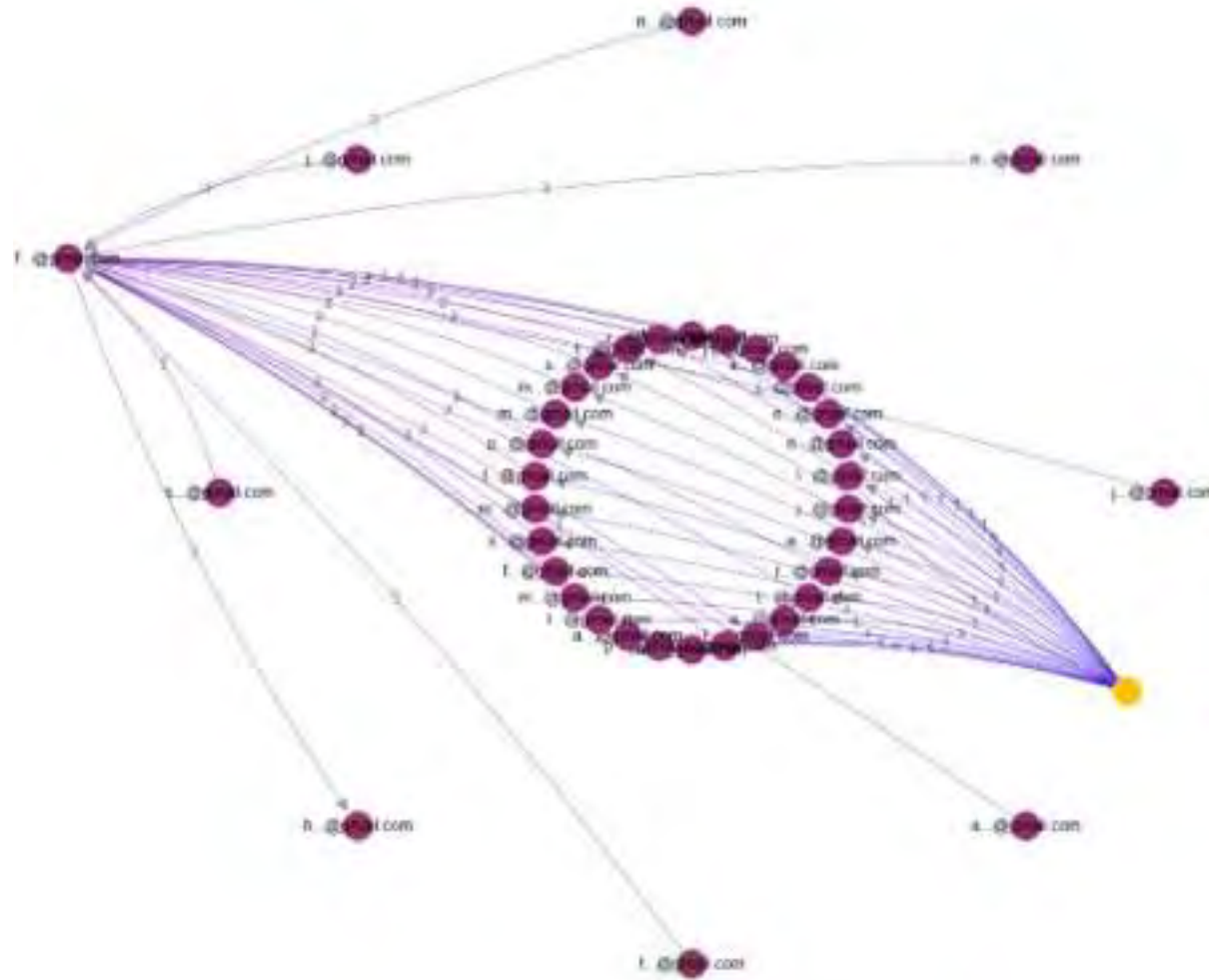
Basic graph



Detected network (one send to many)

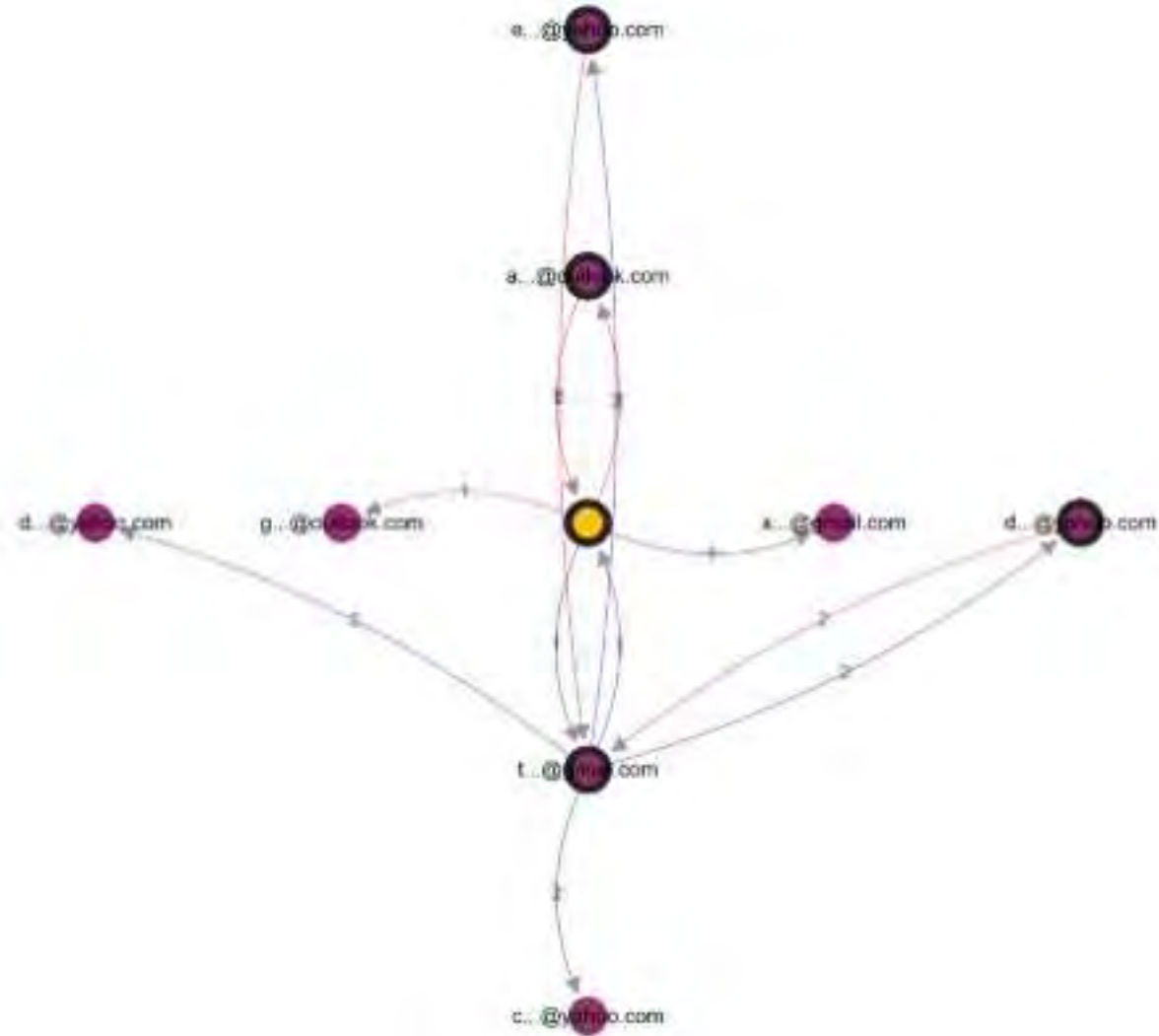


Placement, Layering, Integration



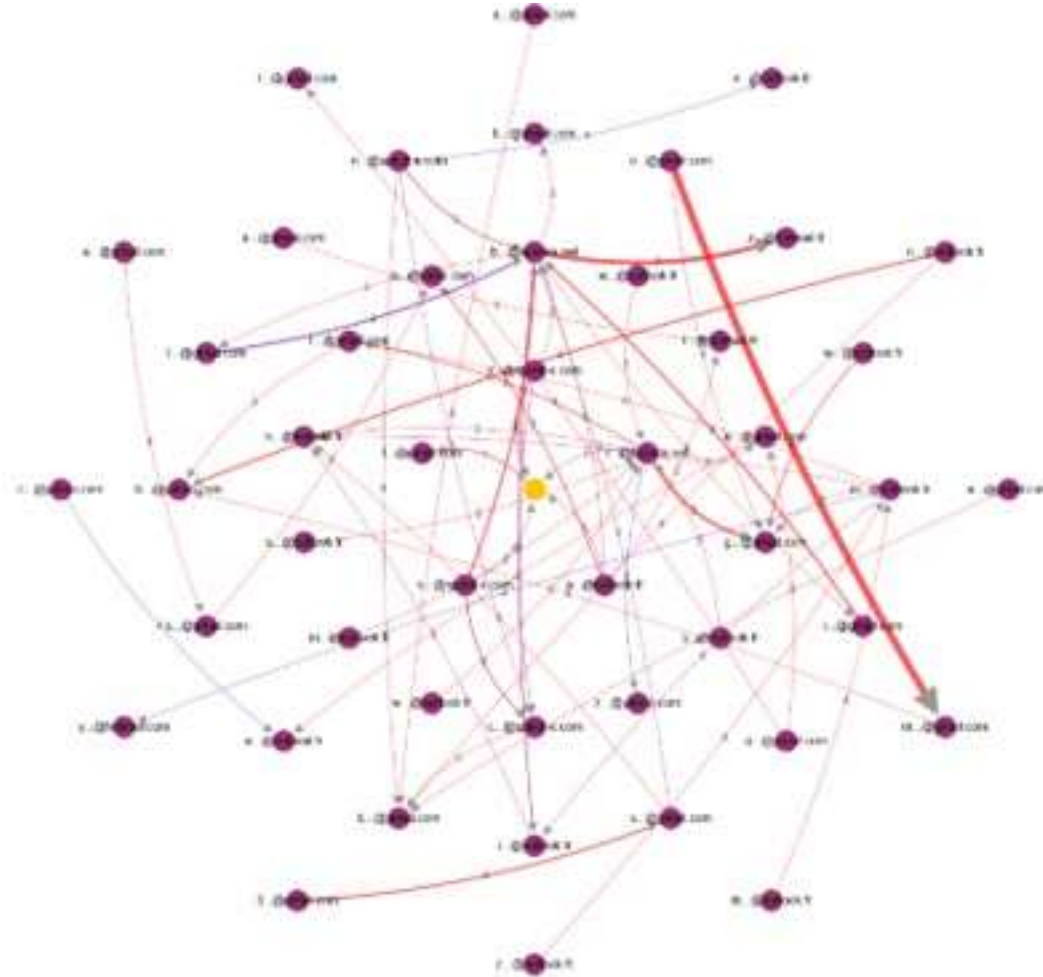
Multi-level network

More than
one level

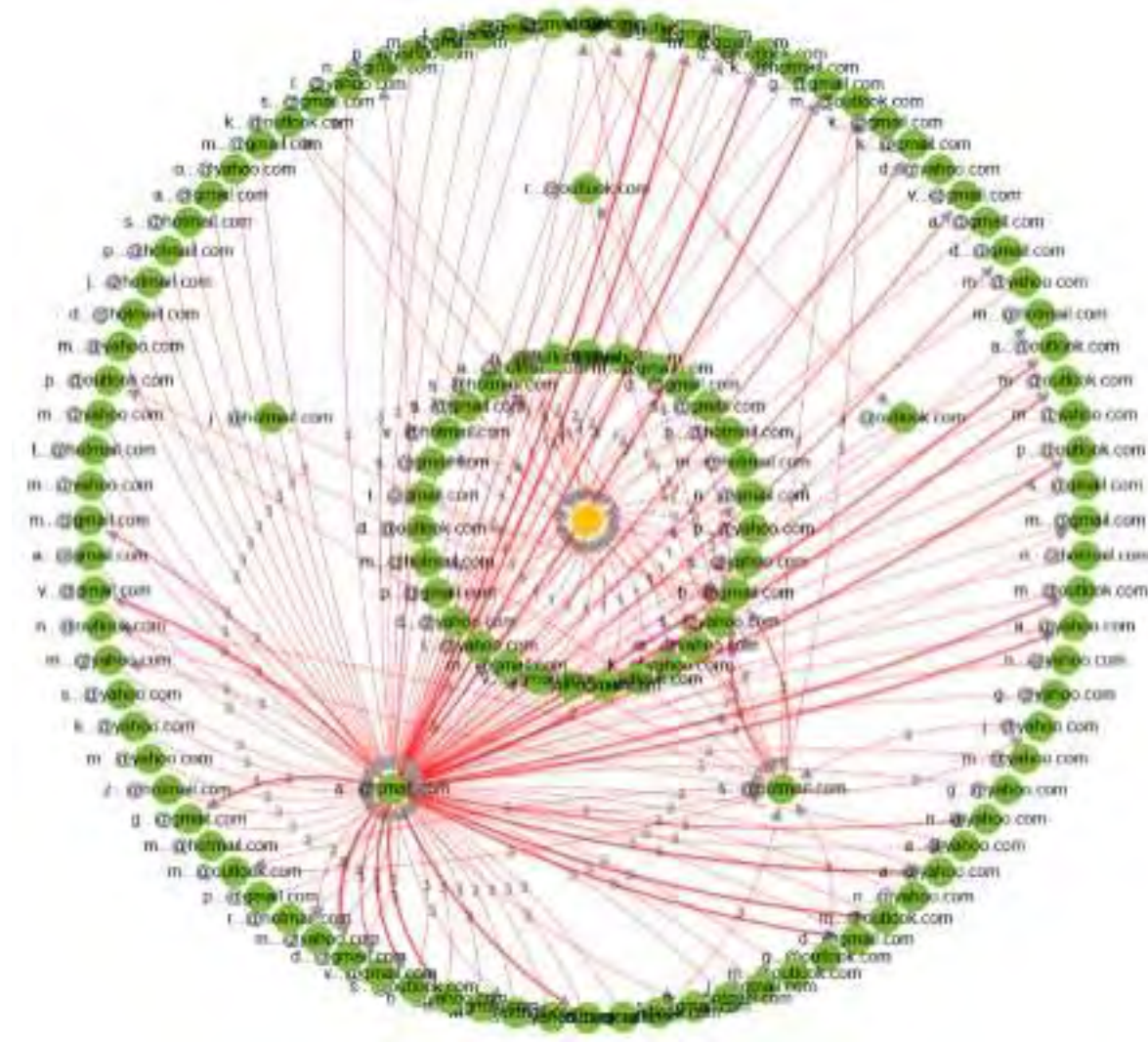


Multi-level network

A bit more complex



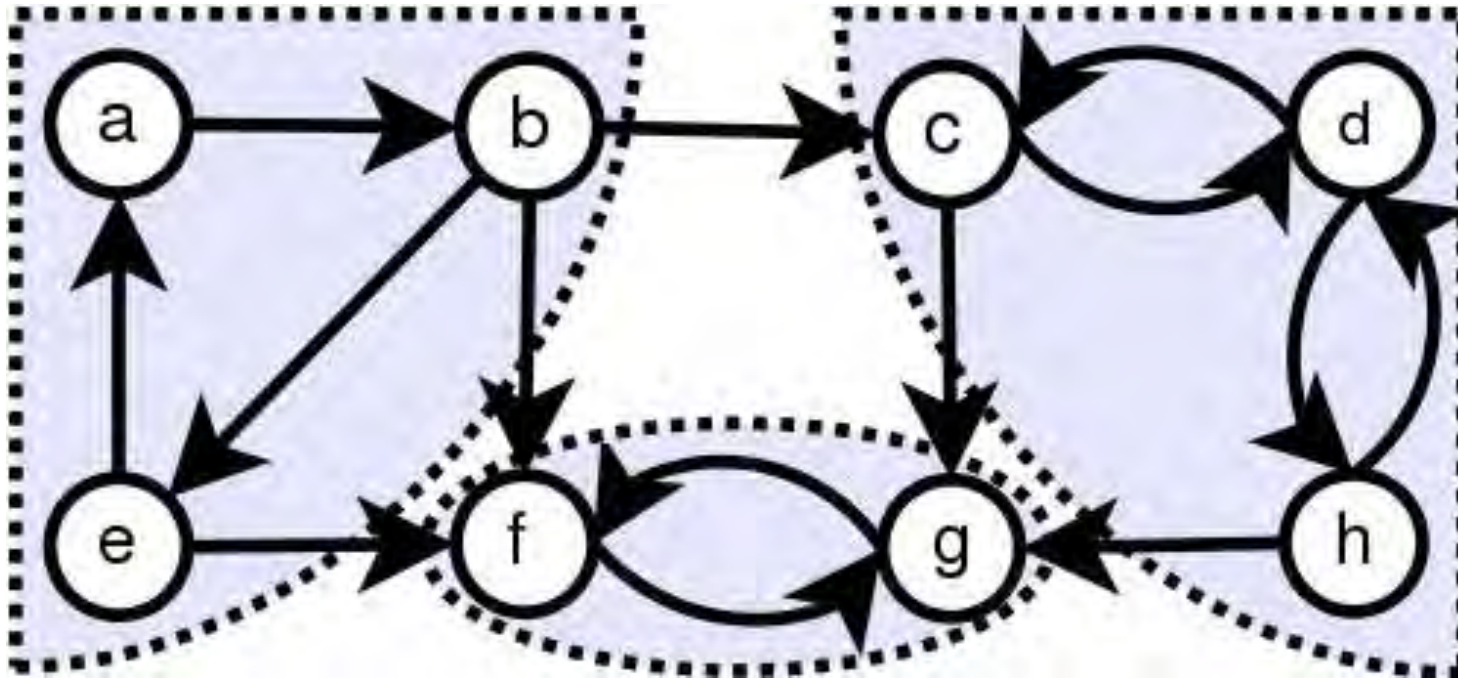
Network of networks



Graph Analytics

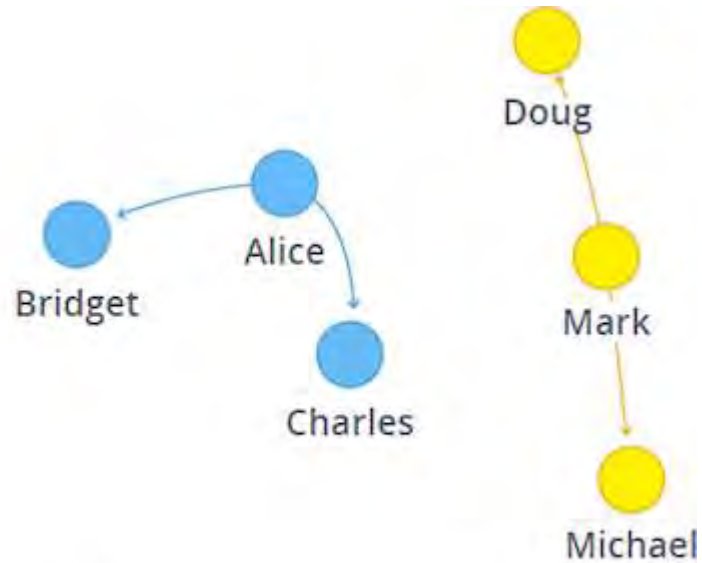
- Page rank
- Community detection
- Strongly connected components
- More built-in algorithms available
- Custom-defined algorithms with Green Marl

Strongly Connected Components



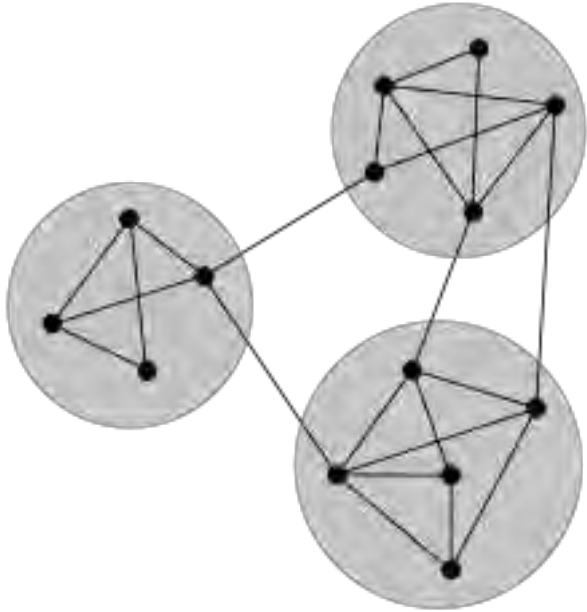
Subset of the graph where every vertex is reachable from every other vertex following the directions of the edges

Weakly Connected Components



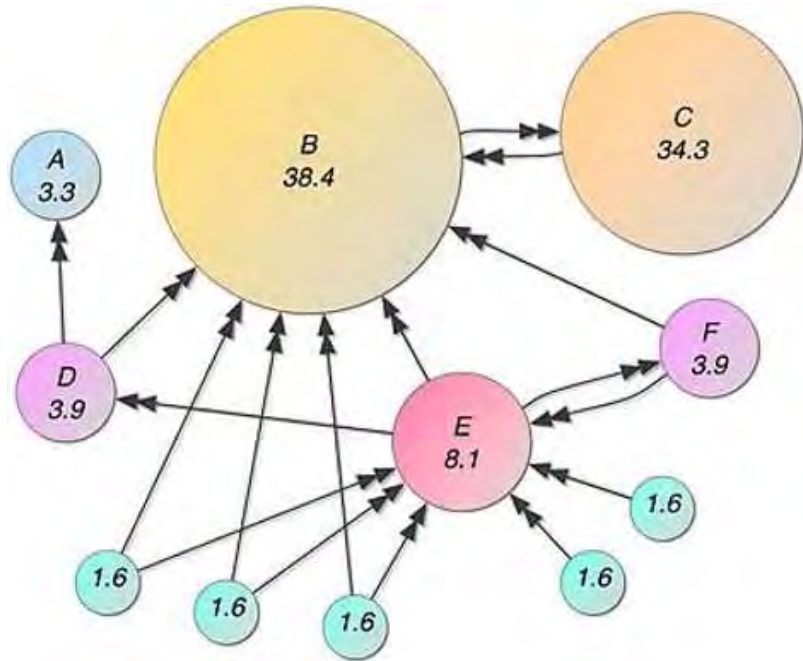
Subset of the graph where every vertex is reachable from every other vertex (directions of the edges are ignored)

Community Detection



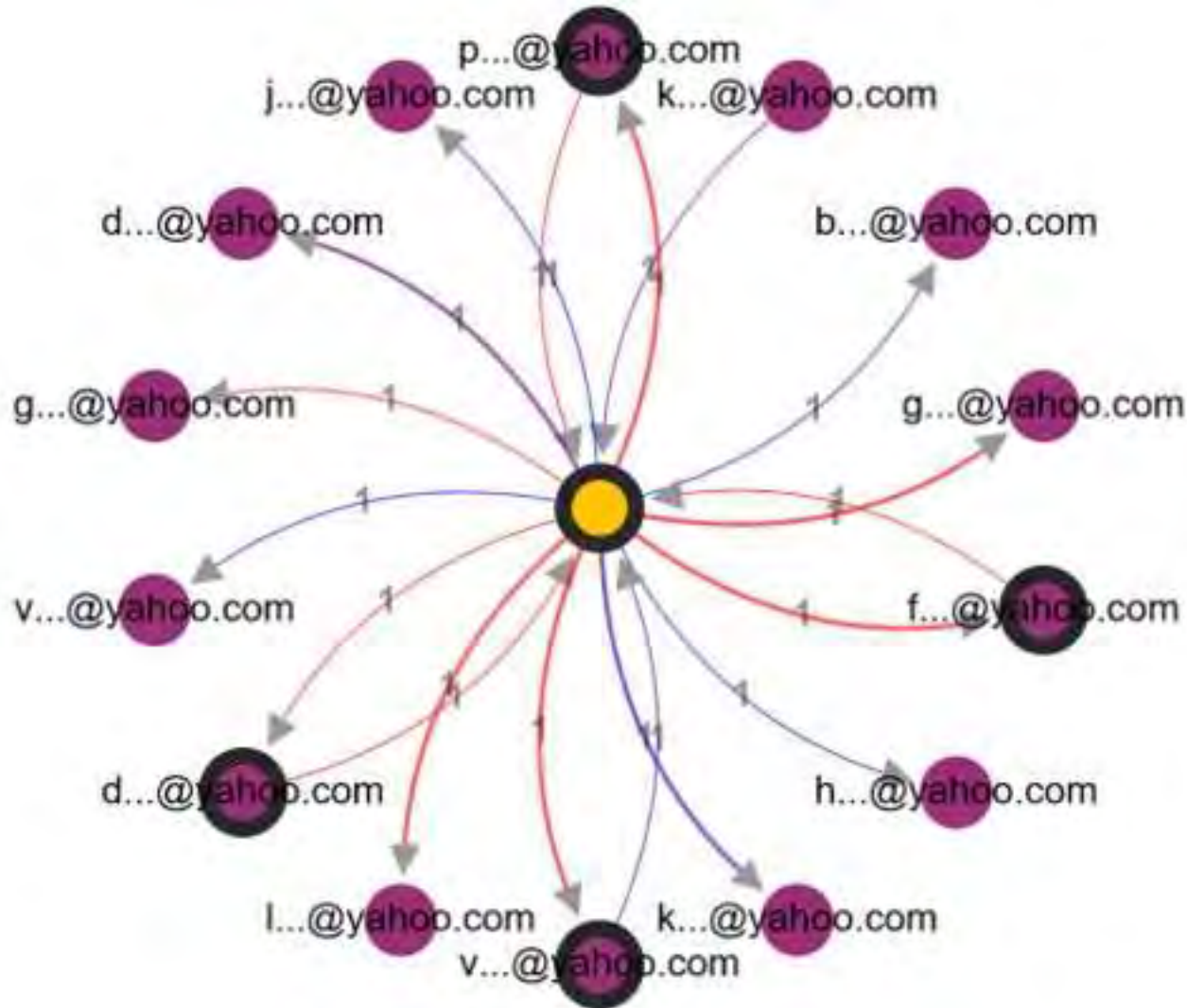
Finding sets of nodes such that each set of nodes is densely connected internally. Community structures are quite common in real networks. Social networks include community groups (the origin of the term, in fact) based on common location, interests, occupation, etc.

Page Rank

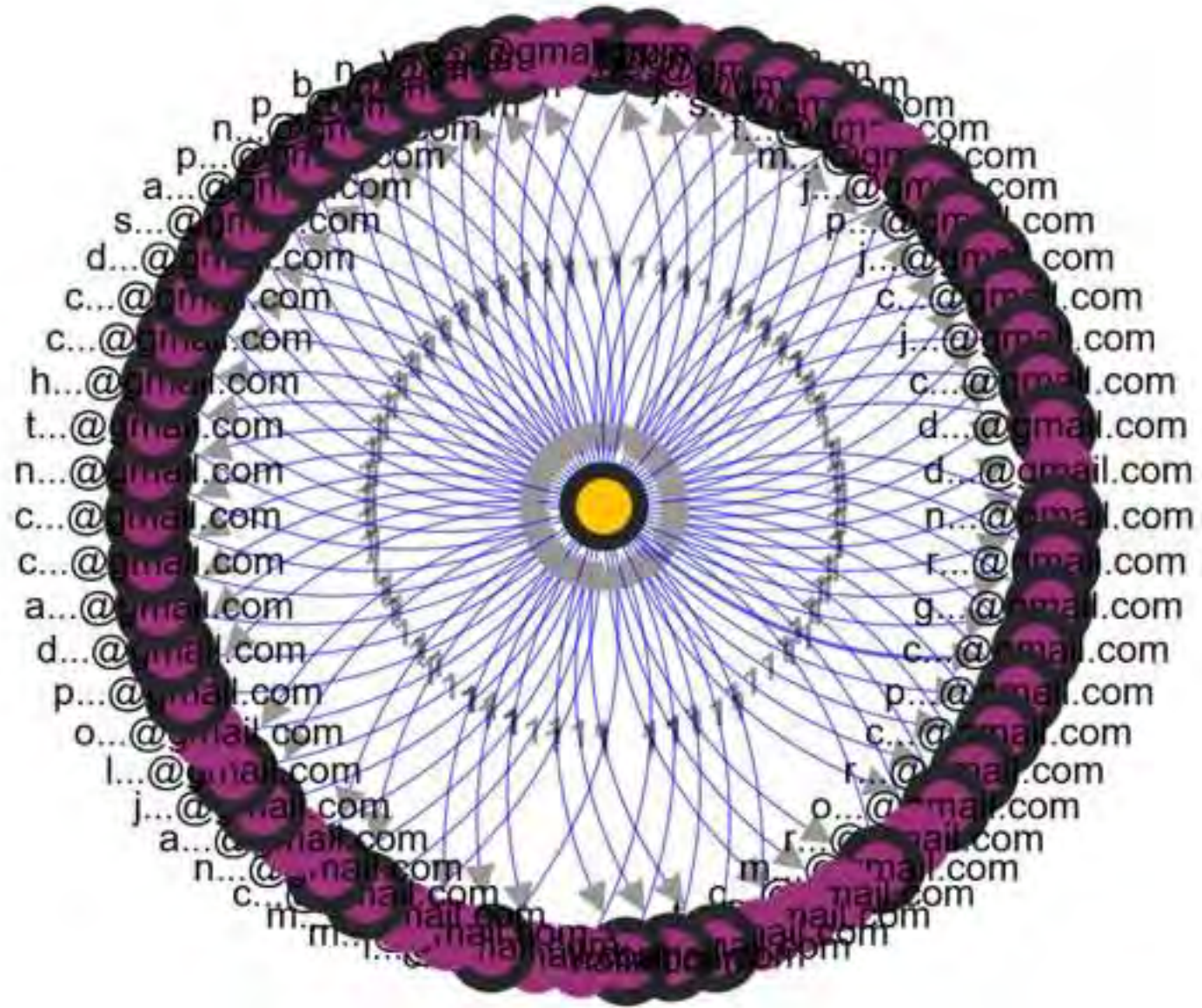


PageRank (PR) is an [algorithm](#) used by [Google Search](#) to rank [websites](#) in their [search engine](#) results. The PageRank algorithm outputs a [probability distribution](#) used to represent the likelihood that a person randomly clicking on links will arrive at any particular page

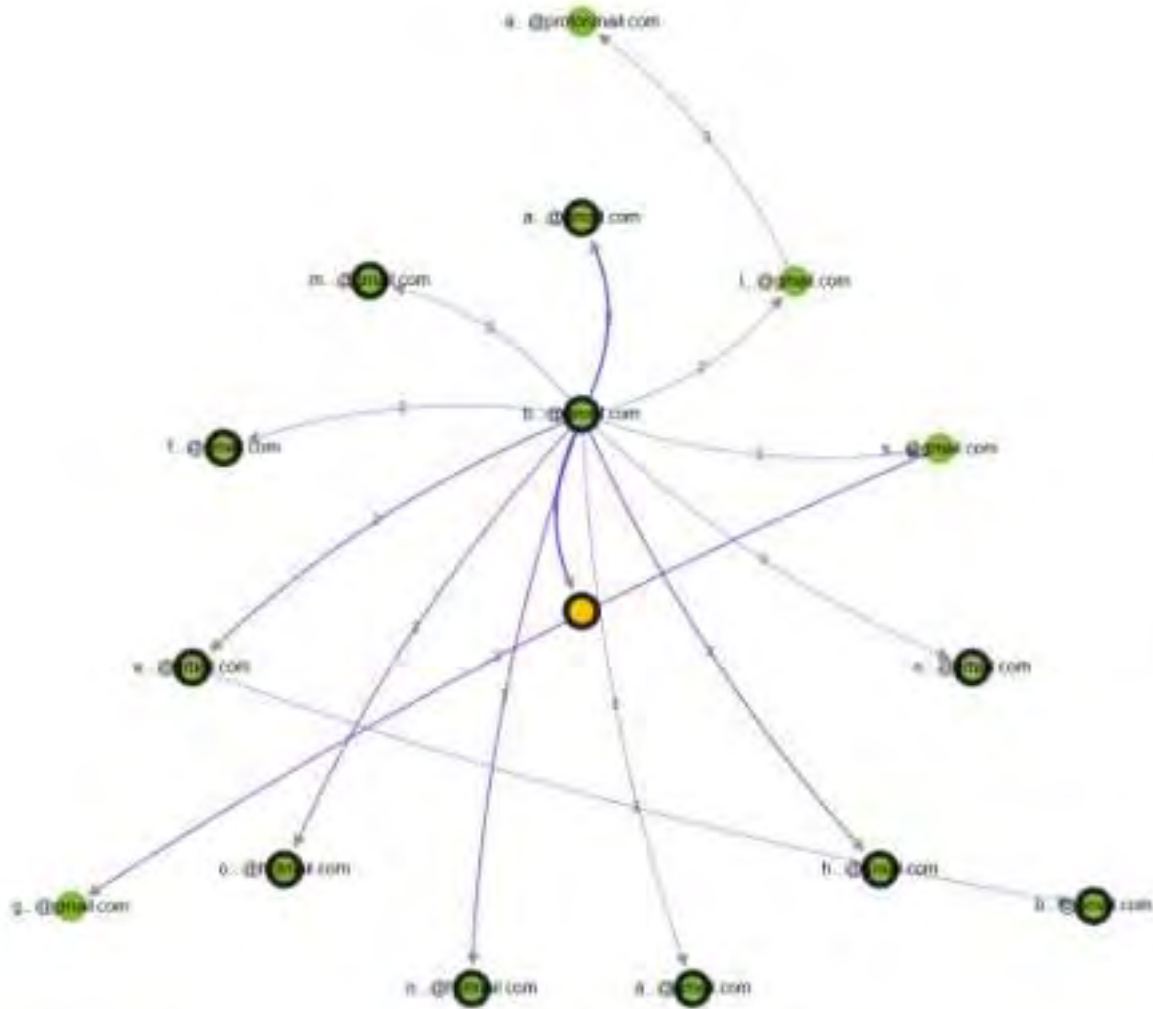
Strongly Connected Components



SCC with 50 members
(always
19 EUR out)



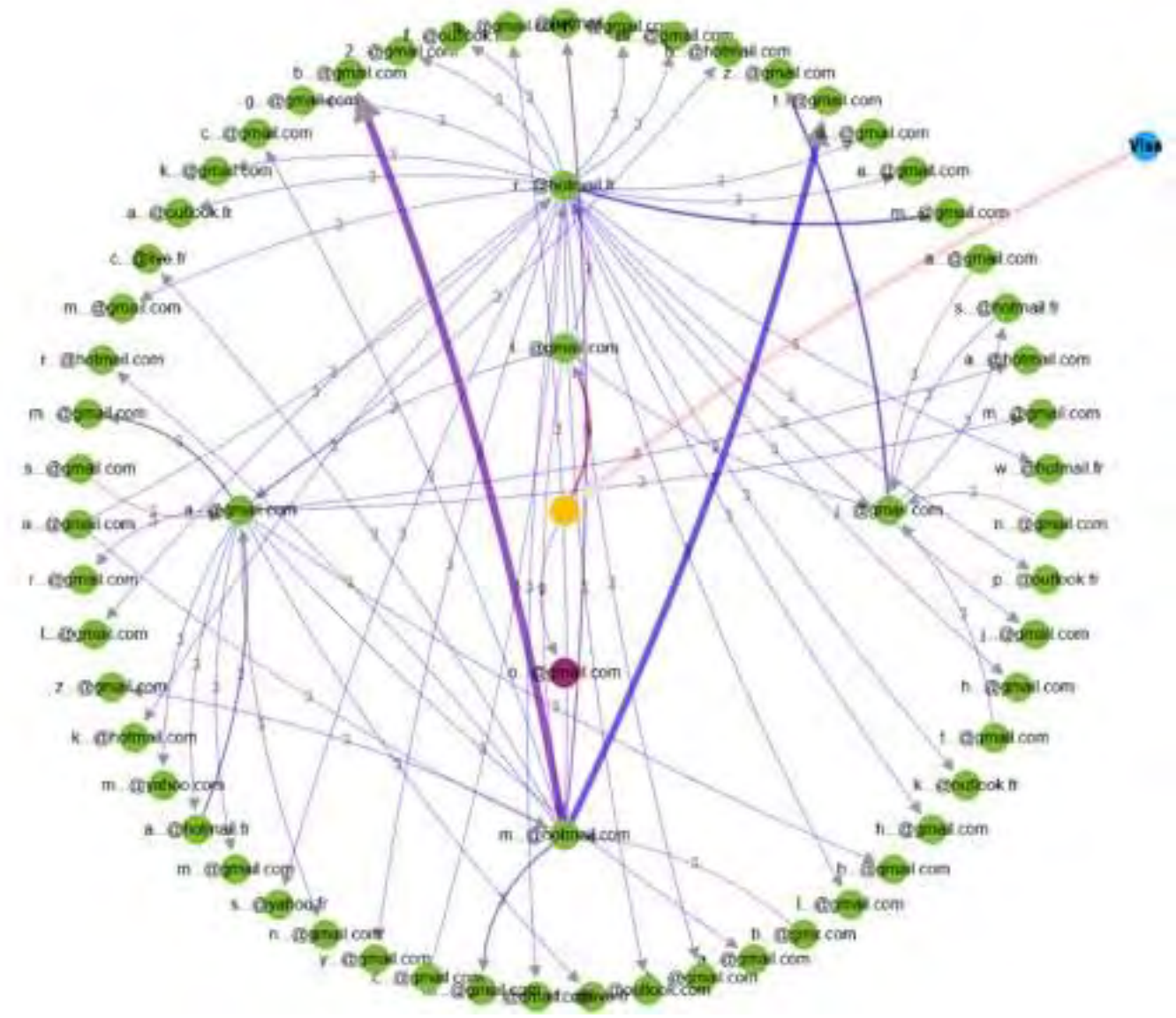
Community detection



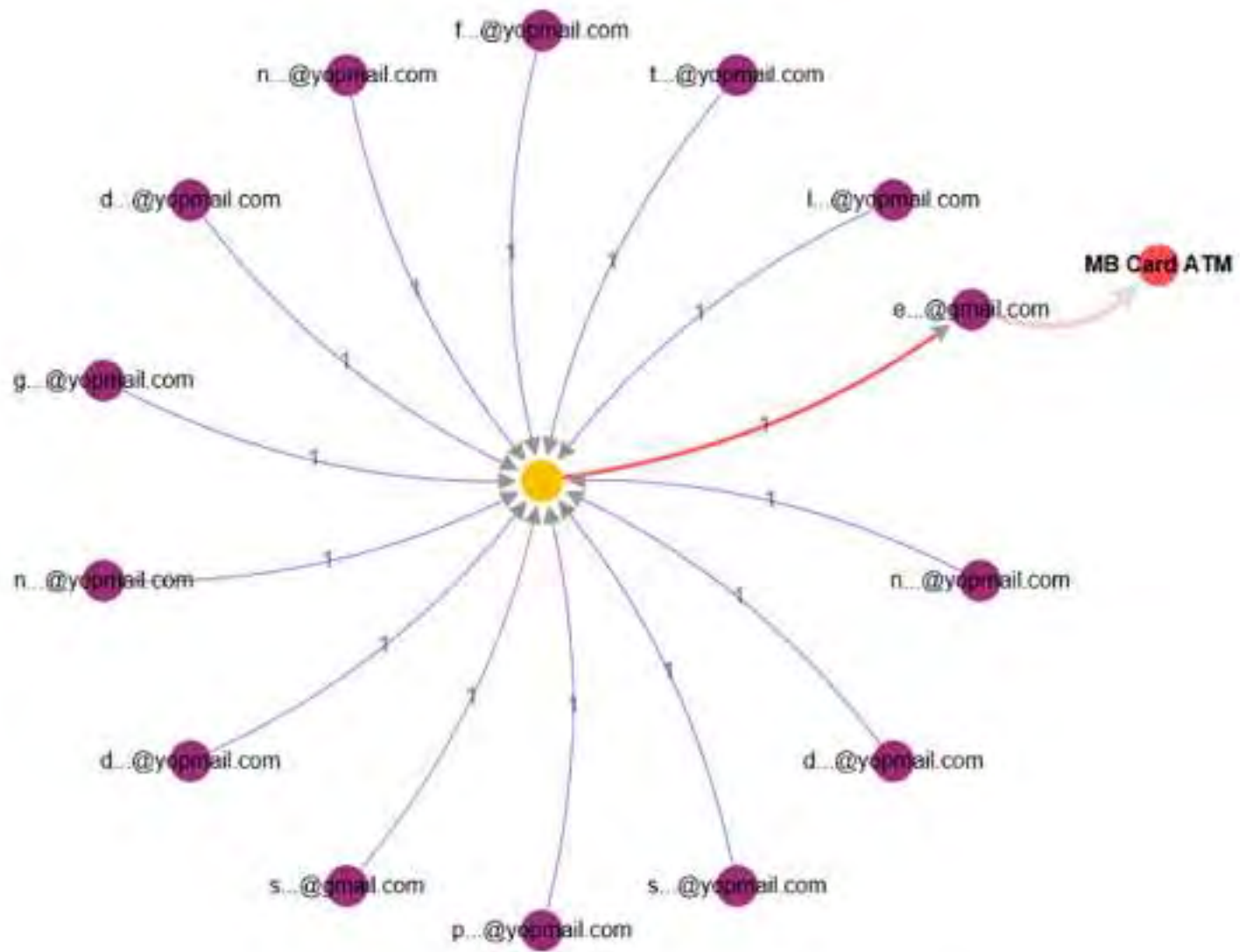
The right tool for the right job

- Payments are in the graph
- Deposits and Withdrawals are in the RDBMS

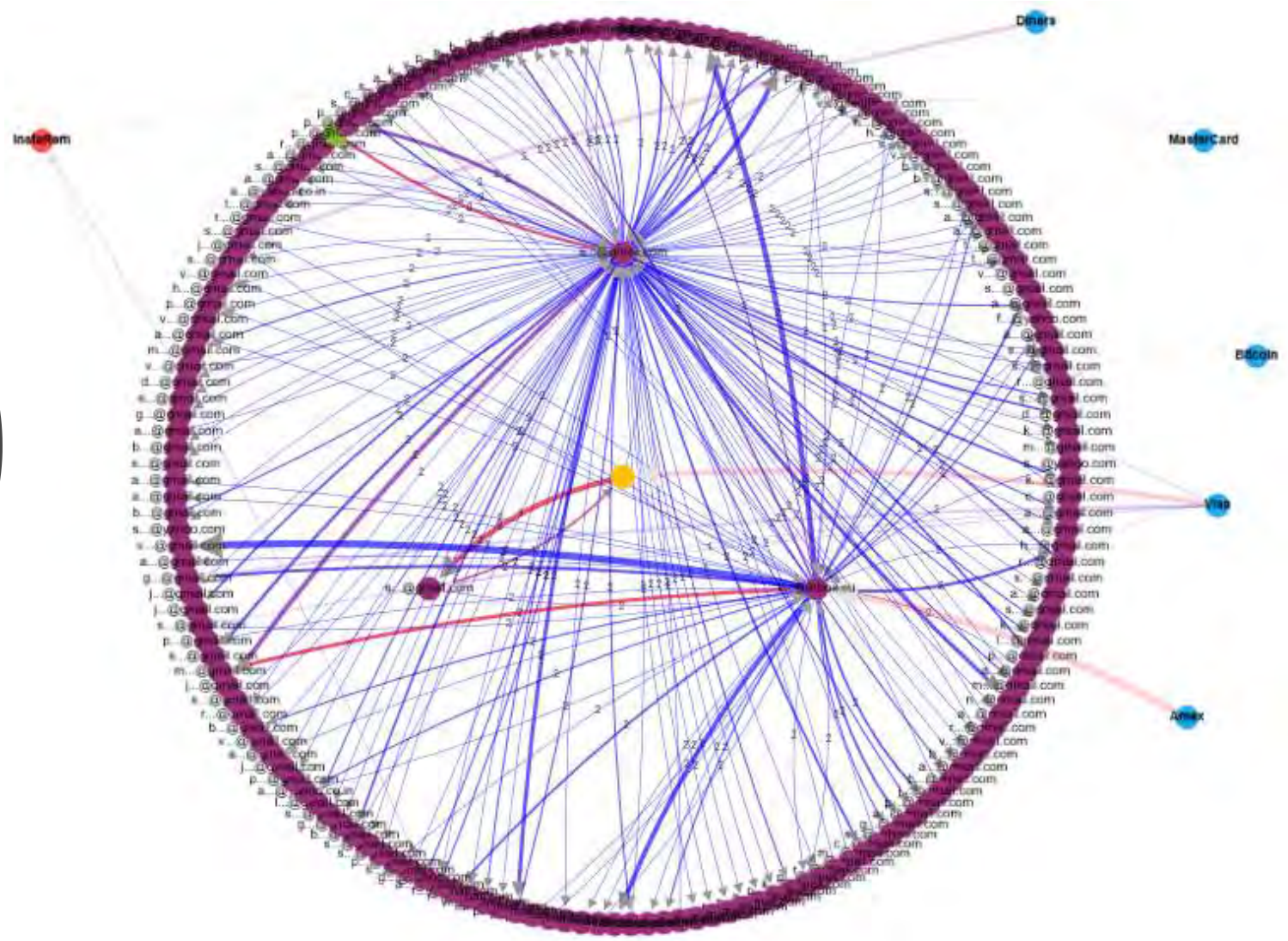
Money entering the system



Taking the money out



Deposits and Withdrawals



Use Case Performance Results

- Finding all communities for a given day up to 3 minutes
 - Community detection for 72-hour period: 7 sec
 - SCC for the same period: 6 sec
 - Top 10 Customers Page Rank: ~0.8 sec
- Memory statistics
 - Total edges count: 70 M with 350M properties
 - Edges size in DB: 72 GB (only the table)
 - Total vertices count: 4M with 12M properties
 - Vertices Size in DB: 2 GB (only the table)
 - Graph in size in PGX memory - 10GB
- Visualizing customer graph, up to seconds, but still depending on the relations
- Performing PGQL query in milliseconds – can be used in real-time

New World of Opportunities

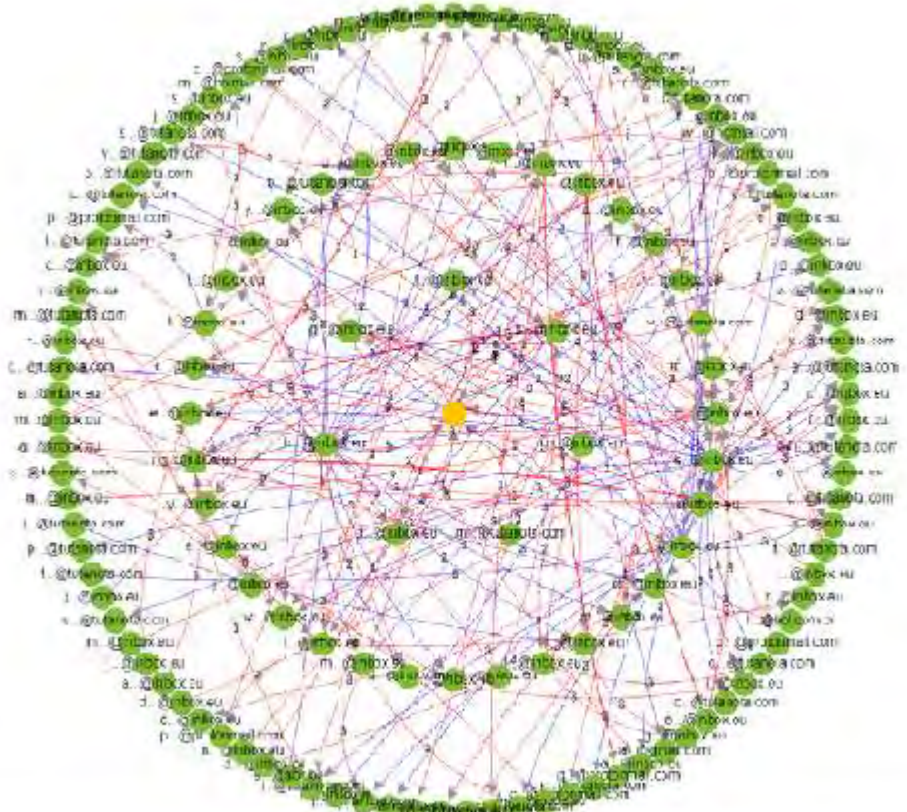
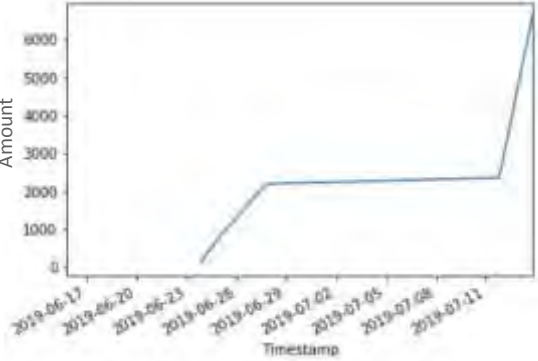
- **Graph queries can be used as normal SQL queries to flag a risk transaction while the payment is being processed**
 - If customer is linked with fraudster in range 2 hops, additional verification can be requested
- **Graphs enhance AI by providing context by enabling connected features to ML. Relations or connected features tend to be highly predictive.**
 - Is there a fraudster in range of 3hops, 4hops, etc. can be a highly predictive ML feature
 - Feed page rank in a machine learning model
- Detect fastest growing networks and examine community evolution

Fastest Growing Networks

- Generate Proactive Report for the **Fastest Growing Networks** in terms of **money flow(edge property)**, **number of payments(edge count)** and **number of customers(vertices)** on a time series data from the graph
- Influencer found by Page Rank calculation

Community Id	Sample Customer Id	rank	Amount Growth Pct	Amount Growth Abs	Edge Count Growth Pct	Edge Count Growth Abs	Vertex Count Growth Pct	Vertex Count Growth Abs
2884	102966	457924810425	8.866444e-07	71.773076	6521.553403	0.25	0.4	0.4

- Community Activity



Example for a fastest growing community by money flow and rolling period of five days and daily time series data.

Graphs are REALLY
powerful



Image courtesy www.networkworld.com

Paysafe:

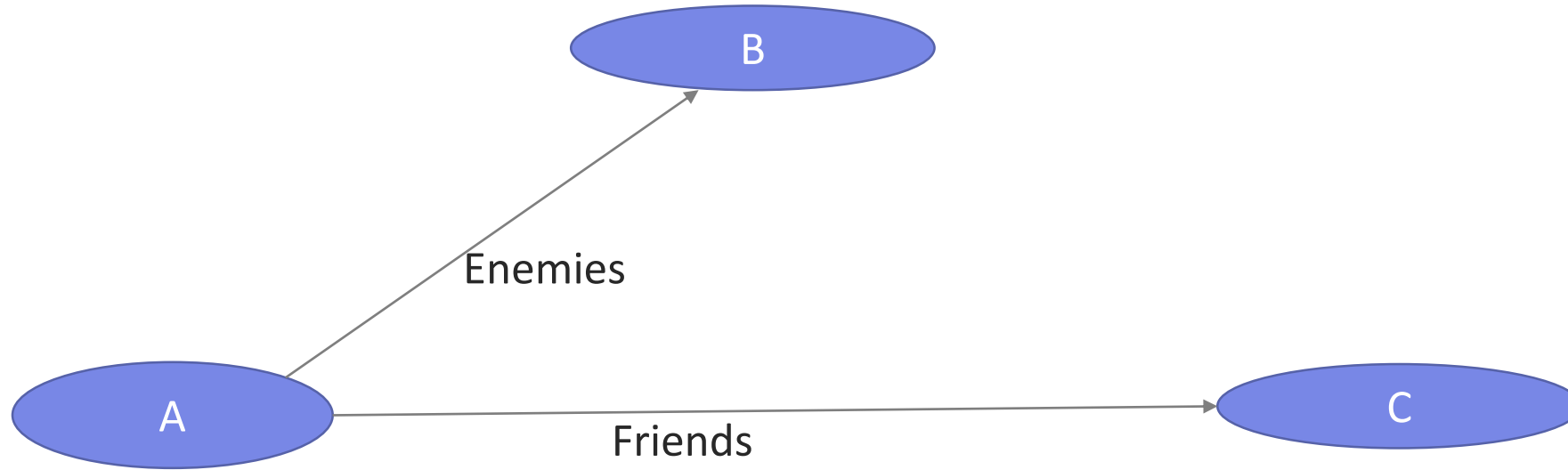
Summary

- In a world of real-time payments, money processing becomes faster and more automated. Fraud checks upon payment should happen fast and the time to identify fraud patterns or networks is really narrow.
- Link analysis can enhance fraud detection by running queries using graph database during key stages in the application lifecycle
 - Upon money move
 - Account creation
 - During investigation
 - When some thresholds are hit
- Traditional technologies are not designed to detect fraud in real-time. Graph databases enable fast and effective real-time link queries.

Takeaways

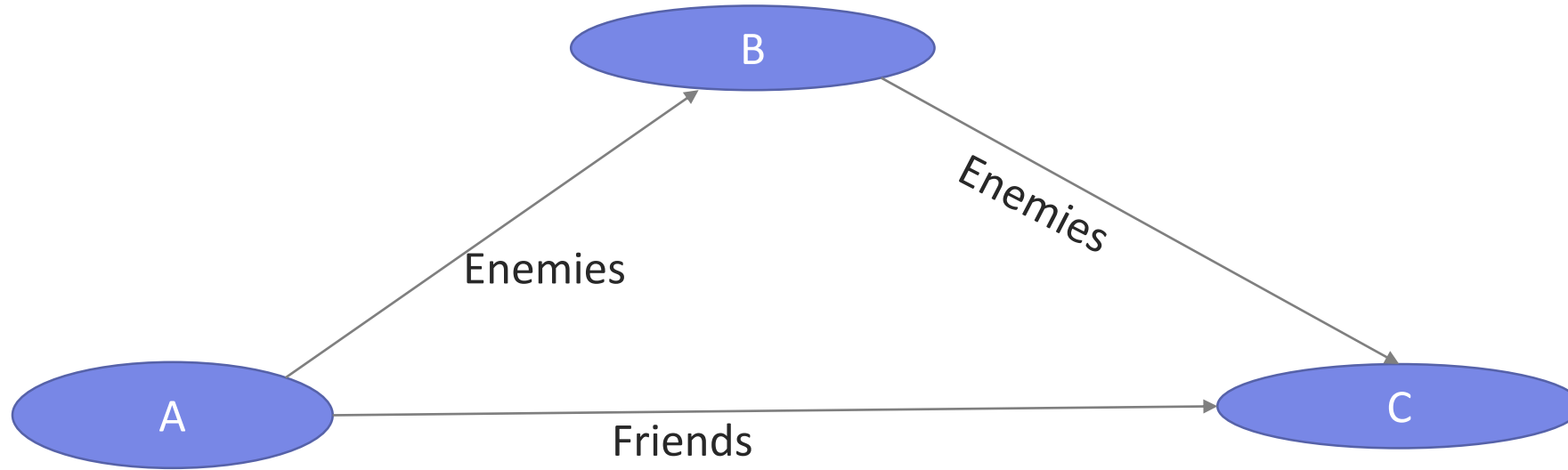
- Graphs are useful for real-time decision making on connected data
- Powerful data analytics
- Go step further with machine learning models
- You can do so much AI with Graph

Link Predictions



Question: What is the connection between B and C?

Link Predictions



Question: What is the connection between B and C?

Resources

[O'Reilly's Graph Databases: New Opportunities for Connected Data](#)

[O'Reilly's Graph Algorithms Book](#)

[Graph Databases: The Next Generation of Fraud Detection Technology](#)

[Cypher – graph query language](#)

[Oracle Property Graph Query Language](#)

[Link Prediction](#)

[Graph Theory with Applications](#)

Very interesting talk:

[How Graph Technology Is Changing Artificial Intelligence and Machine Learning](#)

