PEAK CONSULTING

Social Network Analysis:

Practical Uses and Implementation

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Introduction to Social Network Analysis

Definitions: Social Network

Social Network: A social structure composed of individuals (or organizations) interconnected by one or more specific types of interdependencies such as friendship, kinship, financial exchanges, communication exchanges, etc.

Definitions: Social Network Analysis

Social Network Analysis: The application of graph theory to understand, categorize and quantify relationships in a social network.

In the representation of a social network, nodes in a graph represent the individuals or organizations (actors) and edges in the graph represent interdependencies. Edges may be either directed or non-directed.

Why should you care about SNA?

- Customer are sceptical: if you want to sell your products to your customers, convince their friends.
- If you want to sell lots of stuff to your customers… do it in a viral way (target the “right” customers).
- Use social network analysis to understand more about your customers and their communities.
- Enhance existing reports, modelling tools, and methodologies with social metrics.

Why should you care about SNA?

Traditional marketing practices are becoming obsolete.

- Test and control group methodologies no longer work as intended.
  - Information exchange between individuals within an online social network is extremely high.
  - Difficult to keep control group “pure”.
- Need to understand behaviour across and within communities rather than focusing just on individuals.
- Leverage (and protect against) high velocity of information exchange within on-line social networks.

How does a Customer with the Role of an Influencer in the Social Network Work?

- Influential user adopts a product or behaviour.
- Influential user tells (and influences) his or her immediate contacts within the community.
- These immediate contacts tell their contacts.
- ...and the viral marketing spreads.

It is important…

- To identify these people.
- To influence these people.
- To monitor the behaviour of these people.

Roles in a social Network

Malcom Gladwell characterized key actors in a social network in his seminal work *The Tipping Point*:

Connector: people who "link us up with the world … people with a special gift for bringing the world together". Gladwell characterizes these individuals as having social networks of over one hundred people.

Salesperson: people who are charismatic with powerful negotiation skills. They tend to have an indefinable trait that goes beyond what they say, which makes others want to agree with them.

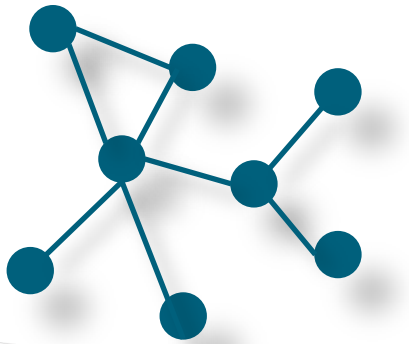
Maven: people who are "information specialists" or "people we rely upon to connect us with new information". They accumulate knowledge, especially about the marketplace, and know how to share it with others.

Social Network Analysis

Recommended Approach

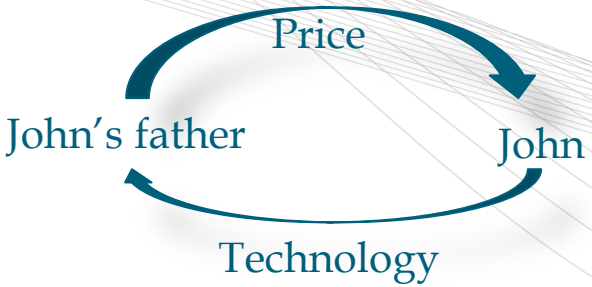
1. Identify the Social Network
   - Who contacts whom?
   - How often?
   - How long?
   - Both directions?
   - On Net, Off Net?

The Social Network



2. Identify Influencers for each Topic
   - Who influence whom, how much, on what purchases?
   - Who influences whom, how much on churn?
   - Who will acquire others?

There is no 'general' influencer!



Definitions: Social Network Analysis

Rather than treating individuals (persons, organizations) as discrete units of analysis, social network analysis focuses on how the structure of ties (links) affects individuals and their relationships.

Not a new science:

- Started in the social sciences.
- Formalized by J.A. Barnes 50+ years ago.
- Six degrees of separation small world phenomena.
  - Stanley Milgram's post mail experiments.
  - Watts, Dodds, Muhamed email study.

A boom of popular press:

- Gladwell: *The tipping Point*
- Watts: *Small Worlds: The Dynamics of Networks Berween Order and Randomness.*
- Barabasi: *Linked: The New Science of Networks*
- Watts: *Six Degrees: The Science of a Connected Age*

Definitions: Graph Theory

Directed Edges: Captures the "direction" of a relationship. For example, A calls B would have a different direction than B calls A.

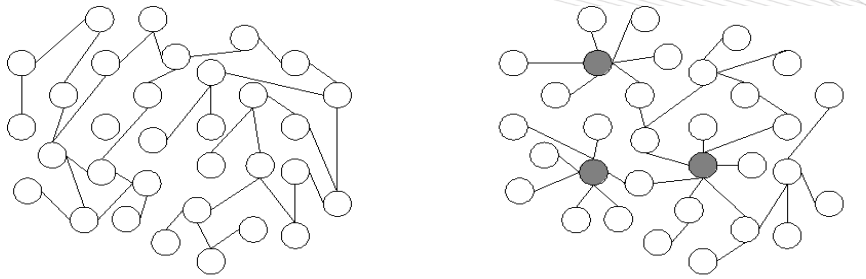
Non-directed Edges: Relationship has no direction. For example A is married to B is the same as B is married to A.

Edges can be binary (e.g., exist or not) or weighted (e.g., representing a count of the number of calls between two individuals).

Definitions: Graph Theory

A **scale-free network** is a network whose degree distribution follows a power law, at least asymptotically. That is, the fraction *P(K)* of nodes in the network having k connections to other nodes goes for large values of k as $P(K) \sim K\text{-}Y$ where *Y* is a constant whose value is typically in the range $2 < Y < 3$, although occasionally it may lie outside these bounds.

Node connectivity is defined by power law.



(a) Random network (b) Scale-free network

Definitions: Graph Theory

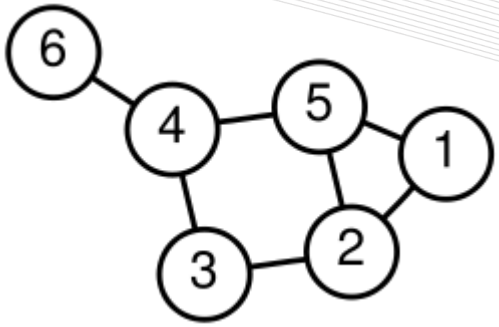
The shape of a social network can influence its behaviour and usefulness.

- "Closed" social networks are tightly knit with many redundant ties.
  - In-breeding of ideas: persons who only interact with each other share the same ideas and opportunities.
  - Characterized by a (near) fully connected graph.

- "Open" social networks have loose ties (weak links) across multiple communities.
  - More likely to introduce new ideas and opportunities to their members.
  - Requires connector nodes to bridge across.

Definitions: Graph Theory

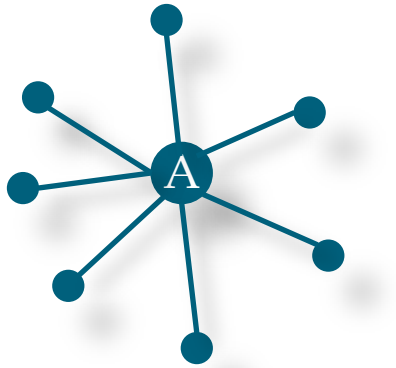
- A clique is a fully connected set of nodes within a graph.
- An N-Clique is a subgraph of N nodes (actors) which are fully connected (“closed” network).
- Maximum clique detection within a graph is an NP-complete computational problem.
- A K-plex is a less strict subset of the graph.
- A giant component is a connected subgraph that contains a majority of an entire graph’s nodes.



Social Network Analysis

Circle analysis:

- Neighbours of a node.
- Count neighbours (degree).
- Count those in circle@
  - Who churned,
  - Who have a product P,
  - Who became customers after node A,
  - …..
- Enrich node label with these metrics.

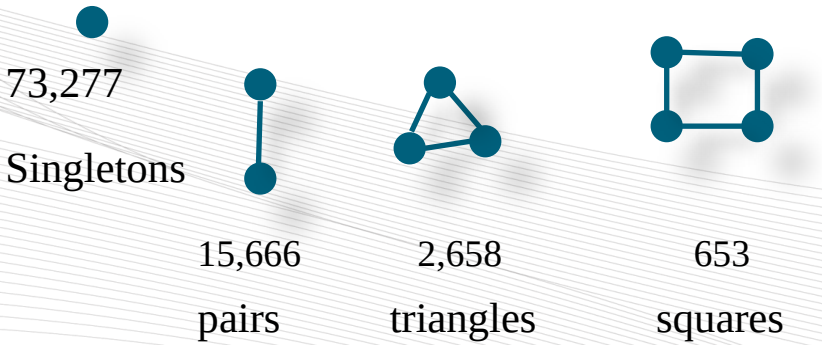


Key Observation: Few Isolated Communities Exist in the Real World

- Most subscribers are part of a single mega-community.
- Splitting them up requires artificial decisions.
- Experiment:
  - Five random starting
  - subscribers.
  - Count number of new subscribers in degree 1, degree 2, etc.
  - Conclusion:
    - Peak numbers between degree 5 and degree 7.
    - Very few new subscribers after degree 8.
    - Most subscribers are interconnected, rather than in discrete communities.

Key Observation: Few Isolated Communities Exist in the Real World

An example with real world data:



From 5 to 22 nodes:

- 320 communities.
- 1905 nodes.

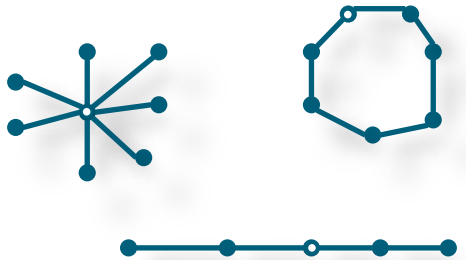
Large Component of **1.1M nodes**

(with off-network nodes = 3.6M)

Metrics and Implementation

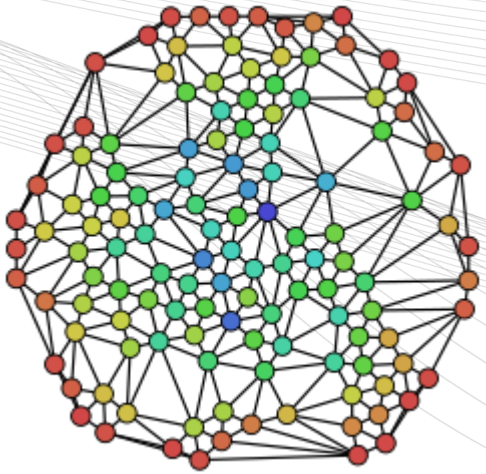
Calculation of Metrics from a Social Network

- In networks, **connection is power**.
  - Centrality is a key measure.
  - "Social Degree" measures how well a node is connected.



- An "influencer" is a node that is well connected.
  - Capable of propagating information to lots of people via Word-of-Mouth (Mouse).

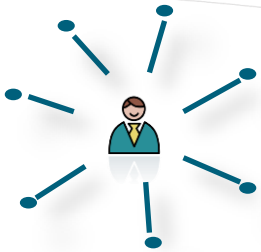
- There exist many measures to identify the power to influence.
  - Depending on your data, some might be easier to compute than others.
  - Some might bring more useful information than others.



Overview of Social Network Analysis

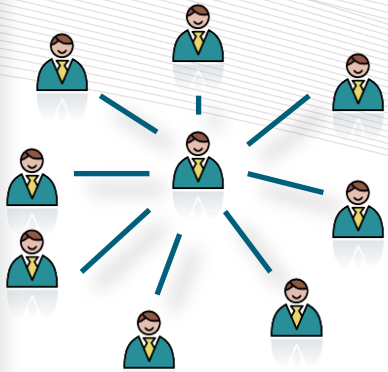
Circle Analysis:

- Count the number of contacts.
- Rank best contacts.



Connection Analysis:

- Profile contacts.
- Describe each customer by its contacts.
- Social boundaries.



Community Analysis:

- Identify communities.
- Add each customer to its community.

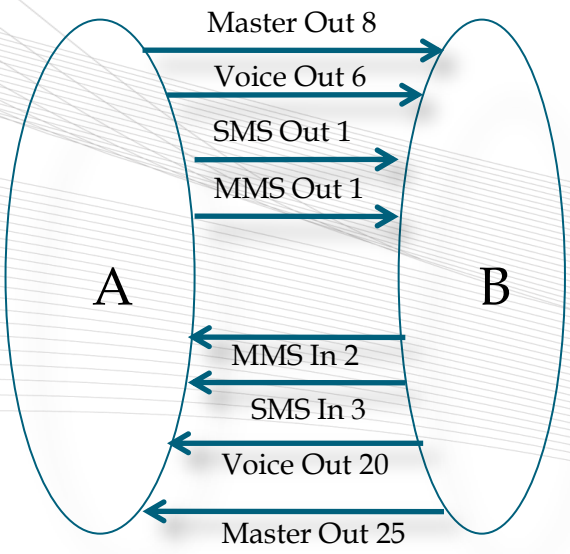
Social Leader Analysis:

- Identify social leaders.
- Analyze impact of the social leaders.

Recommended Approach: Key Steps

- Data preparation.
  - In-database conversion of data to Node: Edge model.
  - Data filtering.
- Metric calculation.
  - In-database calculation of SNA metrics.
  - Degree, Centrality, Betweenness, etc…
- SNA model creation: inverse cascading model.
- SNA model scoring.
- Target and control group creation.
- Measurement.

Data Preparation Example: From XDR to Node/Edge Graph



Performed for on-net and off-net numbers.

- A can communicate with B in various ways: Voice, SMS, MMA. Thus, we allow a separate Edge for each type of communication.
- The Mater Edge defines that a communication exists, and is irrespective of the actual type.
- Of course, B can reciprocate communicate with A in various ways also: Voice, SMS or MMS. Thus, we allow a separate Edge for that too.
- That means from A's perspective there could be a maximum of 8 Edges associated with A if all communication types are used and reciprocated with B.
- Edge IDs are unique system wide.

Data Preparation: Filtering

- Not all numbers are valid:
  - Non-human numbers are identified and filtered.
  - Service numbers are identified and filtered.

- Some links are trivial:
  - Remove links that are infrequently called.

- Different filters can be applied for different metrics.

Data Preparation: Target Data Model

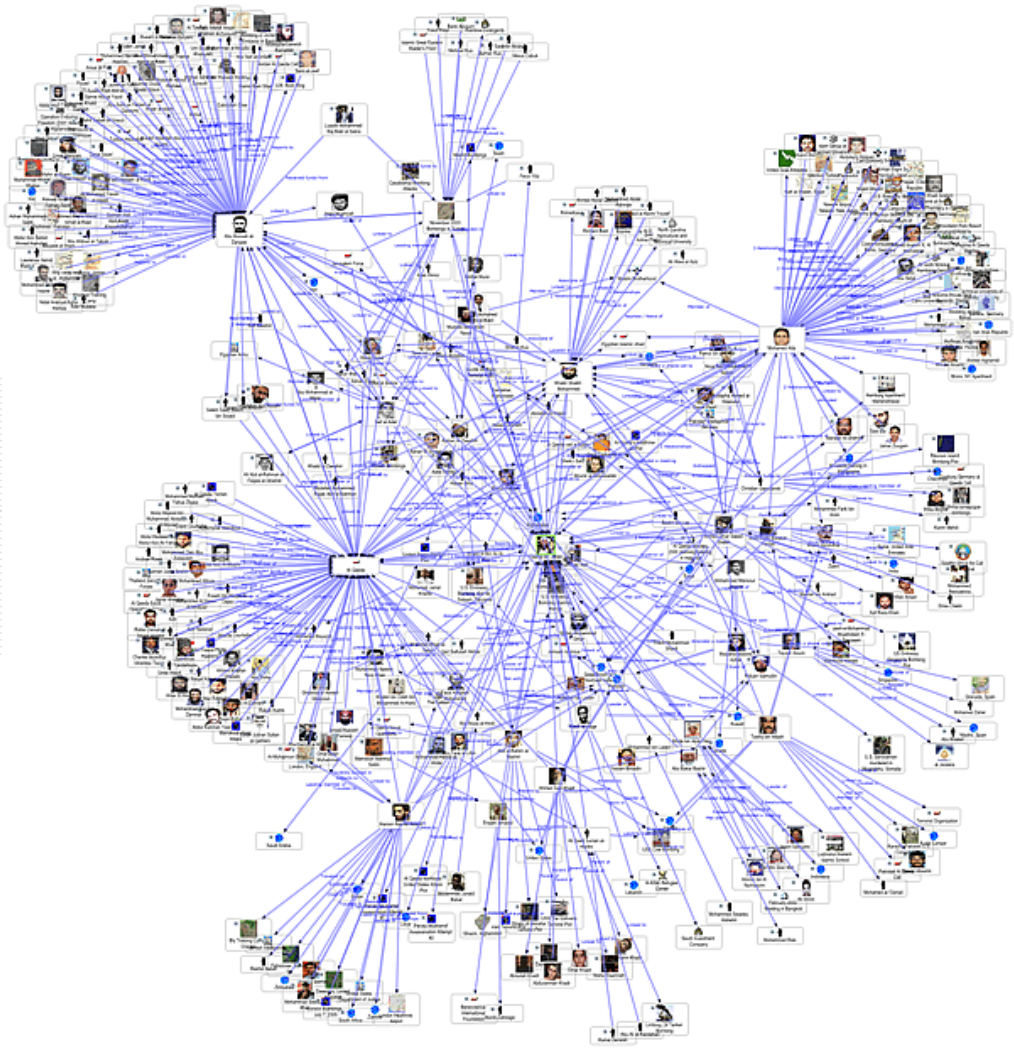
Graph Theory concepts are the foundation of a good model for use in Social Network Analysis.

Metric Calculation

- Social network metrics are calculated directly from the ‘graph’.
- Social Network metrics describe nodes and edges, and attempt to give meaning to position.
- Metrics are typically calculated in-database.
- Metrics are created using scripts that use:
  - SQL for simple metrics.
  - UDFs for complex metrics.

Social Media Metrics

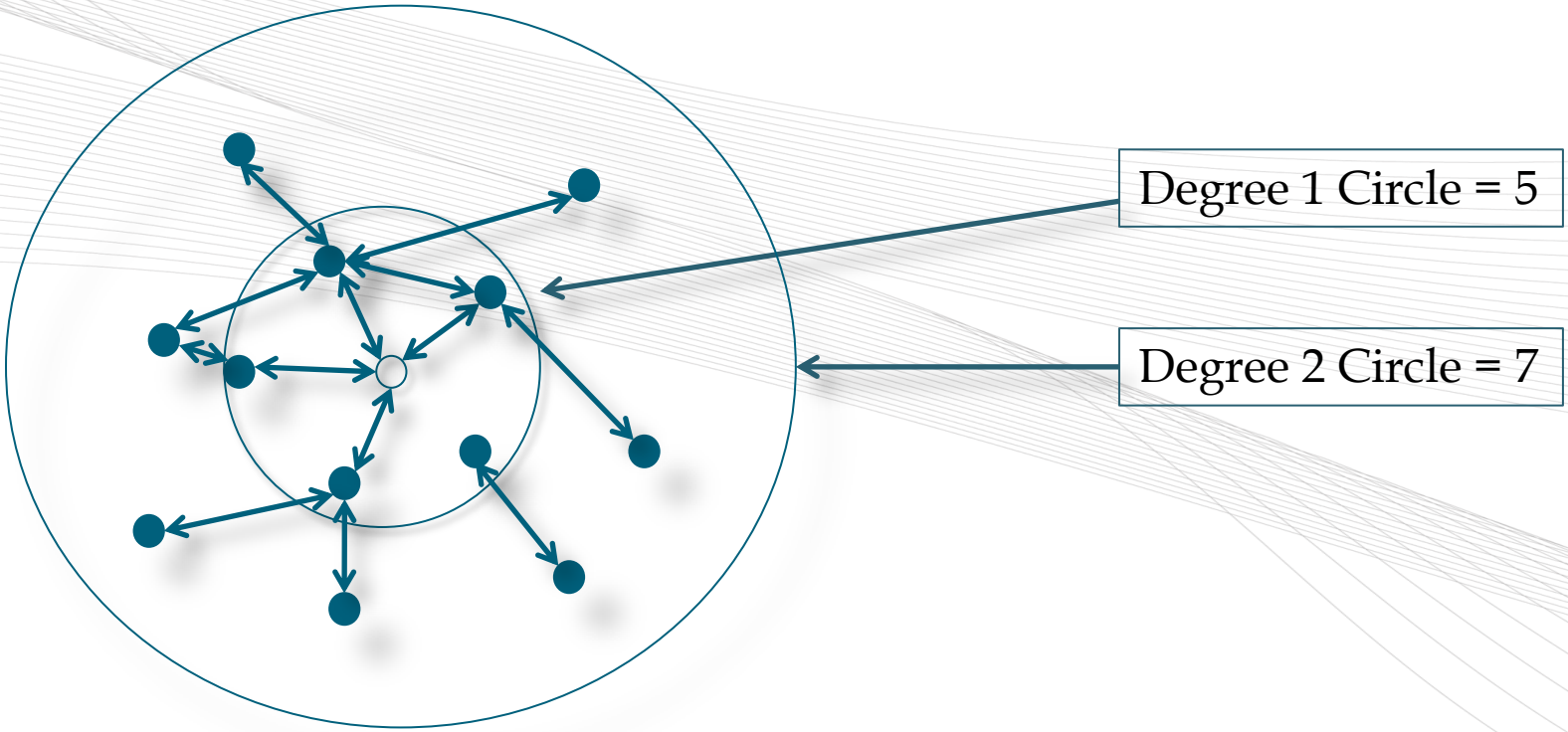
- Identity confidence
- Group detection
  - Degree
  - First/second
  - On-net/off-net
  - Peak/off-peak
  - Etc.
- Centrality
- Betweenness
- Closeness
- Triangles
- Authority
- Cohesion
- Prestige and trust
- Many more…



SN Metrics: Degree

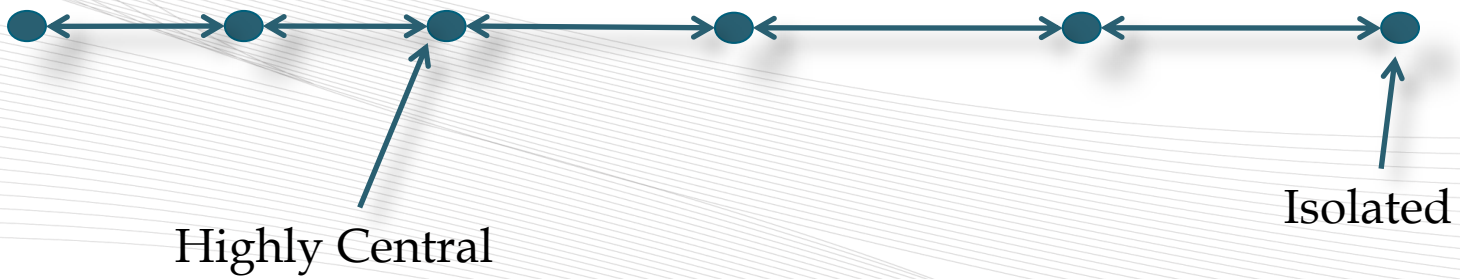
D1: Size of the degree 1 social circle.

D2: Size of the degree 2 social circle.



SN Metrics: Centrality

Centrality measures how 'important' an actor is in the social network.



Appropriate segment for classic approach!

Very low centrality indicates:

- Social network isolation.
- Low impact on calling circle.

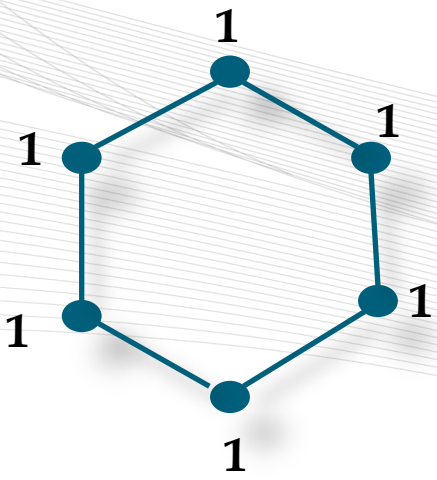
Centrality According to Philip Bonacich

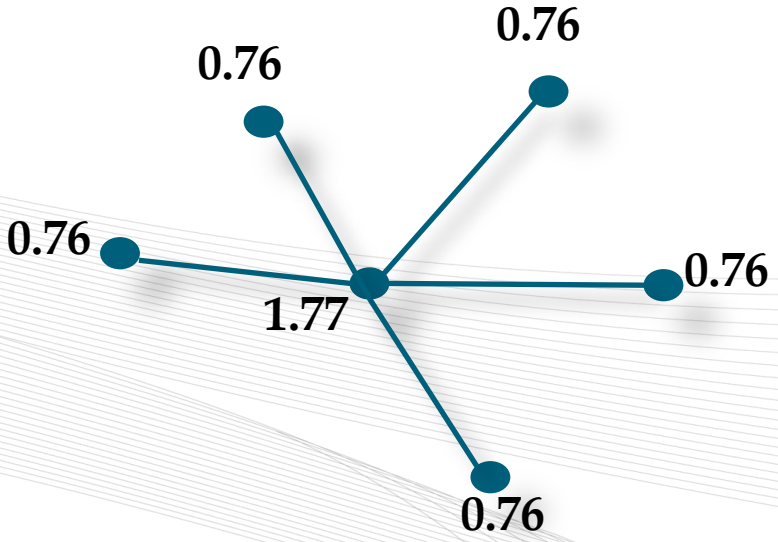
- Being connected to many people is good, but what indicates the most influence is to be connected to ‘important’ people.
  - Similar to Google’s page rank.
- Bonacich Centrality measures the total number of paths starting from a node, with a decay factor favouring shorter paths over longer ones.
  - C is vector of centralities
  - A is graph matrix.
  - Alpha is a scaling factor.
  - Beta is decay factor between 0 and 1.
  - C = alpha * SUM _ (k = 0 to infinity) Beta ^ k * A ^ (k + 1)
  - If Beta = 0, this is degree count.
  - If Beta = 1, this is eigenvalue centrality (page rank).

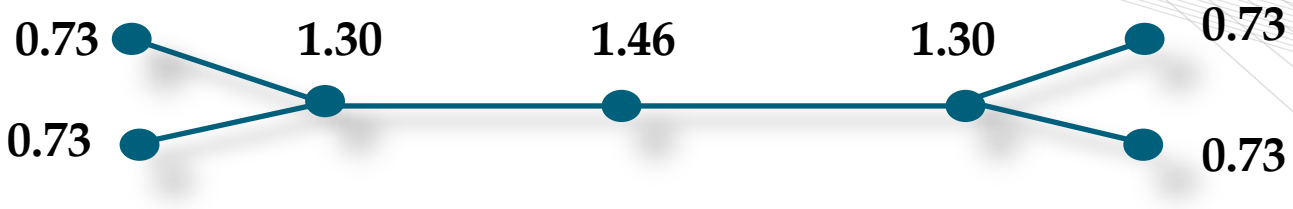
Ideal for computation in parallel!

Examples of Bonacich Centrality

(with decay factor of 0.5)





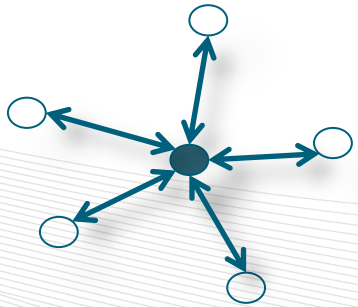


SN Metrics: Reciprocal Degree

RD: Reciprocal Degree.

- Communication in both directions.

Reciprocal Edge

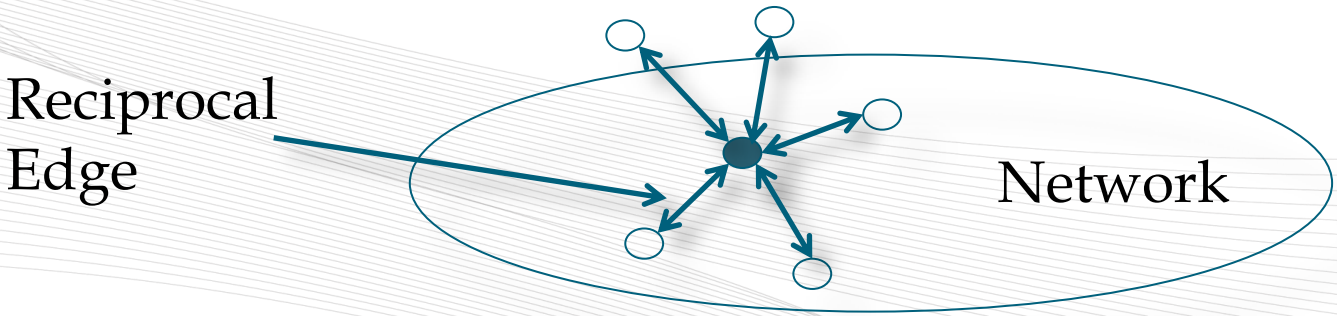


Reciprocal Degree = 2

SN Metrics: In-Network Degree

RDNetwork: Reciprocal Degree within the network.

- Communication on-network in both directions.

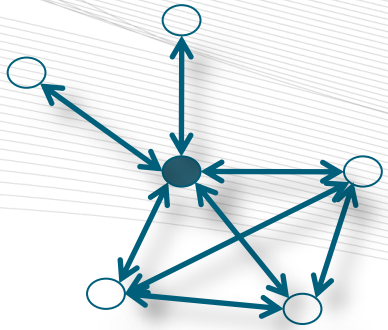


Reciprocal Degree within Network = 1

SN Metrics: Triangles

TRG: a count of the number of triangles within a social network involving a particular focus node.

Degree of interconnectedness in the social network.



In this example, four triangles exist within the social network – three of which involve the focus node.

Triangles = 3

SN Metrics: Betweenness

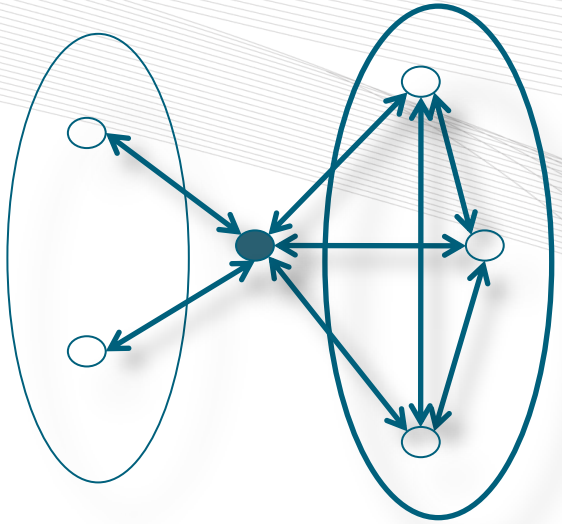
Betweenness: The number of node pairs that have only a direct link through the focus node.

This is a simpler (faster) calculation than the more precise definition that involves an all node pair shortest path calculation.

Betweenness is a measure of how essential the focus node is to facilitate communication within the social network.

Betweenness = 6

These subscribers need the focus node to communicate with each other.



These subscribers do not..

SN Metrics: Density

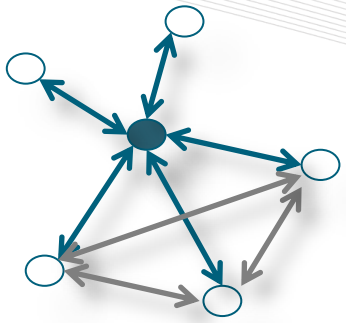
DEN: Density is the number of actual edges divided by the number of possible edges (n * (n – 1) / 2) within a social network (simplified).

How dense is the calling pattern within the calling circle?

Low if many nodes in the calling circle are not connected. Usually low when calling circle is large.

Inversely related to Betweenness.

Density = 3/10



Only three edges for a calling circle of five nodes.

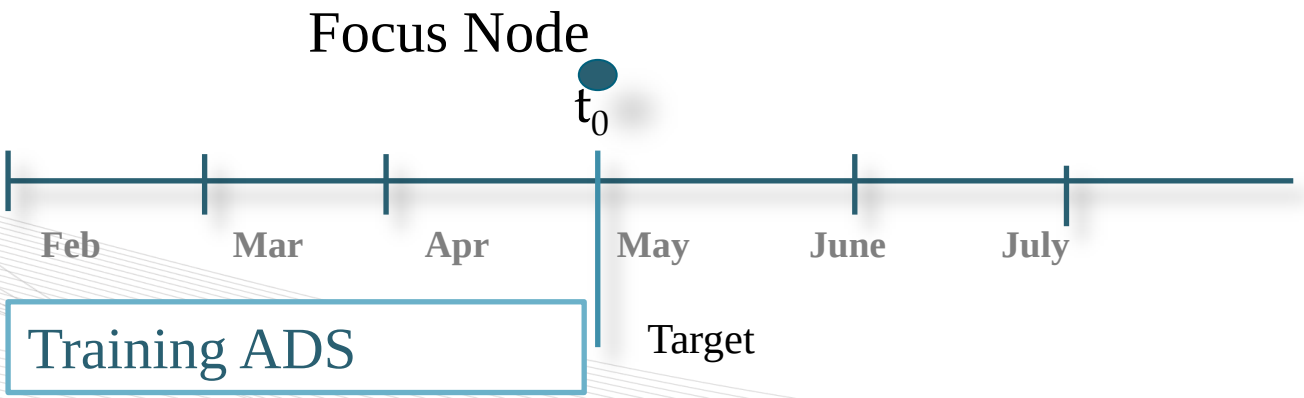
Social Network Model Creation

- Models are created using SN metrics and other data.

- Apply the inverse cascading model: Edges are modelled for the chance that a message or behaviour will be transmitted.

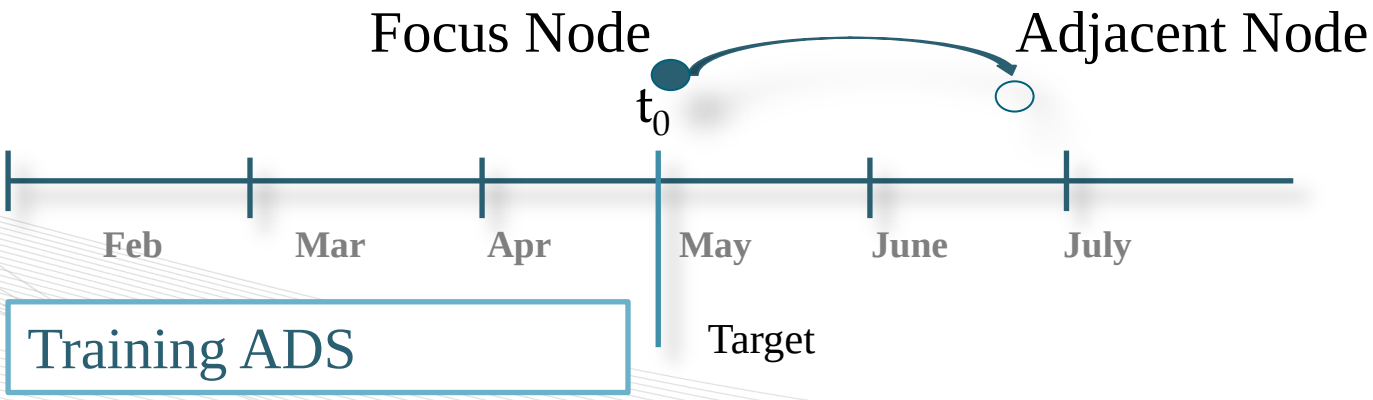
- Example types of models:
  - Churn risk: how likely is churn spread from A to B?
  - Product/service spread: if A uses product/service X, how likely is it to be taken up by B?
  - Viral marketing: if we send A an offer, will they pass it to B?

Example: Product Affinity Model Timeline



- At t_0 the subscriber is still active.
- He does not have product X.
- Has a non-trivial centrality score.
- Positive target:
  - Within 30 days of t_0 the subscriber adopts product X.

Example: Viral Adoption Model Timeline



- At t_0 the subscriber is still active.
- He does not have product X.
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Example: Model Inputs

Affinity Model	Viral Model
Usage History SN Metrics	Focus Node: Usage History SN Metrics Adjacent Node: Usage History SN Metrics Historical Edge Information: Edge Usage History

Measurement and Testing

- Need to define target and control groups.
- The number and size of control groups will vary according to the effect being testing:
  - Control group for direct take up.
  - Control group for viral take up.
  - Control groups for different messages.
- For example: to control for a X-sell message and model
  - A group of high scoring customers should not be contacted (control of message).
  - A group of low scoring customers should be contacted (control of model).

Data Mining Using Social Network Analysis

Output of Social Network Analysis

- A set of metrics than can be input to other analytics and directly to marketing actions. These metrics are applied to each customer:
  - Degree
  - Centrality
  - Betweenness
  - Triangles
  - Etc.
- SN Metrics along with traditional attributes are used to derive characteristics such as influence, but these should scored relative to specific topics (price, technology, churn, etc.)

- Analysis is often done in the context of specific domains…defining time horizon for the analysis, customer segments, types of call to consider, weekly vs weekend call patterns, filtering outliers calls, etc.

Social Network Analysis with Relationships

Social Networks are Not New to Analytics

- The idea of understanding relationships to enhance analytic capabilities is not a new idea.
- Householding, for example, is something that most sophisticated analytic organizations have been doing for years.
- Most common use cases:
  - Marketing analytics.
  - Risk analytics.
  - Crime investigation.
  - Health care.
- Householding is a very simple form of network analysis.

Traditional Householding

Construction of ‘decision-making units’ based on social relationships (marriage, co-habitation) for the purpose of marketing and risk analytics.

Traditional relationship indicators:

- Common address.
- Common last name.
- Marital (or other) relationships.

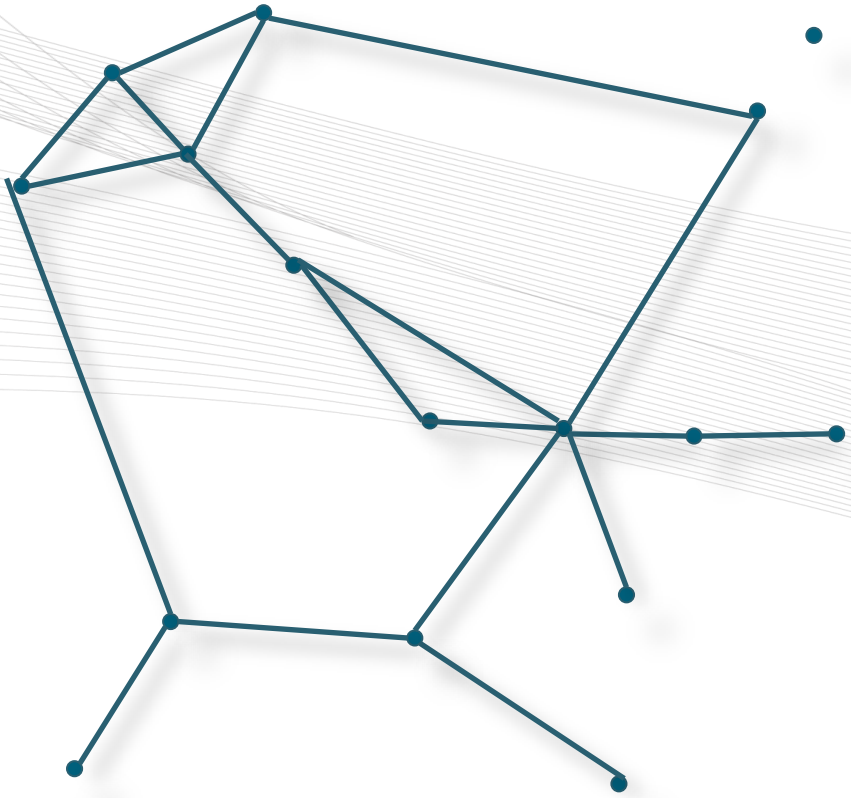
New scoring variables:

- Pooled assets.
- Pooled purchases.
- Pooled behaviours.
- Derived ‘head of household’ variables.

Used to construct new variables for the purpose of propensity scoring, risk scoring, segmentation, etc.

Tracking of relationships over time to give visibility to life stage transitions.

Classic example: 15th Century Florence Family Politics (Padgett, 1994)



- Links are marriages.
- Degree.
- Centrality.
- Betweenness.
- Geodesic distance.
- Influence.
- Pressure.

Beyond Householding

Extend an understanding of name, address, and marital relationships to other kinds of relationships:

- Investment accounts
- Credit card accounts
- Mortgages
- Insurance policies
- Frequent flyer accounts
- Buyer-supplier relationships
- Many other possibilities…

Beyond Householding

There are many different kinds of relationships:

- Joint tenancy with rights of survivorship versus primary owner on a financial account.
- Credit guarantor (co-signer) versus recipient on a loan or credit card.
- Custodian versus trustee on a financial account.
- Beneficiary versus owner on a life insurance policy.
- Insured versus payer on a driver's insurance policy.
- Sponsor versus recipient for frequent flyer status.
- And so on…

Marketing Analytics Use Cases

- Customer acquisition.
- Cross Selling.
- Customer retention.
- Price bundling.
- Profitability management.
- Customer segmentation.

Key concept: Derive new variables for analytic purposes based on characteristics and events related to a group of individuals (social network) rather than looking at individuals in isolation.

Marketing Analytics Use Cases

Simple extension of model variables from an individual level to a household level gives significant uplift in predictive accuracy:

- Total customer value by product category
- Total number of accounts or purchases by product category
- Date of last account open or purchase by product category
- Date of first account open or purchase by product category
- Date of last account close or purchase by product category
- Date of first account close or purchase by product category
- Date of last inquiry
- Date of first inquiry
- Total number of inquiries in the last three months
- Total number of inquiries over customer lifetime
- Date of last complaint.
- Date of first complaint
- Total number of complaints in last three months
- Total number of complaints over customer lifetime
- Etc..

Customer Retention by Identifying At-Risk for Defection Relationships

Individual defection impacts household defection:

When one individual closes all accounts or has a bad experience, all individuals in the household may be put at risk. Retention programs identifying these situations can be put into place to 'save' at-risk for defection customers.

Broker defection impacts customer defection:

If the broker for a customer of a financial or insurance company takes a job with the competition, the customer is likely to be highly at-risk for defection. Again, explicit retention programs can be used to 'save' these customers.

Important note: roles in the relationships matter.

Risk Analytics Use Cases

Better understand financial risk of incurring bad debt based on relationships:

- Scoring for consumer loans/collections based on household characteristics rather than on an individual in isolation.

- Scoring for commercial loans/collections based on supplier and/or customer relationships with insight related to industry or customer concentration as a measure of risk.

Crime Investigation Use Cases

- Fraud rings.
- Likely suspects.
- Terrorist networks.

Terrorist Network

- Shows the associations among the 9/11 terrorist and their colleagues.
- Example of social network analysis.

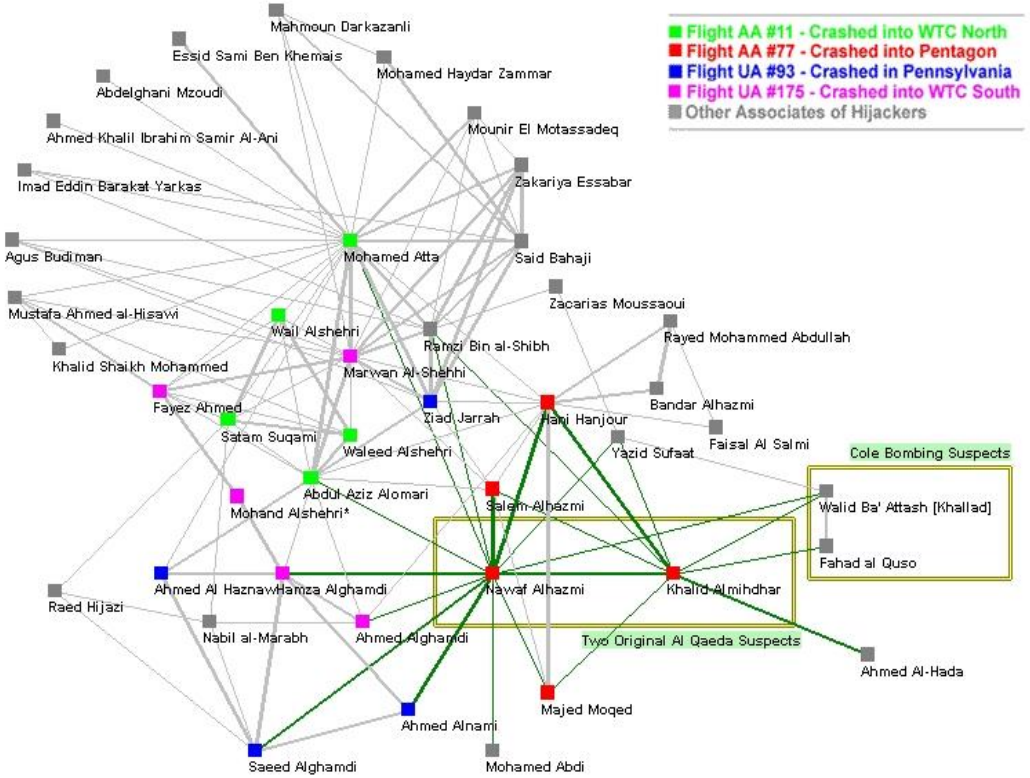


Figure 3 - All Nodes within 2 steps / degrees of original suspects

Health Care Use Cases

Understanding relationships helps to determine how diseases spread and therefore how to better perform disease management:

- Tracing epidemics to their origin.
- Prioritizing vaccines and health education.

Social Network Analysis with Transactions

Social Network Analysis with Transactions

Relationships can be inferred through transactions.

There are many different kinds of transactions:

- Telephone calls.
- Messages (SMS, MMS, etc.)
- Emails.
- Package Shipments.
- Financial transactions.
- Physician referrals.

Cardinality of transactions can be used to indicate intensity of the relationship.

Employee Retention

Google was given a '2010 Best HR Ideas' award from HR Executive for using analytics to improve employee retention.

Social network analysis can enhance algorithms used to predict risk of defection.

Use intra-company interactions to understand social network within the company:

- Telephone calls.
- Messages (SMS, MMS, etc.)
- Emails.
- Meeting interactions.
- Organizational Structure.
- How 'connected' is the employee to the company?
- If one employee leaves, what is the risk of defection for adjacent nodes in that employees social network.

Combine SN Metrics with traditional metrics (salary, years of service, performance evaluations, commute distance, etc.) to build predictive models.

Organizational Effectiveness

Social network analysis can be used to build algorithms to identify dysfunctions within an organization.

Use intra-company interactions to understand social network within the company:

- Telephone calls.
- Messages (SMS, MMS, etc,.)
- Emails.
- Meeting interactions.
- Organizational Structure.
- What is the level (intensity) of communication between departments that should be cooperating?
- What is the richness' and 'diversity' of the communications between departments?
- Always email with no face-to-face meetings or telephone conversations may indicate a problem.
- Are there a small number of connectors between the departments?
- At what level are they within the organization?

Social Network Analysis (SNA) in Telecommunications

Social Network Analysis (SNA) is focused on the **relations** between subscribers (customers); traditional propensity or segmentation models are based on **individual** subscriber attributes.

Map of ties among subscribers provide a useful framework to identify **role** played by each individual within the network.

Ties between two subscribers can be identified using voice, calls, sms, mms, etc.

SNA is often used to:

Define **targeted treatments** based on network roles of an individual to encourage/discourage specific events (churn, acquisition, product adoption).

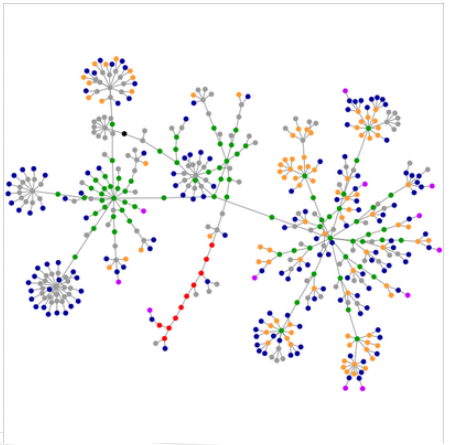
Monitor new **product adoption** by studying diffusion within a social network.

Identify **unusual behaviours** (fraud detection).

Social Network Analysis for Mobile Network Operators

- Mobile communication is an essential and basic form of communication between persons in a social network.
- There are many communication channels/mediums; call data captures just a portion of communication among people.
- Data availability is quite good for mobile network operators who capture CDR data – more data leads to better results.

Application of Social Network Analysis



Critical success factors for effective social network analysis:

Need a critical mass of mobile phone penetration within the country.

Market share matters:

- New versus established operators.
- The flower pattern.

Data collection: Need detailed and cleaned history data.

Understand the profile of your customers segments (consumer, small business, corporate, pre-paid, post-paid, etc.)

Application of Social Network Analysis

Challenges with high returns:

- Uncover hidden social network information in your data – such as phone books in the phones of subscribers.
- Identify key parameters of measured call data (normalization, skew elimination).
- Separate random connections and weak connections.
- Understand the size and density of the social network.
- Understand the dynamics in the social network: stable versus volatile communities.
- Target selection, test/control groups, and measurement.
- Read correctly and understand the results of the Social Network Analysis.

What Kind of Social Networks can be created?

CDRs (Call Detail Records) are generated for each call:

Node1	Node 2	Date	Class	Duration
705 626 2002	416 414 6454	1 Dec 07	Voice	00:04:22
778 388 4363	604 805 5682	1 Dec 07	SMS	00:00:12
…	…	…	…	…

From these CDRs, **many different social networks** can be built:

- Product focused:
- Voice Network (Individual A calls Individual B on voice)
- SMS Network (Individual A sends a SMS to Individual B)
- MMS Network *Individual A sends a MMS to Individual B)
- All services Network (Individual A calls or sends SMS or MMS to B)
- Intensiity focused:
- At least 5 communications; duration at least 15 seconds.
- Period focused:
- Interactions during this month, or week, or day…
- Directed or Un-directed

Using different definitions to calculate links gives different networks for different purposes.

Network Structure

Weak ties: Connection between communities; connection to the rest of the ‘World’.

Strong ties: Communication ties with high call frequency and/or high call duration.

Importance of ties from the perspective of:

- Information diffusion..
- Networrk integrity.
- Kind of tie (driend, intimate, parent/child).

Calculating Social Network Attributes

- Counts for incoming and outgoing contacts.
- Triangle counts (centrality measure).
- First Circle Statistics: counts, averages, proportions. Separate counts for nominal variables (gender, brand).
- Counts and ratios for neighbours on-network and off-network.
- Sums for link labels (total minutes between phones).
- Statistics for the community of a user (more than first circle).

Conclusions

Conclusions on Social Network Analysis

- Social Network Analysis is not a silver bullet:
  - Can enrich existing marketing, fraud detection, and other analytic capabilities…
  - ….but does not replace traditional analytical techniques.
  - Combine SN Metrics with traditional metrics for scoring.
- Social Network Analysis provides insights as to how individual customers behave in the context of larger communities.
  - Need to think differently about test and control groups.
  - Viral marketing opportunities.

Conclusions on Social Network Analysis

The success of marketing with techniques based on Social Network Analysis will depend on many factors:

- Success rates will be different in different cultures and demographic groups.
- What works in Europe will be different from what works in Asia or the United States.

The answers are in your data!

For marketing activities to have a viral component there has to be value to both the A and B nodes:

- Value can be in terms of prestige (true viral marketing) or can be financial.
- Most marketing messages have no viral component.
- Any viral marketing must have a fulfilment method to match.
- Product and offer characteristics can have a dramatic impact on effectiveness of program targeting.

Conclusions on Social Network Analysis

Data! Data! Data!

- It's all about the data!
- Don't under estimate the amount of work and time required to cleanse and understand the data.
- Want to combine event data with SN data to maximize impact.
- Scalable solutions needed when dealing with large volumes of data.

Social Network Analysis is different than traditional analysis.

- New lingo, new concepts.
- Many different forms of SNA.
- Lots of market confusion between social network analysis and social media analysis.
- Want to track how networks change over time.
- Measure, learn and improve.

Contact PEAK for more information

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Recommended Reading

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