

Managing in a “Small World Ecosystem”: Some Lessons from the Software Sector

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Abstract

We examine the stability of the topological structure of the network of alliances between firms in the software sector during considerable shifts in the underlying technology architecture during 1990-2001. We find that the software sector exhibits ‘small world’ characteristics and that the structure is remarkably stable during this period. Based on the implications of this analysis, we develop lessons for managers to effectively master the challenges of navigating in dynamic networks. Our empirical setting is the software sector, but the lessons also have broader applicability.

Managing in a Small World Ecosystem: Some Lessons from the Software Sector

Consider the following:

Google, Yahoo!, Amazon and Microsoft are intricately interconnected through a complex web of cooperation and competition. Yahoo!, an early investor in Google, used Google's search engine technology until it bought Inktomi in 2002. Besides buying online advertisements from Google, Amazon's subsidiary, A9, uses Google's index on the Web with its own content to create search results. The relationship between these two firms is further reinforced by the presence of John Doerr (of Kleiner Perkins – the venture capital firm that promoted both Amazon and Google) on the boards of both companies. . However, to differentiate itself from Google, Yahoo! allowed users to search inside Adobe's postscript files.ⁱ Google then upped the ante further with a desktop search feature to enable users to seamlessly search through files and e-mail on their computers and the web.ⁱⁱ Microsoft, which currently relies on a Yahoo! subsidiary, Inktomi, for its search services, released a beta version of its own search engine, a version which will be a core part of the next major release of Windows Vista operating system.ⁱⁱⁱ

In 2002, Yahoo! acquired Overture, a platform for paid-search in the online advertising market, which is also used by Microsoft. In March 2005, Microsoft announced its own technology (AdCenter) for advertisement placement, while simultaneously maintaining a prior advertising agreement with Yahoo! that runs through 2006. In short, Microsoft, Yahoo, Amazon and Google are all connected in a complex and fast changing web of competition and cooperation.

This example illustrates the complex pattern of relationships amongst key players within the software sector, where no one firm can supply every software product that customers need. Software firms need to interoperate with complementors (e.g., those that provide complementary software applications) and competitors. To ensure interoperability, firms form alliances to share information on the features and functionality of products as well as to coordinate product release times. Since software evolves at a rapid pace, alliance formations must be dynamic to respond to technological shifts.

In contrast to vertical integration, which called for ownership of assets to establish patterns of control in the industrial age, software companies resort to virtual integration through alliances to establish networks of influence and interoperability. While it is true that this sector has characteristics of an ecosystem, we know little about the underlying topology or its change during profound technical transformations. We analyze the network of alliances and partnerships established by 509 firms in the packaged software industry during the period 1990 to 2001 in order to understand the characteristic of the network topology and changes, if any, during these twelve years. Using this analysis, we offer a specific way for managers to map their own ecosystem and derive insights into the best ways to navigate within such ecosystems. The research that forms the basis for this paper is summarized as a box 1 (insert).

INSERT BOX 1: CALIBRATING SOFTWARE NETWORKS (1990-2001)

Over the last two years, we assembled a database from multiple sources focused on software firms operating within the SIC code 7372 that design and deliver ‘packaged software’ in functional markets such as databases, accounting and human resource management. Firms such as BEA Systems and Oracle squarely fall into this SIC code because of their core product offerings. In addition, other diversified companies such as Hewlett Packard that offer software products, in addition to hardware or other components, are also included. For these firms, we collected data on their major alliances and relationships from Mergent, International Data Corporation proprietary database, Lexis-Nexis, and Thomson Corporation’s Securities Data Company (SDC) Platinum database.

For each software firm, we identified their network activities through their participation in different types of alliances: marketing relationships, licensing agreements, consulting services, data processing services, and research and development services. We used the SDC Platinum database to identify all such alliances formed from 1988 – 2002. The collected data was validated by taking care of redundant entries and filling out missing elements by consulting other sources such as Lexis/Nexis and Compustat. Our sample has 509 focal software firms. [More details on the database are available from the authors].

EXAMINING THE SMALL WORLD IN THE SOFTWARE SECTOR

To understand the topological structure of the software ecosystems, we focus on the “small world network,” which is characterized by a high degree of clustering and short path length between any two nodes. We expect this structure to operate in the software sector because it allows for quick and efficient sharing of information across clusters. The idea of “small worlds” can be illustrated through a common expression “six degrees of separation.” In 1967, Stanley Milgram sought to understand the probability that two random persons in the world are linked. He setup an experiment by sending 300 letters to randomly selected people in Nebraska and asked them to use their personal contacts to reach an individual (a stockbroker friend) they did not know in Boston. At each step along the way, these individuals were asked to send the letter to someone that they believed might be closer to the Boston stockbroker. That person receiving the letter was requested to do the same until the letter reached the final destination. In the end, Milgram found that letters had passed through, on average, six individuals en route – thus the phrase ‘six degrees of separation.’ The corollary is that we live in a “small world.”^{iv}

The phrase “six degrees of separation” has been popularized by a game^v developed through the actor Kevin Bacon. In this game, an actor who starred in a movie with Kevin Bacon has a number of one. An actor, who has never starred with Kevin Bacon but has been in a movie with someone who has, gets a number two and so on. An interesting empirical finding is that with thousands of movies made every year across languages and geographical boundaries, the highest number ever assigned to an actor was eight! Hollywood indeed exhibits small world characteristics. In mathematics, this is known as Erdős number, because of researchers who worked with different degrees of separation from the famous mathematician, Paul Erdős.^{vi} Additionally, both the Internet, despite its seemingly sprawling nature, and the artists who collaborate to create Broadway musicals^{vii} also exhibit small world characteristics.^{viii} Ties between members of corporate boards have been postulated to serve as a mechanism for diffusion of corporate practices, strategies and structure. In a study of the corporate elite network in the US during the 80s and 90s, researchers analyzed the topology and found it to be a “small world” and that this characteristic explained why they are resilient to macro and micro changes affecting corporate governance.^{ix} These general ideas have been recently used to

understand the evolution of the biotechnology sector, Broadway musicals, bilateral trade between countries and more.^x

Intrigued by the aforementioned studies, we wondered if they have any relevance for the software sector. Software firms form relationships with other companies to access different types of resources, and such links create a network of relationships that shape competition and value delivery. We ask the questions: what does this network look like? Is it comprised of cliques connected to one another? Does it emerge as a hub-and-spoke network? Is it a random network? Is it a small world network? Does the structure change over time or is it stable? What role do networks of relationships play in developing successful business models in this sector? Can we offer management prescriptions based on analyzing the evolution of networks over time?

Box Insert 2: Network Perspective in Other Domains

Analyzing networks is not new to the academic world; an emerging view within strategy and organizations is that a firm's success depends on how it accesses resources within a network of relationships. Management researchers have studied how network topology shapes the evolution of competition in biotechnology,^{xi} stability in the structure of corporate elite^{xii} and competition in the semiconductor industry^{xiii}--entire issues of journals have been dedicated to this subject matter.^{xiv} In particular, there has been a flurry of interest in network structure. For example, small works have been found in such diverse areas such as the World Wide Web,^{xv} the venture capital industry,^{xvi} commercial airline hubs,^{xvii} the boards of directors,^{xviii} the German industry elite,^{xix} and Broadway actors.^{xx}

We use five network metrics based on a comprehensive review of network research in other domains (see Box Insert 2). These metrics are: average degree of nodes, average degree of partners, path length, clustering coefficient and network density. In Table 1, we summarize the values for these metrics for each year. The sixth column (F) in the table is used to show that the software networks are indeed "small worlds."

Table 1: Five Indices for Calibrating Software Network: 1990-2001

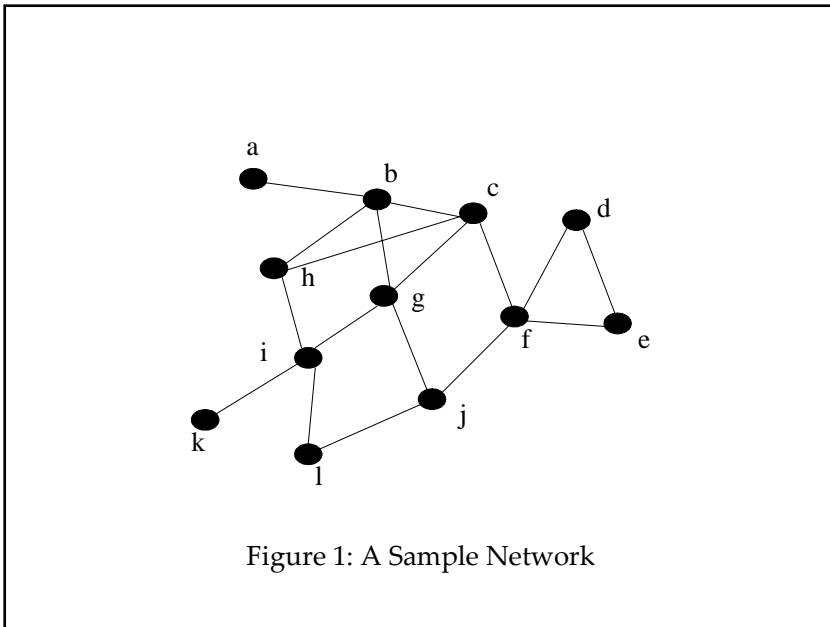
Year	(A) Average degree of linkage	(B) Average degree of partners	(C) Average path length	(D) Clustering Coefficient	(E) Network density	(F) Small World Coefficient
1990	3.1	2.33	5.1	0.22	0.00489	56
1991	3.3	2.84	6.4	0.26	0.00376	88
1992	3.5	3.08	5.8	0.30	0.00348	124
1993	3.6	3.25	6.1	0.32	0.00198	144
1994	3.5	3.22	5.8	0.33	0.00243	163
1995	3.3	3.01	5.9	0.33	0.00327	169
1996	3.1	2.73	5.5	0.28	0.00289	165
1997	2.9	2.41	6.4	0.24	0.00285	160
1998	2.9	2.24	6.9	0.23	0.00172	185
1999	2.9	2.33	7.9	0.25	0.00124	273
2000	2.9	2.14	8.3	0.23	0.00121	261
2001	2.8	2.14	7.5	0.22	0.00130	248

Network Metric 1: Degree of Links

Degree of links refers to the number of links a firm has at a given point in time.

In Figure 1, node g has a degree of four, node h as a degree of three and node l has a degree of two. Recent studies have shown that real world networks are not random but resemble power-law distributions: namely, a majority of nodes with few connections and a few nodes with a great many connections. The conventional expectation is that links would be randomly distributed across nodes, but recent data on many networks has uncovered the existence of long tails. A dominant explanation is that new linkages are based on the number of pre-existing links. For example, scale-free characteristics have been found in areas such as film actor networks, Internet websites and citations of scientific publications and alliance networks. This result does not occur by accident. In fact, Albert-Laszlo Barabasi argued that for a network to be scale-free,^{xxi} a new node should preferentially attach with an existing node based on the number of connections that the node already contains.

Look at column [A] in Table 1. The number of linked software firms shows a decreasing trend from 3.1 in 1990 to 2.8 in 2001. During the 1990s, firms such as IBM (1368 alliances),



Microsoft (855 alliances) and HP (671 alliances) were active in forming links; the end result is that the network has high values for degree of linking. The bigger firms with more diversified product portfolios have resorted to more relationships to support their diverse product scope. For example, IBM has a product in both the middleware and the

database category. For its middleware product (IBM Websphere) to be successful it has to interoperate with many operating system vendors, calling for the establishment of formal linkages and coordinated product releases and updates. Similarly, its database product (IBM DB2) has to work with many middleware providers including competitive products such as BEA System’s WebLogic, again calling for cooperative links with competitors.

Look at Table 2 where we highlight the top five firms with high values for degree of linkage for three time periods: 1990, 1995 and 2001. The list of top firms is remarkably consistent during 1990-1995 while we observe AOL joining the group in 2001 due to the rising importance of the Internet during the late 1990s. Clearly, AOL sought linkages to maximize its goal of being a leading Internet portal.

1990	1995	2001
Apple Computer, Inc.	Apple Computer, Inc.	AOL
Oracle Corporation	Sun Microsystems, Inc.	Sun Microsystems, Inc.
Sun Microsystems, Inc.	Oracle Corporation	Oracle Corporation
IBM	IBM	Microsoft Corporation
Microsoft Corporation	Microsoft Corporation	IBM

Table 2: Five firms with highest values for degree in the network, 1990-2001

Network Metric 2: Average Degree of Partners

Average degree of partners is the average number of links that a firms' partners have at any given time.

Firms link with other firms to exchange information, to develop their product jointly of products or to gain status within the network.^{xxii} In Figure A, node g has four partners b, c, i and j. Partners b, c, and i have four links each and partner j has 3 links. So the average degree of g's partners is 4.75 (15/4). A high value indicates that firms have indirect ties to a larger set of nodes. The logic of indirect ties is based on a belief that links act as channels of communication and resource access.^{xxiii} A firm's partners bring not only the internal resources but also their knowledge and experience from their interactions with their network partners. Selecting the right set of partners with whom to link is therefore crucial to maximize access to the requisite resources while minimizing the cost of coordination of a wide array of alliances. Thus, firms seek links to partners that are well positioned as conduits and connections to other firms. In general, firms that are well connected in the network will attract more requests for links than otherwise.

Looking at column [B] in Table 1, we see that the average degree of the partners shows a declining trend: 2.33 in 1990 to 2.14 in 2001. Table 3 highlights the five firms with high partner degree values during three points in time. Microsoft continues to be in the top of the pack throughout the period while it dominated the market for the PC operating system. Many providers of complementary software products sought formal links with Microsoft. In addition, some of these complimentary product providers themselves have started to form alliances with other companies in different segments. The end result is that Microsoft has a consistently high score for partner degree, implying that Microsoft's partners themselves are highly connected in the software ecosystem. Once such company with high value for partner degree is Vignette in 2001. Vignette "provides comprehensive applications that give customers the ability to deliver enterprise Web applications consisting of integrated information, composite applications and business processes to effectively meet business objectives." It needs to ensure that its products interoperate with complementary applications that work on .NET or Java. Consequently, Vignette has a close relationship with Microsoft. Furthermore, since enterprise applications need customization, Vignette has also formed partnerships with IBM and Accenture for system integration.

SAP's entry into the top category in 2001 is noteworthy. While it was not in the top tier during the earlier periods, it has high scores for partner degree because of the central role of its suite of applications within major global companies. Independent software vendors have begun to develop complimentary software packages such as report generators that work on the SAP platform. The rising dominance of SAP within the enterprise domain has meant that many software firms needed to formalize their relationships with SAP to coordinate releases of products for maximal customer value. SAP's partner degree was 34.69 in 1990 and 45.22 in 2001.

1990	1995	2001
Sun Microsystems, Inc	Apple Computer, Inc.	Hitachi Limited
Microsoft Corporation	Symantec Corp.	SAP AG
IBM	IBM	Vignette
Apple Computer, Inc.	Microsoft Corporation	IBM
Novell, Inc.	Sun Microsystems, Inc.	Microsoft Corporation

Table 3: Five firms with Highest Values for Average Partner degree in the Network, 1990-2001

Network Metric 3: Path Length

Path length refers to the number of steps to reach a specific firm in the network.

The path length between two nodes is the number of hops that it takes to get from one to the other. For example, in Figure A, we can potentially go from node a → c in two hops (a→b and b→c). The average path length is derived by counting the number of steps to get from one node to another in a network; it can also be calculated for each node, and as a network as a whole, by taking the weighted average of path lengths across the entire network.

Look at column [C] in Table 1: the average path length varied from 5.1 in 1990 to 8.3 in 2000. Between 1996 and 2001, the path lengths have steadily increased, along with the number of new alliances formed. This is the period of the dotcom revolution, with a great deal of uncertainty in the sector. There is some belief that during uncertain periods, firms engage in alliance building activity to gain access to resources.^{xxiv} Incumbent firms tend to form links with new entrants to infuse their organizations with innovation and fresh thinking. New entrants gain status and access to complementary resources (channels, marketing, etc.) from incumbents.

This combination of many new entrants and their proclivity to linking to established players, while choosing not to link amongst themselves, leads to a reduction in average degree.

In general, short path length implies faster communication or easier and more efficient access to resources. If a firm can reach another firm via fewer intermediaries, there is a higher chance of useful information flow, resulting in synchronized product releases. For example: if Business Objects coordinated the release of its report writer software with IBM's application transaction server, the customers benefit because they can exploit the enhancements in the transaction server to create more meaningful reports using Business Objects' report writer.

In the top-five list of firms shown in Table 4, we see that Microsoft, HP and IBM occupy key positions across the years. Since these firms are able to connect to most other firms in a few steps, they are able to influence and be influenced the most by other firms in the network. It is also interesting to note that Apple occupied a key position during 1990-1995 while its path length increased; its prominence waned during the later half of the 1990s as it lost ground to Microsoft.

1990	1995	2001
Apple Computer, Inc.	Apple Computer, Inc.	AOL
Oracle Corporation	Siemens AG	Microsoft Corporation
Sun Microsystems, Inc.	Sun Microsystems, Inc.	Fujitsu Limited
Microsoft Corporation	IBM	Sun Microsystems, Inc.
IBM	Microsoft Corporation	IBM

Table 4: Top Five Firms with Smallest Average Path Length in the Network, 1990-2001

Network Metric 4: Clustering Coefficient

Clustering coefficient of a firm captures the degree to which a firm's partners are also partners which each other.

Let us go back to Figure 1 and consider the node h. It has three neighbors: b, c, and i. Of its neighbors only b and c are linked to one another. This means that out of a possible three links between b, c and i, only one link exists, thereby giving h a clustering coefficient value of 0.33 or 1/3. The overall clustering coefficient for the network is the average clustering coefficient for all nodes that have two or more neighbors. This coefficient can be computed for the network as a whole as well as for specific firms within the network. Some networks, such as software and entertainment, may be highly clustered, while other settings, such as manufacturing or agriculture, may be sparsely clustered. Similarly, some firms may have high

clustering coefficient relative to others that may be less well connected to others within the networks. To illustrate: Microsoft has partnered with HP, IBM, and Intel over the years; since Intel, IBM and HP are likewise connected through partnerships, Microsoft has a high value of clustering coefficient. In contrast, companies such as Symantec and CompuWare, which primarily augment their product offerings through acquisitions, have low values.

The clustering coefficient for the software network as a whole ranged between 0.216 in 1990 to 0.326 in 1995, with values in the range of 0.23 to 0.28 during 1996-2001. Table 5 summarizes the list of firms with high values for clustering coefficient during three points in time, 1990, 1995 and 2001.

1990	1995	2001
Software AG	SAP AG	Siebel Systems, Inc.
Novell, Inc.	Sun Microsystems, Inc.	Hitachi Limited
SAP AG	Apple Computer, Inc.	NEC Corporation
Apple Computer, Inc.	Microsoft Corporation	Fujitsu Limited
Sun Microsystems, Inc.	Novell, Inc.	Vignette

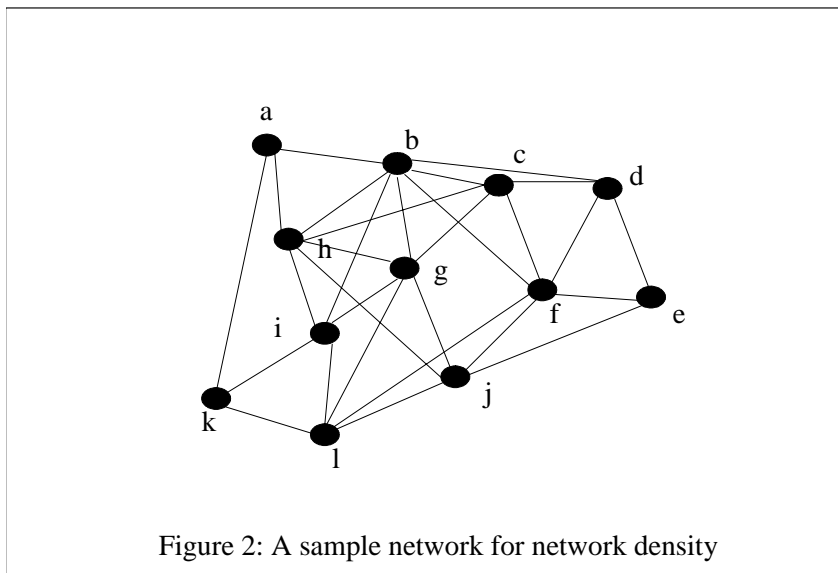
Table 5: Top five firms with Highest Values for Clustering Coefficient, 1990-2001

Clustering coefficients could be an important property of firms in an era that call for close interactions. Let us look at IBM and Microsoft, to illustrate. Figures 3 (A & B) depict the networks of relationships for IBM and Figures 4 (A & B) depict the network of relationship anchored on Microsoft as two snapshots in time (1990 and 2001). Clearly, both have increased their alliance activities as seen by the number of links in the network. In 1990, IBM had relationships with HP, Microsoft and Sun. In 2001, they have established key relationships with nearly all major players in the broader technology sector (e.g., SAP, Oracle, Palm, Nokia, Lucent, Cisco and AOL). Similarly, if we look at Figure 4A, Microsoft had few major partners in 1990; they had relationships with IBM (for the PC operating systems), Apple Computers (for applications), and Compaq (for the operating systems for IBM PC clones). However, by 2001, they have an extensive network of firms in the broader technology sector; indeed, Microsoft is considered to be a leader at understanding the power of a network of relationships for competitive success.

How do these two companies stack up in terms of clustering coefficients? IBM’s clustering coefficient in 1990 is 0.151 and is 0.015 in 2001. Microsoft’s coefficient is 0.156 in 1990

and 0.013 in 2001. In spite of the increase in the number of partners, IBM and Microsoft have low values for their clustering coefficients because most of their partners are not connected to one another. One reason for this could be the fact that small to mid-size software vendors want to gain status and recognition by forming partnerships with major platform vendors such as Microsoft and IBM. These partnerships help them synchronize their products with those of the major platform vendors. For example, when Microsoft includes Bluetooth compatibility with their new operating system release, vendors could release complementary products in time to use this protocol to synchronize their services with the desktop. These partnerships allow the vendors to focus on their technology and allow the platform provider (e.g., Microsoft) to create the awareness and demand for their products. However, these small to mid-size vendors do not see any value in connecting amongst themselves.

Contrast Microsoft and IBM with SAP (see Figure 5a and b), which has formed strategic alliances with a few select partners. The interesting observation is that these partners are highly connected between themselves, giving SAP a high value for its clustering coefficient. Since SAP provides products and services in a very specific market, namely ERP, its alliance partners appear to be central players in the ERP domain of operations. SAP's pattern of cultivating a highly connected ecosystem has contributed largely to its dominance in the ERP market. IBM and Microsoft, on the other hand, have many relationships with large and small firms.



Although their large partners are connected to one another, their legions of smaller partners are not. Therefore, any high value that IBM or Microsoft accrues on this metric is decreased by the lack of connectivity within the smaller partners. Thus, mapping the network of relationships and calculating the values of

cluster coefficient provides insights in the overall intent and role of alliances and relationships under different conditions.

Network Metric 5: Network Density

Network density describes the ratio of links that exist in the network to the number of potential links that could be if all possible pairs of nodes were directly connected.

Going back to Figure 1, there are a total of 12 nodes in the network. These nodes can form a total of 66 unique links. However, only 17 links exist, giving that network a density score of 0.25 (17/66). In contrast, the network depicted in Figure 2 has a higher network density of 0.44 (29/66). Network density has been used to measure group cohesion and can take on values between 0 (empty graph) and 1 (complete graph). Plotting the network density over time gives us a general understanding of the degree of interconnections through alliances and partnerships. Over time, such densities can be compared across other sectors to identify similarities and differences in network topology structures.

In our analysis, the network density for the software ecosystem in 1990 was 0.00489. This means that the total number of links seen in the figure is less than 1% of the total possible. During the twelve year period that we studied, 1990-2001, the number of active firms grew from 445 to 3202 ; the overall density showed a decreasing trend (0.005 to 0.001). As software firms are becoming increasingly specialized, they are focused in their alliancing activities, which reduces the overall density of the network. Similarly, when a software vendor such as Business Object seeks to increase customer satisfaction by providing add-on services, such as architecture review, implementation or domain knowledge, they form close partnerships with select consulting companies such as Accenture, BearingPoint and CapGemini, which in turn can increase network density.

Software Network: An Overall Assessment of the Small World Ecosystem

For a network to be a small world, two criteria must be satisfied: (1) the ratio of the random and actual average path lengths should be approximately 1 and (2) the small world coefficient should be greater than 1. The small world coefficient is the ratio of the clustering

coefficient of a network to that of a random network. This helps us understand if we have clusters that are similar to that of a random network or if they are small worlds. In table 1, we summarize the small world coefficient in column [F]. Based on our analyses of 509 software firms using five metrics over a twelve-year period, we conclude that the software sector operates as a *small world ecosystem*. The values of small world coefficient are well above 1 (the range is from 56 to 248). In addition, the networks over the years have low density and short path lengths (Table 1; Column C). The central conclusion is that the topology of the network continued to be small worlds, during the emergence of the Internet which called for web based applications and despite technological changes such as the client-server architecture (where companies began to separate functionality between the client and the server).

Since the locus of competition is shifting from the firm to the network, it is useful to explore the impacts of network metrics on firm performance. In separate academic work, we have used these metrics as predictors of software firm growth and found strong predictive effects – providing further evidence that network positions do matter. Our findings in the software sector may serve to explore the impacts of network positions, which represent tight interconnections among firms for resource exchange, in sectors such as biotechnology, healthcare, financial services and entertainment.

What does this finding mean and why should managers care? What should this mean for companies in the software sector? What are the implications beyond the software sector? We think that we are in the early stages of understanding how companies position in complex network of inter-firm relationships that characterize intense and dynamic patterns of cooperation and competition. We believe that our analysis over a 12-year period provided some useful insights as we deconstructed the network using a set of key metrics. In the section below, we develop some implications and lessons for managers. Our approach is informed by our detailed analysis in the software sector but our implications have broader applicability.

IMPLICATIONS AND LESSONS

1. Dashboard of the Business Ecosystem

Business ecosystem has emerged as the new referent for strategy formation. Hence, mapping the ecosystem in terms of inter-firm interconnections is important in order to understand how firms access complementary resources through relationships. A diagrammatic

representation of the ecosystem with key relationships provides the context for strategy formation and implementation.

The mapping exercise can be approached incrementally over time, depending on the scope of decisions and strategic options under consideration. The analysis starts with a focal firm's set of key relationships. Then, for each partner, one can identify relationships formed with others in the network. Recognizing the key competitors and their set of relationships can complete this analysis. The data requirement to carry out such an analysis may initially appear onerous, but most firms have adequate data on its set of key relationships, which serve as the starting point. Using secondary data sources and proprietary databases, the map can be enhanced to recognize the critical set of alliances and relationships that define competitive and cooperative interactions. Data sources exist for mapping the network; often significant relationships are announced over the news wires, as they could be material information for the stock market to consider in the trading of securities of relevant firms. In our analysis, we constructed the network using specific inter-firm alliances pertaining to technology and related resource flows using multiple databases for a 12-year period. Those seeking to understand software networks can use what we have done as a starting point. Those in the other sectors may wish to dashboard the historical patterns of their ecosystems to understand stability or shifts as a referent for their analysis. The scope of networks could be expanded to include financial linkages (e.g., minority equity investments) or interlocking boards of directors depending on the objectives and purpose. Software programs are available to map these networks in visual forms as they enhance managers' ability to make sense of the intricate interconnections as well as potential opportunities and pitfalls (for an overview of visualizations of different types of networks, see www.visualcomplexity.com).

2. Calibrate the Network through Key Metrics

The next task is to calibrate the network through a set of key metrics. We used five metrics that we believe are a good starting point in most settings. Some metrics (such as network density) describe the network as a whole and can be used to track macro level dynamics. Other metrics (such as path length, clustering coefficient and degree) can be used both at the network level to understand macro characteristics and at the level of an individual firm to understand relative positions against direct relevant competitors. For example, doing the analysis from the point of view of IBM software, one can compare firm-level network

metrics against Microsoft, Oracle and SAP to examine relative network positions as drivers of competitive advantage. Does IBM have shorter path length to access complementary resources than Microsoft, Oracle and SAP in the enterprise software market? If so what should be done to preserve and protect such a position over time? Analyses such as those summarized in Figures 3 through 5 for three companies using one metric (clustering coefficient) serve to bring a network perspective to strategic analysis and trigger more focused assessments of strategic options for alliances and partnerships.

3. Examine Central Roles in the Network

Although software network is sparsely connected with low density, the existence of 'small worlds' indicates that this network is very efficient in moving information, innovations and other resources through the ecosystem. These small worlds could result from the control partnering by firms trying to maintain the network status quo or as a result of insurgent partnering by firms trying to destabilize the network or by chance (or random) partnering.^{xxv} In small world's regime, several sub-networks or cliques exist, and a small number of firms cut across these cliques. As firms enter into alliances, they can strengthen the clique and become part of the core, or they can straddle cliques and act as 'brokers' between disconnected cliques. By strengthening the core, firms foster cooperation between clique members. In contrast, firms playing the role of a broker foster a more competitive approach as they allow selective flow of information between sub-groups.

EMC, HP, Computer Associates, and IBM appear to be using control partnering within the storage industry with their support for the Storage Management Initiative Specification (SMI-S), an open storage management standard. This reinforces the clique by creating a 'universal translator' between storage arrays and management applications, which acts as a middleware layer with its hardware and software products. This middleware layer allows customers to use hardware from multiple vendors. Those supplying storage devices benefit by releasing products on this common standard.

Three roles are important in most networks: the *hub* (a firm with a disproportionately high number of links), the *broker* (a firm that creates a connection between two sets of firms) and the *bridge* (a link critical to the overall connectedness within the network).

Hubs: Established firms such as Microsoft, Oracle and IBM have become critical hubs over the years by offering platforms that allow for interoperability and newer firms such as Siebel and BEA Systems are recently striving to become hubs. Some hubs exist in the network as a whole while some are relevant in more focused micro-systems. For example, Redhat may be an important hub in the Linux micro-ecosystem but may not be a hub in the software ecosystem as a whole. By occupying the position of a hub, firms can choose between three operating strategies: keystone, dominator or niche.^{xxvi} Keystone strategies involve creating standards for an exchange of information between programs, regulating connections between firms and creating platforms on which other firms can base their products. Keystone firms are also involved in value creating and innovation but not necessarily in its appropriation (they allow the other firms in the ecosystem to appropriate some of the value). This results in an efficient, robust, innovative and healthy ecosystem. Firms that apply the dominator strategy try to appropriate all the value created by absorbing and integrating external assets into internal operations. Niche firms constitute the bulk of the ecosystem because they thrive by leveraging platforms provided by the keystone.

Broker: Social network analysis literature describes five types of brokerage roles: liaison, representative, gatekeeper, itinerant broker and coordinator.^{xxvii} The liaison is a brokerage relation in which all three firms belong to different groups. A typical example is the “arbitrator” between two firms, which is trying to establish a standard within a standards body. A second type of brokerage is the representative, created “when one member of a subgroup takes it upon itself or is given the role of communicating information to, or negotiating exchanges with outsider.”^{xxviii} Such a situation was created when the DOJ asked Sun Microsystems to testify on behalf of other platform providers in its case against Microsoft. A third type is the gatekeeper role in which an “actor screens or gather resources from the outside and distributes them to members of his or her subgroup.”^{xxix} Standards bodies such as RosettaNet or Java/Linux community play this role. The itinerant broker is the one where an intermediary actor mediates an exchange of information between two principals belonging to the same subgroup. The fifth and last type of structural brokerage, “the coordinator,” is found in a situation where all three actors belong basically to the same group.

In 2003, SAP played the role of a broker. In that year SAP AG announced an alliance with MySQL, the largest distributor of open source database. This was interesting because

Oracle was a complementor to SAP, and close to two-thirds of Oracle's DBMS were sold for SAP application. Since Oracle was fierce competitor with SAP in the ERP market, SAP was trying to build leverage by embracing MySQL and playing the role of a broker. Oracle had a vibrant ecosystem in the relational database market with over 30% of the market share in 2001. MySQL ecosystem was growing fast with over a million downloads of its software per month in 2003. By straddling two cliques (proprietary relational database management developers and open source developers), SAP is trying to play the role of a broker and use the network to its advantage.

Bridge: Since middleware is the software technology used to interoperate across multiple otherwise disconnected applications (or in some cases across operating environments such as Linux, Unix and Windows), companies that develop such products are especially suited for playing the role of a bridge. Examples of companies that develop middleware products are BEA Systems, TIBCO software, Webmethods, Vitria and CommerceQuest. It is key to track bridge products because if they fail or if their release is delayed, it fragments the set of nodes within the network. What this means is that products that are supposed to interoperate will fail to do so, causing major disruption to the services provided by the network.

As managers develop deeper insights into the functioning of small world ecosystems, one of the major challenges will be to understand the impact of these specific roles in the particular situations and identify specific targets that maximize value from relationships.

4. Construct a Network Scorecard

The pragmatic usefulness of a network perspective can be seen through the development of a scorecard, which reflects how an individual firm seeks to leverage network positions for competitive advantage. It is futile to rely on using generic network scorecards with metrics that work for all firms in an industry. It is critical to construct one that reflects how a particular firm seeks to access complementary resources from external partners.

We urge managers to view their company's network scorecard as the blueprint for navigation in complex dynamic settings that call for intense degree of competition and cooperation. It is a scorecard that allows for multiple managers involved in different types of relationships to know how their actions and interactions are constrained or facilitated by other existing and potential ties in the network. In particular, managers can use this scorecard to

track their alliance moves and their impact on their network topology. While they can track their individual moves, simultaneously, however, each move by a firm elicits a response from competitors (they form their own set of alliances) and these counter moves impact the overall network topology.

It is this emergent dynamic topology that should be tracked closely. For example, did any particular move by a competitor change the topology significantly? Some companies may focus on supplier networks while others may focus on R&D or marketing networks. Some others may focus on financial resource flows through venture investments or interlocking directorates within their networks. However, our main message is that network scorecard is more than functional-level inter linkages but more holistic connections amongst firms that reflect resource flows between companies.

However, network-based analysis is not a one-shot exercise. Thus, network scorecards are not periodic summaries of network position. They are continuous, dynamic dashboards that rely on dynamic updates of networks of relationships. This ensures that the network representation is dynamic, allowing for continuous adjustment of how best to navigate under fast-changing conditions. We now have the possibility of designing and deploying executive dashboards of network positions based on data feeds from wire releases, information sources such as Reuters, WSJ, Google and also XML and RSS based news feeds. Such dashboards will go a long way to enhance a manager's ability to comprehend, analyze and act on moves and counter-moves by different players.

Table 6: Summary of Implications and Lessons

	Step	Management Implications
1	Dashboard of the Business Ecosystem	<p>Develop a representation of the business ecosystems as a way to highlight the role of key players embedded in a rich, dynamic network of interconnections for key resources.</p> <p>The dashboard is to be dynamically updated based on key moves by the focal firm, its set of alliances and partnerships as well as moves by competitors in the extended ecosystem.</p>
2	Calibrate your network	<p>Look for similarities and difference between you and your competitors over time using the five identified metrics – degree of links, average degree of partners, path length, clustering coefficient, network density and structural holes</p>
3	Examine central roles in the network	<p>One way to understand networks is to examine the importance of specific roles such as hubs, brokers or bridges. Who is playing these roles and what moves could they make to influence competition?</p>
4	Construct a network scorecard	<p>Network based competition calls for a new scorecard for managers in different functions to understand the reliance and limitations of resource exchange in the network. These scorecards are not generic but reflect how a particular company seeks to exploit network resources.</p>

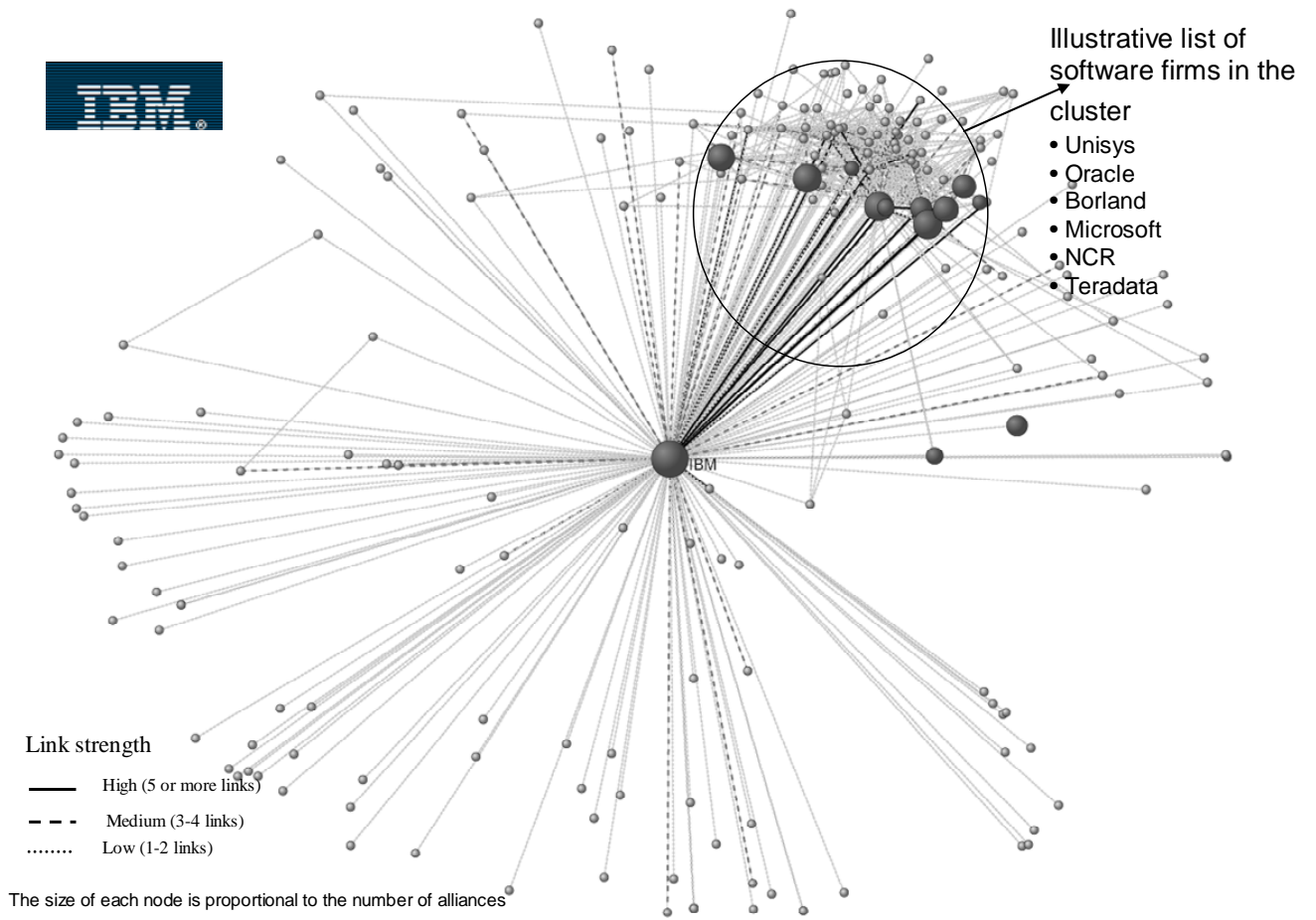


Figure 3A: IBM's Network Position in 1990

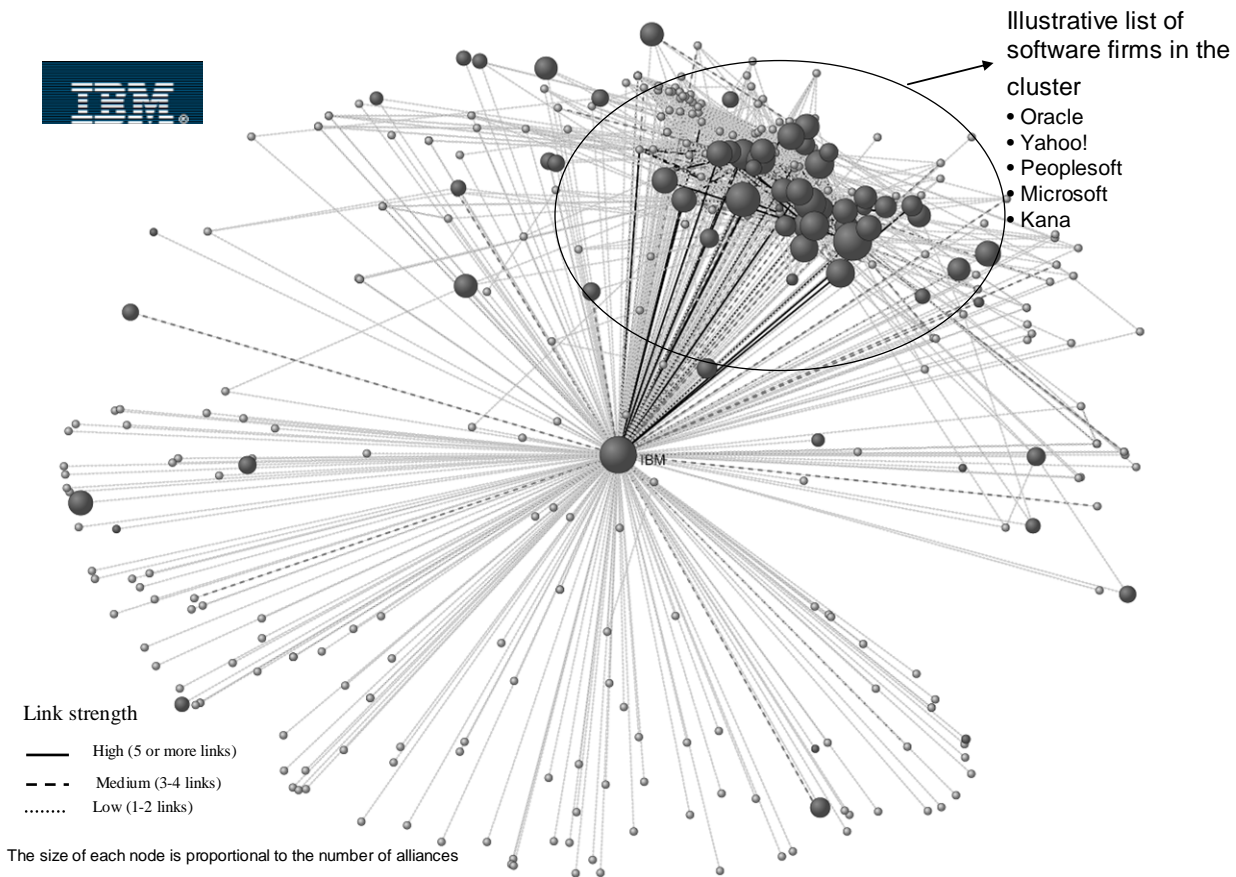
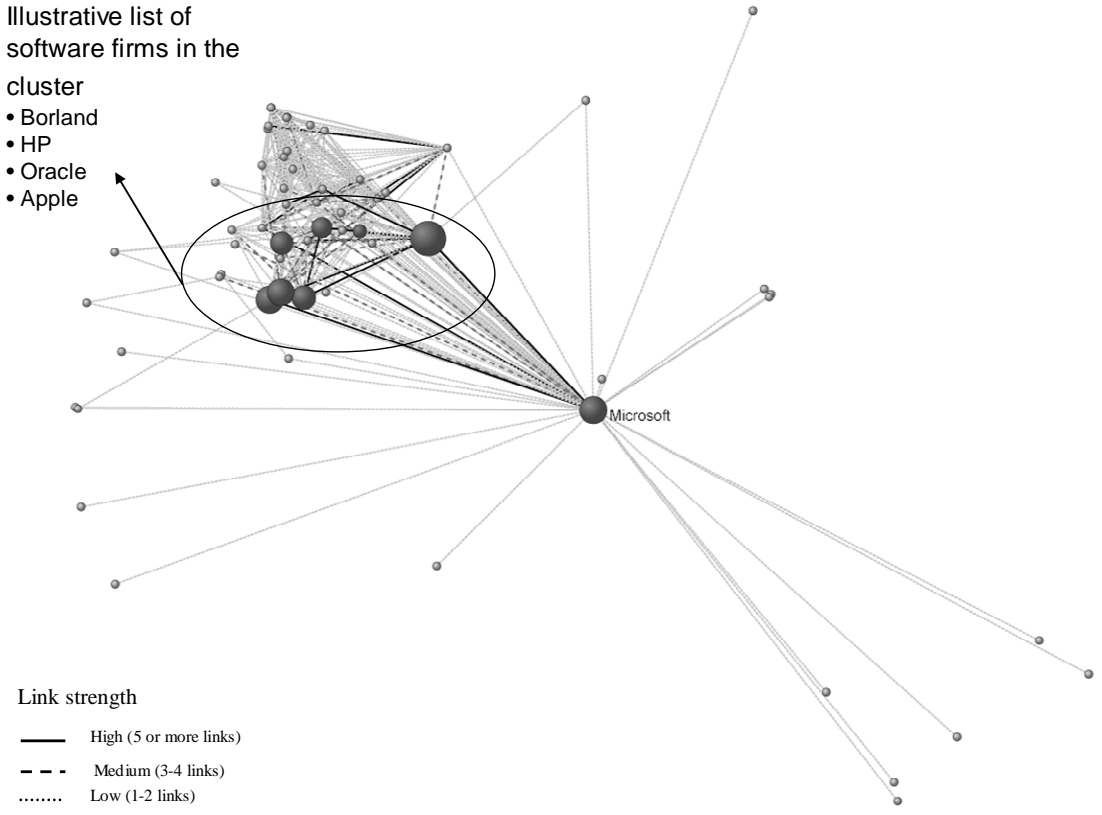


Figure 3B: IBM's Network Position in 2001



Illustrative list of software firms in the cluster

- Borland
- HP
- Oracle
- Apple



Link strength

- High (5 or more links)
- - - Medium (3-4 links)
- Low (1-2 links)

The size of each node is proportional to the number of alliances

Figure 4A: Microsoft's Network Position in 1990



Illustrative list of software firms in the cluster

- NEC
- Computer Associates
- RealNetworks
- CheckFree Corp.
- Yahoo!

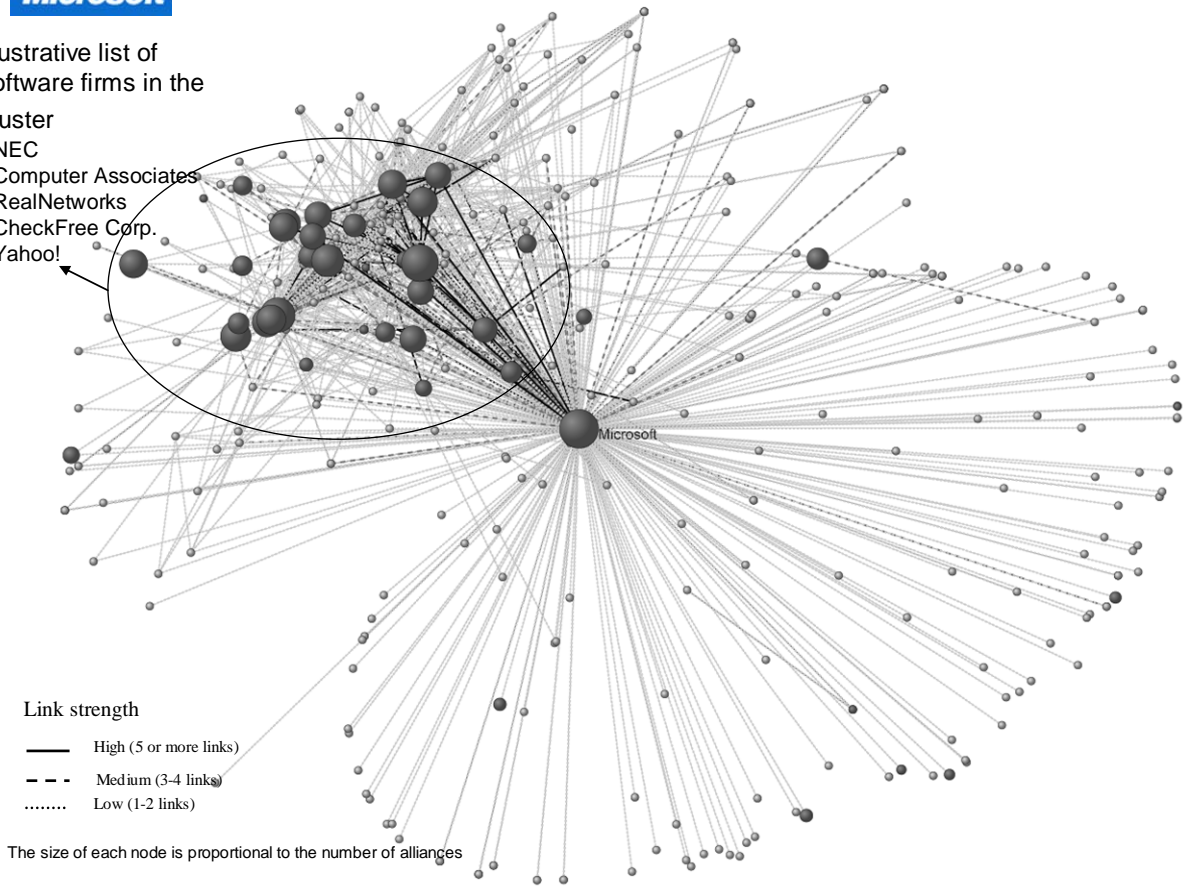


Figure 4B: Microsoft's Network Position in 2001

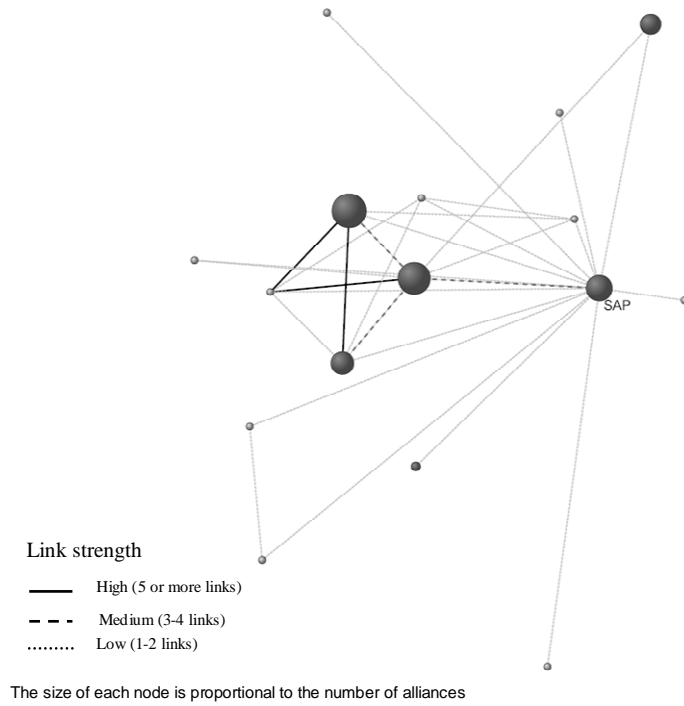


Figure 5A: SAP's Network Position in 1995

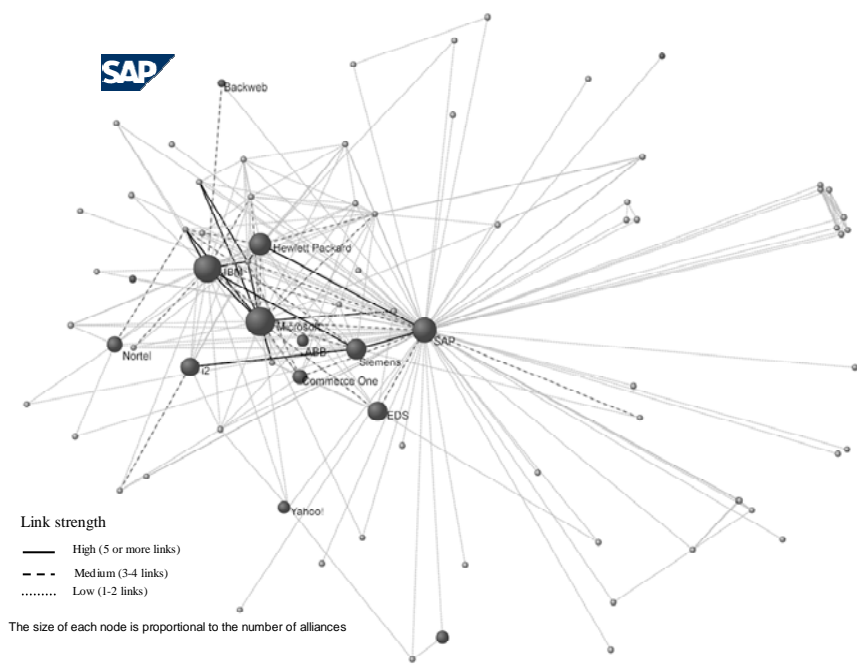


Figure 5B: SAP's Network Position in 2001

Notes

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http://news.com.com/Yahoo+to+test+desktop+search/2100-1032_3-5486381.html?tag=nefd.top, 2004.
- iii Delaney, K. 2004. Google Offers Software for Desktop Search, *the Wall Street Journal*.
- iii Evers, J.; Microsoft demos Web, desktop search Desktop search application would make it easier to find e-mail messages, Word documents, other files, *Computerworld*, 2004.
- iv Watts, D.J. *Six Degrees: The Science of a Connected Age*. W.W. Norton & Company, New York, 2003. Recently, Watts has launched a large-scale follow up study, using email as the communication mechanism, to test the earlier claims from the Milgram study (see <http://smallworld.columbia.edu/description.html>).
- v The Oracle of Bacon at Virginia (<http://www.cs.virginia.edu/oracle/>). This website uses the Internet Movie Database to find out the shortest path from any given actor and actress that can be connected to Kevin Bacon.
- vi <http://www.oakland.edu/enp/>. This website is used to understand research collaboration among mathematicians. In particular Paul Erdős. Just like the Kevin Bacon number, by entering the name of a mathematician, you can compute his or her Erdős number.
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