Is Linux Ready for Prime Time?

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Many corporations are faced with an important question: is it time to adopt Linux? This is not just for the end users to decide on their information technology architecture. It is equally important for the software companies to decide whether to offer their products on Linux. Will this "free" operating system currently backed by IBM, HP, and others break Microsoft's monopoly? Individual programmers are increasingly drawn toward the open source movement through various communities (SourceForge.net, IBM DeveloperWorks Linux zone). In the trade press, open source software is depicted as a direct competitor to commercial software. But what is the reality? Will 2005 be the year for Linux to grow up to be viable? Is it ready for 'prime time'? We analyze five years of data on software sales supporting different platforms to offer some key insights into these issues.

COMPLEMENTORS: WHERE ART THOU?

The software industry is unique. Software companies deliver a product which functions with complementary components from other companies to deliver business value. So, software companies pursue one of two directions: 1) they make their product as modules that subscribe to the architecture specified by another company or 2) they seek to become a platform architect by gaining the support of complementary developers.

A platform is successful—only if a set of complementors supports it: this phenomenon is often referred to as network effects or system-based competition [6, 7]. The success of a platform can be seen through the interaction of two forces: the degree of acceptance and adoption by customers ('customer network effects') and the availability of supporting software modules ('complementary network effects'). Often, complementary network effects act as a lead indicator of the future success of a platform, although they are highly interdependent. By this logic, we should be able to see if Linux is a viable platform by looking at the support it enjoys within the set of companies that design and deliver software products on the Linux platform.

We know a lot about the support enjoyed by Linux within the developer community [5]. Very little is known about the support it has from complementors. So, we began by looking at the data on the number of software products companies supporting Linux since 1997. Our analysis is based on the database that has been collected and assembled by the International Data Corporation (IDC). Since 1990, IDC has systematically tracked the global software sales of over 1,200 software companies. This database is widely considered the best source on the software industry: it has been used in the US DOJ case against Microsoft and in academic research.

The IDC database contains the global revenue generated by software companies at the level of products (e.g., SAS/Stat and PeopleSoft EnterpriseOne) for specific platforms. We excluded revenue from other sources (e.g., services) and focused on nine different platforms: We consider Unix, Linux and Windows separately and aggregate the rest into one category and call it 'other' for expositional clarity. So, we focus on the network consisting of Unix and its variants (e.g., IBM's AIX, Sun's Solaris, and Hewlett-Packard's HP-UX), Windows and its variants (e.g., Windows 3.x, 32, and 64), and Linux. Since software companies first generated revenues from software products on the Linux platform beginning in 1998, we focus on the period 1997-2002.

Our first quest was to see how many companies offer software products on Linux[1]. Table 1 indicates that there is a steady increase in the percentage of software companies supporting Linux. As of December 2002, nearly 16% of the firms in the software industry support Linux.

Table 1: Software Product Companies Supporting Linux

Year	% Companies offering at least one software product on Linux	% Change in the average yearly revenue of first time adopters of Linux	Average number of platforms supported by the first time adopters of Linux
1997	0%	0%	0
1998	1.2%	96%	2.8
1999	5.7%	167%	3.7
2000	9.2%	-60%	3.4
2001	12.4%	-52%	3.5
2002	15.9%	151%	3.5

It is also clear from our analysis that most companies *derive a small percentage of their revenues from Linux*. So, we wanted to go further to see how the network of complementors for Linux as a platform evolved over the six years, 1997-2002.

IT IS THE NETWORK, STUPID!

In the US DOJ case against Microsoft, a key contention was that Microsoft enjoyed *applications barriers to entry*. Judge Thomas Penfield Jackson based his ruling against Microsoft on the claim that the company's monopoly in operating systems is protected by an applications barrier to entry made up of 70,000 Windows-based software programs. As a result, to enter the operating-system market a newcomer would need a large and varied base of compatible applications like those available to consumers who might otherwise choose Windows. So, to understand Linux, we need to look at the network of complements supporting Linux.

Does Linux enjoy strong support from developers that confer significant benefits? As we said at the outset, we are interested in seeing the pattern of complementary network effects of software products on the Linux platform over time. For this purpose, we adopt a network visualization approach that complements the statistical approach that we have examined elsewhere [8].

We build the network using the following: software developer firms that build complementary products, platforms that provide the basis to build complements and links that connect a platform to a firm. Firms are depicted as circles, platforms as squares and links as lines. A link connects a firm to a platform if and only if the firm sells a product on that platform. When a firm sells products on more than one platform, a separate link is created to each platform.

Our network scheme is based on a color-coding scheme as follows: We draw a link between a developer and an environment if the developer sells a package that runs on that environment. We

[1] In this study we do not track open source application software distributed under the open source license such as Apache, Mozilla, MySQL, KDE, GNOME, and PHP. But we recognize it as an important direction for further inquiry.

use the following coloring scheme for the links: light green if they generate less than 15% of their sales from that environment, green if they generate between 15% and 30% of their sales on that environment, spring green if the sales generated is between 30% and 45%, golden red if the sales generated is between 45% and 60%, yellow if the sales is between 60% and 70%, orange if the sales numbers are between 75 and 90%, and red if the percentage of sales is over 90%.

The size of the node indicates the total revenue that is generated by a software product company. The software company, as nodes, are color-coded as follows: first time supporters of Linux are colored yellow; purple color denotes companies that have already supported Linux in previous years; and finally, magenta nodes denote firms that are yet to support Linux at that time. Platforms are represented by squares that are colored green. The size of the platform is based on the total revenue generated for that platform (a natural log transform of that).

Using Pajek, which is new network visualization software, we present a series of discrete-time images of the evolution of the software network. Pajek employs "spring-embedded" drawing algorithms to represent network data in two-dimensional Euclidian space. These algorithms simulate the network of collaborations as a system of interacting particles, in which organizational nodes repel one another unless network ties act as springs to draw connected nodes closer together. It has been recently used to model business networks (Powell et al, 2004).

A PICTURE IS WORTH A THOUSAND WORDS

We present three network pictures representing the years 1997, 2000 and 2002[2].
Figure 1 shows the initial state of the network of complementors at the end of year 1997. Only one independent software firm supports Linux exclusively; one supports Linux and Unix together; and five firms support Linux, Unix and Windows. Except for the exclusive developer, all other links to Linux are shaded green (i.e., they generate less than 15% of their revenue from Linux). Look at the support for Windows: it has close to 100 software firms that support it exclusively. Moreover, many firms support Windows with other platforms such as Unix. It is interesting to note that the links are all either orange or red in color indicating strong commitment to Windows (i.e., greater than 90% of the firm's sales comes from Windows). At the end of 1997, *Linux as a platform is in its infancy*.

Let us fast-forward to the end of 2000, depicted in Figure 2. By now, about 50 firms support Linux. Oracle and IBM now support all major platforms including Linux. However, Microsoft (pink) and SAP (lavender) still do not provide adequate support for Linux. During these three years, Linux attracted few exclusive developers. It appears that the developers provide symbolic support to this platform—denoted by green links that connect developers to Linux. As a comparison, look at the links to Windows or Unix: the number of software firms supporting the platform is higher and the links show substantive commitment (as shown by exclusive links with red coloring and several links with yellow/orange/red colored links from firms that support multiple platforms). Now, look at the center of the picture: many larger and important firms are at the center. This region shows firms that support many platforms. To the right are firms (Microsoft, SAP) that support the Windows, Unix and other platforms. To the left are firms (Oracle, IBM) that support all four

[2] *Note to the Editors: We will provide a dynamic presentation of the 6 years on ACM website if interested or on our website*

platforms including Linux. However, these firms are connected by green links to Linux, showing weak commitment. IBM announced a $1 billion dollar commitment to Linux but it has not yet translated into software product sales. *Linux network is showing signs of support from complementors but is not yet a strong contender as a platform.*

Now, let us look at the network at the end of 2002. Linux is beginning to show stronger network effects: more firms are linked to it. Very few software firms are exclusive to Linux (< 2%). Interestingly first time supporter of Linux (nodes that are yellow) continue to support multiple platforms. The firms to the left of the page show commitment to all environments including Linux. Once again, these are large firms such as IBM, SAP and Oracle. Just as in 2000, these firms are connected by green links to Linux indicating that they exhibit symbolic commitment. Almost seventy-five firms including SAP (lavender), and IBM (pink) support all platforms. Microsoft that supports three platforms is shown in tan color—as expected, Microsoft shows symbolic commitment to Unix and others and no commitment to Linux. Once again, except for the exclusives, all other firms show symbolic support to Linux (note the light green links).

What do we conclude? Linux—despite the buzz in the trade press—has not yet emerged as a serious alternative platform. The complementor network is small and weak at the end of six years of support for the platform. There are over 80% of software product companies that do not yet have any product on Linux. While Linux may have received symbolic support from many of the bigger software companies, the support is not substantive yet. At the same time, the network supporting Windows and Unix do not seem to be getting weaker during the period. *Thus, Linux is gaining support but not yet emerged as a serious contender to dislodge Microsoft in the near future.*

STACK 'EM UP!

So far, we looked at the complementor network for Linux at a high level of analysis. Now, we go deeper to see if we can discern any specific trends within the different layers of the software industry.

Computer industry has evolved over the years from being vertically integrated to horizontal layers. This layering started with IBM's historical decision to separate hardware and software. Today the industry is generally described using four layers: services, application software, middleware software and systems [3]. This layering has changed not only the computer architecture but also the basis of competition. We see divided technical leadership with different firms specializing in each layer [2] [1].

We used the layered model representation to further understand the degree of support for Linux. In Figure 4, we depict the firms based on the layer of the industry stack [3, 6] where they generate the largest part of their revenue. For example, if IBM generates most of its sales from middleware markets, it is represented as a diamond. Microsoft, on the other hand, generates most of its revenue from systems (OS, networking, etc.) and is represented as a triangle. Using this notation, we see that firms that support Linux exclusively are all providers of systems software (triangles). Application providers support more that one platform, which suggests that they could be porting applications to the Linux environment. The center of the figure shows firms that support all platforms—dominated

by middleware and application providers. Service providers, like application providers, do not support Linux exclusively.

This indicates that ecosystem that supports Linux is based on smaller and more focused companies. It has not yet received support from broad-based companies that straddle the different layers of the stacks.

SO WHAT?

Software industry is different from other industries because of the requirement of interdependence across different products. A platform succeeds because of the degree of network effects of complementors, which has been typically modeled analytically and/or statistically. In this paper, we have used recent approaches to network visualization to offer insights on the evolution of the software network to assess the growing importance of Linux.

Our representation over time tells a compelling story. The surfeit of greens within the links to Linux shows that software product companies are making at best symbolic commitment. If you look at the links to the Windows environment, you will notice exclusive links (represented in red), where these firms are "betting the farm" by linking to Windows. Viewing the pictures from the perspective of nodes, we notice that large companies such as IBM and SAP still hedge by supporting many platforms. Also, first time committers (shown in yellow), do not form exclusive links with Linux: they also hedge.

We come back to our opening question: Is Linux ready for prime time? Has it arrived on the main stage? We may have seen advertisements on major networks, but our answer based on systematic analysis of the degree of support provided by third party software companies is: No.

Four points are worth making. One: not many firms have made substantive commitments to it although many major firms have signaled their intent to support Linux. Two: we have not seen droves of new software product companies entering the market only to support Linux at the expense of other platforms. Three: most firms that embraced Linux have made symbolic commitment and have not abandoned their support for any other platforms. Four: when we delved deeper into the layers of the software stack, we did not see broad-based support in all the layers. So, the hype is ahead of reality. Nevertheless, since the growth in number of companies supporting Linux is strong (see Table 1), Linux may emerge as a platform due to possible nonlinear growth since in the networked economy, the network can tip at any time.[4]

WHAT TO WATCH FOR?

What should we watch for to see how quickly could Linux gain prominence and be ready for prime time?

One: monitor the number of new entrants supporting Linux by developing new applications that are not available on other platforms. This changes the network from Linux as a plausible alternative to Linux becoming more central in the software network.

Two: track the level of porting of critical applications from established operating environments to Linux. Porting changes the network structure by increasing the depth of applications available on Linux.

Three: watch for announcements of substantive commitments to embrace Linux from key players. It is clear that IBM's announcement of $1 billion commitment galvanized the open source software movement. They serve as lead indicators of future competition among alternative platforms.

Four: look for announcements from governments in developing countries that may trigger software product companies to embrace Linux more readily than otherwise. Government mandates may realign the software network radically and quickly.

Five: Look for announcements from major users such as Wal-Mart or GM or GE to see how the direction of enterprise IT architecture is recognizing the role of Linux. In a recent survey of over 3000 end-user firms conducted by IDC, close to 30% of the firms planned to invest in the Linux environment.

Six: Track the emergence of middleware software that makes it easier to embrace Linux. (for example, Oracle is pushing Linux as an option for companies that are transitioning their data centers from proprietary to open source software.); the availability of such software makes it easier for enterprises to refine their IT architecture and incorporate Linux as part of it.

Seven: Monitor the distribution of applications under the open source licensing agreements in addition to commercial software product companies delivering 'for-fee' products on Linux. In particular, track open source application software such as Apache, Mozilla, MySQL, KDE, GNOME, and PHP. These applications are part of the infrastructure on which the 'for-fee' companies launch their own products.

We believe that companies should develop the capability to monitor the structure and dynamics of software networks on a continuous basis. Firms such as IDC have started to perform such analysis and may soon launch these pictures as part of their offerings. Our view is that managers need to understand how software networks—with interdependent components across different platforms emerge—because of the pervasiveness of software in business today.

Linux may not yet be ready for primetime but it could well be there sooner than one may think. Astute managers who follow these recommendations as part of their IT plans, will be in a better position to know if and when Linux will tip to be a contender in the prime-time lineup of operating systems for enterprises. Network support from both independent software vendors and the community at large together influence the likelihood of Linux success unlike the case of other proprietary operating systems. Stay tuned and watch out for triggers that change the software network dynamics.

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Figure 1: Linux Network -- 1998

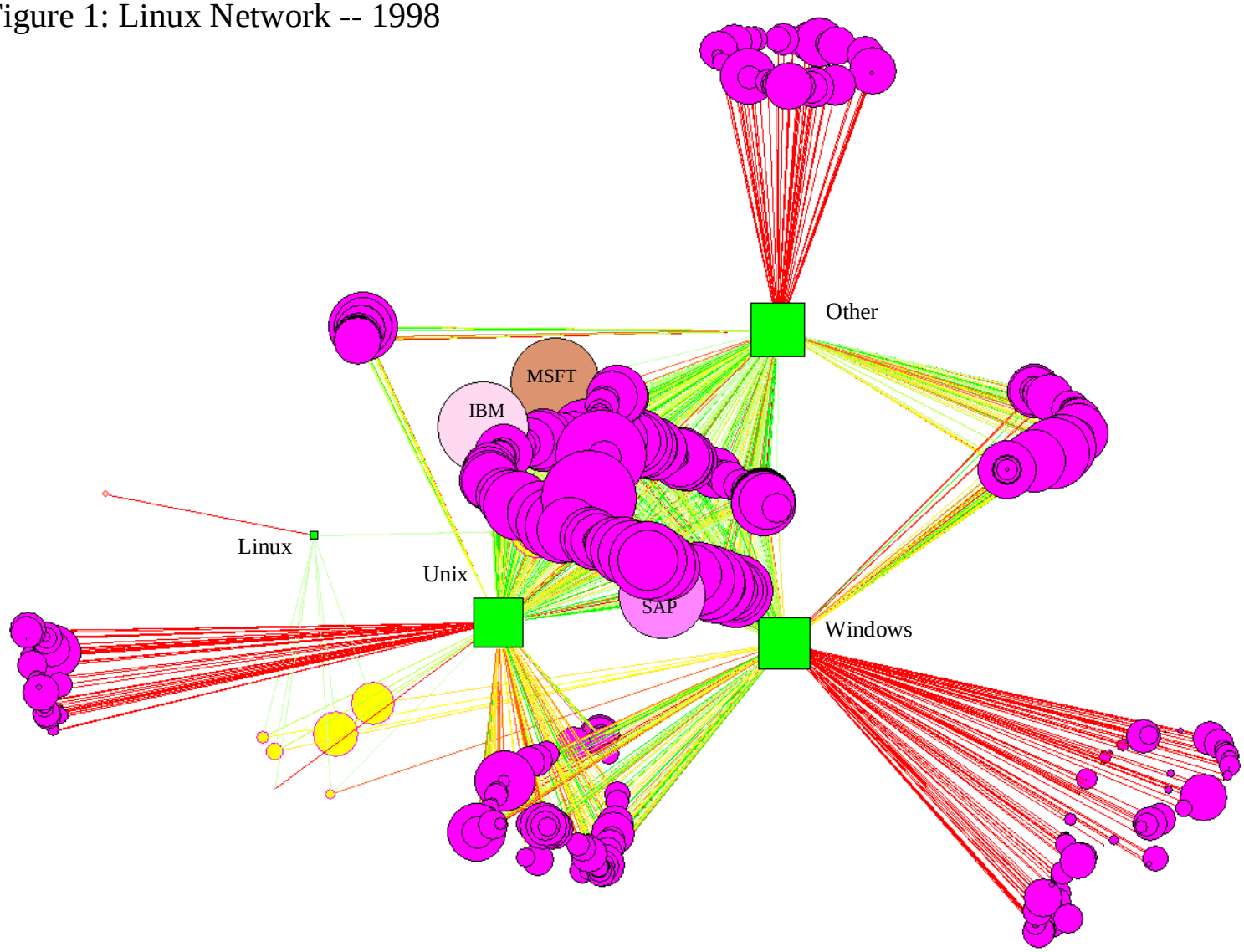

Figure 2: Linux Network -- 2000

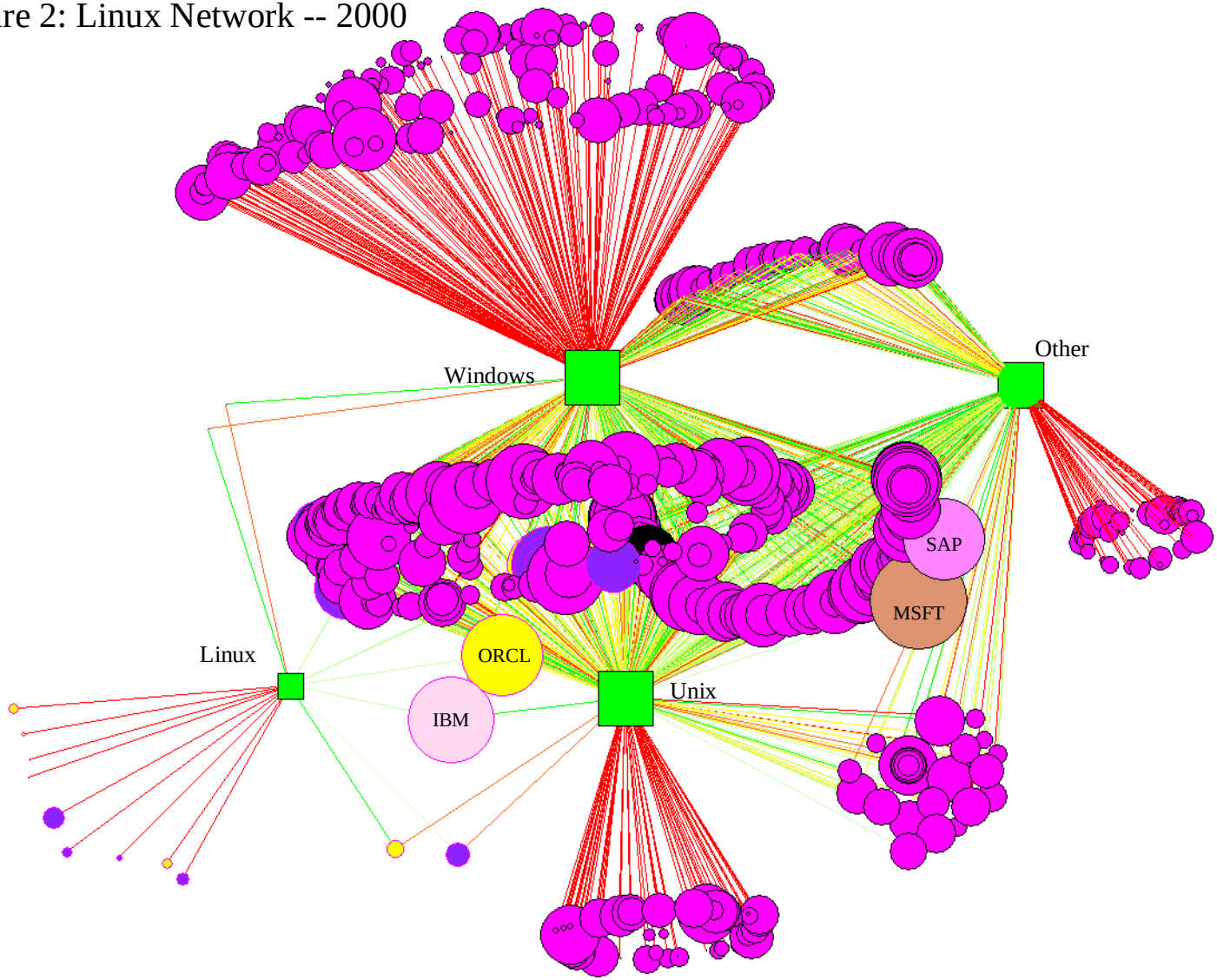

Figure 3: Linux Network -- 2002

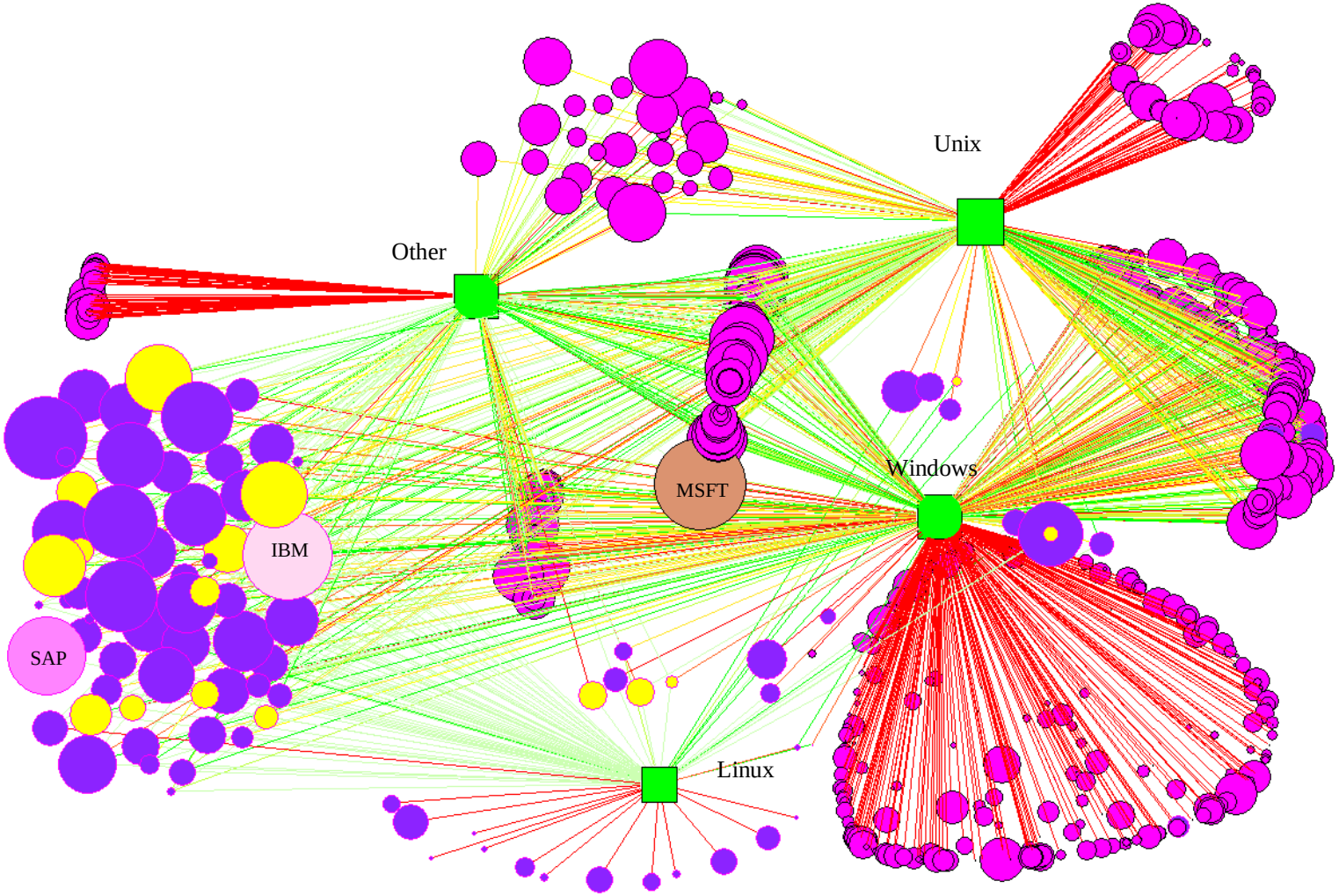

Figure 4: Linux Network – 2002
(by stack)