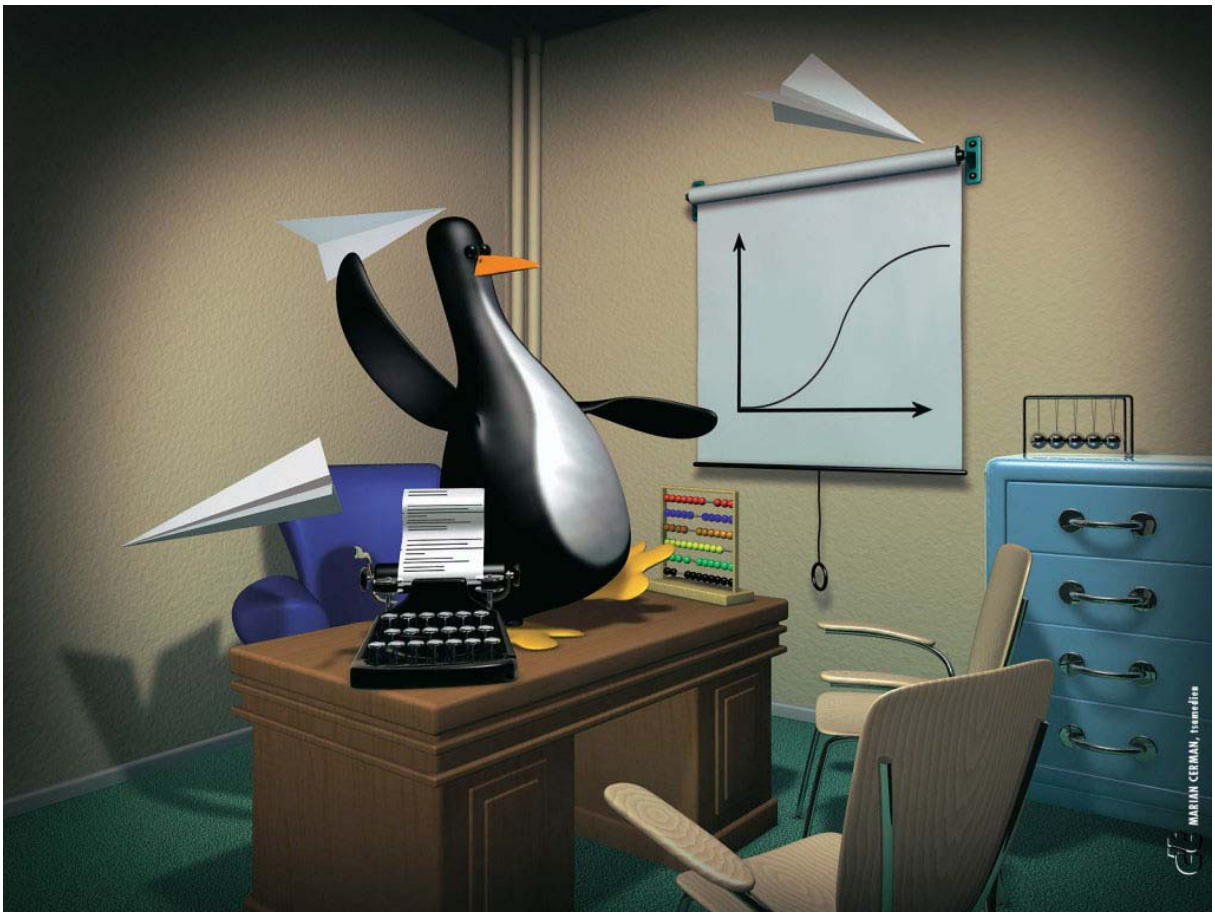
Analysis

Linux' pattern of diffusion



Last updated: 12 January 2005

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1. Introduction

This paper is meant to describe the diffusion pattern of Linux. A diffusion pattern describes the market adaptation process of a certain technological invention, which in this specific case will be Linux. The result of this diffusion pattern analysis will be used by Dr J.R. Ortt in a more general analysis concerning diffusion patterns. This general approach tries to answer to the question whether technologies always diffuse in the same pattern.

This analysis starts in chapter 2 with a description of the history of Linux, and gives a compact overview of events from the date of invention until today. After this description the technological scope of this analysis will be defined in chapter 3 and chapter 4 will give a more technical explanation of Linux. Then Linux' current market position will be described in chapter 5, by looking at recent developments in the open source world and by looking at the competition. Chapter 5 will wind up with some IT strategy implications caused by the fast rise of Linux.
Last but not least chapter 6 will describe Linux' diffusion pattern based on the information given in the previous chapters, and chapter 7 will give some concluding words with which this analysis will come to an end.

2. The Linux story[1]

2.1 UNIX[2]

At the end of the 1960's Bell Labs was working on a new operating system under the supervision of Dennis Ritchie en Ken Thompson. This new operating system had to be able to handle multiple users simultaneously, had to contain networking possibilities and had to be able to run on a wide variety of computer hardware. As a result the UNIX operating system was born in 1972 and publicly unveiled in October 1973. In the beginning UNIX was not used on a wide scale, but the development slowly continued.
UNIX became very popular among universities because the source code was public to them. The university of Berkeley implemented a lot of improvements and finally came up with BSD (Berkeley Software Distribution) late in 1977. This UNIX spin-off became very popular and companies became interested in UNIX.
Companies started to develop their own UNIX systems with the BSD- or Bell Labs version (which was by then renamed to System V) as the basis. As a result the development of UNIX systems exploded in the beginning of the 1980's. Sun was first with their SunOS, which was in the future renamed to Solaris. HP followed quickly with HP-UX, IBM with AIX, SGI with IRIX, etc … even Microsoft had worked on their own UNIX version: XENIX.

2.2 GNU[3]

In the 1970's Richard Stallman was a software developer at MIT (Massachusetts Institute of Technology). He argued that closed source was not good for the society, because it build walls between people instead of bridges. In 1984 he hit on the idea to make free UNIX software and as a result he founded the GNU (GNU's Not Unix) project and later the Free Software Foundation.
Stallman started off with the development of an editor called Emacs, which became very popular and in fact still is. But the intention was to create a entire free operating system and Stallman chose UNIX as the basis. Eventually an entire UNIX system was build with the use of GNU software, but this system was lacking a good kernel (the heart of an operating system).

2.3 Linus Torvalds[4]

In the beginning of the 1990's Minix was a popular light-weight UNIX based operating system among students and was developed by Andy Tannebaum. Linus Torvalds (a Finnish student) also used this operating system but found its terminal emulation not good enough. Because he was interested in the Intel 386 processor, he decided to develop a new terminal emulator. By accident he crashed his Minix system and therefore he continued to work on his terminal emulator, which developed into an entire operating system.
After a lot of programming he published his creation (Linux) in the Minix newsgroup in 1999. The newsgroup users implemented a lot of improvements and the Linux source code became public.
(Of course Andy Tannebaum was not happy with this and had a lot of criticisms upon Linux.)

[1] http://www.nedlinux.nl/modules/article/index.php?id=3&page=1
[2] http://www.computerhope.com/history/unix.htm
[3] http://www.gnu.org/
[4] http://en.wikipedia.org/wiki/Linux and http://www.linux.org/

2.4 GNU/Linux

Linux did not have a system and was merely a kernel. GNU however, was a complete system, but was lacking a decent operating system. This resulted into GNU/Linux. In the early 1990's GNU/Linux systems consisted of a mediocre Linux kernel and a small collection of software from the GNU project. It was a so called hackers operating system. There were no CD-ROM's or GUI (Graphical User Interface) installation tools; everything had to be compiled and configured by the end user.

Towards the middle of the 1990's several GNU/Linux distributions began appearing. One of the first distributions was Slackware in 1993 and many other 'flavors' did follow. Some popular distributions nowadays are: Red Hat, Debian (which I am using myself), Gentoo, Suse and Mandrake.

The main purpose of such a distribution is offering features for automating the GNU/Linux installation and configuration, taking the burden off of the system administrator. The different distributions try to differentiate from each other by answering to this 'main purpose' in a specific way, by offering certain features. Therefore every distribution has a large number of users who argue that, the distribution they are using is the 'best one', because they value the 'extra features' of their specific distribution highest.

3. Defining the technological scope

In the previous chapter we saw that the name Linux is often used to refer to the GNU/Linux project. We also saw that this is officially incorrect, because Linux itself is only a kernel (an operating system) and GNU is a project in which open source software is developed.

This analysis focuses on the diffusion of a specific technology. Therefore the scope of this technology has to be defined. In this analysis I focus on the **Linux kernel**, which in my eyes is equal to Linux. It is the Linux kernel which is used throughout all current Linux Distributions and which was created by Linus Torvalds in the 1990's.

Throughout the rest of this article I will regularly refer to the Linux kernel as 'Linux'.

4. The Linux kernel in a nutshell

This chapter tries to give an overview of the Linux kernel. What is the Linux kernel and what does it do? Notice that most of the topics in this chapter could be worked out in much more detail, but because I am only trying to illustrate the more general picture, the details will be left for the enthusiasts among us, which can dive into the discussed matters themselves.

4.1 Operating systems explained[5]

Before explaining what a kernel does, lets begin with a short explanation of the operating system. A computer system basically exists out of three parts:

- Hardware
  These are the parts like a screen, a hard disk, a floppy drive and numerous chips which are the building blocks of a computer system.

- (Application) Software
  This form of software is also referred to as application software. These are computer programs which are 'visible' to the user in the form of for example: text editors, games, email programs, administrative tools, etc.

- Operating system.
  The operating system is also software, but is 'invisible' to the user. The operating system basically does two things:
  1. It manages the resources of a system.
  2. It provides a 'universal' platform for application software to run on a computer without knowing the details of the hardware.

So I would say that the operating systems handles the communication and cooperation between all the hardware components inside a computer system, and provides a universal platform for application software: *The operating system is the intermediary between the hardware and the software.*
Application software on the other hand makes it able for a user to exploit the computer systems resources/processing power: *The application software is the intermediary between the operating system and the user.*
Lets visualize this:

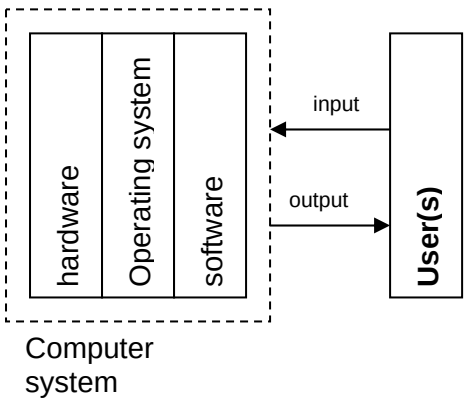


Figure 1: a computer system

[5] http://computer.howstuffworks.com/operating-system.htm

4.1.1 Multiple flavors

Operating systems exits in various sorts and sizes. However we generally distinguish 4 categories[6] which have all different characteristics:

1. Real-time OS
   Often used to control machinery. Make sure every operation executes in precisely the same amount of time every time it occurs. No to little user-interface capabilities ("sealed box")

2. Single-user, single task OS
   One user who can do one thing at a time. (example: Palm OS)

3. Single-user, multi task OS
   One user who can do more things at the same time. (example: Microsoft's windows, Apple's Mac OS (not X))

4. Multi-user OS
   Multiple users who can take advantage of the computer's resources simultaneously. (example: UNIX, windows XP)

It is important to notice that for example windows 2000 supports hundreds of network users, but the operating system itself is not really multi-user.

4.2 Kernels explained[7]

One of the things that you should learn from this article is that a kernel is not the same as an operating system, although the terms are often mixed up. The kernel is the fundamental part of the operating system which provides basic services for other parts of the operating system. A kernel manages the machine's hardware resources and provides and controls the way any other software component can access these resources.
An operating system on the other hand can be seen as a larger collection of tools and the kernel which then together serve the same purpose and a little bit more.

Example
An operating system manages the files and directories on a hard disk, while the kernel as a part of the operating system only handles the low-level access of the hard disk.

Derived from this example, one can say that the kernel determines on which hardware components an operating system can run. The Linux kernel for example was originally designed to run on 32-bit x86 based PC's (386 or higher), but today the Linux kernel runs on much more architectures like for example: SPARC, PowerPC and the new 64 bits architectures form Intel (IA-64) and AMD (x86-64). Notice that the Microsoft Windows platform runs on much less architectures.

[6] http://computer.howstuffworks.com/operating-system3.htm
[7] http://www.google.nl/search?hl=nl&q=define%3A+kernel&btnG=Zoeken&lr=

4.2.1 Multiple flavors

Also kernels come in different flavors. We generally distinguish 4 kernel categories[8]:

1. Monolithic kernels
   Monolithic kernels provide rich and powerful abstracts of the underlying hardware in the form of a high level virtual interface. Modern monolithic kernels can load executable modules at runtime, allowing to extend the kernels capabilities at runtime. The amount of code running in kernel space is normally kept as small as possible. A bug in the kernel or the modules brings down the whole system.
   Examples: UNIX, BSD, Linux

2. Microkernels
   Microkernels provide small and simple abstracts of the underlying hardware (relatively simple structure). Applications called 'servers' are used to extend the kernels capabilities. Modules provided by the servers can be restarted separately, so a bug in a module does not crash the whole system.
   Examples: Minix, Mach (partly used in Mac OS X)

3. Hybrid kernels
   Hybrid kernels can be seen as a mixture of monolithic and microkernel with some non-essential code. Non-essential code in kernel space instead of user space has the advantage of performance increase.
   Examples: XNU (= Mac OS X kernel), Windows NT

4. Exokernels
   Exokernel are rather new and radical. The idea is to empower the developer of software with the implementation of hardware abstracts, make his/her own decisions concerning the hardware. The kernel itself is extremely small, because its function is limited to controlling the systems resources. In theory an Exokernel makes it possible to run multiple operating systems running on a single exokernel system.
   Examples: concept OS Nemesis

4.3 Linux' recent form

By now you should have a basic idea of what a kernel is and what it does. You also read that the Linux kernel is a monolithic kernel. But so far, I did not mention a word about the latest kernel developments and versions. This paragraph gives a short summary of the latest changes in the Linux Kernel in as little as possible technical terms.

One of the most important strengths of Linux-powered operating systems is their flexibility and their ability to support a wide range of hardware platforms. The latest Linux kernel version 2.6, which was released on 17 December 2003, adds even more to this[9].
The most important changes in the 2.6 kernel, make Linux more suitable to run on significant larger systems and significant smaller ones. As a result a lot of functionality was added to support embedded systems, but on the other hand some very progressive changes were made to support a new kind of multi-processor systems, which provide a major performance increase compared to 'old' multi-processor systems.
Furthermore a lot of existing capabilities were improved and new capabilities were added. Some examples are: Hyper threading support (which is a feature in the new Pentium 4 processor), but also the addition of a concept called "subarchitecture" was standardized in

[8] http://en.wikipedia.org/wiki/Kernel_%28computer_science%29
[9] http://www.kniggit.net/wwol26.html

the 2.6 kernel, which enables Linux to handle the separate components inside a system more efficiently.

Of course there is a lot more to tell about the current Linux kernel, and I could easily bore you by going much more into detail, but that is not what this article is about. It is more important that you notice, that Linux is constantly improving and that its scope has been widened to support a large range of hardware. This implies that Linux is not only a fierce competitor in the area of low-end servers and desktops, but also in the area of embedded devices like PDA's and mobile phones and in the area of 'big'-servers.

5. The ongoing battle

This chapter mainly focuses on Linux in the market and its growth. While comparing Linux with the competition I try to describe the current situation.

5.1 Two markets

Before trying to illustrate Linux' current position in the market and the factors related to this, it is important to distinguish two main branches in the growth of Linux. Two branches we also see while looking at competitive operating systems from Microsoft and Apple:

1. the server market
2. the desktop market

Linux' market share in the server market is much bigger and stable then the market share in the desktop market. The server battle is of course a continuous process, where Linux has already conquered a substantial part of the market share, having Microsoft as the most fierce competitor.
On the desktop market there is still a lot to gain. Linux' market share in the desktop market is still very small, which makes not only Microsoft but also Apple a fierce competitor. However, you will see that Linux is about to hit this market big-time and that it will soon be closing in on Microsoft, leaving Apple behind with their relatively stable market share in the graphics industry. Some even say that Linux' market share in the desktop market will

5.1.1 The server market

Linux' presence in the server market has been a fact for some years. But despite the fact that Linux already has a substantial share in this market, there is still a lot to conquer. With Linux becoming more mature there are numerous of companies and governments which are currently considering the switch towards Linux. There are several reasons for this switch. Two of the most important factors are the costs and the security. Especially the last factor is currently very hot, as many companies are trying to cope with viruses, spy- and spam ware. Related to this is the speed at which security issues are solved. As Linux is an open source system, problems can be found easier and issues can be fixed sooner, because of world-wide participation of developers.
Linux' current market share in the server market, which is currently around 28%[10], shows that companies are aware of the advantages of Linux' over another server operating system. A lot of companies started using Linux some years ago, and but as these issues like costs and security become more serious, an increasing amount of companies are considering Linux as a possible solution to these problems.

5.1.2 The desktop market

The factors which apply to the server market, also apply to Linux' market share in the desktop market. Linux is free and has less bugs then its biggest competitor Microsoft, but apparently this incentive was not big enough to get people to use Linux on their desktop pc's. The current market share of Linux in the desktop market is around 2%[11], and I think this is related to some factors.

[10] http://www.alwayson-network.com/comments.php?id=P5013_0_6_0_C and http://news.com.com/2100-1001-253320.html?legacy=cnet
[11] http://www.itfacts.biz/index.php?id=P1193 and http://www.itfacts.biz/index.php?id=P723

Servers are often maintained by IT specialists who know what they are talking about, so for such people a switch to Linux is often easier. This is different for the desktop market, where a user can be practically anybody who would like to use a computer, without have a lot of knowledge about it. I roughly distinguish three factors which have been holding people from choosing Linux for the desktop:

1. the difficulty of installing and maintaining
2. the lack of user friendly and mature GUI systems.
3. The availability of software.

These factors have been a large barrier for people to switch to Linux, and most still consider these factors to be a too large barrier. The good news is that these 'problem' factors are being solved. Today many available distributions offer very easy installation features. GUI systems are becoming more stable and mature and last but not least there are currently a lot of companies which are porting their software for usage on a Linux based operating system. Eventually this will result in an increase in desktop market share for Linux, whereas some say that in 2008, Linux will have a desktop market share of 20%[12].

5.2 The competition

Now lets look at the competition. In general I roughly distinguish three operating system possibilities:

1. open source systems: Linux
2. Microsoft windows
3. Apple Mac OS X.

As you can see Linux belongs to first group. However, Linux is not the only player in this group. There are a lot of flavors in the 'open source' group, but concerning this article I will only consider Linux-based operating systems. As a matter of minor importance it is nice to notice that Linux is by far the most popular player in this group.
Because Linux was already discussed more detailed throughout this article, I will only discuss the Microsoft and Apple operating system in this paragraph.

[12] http://www.newsforge.com/business/03/08/13/1424212.shtml?tid=3

Microsoft[13]

At the time of writing Microsoft dominates the market with their flavors of the windows operating system. The windows story starts in 1985, when windows (version 1.0) was just a program which would run on the MSDOS 16 bits operating system, also developed by Microsoft and introduced in 1981. Then it seems that Microsoft's operating system developments are split up in two parts: The consumer version and the business version.

Windows 1.0 evolved into windows 3.1 (16 bit) which was released in 1992 and in 1993 Microsoft released its first business operating system with an NT-kernel (32-bit).
These separate developments eventually resulted in Windows 95 (the 16/32 bit consumer version, released in 1995) and windows NT 4.0 (the 32 bit business version, released in 1996). Both versions had the well known windows 95 interface.
Microsoft continued developing these operating systems. Windows 98 Second Edition was introduced in 1999 as the successor of windows 98 which was the successor of windows 95. Windows NT 4 was recently updated through the release of service packs, which added functionality and fixed bugs.
In 2000 Microsoft tried to combine their consumer and business operating systems into one single operating system: 'Windows 2000'. Unfortunately windows 2000 failed. Windows 2000 became the successor of NT 4 and Microsoft ceased development of the consumer version. Windows ME was released instead, which was basically the same as windows 98 SE with some extra functions and windows 2000 looks.
Microsoft's second attempt to combine business and consumer operating systems, was in 2001 when they introduced windows XP. This version became a large success and was widely accepted. The business version of windows XP became windows 2003, which is the official successor of windows 2000.

Apple[14]

It was Apple who introduced the Macintosh in 1984. It was the first computer using a Graphical User Interface. Although Macintosh computers are less popular then for example the Microsoft windows system, they should not be forgotten. In the graphics industry the Macintosh has always been and is still the most popular choice.
Over the years the Macintosh computers have had several versions of Apples own operating systems. Features were added and bugs were fixed and from version 7.5.1 this operating system by Apple became known as 'Mac OS'. Important to know is that the Macintosh computer did not have the same hardware parts a IBM clone with a Microsoft operating system. Apple has always been a separate world with a lot of differences, which by some are described as advantages and by others as disadvantages.
However, the most important step in the Mac OS development was in 2001 when Apple introduced a modern and more secure Unix-based successor named Mac OS X (X as in 10). A server version is this operating system is also available and is know as Mac OS X server. The difference with the normal Mac OS X is the availability of several tools which make it possible to run and offer network services. The backwards compatibility of this new Unix-based OS is maintained by offering a virtual environment where 'old' software can be run.

[13] http://en.wikipedia.org/wiki/Microsoft_Windows
[14] http://en.wikipedia.org/wiki/Apple_Macintosh

5.3 In the spotlights

Recent news indicates that Linux' popularity is increasing and that Linux is on its way to nest itself steadily in the markets of operating systems. While the word 'Linux' was ranked fifth in Google's annual list of most-searched "popular tech" terms[15], many discussions regarding the security and costs of operating systems took place throughout 2004[16].

It already began in the beginning of this year with Microsoft's campaign 'Get the facts', where Microsoft states to be cheaper and more secure than Linux, despite earlier research indicating that Microsoft software is more expensive and less secure than Linux software. This resulted in several reaction from for example Novell and the British Commercial Code Committee stating that Microsoft is twisting the facts and is embellishing the truth.
Anyway, this discussion increased the interest of companies in Microsoft alternatives. This because more and more companies have to carefully monitor their expenses. Some large European cities like Munich and Paris decide to let their civil servants work with Linux instead of Windows.
Also the Dutch government concluded in the beginning of 2004 that a switch towards open source software would save them 25 million Euro per year. Therefore it was really strange that they started negotiations with Microsoft about software licenses for desktop environments. Just before Christmas the negotiations failed, but in the beginning of this year, it seemed that a contract was signed anyway[17].
Another important topic from 2004, was the patentability of software. Among the Dutch ministers there is strong diversion with respect to the patentability of software, but in spite of that minister Brinkhorst officially informed the European Union that the Netherlands support the patentability of software. This caused a lot of discussions, but eventually the Dutch government formulated a letter which stated that the Netherlands are against the patentability of software. The new EU vote will take place in 2005.

The year 2004 was a year full of movement in the IT market, but we are still very far from the end. The coming years also promises to be contributing towards open source software and Linux. The Dutch Internal Revenue Service ('belastingdienst'), recently announced the future possibility for Linux and Mac users to digitally fill in their tax return form, which was already possible for Microsoft Windows users.[18] Adobe announced Linux support for their Acrobat Reader version 7[19] and the CodeWeavers[20] recently introduced version 4.1 of their CrossOver Office, which is a Linux emulator making it possible to run several Above and Microsoft software applications on a Linux system. Version 5 which will be available in 2005, will support Microsoft Office 2003.
Furthermore it is interesting that in 2004 the word wide server sales increased by 27,1% with a clear movement towards low-end servers and the Linux operating system[21]. And the European Union has subsidized a Linux-project with 2,2 million Euro's to make Europe more competitive in the IT market[22].

All these examples indicate that the open source market is moving. Figure 2 below also indicates the growing popularity of open-source software. It shows the usage of web server

[15] http://www.linuxworld.com/story/47633.htm
[16] http://www.webwereld.nl/nieuws/20400.phtml
[17] http://www.webwereld.nl/nieuws/20451.phtml
[18] http://www.webwereld.nl/nieuws/20289.phtml
[19] http://www.linuxworld.com/story/47707.htm
[20] http://www.desktoplinux.com/news/NS3643360142.html
[21] http://www.computerweekly.com/Article130835.htm
[22] http://www.webwereld.nl/nieuws/20374.phtml

software from October 1995 till the moment of writing[23]. Notice that Apache is an open source web server and is mostly run on a Linux-based operating system.

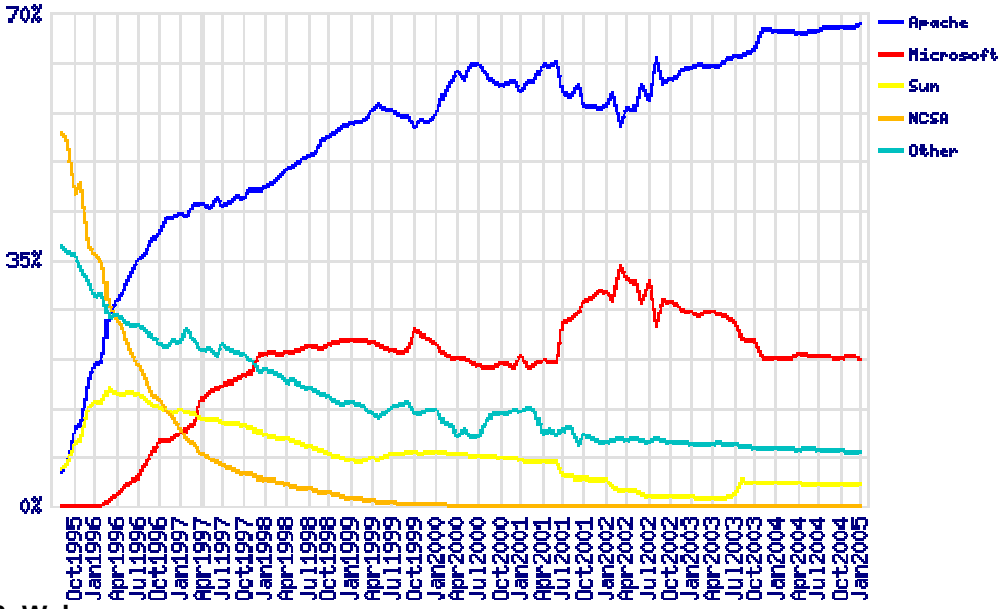


Figure 2: Web server usage

These examples are just a few out of thousands, but they indicate that the open source market, including Linux, is moving very fast. An increasing amount of companies are supporting Linux and governments are pressurized more and more to consider open source alternatives like Linux.
Some movements however still look a little uncertain to me, but on the other hand it is good to see that there is movement. A lot of recent movements indicate that Linux is closing in on the competition in the desktop market. But other movements indicate that the struggle in the server market is also not over yet, and with the coming of Linux 2.6 it has become even more exciting.

5.4 Bugs and security

We have read that Microsoft and Apple are Linux' main competitors. Microsoft on both the server- and desktop market, whereas Apple is only a minor competitor on the desktop market. Throughout this article is has become clear that Linux is growing fast and is becoming a serious threat to their competitors. This can be derived from the latest kernel developments, but also from the movements in the entire IT market, which are illustrated by thousands of article (of which a few examples were given).
This part focuses on an ongoing discussion about the number of bugs and the security of Linux compared to its main competitor Microsoft. Several strategic actions from Microsoft indicate that Microsoft is not underestimating Linux as a competitor, as they are trying to convince the public that Microsoft is still the most secure operating system there is. Together with the ongoing battle against hot issues like 'spam', 'ad ware' and 'spy ware', this discussion has become 'hotter' then ever before.

Innumerable articles have been written about Linux being more secure that Microsoft. One of the latest is based on the research of five Stanford University computer science researchers[24]. This research report states that a Linux 2.6 kernel had 985 bugs in 5,7 million lines of code. This is an average of 0,17 bugs per 1000 lines of code. Microsoft on the other

[23] http://news.netcraft.com/archives/web_server_survey.html
[24] http://www.wired.com/news/linux/0,1411,66022,00.html?tw=wn_story_top5

hand copes with an average of 20 to 30 bugs per 1000 lines of code, which would result in 114 000 bugs in 5,7 million lines of code (assuming 20 bugs per 1000 lines).

Maybe this is just one out of many opinions, but no matter how you like to see it; in my eyes this is an important factor in the growing popularity of Linux. Especially on desktop systems, where the average computer users are losing faith in Microsoft.

5.5 IT strategy implications

We saw that Linux is accelerating fast, but how does this relate to a companies IT strategy? This paragraph will shortly describe the strategic implications companies are facing now that Linux is closing in.

Concerning the growth and development of Linux, it becomes more and more interesting for companies to start using this open source operating system. Linux does not only fulfill its promises in datacenters, but also for desktop environments Linux will soon be as promising as it already is in datacenters. Altogether Linux is becoming an end-to-end enterprise solution.
For companies this means adjusting their strategies, training their employees in the area of Linux and a fast increase of Communities of Practice, as they often feel then cannot afford to lag behind the competition when it comes to Linux. On the short term this means an increase in Linux testing environments, were companies can experiment without causing harm to the actual business.
In spite the fact that Linux in itself is much cheaper than competitive operating systems, the switch towards Linux is still costly for a lot of organizations. The switch towards a Linux environment is often very complex and time consuming[25], causing it to be expensive after all. Despite these disadvantages, there is still an increase in the usage of Linux in the server market[26] as well as on the desktop market[27].

However it are not just the companies as a whole who become interesting, but also the employees (IT specialists and regular desktop users) become increasingly interested in Linux. Notice that this increasing popularity, could actually work as an incentive for companies to make the switch to Linux.

Linux is increasingly integrating into existing environments. However, the actual switch is still concerned as being risky by many organizations, which indicates there is still a lot of work to do. We are on the way, but not there yet.

[25] http://www.itfacts.biz/index.php?id=P996
[26] http://www.itfacts.biz/index.php?id=P940
[27] http://www.itfacts.biz/index.php?id=P1467

6. Linux' market adaptation

This chapter illustrates how Linux' has adopted to the market throughout the years.

6.1 Indicators

Throughout this paper we have seen that the success of Linux and therefore also the market adaptation is related to a lot issues, which I would like to call indicators. These indicators can be seen as the success factors of Linux. The list below shows some indicators and explains what they mean. Notice that some of these indicators are related to each other and that there are of course a lot more.

The monopoly position of Microsoft
Microsoft has a lot of supporters but also a lot of enemies. A lot of these enemies would like to see a fierce competitor in the server and desktop market. Microsoft on the other hand, will do everything in its power to maintain its current position.

The presence of GNU with its lack of a kernel
The availability of a lot of software which could be used on Linux, was an extra incentive for Linux to grow. Because of the software availability people find it easier to adapt. If GNU's own kernel would have been stable enough, then Linux might have never become so popular.

The development of GUI systems
With the introduction of GUI systems Linux lost it's 'hackers only' image and became interesting for a wider range of people. This factor is going to play a very important role in the coming time.

It's Free
A lot of companies, private persons and governments look for cheaper methods to fulfill IT requirements. This is also related to the economical crisis we have been facing. We saw that Linux is free, but that it is still costly for organizations to change.

Lots of 'flavors'
If you don't like a specific Linux distribution, you can choose another. As it is sometimes said: there is always a flavor you like.

Open source nature
Due to Linux' open source nature, the development went extremely fast. Together with its growing popularity, it made Linux a fierce competitor.

Bugs and security
As described earlier in this paper, the 'famous' discussion concerning bugs and security will certainly strengthen Linux' position.

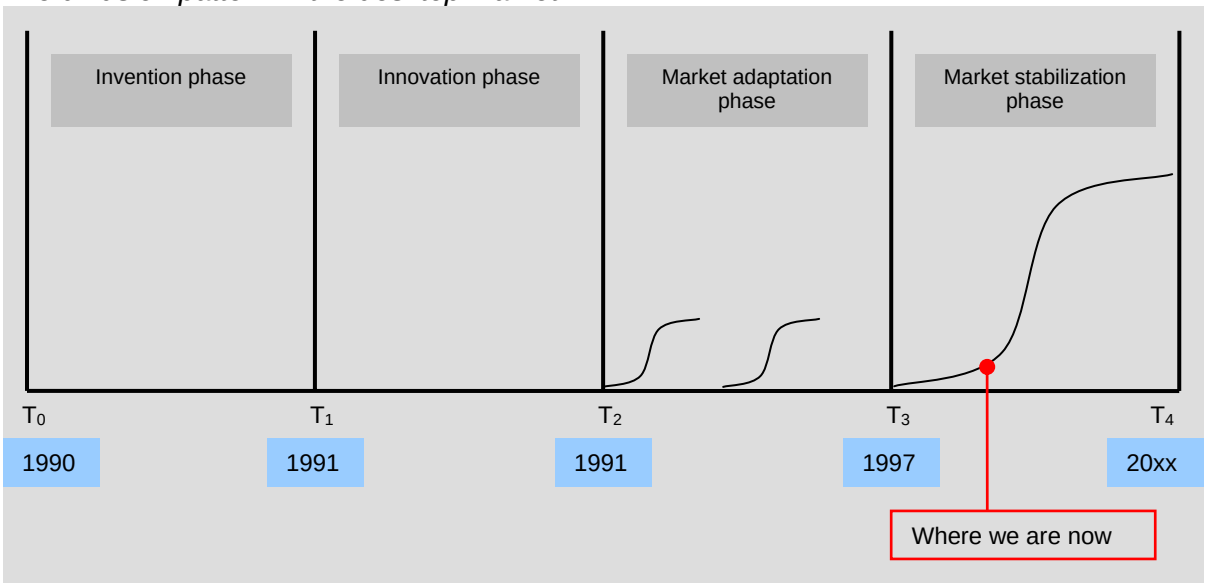
6.2 The diffusion of Linux

This section illustrates the diffusion of Linux.

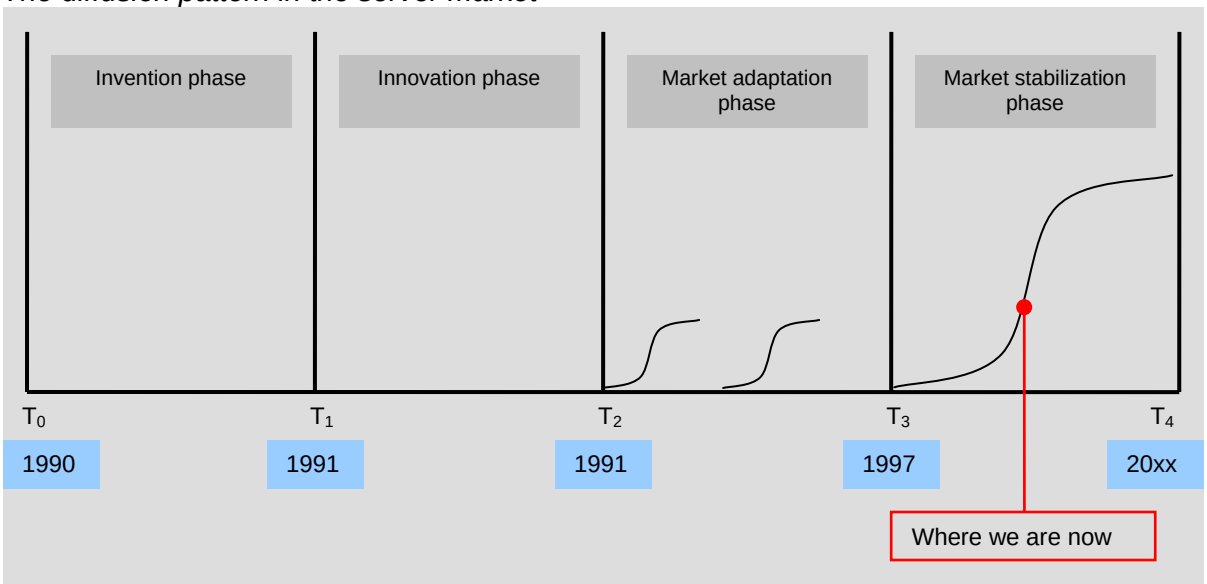
6.2.1 Two patterns

Because I clearly distinguish 2 markets in the diffusion of Linux, this section shows 2 different patterns. One for the desktop market and one for the server market. Examine these patterns and read the explanation of the phases in the enclosed table on the next page. After that read the explanation of these patterns in the next paragraph: 6.2.2.

The diffusion pattern in the desktop market



The diffusion pattern in the server market



	description	*Actors from T_x till T_{x+1}*	*Explanation*
T_0	*1990* Start to work on invention	Linus Torvals	Here Linus developed his 'new' terminal emulation for Minix and 'accidentally' developed Linux.
T_1	*1991* Invention with proof of concept	Linus Torvals and Minux newsgroup users	Torvals spread Linux among newsgroup users. Lots of improvements where made to the kernel and open source developers where attracted.
T_2	*1991* Market introduction (actual use, "commercialization")	The open source community. (So basically everybody who wanted to participate.)	I consider the introduction of Linux to the Minix newsgroup as the 'market introduction'. During this period distributions began popping up, GUI's were developed and GNU grew.
T_3	*1997* Start large-scale diffusion	The open source community. Corporations and Governments.	At the end of the 1990's, more and more people started using some form of Linux. Companies and governments are starting to see the advantages. Several factors described later on in this chapter contributed and are still contributing to the diffusion of Linux.
T_4	20xx Total substitution		There will always be a struggle between operating systems in the market. But one thing is for certain: Linux is growing.

6.2.2 Patterns explained

Despite all information available it is very hard to choose fixed dates for the beginning and the end of the phases in the diffusion pattern. It is very clear that Linux has become really mature throughout the years and that it has become a very fierce competitor in both the server and as the desktop market, but there exists no real fixed date from which Linux was accepted. This might also be related to the fact that it is much more difficult to track the usage of open source software as there are no sales numbers which are often a good indication for the acceptance/growth of software.

As the patterns show, Linux is already generally accepted in the server market, but there is still a lot of space for improvement/growth. The diffusion pattern of the desktop market is currently balancing on the edge of a breakthrough, distinguishing 2 scenario's. As figure 3 shows, the first scenario will be a continuous growth as we have been experiencing, and the second scenario will be an actual breakthrough. Considering the information described throughout this paper, I personally think (hope) that the breakthrough is about to happen, but of course I can be wrong.

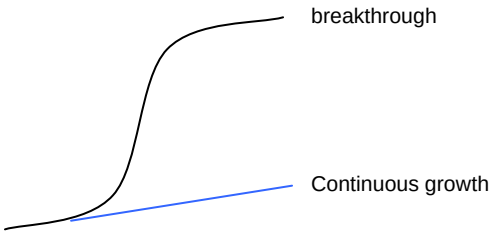
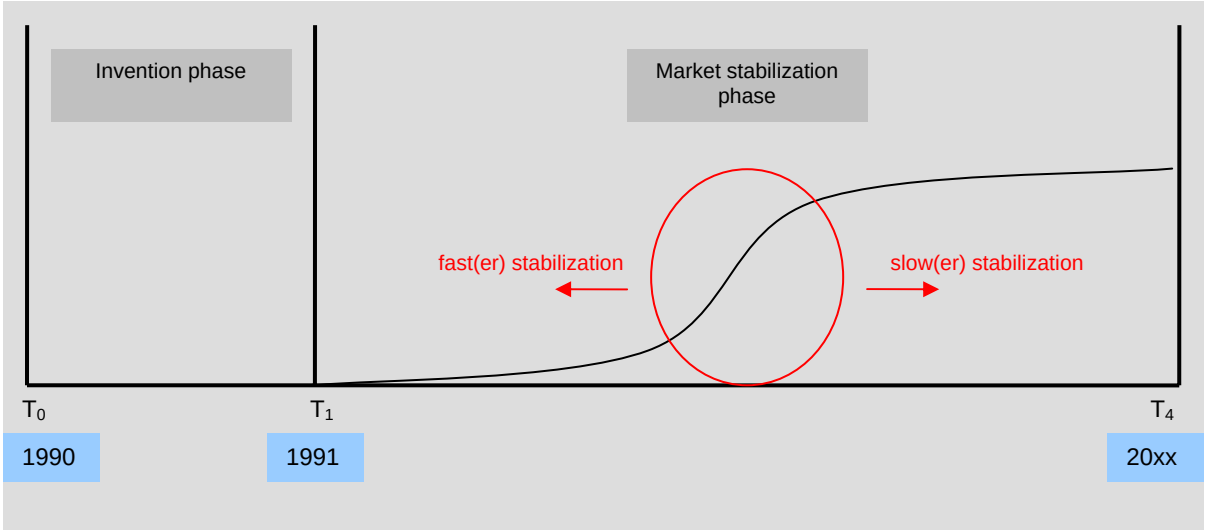


Figure 3: possible scenario's for the desktop market

Linux has adopted to the market very fast, but the actual motive for this adoption is related to a lot of factors which in itself often have nothing to do with Linux as a kernel. This becomes very clear while analyzing the diffusion of Linux in the desktop market. The fact that there is a big difference between the diffusion of the desktop and the server market, illustrates that the acceptance of Linux in the desktop market is much more related to the availability and mature ness of software. Something which was less important in the server market.
I believe that this is all related to the development speed of open source projects. It simply takes some time for open source software to become mature and accepted. So when deviating from the 4 phases in a normal diffusion pattern, I would say that the diffusion pattern of Linux looks like this:



In the pattern above you can see that I distinguish an invention phase, where a person or a group of people start a project, which is made open source. Then depending on a number of factors, the market for this open source project is stabilized fast or slow, meaning that the steep part of the graph moves to the left (fast stabilization) or to the right (slow stabilization). In the case of Linux the market stabilization for the server market was very much to the left and for the desktop market it is much more to the right.

However, considering the classic phases of the diffusion patterns shown in the previous paragraph (6.2.1), I still believe that in the end of the 1990's, which I indicate as 1997, Linux became much more known and popular. But here the problem remains that the popularity and the publicity of a certain technology is not an indication for the market acceptance. So concerning fixed dates I'm still feeling in the dark.

6.3 What is next?

The big question nowadays is the one stated in the title of this paragraph and that is: "what is next?". What has to happen in order to make Linux successful in the desktop market and to establish growth in the server market?

We now that Microsoft will do everything in its power to maintain their monopoly position. The best thing to do would be to focus on the most opposing success factors and take away all their disadvantages. Then the move towards Linux will become more and more easy. And last but not least, I would search for a possibility to start a large advertising campaign to make Linux even more known. Especially among the general public.
One of the most important issues for the future might be the organization of all open source projects. The existence of an open source institute would be a good initiative to combine forces and focus on more general factors.

7. Conclusion

Linux is commercializing very hard. It is more and more used in a commercial perspective, which is emphasized with the coming of kernel 2.6 Industrial production of Linux itself is of course impossible, but industrial production of equipment using Linux as an operating system is becoming increasingly common. This can be PDA's, but also commercialized operating systems which use Linux as a core. Apple is a good example of a commercialized operating system, which uses an open source kernel.

Although Linux has diffused very fast it is not an exemplary example of a diffusion pattern.
Linux does not really fit in the standard pattern of diffusion, which goes for the majority of the technologies. This is mostly related to the open source nature and some major factors as described in the previous chapter (6.2.2).
Concerning a more general analysis concerning diffusion patterns, I would say that it might be interesting to related the success factor characteristics towards certain forms of diffusion patterns. In the case of Linux the factors cover a very wide range of people and focus on a lot of different aspects. It seems to me that this 'broadness' made Linux diffuse faster. At least this is very typical for the open source world, but maybe also for other technological fields.

Anyway, for Linux itself it is hard to predict where it will go the coming period, although I find the 'proof' very convincing and I tend to say that Linux is about to set off big time in the Desktop market. The server market on the other hand is much more stable and I think that the acceptance of Linux in the desktop market, will be an extra incentive for Linux to grow even more in the server market.

One thing is for certain though: Linux is sick of being the future, it wants to be the present.

8. Used sources

I basically used 2 sorts of sources for this article:

1. *Information found on the Internet*
   Normally one would expect book references, but in this specific case I only used the internet as an information source. Of course I cross checked all the dates and therefore I dare to say that the information in this article is reliable.

2. *Knowledge I already possess*
   Because of my continuous interest in IT and therefore also Linux, I already possessed a lot of knowledge concerning this topic. This information was also used in this article.