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Abstract

This paper seeks to shed some light on the progress of Linux adoption in Singapore. The paper, based upon the opinions of industry experts and two case studies (the National Library Board of Singapore and Golden Village Multiplex Pte. Ltd), clarifies key Linux-adoption issues. It further discusses the pros and cons of Linux and the challenges facing this open source rival of Microsoft Windows. The paper concludes that while Linux is likely to co-exist with Windows, it is set to make some significant changes in future IT infrastructure.

Keywords: Linux, Open Source, Windows, Unix

1. Introduction

Linux has emerged as an acceptable alternative operating system to the dominant Microsoft Windows not only for servers but also for clients (Anonymous, 2004). Linux adoption rates have been soaring, particularly in developing countries concerned with the high cost of Windows such as China and Pakistan. The domain of Linux has moved beyond traditional desktop clients to other portable devices including mobile phones and PDAs. Linux's march and its promise for future computing appear to have been noted by market analysts and investors ; the share price of IT vendors offering Linux products and services have soared — Red Hat's share price has more than doubled from US$11.00 in March 2005 to US$26.00 in May 2006 (www.nasadq.com) . IBM, the largest IT company, has dedicated an entire division to Linux. Google, the current hottest news on Nasdaq, has been a strong advocate for Linux and relies on their Linux cluster of thousands of servers to handle their hundreds of million queries a day (Hoelzle, 2002). Other big Internet names relying heavily on Linux servers for their successful online business include eBay and Amazon.Com.

What is clear is that Linux is here to stay and appears to be that long-awaited challenge to Windows. As a nation continually seeking to be at the fore-front of technology exploitation, Singapore should therefore find Linux a technology to reckon and exploit. Where is Singapore on the Linux road? This paper, based on interviews with IT experts, two local Linux case studies and evidence from the literature, clarifies Singapore's position with regards to Linux. It further suggests how organizations could proceed to adopt Linux in a world dominated by Microsoft Windows.

2. Background of Linux

Open source software (OSS) is freely-available software with full access to its source codes. OSS offers the freedom to study, modify and run software without restriction, and the liberty to freely redistribute copies of original or modified source codes. Linux, a popular and growing OSS, was developed by Linus Torvalds as a logical sequel to the UNIX operating system (OS). It provides an efficient kernel with critical component modules, loosely coupled, to serve the OS needs of clients and servers in today's IT architecture (see Figure 1). As a lean OS, Linux's kernel manages the key resources (e.g. memory and processes) of a computer and invokes necessary component modules such as device drivers when they are needed for application software to deliver the output and services required (Petersen, 1999).

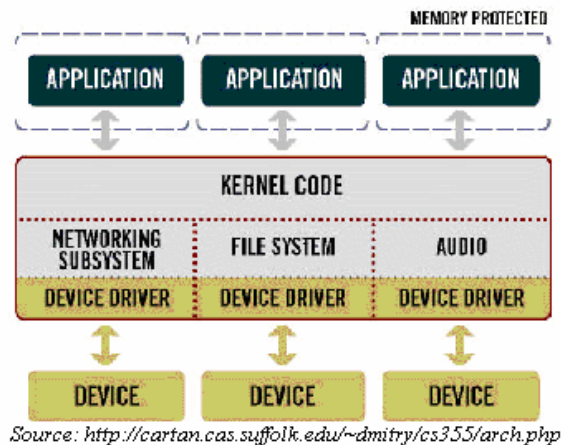Source: http://cartan.cas.suffolk.edu/~dmitry/cs355/arch.php

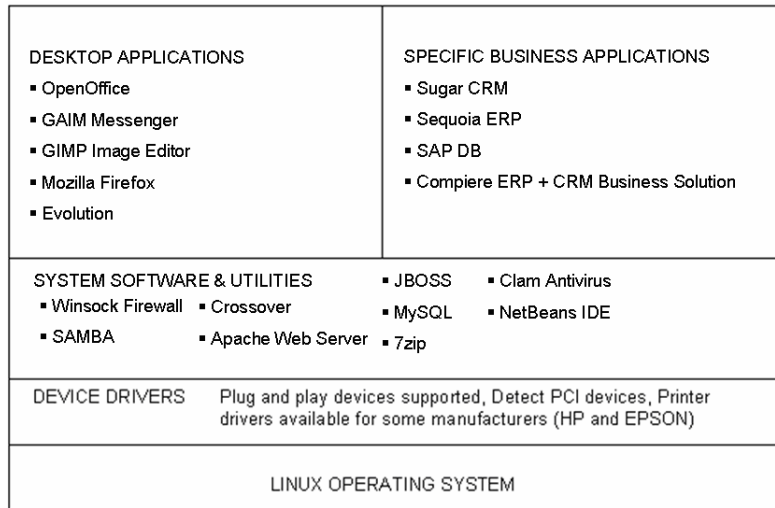Figure 1: The Linux Kernel and Modules

OSS is the foundation on which Linux has been built. The opportunity for anyone with expertise and interest across the globe to collaboratively develop and refine a non-proprietary software and make it freely available to all is well-exemplified in Linux. Linux, though not as pervasive as Windows, has been progressing in feature and capabilities since its inception in the

early 90's. Today, it provides a highly responsive and scalable operating system with good networking and multimedia capabilities supporting a variety of workloads (Hubley and Lubrano, 2005). While the Linux global community together with the IT industry continues to enhance Linux, the industry is actively developing more desktop applications, utilities and device drivers for the OS. These efforts will result in Linux maturing into a comprehensive and effective operating system, as shown in Figure 2 (Gagné, 2004).

DESKTOP APPLICATIONS	SPECIFIC BUSINESS APPLICATIONS
▪ OpenOffice	▪ Sugar CRM
▪ GAIM Messenger	▪ Sequoia ERP
▪ GIMP Image Editor	▪ SAP DB
▪ Mozilla Firefox	▪ Compiere ERP + CRM Business Solution
▪ Evolution	

SYSTEM SOFTWARE & UTILITIES ▪ JBOSS ▪ Clam Antivirus
▪ Winsock Firewall ▪ Crossover ▪ MySQL ▪ NetBeans IDE
▪ SAMBA ▪ Apache Web Server ▪ 7zip

DEVICE DRIVERS Plug and play devices supported, Detect PCI devices, Printer drivers available for some manufacturers (HP and EPSON)

LINUX OPERATING SYSTEM

Source: SourceForge.net: the world's largest Open Source software development website

Figure 2: Model of the Linux Operating Set-up

As a server-OS, Linux does a credible job in fulfilling web-browsing requirements and is the preferred OS for web servers across the world (Brunelli, 2005. Linux servers have posted their 12th consecutive quarter of double digit growth (IDC, 2005). Linux is also running as embedded OS in many devices such as mobile phones, portable media players, PDAs and network routers (Kaven, 2005). However, Linux is still a very distant second to Windows in the desktop scene (Ferguson, 2005).

3. Benefits of Linux

3.1 Free Availability of Software and Source Code
The most prominent benefit of Linux is rooted in its membership of the OSS domain – unrestricted usage and free access to sources codes (Tapia, 2003). Access to source codes allows an organization's software engineers to customise Linux OS for their organization's IT clients and/or servers in synch with the enterprise IT architecture and infrastructure, and the organization's requirements, characteristics and business plans. This capability has become particularly significant today with growing concerns about hacking and other IT security threats. The Linux engineers, while tapping on the global Linux community's expertise to address relevant bugs and other IT threats, could tailor

and structure their specific Linux OS implementation to be unique and not susceptible to global IT threats applicable to vanilla OSs such as Windows (Guardian Digital, 2004).

3.2 Choice of Operating System

Microsoft Windows has long dominated the OS market. As Linux evolves into a viable alternative, individuals and organizations are recognising that Linux is a pragmatic OS that can meet their operating system needs. They see Linux as a way to escape the grip of Microsoft's near-monopoly in the OS market (Ferguson, 2005).

3.3 Total Cost of Ownership

Total Cost of Ownership (TCO) is a model developed by Gartner to analyse the direct and indirect costs of owning and using software (Bailey and Heidt, 2003). While Linux's free availability might suggest that its TCO should be significantly lower than that of Windows, opinions are divided and the debate is still in progress. Nonetheless, the goals driving Linux (freedom from proprietary OS and need for more efficient and effective OS) and the growing positive experience of its adopters should give Linux an edge over Windows beyond the TCO-OS factor (Greenemeier, 2005a).

3.4 Security

Granneman (2003) notes that Windows, in its aim to be more user-friendly, comes with all its "ease of use" functions activated while Linux has them deactivated until explicitly configured. These "ease of use" functions in Windows are potential security vulnerabilities. Linux deployment may be more tedious but the tailoring and configuration of the OS at installation reduces the vulnerability of the system. Each Linux implementation can be unique, making the system less vulnerable to global virus/worm outbreaks and to hacking inspired by weaknesses in a pervasive common operating system with similar configurations.

3.5 Clustering

The customisability of Linux reduces OS overhead and delivers better performance (Thibodeau, 2006). It enables easier clustering of servers without significantly impacting performance. This characteristic, in addition to others such as greater security, explains the dominance of Linux in the Web server domain and its progress beyond - "Linux now has become so technically powerful that it lays claim to a prestigious title--it runs more of the world's top supercomputers than any other operating system." (Lyons, 2005).

4. Challenges Faced by Linux

4.1 Switching from other OS to Linux

Is Linux backward compatible whereby applications from the old OS (more specifically, Windows) can continue to run in the new Linux environment? The answer has generally been unfavourable to Linux. There is also the other big advantage which Windows enjoys when it comes to switching OS: user-familiarity and experience with Windows and the steep learning curve for Linux (Guardian Digital, 2005).

4.2 Too Many Linux Distributions

Although the Linux kernel remains the same, many different distributions are packaged with different software components on top of the kernel and with different levels of support. These distributions are being released into the market so frequently by competing vendors such as Red Hat and Novell that potential adopters are faced with the dilemma of not only which but also when to implement Linux (Hubley and Lubrano, 2005).

4.3 Support for Linux
Organizations have been torn between the unstructured informal support for Linux from the OSS and Linux communities and the contractual formal support from Microsoft for Windows (Greenemeier, 2005b). Lack of internal expertise in Linux has caused some organizations to ignore Linux and in some cases to switch back to Microsoft (Greenemeier, 2005c). Fortunately, the emergence of Linux vendors such as IBM, Novell and Red Hat is beginning to make the long overdue difference in reliable support for Linux as compared to Windows.
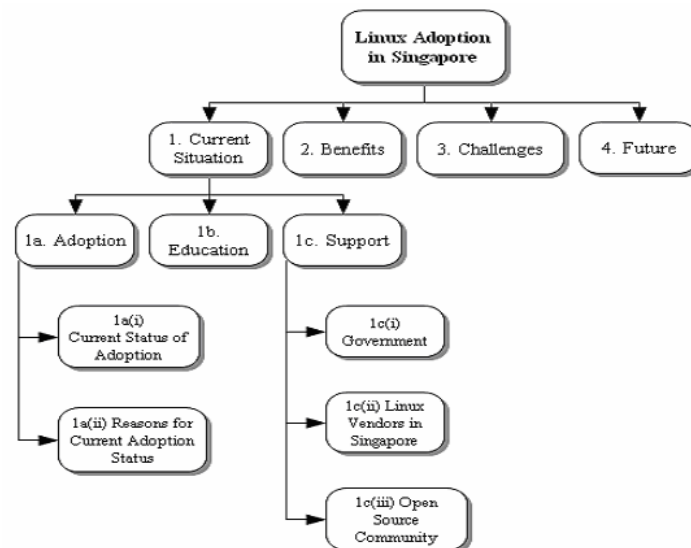
5. Research Model

Figure 3: Research Model

Linux is a technology with lots of potential and is beginning to shape computing and IT infrastructure worldwide. Tan, Ang and Foo (2005) found in their study that Linux was slow to take off in Singapore. They also noted that there was significant interest in Linux, but there was a wait-and-see-what-happens attitude prevailing amongst Singapore organizations. Why has this leading-edge OS, which many herald as the OS for the future, not taken off in the tech-savvy Singapore? Where is Singapore in the adoption and exploitation of Linux today? These were the questions which paved the way for this paper and its underlying research. A research model (Figure 3) was developed to investigate these questions on the basis of Tan, Ang and Foo (2005)'s work and literature review on the state and status of Linux.

6. Research Methodology

The research model and question were researched through 2 case studies of Linux implementation and interviews with 7 IT experts. Open-ended questions on each of the items shown in the research model were used in the interviews and case studies to collect data.

6.1 Case Studies

Case studies provide the ability to go in-depth into organizations and focus on any specific aspect of a research (Zikmund, 2003). However, this is limited by the nature of a case study and the level of cooperation the organization is willing to provide. With this in mind, two organizations were approached: Singapore's National Library Board (NLB) and Golden Village Mulitplex Pte Ltd (GV) agreed to contribute to the study. The NLB (http://www.nlb.gov.sg/CPMS.portal) uses IT extensively for both internal and external operations and requires their systems to remain functional 24/7. In order to fully understand their implementation of Linux with regards to the provision of library services, two senior IT executive and a system engineer from the Board and a director from Resolvo Systems (the vendor who supported the Linux implementation) were interviewed. GV (http://www.gv.com.sg/Booking/) implemented Linux as the OS for their movie theatre operator's ticketing system. Data for the case study was gathered from secondary sources and an interview with the IT Applications Manager.

6.2 Interviews with IT Experts

Following the two case studies, interviews were conducted with 7 IT experts to obtain information and opinions on various aspects of the research, including an assessment of the current status and future of Linux in Singapore:
- o Jennifer Toh, Manager, Corporate & Marketing Communication, IDA (Singapore)
- o Michael Clark, Vice President of Singapore Linux Users Group
- o Lim Kin Chew, Singapore Representative, Asia Open Source Software Symposium
- o Tham Joon Nam, Corporate Business Strategist, Novell, Singapore
- o Hemant Shah, ASEAN/SA Executive, Infrastructure Solutions, IBM, Singapore
- o Amit Das, Professor (Information Technology & Operations Management), NTU
- o Goh Teng Chew, Director (IT Operations), Centre for IT Services, NTU

7. Analysis

The data from the case studies and interviews were analysed, summarised and tabulated on the basis of the research model. The tables, shown below, were then examined for consensus and conflicts of opinions and explanations on specific issues.

7.1 Current Situation of Linux

Linux adoption in Singapore is slow and scattered, but there is a lot of interest in Linux. The implementation is primarily for Web servers and, in isolated cases such as NLB and GV, for servers supporting production systems including mission critical ones. Linux on desktops is still a rarity in organizational IT infrastructure in Singapore. That is the

general message from the interviews with experts and case studies, as reflected in Table 1 below.

Table 1: Current Status of Linux Adoption in Singapore

Information from Case Studies	
National Library Board	• Implementation on domain controllers' servers only
Golden Village Multiplex Pte	• Implementation for mission-critical ticketing application
Opinions of Local Industry Experts	
Michael Clark	• Popular for desktops using OSS applications such as Firefox, Thunderbird • Application software vendors, such as Oracle and SAP, starting to offer Linux versions • Increasing attendance in LUGS meetings and gatherings
Lim Kin Chew	• Increased Linux usage on enterprise - becoming popular with selected server end application e.g. NLB • But no really big demand for OSS on enterprise • Embedded Linux have niche market • Slow adoption with desktop
Tham Joon Nam	• Linux mass adoption - Long way to go • Growing interest in Linux and OSS by governments, telcos and banks, especially for security reasons • Increasing number of proprietary applications for Linux
Hemant Shah	• Adoption in Singapore is slow • Widely used in research programming e.g. life science • Many commercial software offered for Linux platform
Wong Onn Chee	• Singapore behind others in Linux adoption • Many feasibility studies but not only a few follow-ups • Primarily for Web servers

7.2 Reasons for Adopting Linux

One way to understand why adoption of Linux is slow is to examine the reasons for adopting Linux, and examine whether these are applicable to a more pervasive adoption. Table 2 was hence constructed. The table suggests the following reasons for Linux adoption:

- A suitable alternative for obsolete OS (Unix and Windows NT)
- Addresses downtime and system failures caused by weaknesses in existing OS
- Addresses security concerns
- Can fit organization's requirements and required applications are supported by Linux
- Costs are lower
- Easier scalability and maintenance of OS
- Facilitates future development of platform independent of proprietary technologies

Table 2: Reasons for Linux Adoption

Information from Case Studies	
National Library Board	• Previous operating system unable to meet requirements →

	Windows NT end of life, IT security concerns, user mobility requirements, budget constraint
Golden Village Multiplex Pte.	• Windows servers failed during mission-critical activities • Unable to optimize system due to server specifications • Capabilities and potential of Linux
Opinions of Local Industry Experts	
Jennifer Toh	• Government general stand on technology adoption: "value-for-money and fit-for-purpose"
Michael Clark	• Significant cost difference between Linux and Windows • Support from informed management
Lim Kin Chew	• Becoming a viable alternative to Windows • Replacement for end-of-life Windows NT servers • Good for organization with closed IT environment
Tham Joon Nam	• Suitable replacement for UNIX and Windows NT servers: • A cheaper option for the cost conscious SMEs • Pragmatic option if applications are browser-based and independent of platform
Hemant Shah	• Enables informed decisions on OS for IT infrastructure • Can fulfill organizations with high processing needs
Wong Onn Chee	• Strategic reasons – Business fit • Budget constraints - lower cost at the point of acquisition • Increasing Linux awareness

7.3 Support for Linux

As reflected in Table 3, there is a concerted effort from committed and capable vendors in Singapore to assist customers in the migration to Linux. Vendors have formed an alliance to increase the faith of the government and business for Linux. Big names such as IBM, Oracle, Sun and Novell are all actively engaged in progressing the adoption of Linux in Singapore. The vendors are supported in this matter by the small Linux community in Singapore and the broader Linux enthusiasts around the world. Michael Clark, Vice President of Singapore Linux Users Group, noted that though Singapore has LUGS as a formalised local support Linux community, it lagged behind other countries in terms of support and activities.

Table 3: Support from Linux Vendors

Information from Case Studies	
National Library Board	• Required support available from Linux vendor engaged • Support for Linux available from big names - IBM, Oracle
Golden Village Multiplex Pte.	• Linux vendor committed to support normal ticketing system operations and system failures
Opinions of Local Industry Experts	
Michael Clark	• Linux vendors adopt collaborative model to provide support • Unix vendors (IBM, Sun) switching to Linux
Lim Kin Chew	• Local firms such as Resolvo provide support for Linux

Tham Joon Nam	• Novell :
	  - Supports Linux implementation
	  - Offers advice on solutions and applications

	- Provides customization and technical services - Offers SuSE Linux which is well-endorsed in industry
Hemant Shah	• Full-range Linux solutions from IBM • IBM invests heavily into developing and supporting Linux • Linux based business solutions provided by IBM • IBM works collaboratively with partners in Linux • IBM interacts with other vendors and government • IBM is a founding member of SOSA
Wong Onn Chee	• Support from big players like. IBM, HP, Oracle, RedHat • Efforts by major vendors to make Linux user-friendly

7.4 Benefits of Linux

As reflected in the data shown in Table 4, Linux is able to deliver required IT services in a more secure stable and manner to an organization. As it follows open standards, Linux facilitates customisation, flexibility and control of the IT infrastructure. Performance of applications is perceived to be better than that under Windows. Linux installations also incur less downtime as it generally does not require reboots during patching and system maintenance activities. Of all these benefits, the two most significant ones reflected in the data are: lower TCO, and being free from vendor lock-in or, more specifically, being able to avoid the Microsoft stranglehold.

Table 4: Benefits of Linux Adoption

Information from Case Studies	
National Library Board	• Lower cost - cost savings can be reinvested in other areas • Linux is able to perform what is required • Linux system - less downtime
Golden Village Multiplex Pte.	• Cost savings • Stability of system and high uptime • Better performance than Windows • Open source – customizable; allows integration of old database onto Linux systems
Opinions of Industry Experts	
Kuan Sung, NLB	• A stable technology offering substantial cost savings • Enables reverse engineering of OS from source code • No vendor lock-in. Does not require special hardware • Do not have to change/upgrade hardware often • Linux has less downtime, meeting 24/7 IT requirements
Michael Clark	• Lower licensing costs • More secure system than Windows • Flexibility and empowerment for better integration • No vendor lock-in • Allows system administrator to better manage servers • Allows application of patches without system reboots • Cheaper (free)alternative OS for poorer countries
Lim Kin Chew	• Reduces cost of investment in proprietary licenses • Allows freedom to work on other people's codes
Tham Joon Name	• Cost effective - low OS acquisition costs

	• GPL - hence not on per user license and very little royalty • Ability to run over different hardware platforms • High reliability - a secure product • Cheaper than UNIX boxes - Intel machines on Linux can be clustered together into server farms • Availability of many OSS reduces requirements for porting • Linux helps stamp piracy - free • Open source allows skills transfer and knowledge sharing
Hemant Shah	• Linux drives choice • Universal, cheaper and more stable for development • Programs developed under Linux can run under OS • Stable and reliable platform hence cheap - Rarely hangs or require reboot – Business can be up 24/7 • Performance is better than that of other operating systems • Can be constantly improved is it is not hardware specific • Lower TCO – Also indirect savings via less system downtime and savings in hardware migrations/upgrades
Wong Onn Chee.	• Cost savings • Complies to ISO standards - facilitates code modifications

7.5 Challenges Faced by Linux

The evidence in Table 5 suggests a number of major challenges relating to Linux adoption:

- Problems in migrating applications to Linux platform
- System compatibility
- Interoperability issues between software and hardware
- Lack of internal IT support for Linux
- Acquiring good commercial support for Linux
- Resistance to change from users
- "Chicken and Egg" problem between demand and supply for the OS and support
- Familiarity and usability of Linux is low
- Lack of sufficient awareness about Linux, OSS and its licenses
- Lack of tangible evidence to support arguments such as lower TCO for Linux - even the two case study organizations have yet to assess the actual TCO.

Table 5: Linux Adoption Challenges

Information from Case Studies	
National Library Board	• Risky without internal people trained on Linux • Risk of disruption • User acceptance problem • Interoperability issues • People fear change • Changing the mindset of people about Linux • Finding a good vendor who is able to support is critical
Golden Village Multiplex Pte.	• Interoperability – running old database under Linux • Apprehension from people without Linux skills
Opinions from Local Industry Experts	

Michael Clark	- Acquiring commercial support - Interoperability issues between systems - Customers' unawareness about open source licenses - Convincing customers about maturity of Linux to even handle mission critical applications - Lack of internal support - Customer feels uncomfortable and unwilling to deploy Linux - Shortage of Linux skills - Linux currently not for average user
Lim Kin Chew	- Usability issues and resistance to change for ordinary users - No common GUI and distributions do not talk to each other - Lack of internal support: Limited resources for IT - Chicken & Egg story – less demand → education sector do not see the need → level of support → less demand - Strong inclination of people to conform to majority - People's lack of understanding about software licenses - System compatibility issues
Tham Joon Nam	- Lack of internal IT staff competent in Linux - Interoperability of current systems with Linux - Migration challenge: familiarity with Windows
Hemant Shah	- Migration from a full Windows outfit to Linux can be costly - Skills- easier to change from Unix, than Windows, to Linux - Vendor support still not as good as that for Windows - People are resistance to change due to being product focused

7.6 Future of Linux in Singapore

The views reflected in Table 6 suggest that Linux adoption in Singapore is a slow process. This situation could be attributed to the risk-averse nature of Singapore organizations. The number of people with Linux skills, however, is expected to increase, and this should help to address current concerns about the lack of Linux skills and support in Singapore. The consensus is that Linux adoption will continue to grow, given the increasing awareness about Linux, the enhancements being progressively made to the OS, and greater collaboration between industry, academia and individuals on Linux. Linux, however, is unlikely to be a major threat to Windows in the short-term.

Table 6: Future of Linux in Singapore

Information from Case Study	
National Library Board	• There will be a mixture of OSs including Linux
Golden Village Multiplex Pte.	• More server deployments in the future under Linux
Opinions from Industry Experts	
Michael Clark	- Short to medium term: no changes from what now is - Long-term: the future for Linux is complex
Lim Kin Chew	- Desktop: Microsoft will continue to lead but Linux will capture some of Microsoft's market share - There will be co-existence of Microsoft and Linux
Tham Joon Nam	- More people will be Linux certified and experienced → More people will be available for Linux support - UNIX and Microsoft have reached saturation, while Linux

	will be growing because: − Awareness and training of Linux is increasing − Bigger ecosystem of individuals and organizations − Growing ability to run on many chipsets and platforms − Applications with fixed functions perform very well under Linux
Hemant Shah	• Adoption is a slow process. Singapore companies are risk-averse and wait for market leaders to make the first move • Linux is an inevitable platform in the long term
Wong Onn Chee	• Linux in Singapore not as promising as in the region, as Singapore companies are risk-averse

8. Discussion

8.1 Competition: Linux Vs Windows
Although there is strong support for Linux as a viable alternative to Windows, widespread changes are not expected in the state of Linux adoption in the short-term. UNIX has been cannibalised by Linux and continues to be a victim of Linux, but Windows remains strong and practically un-dented (Sliwa, 2005). New Linux servers (especially for the Web) have, nevertheless, raised concerns for Windows (Martens, 2005). Further, Linux's growing popularity in niche industries such as oil exploration and car rentals are also worrying Microsoft. These developments have spurred Microsoft to look into the benefits of the open source model in their marketing of Windows.

Linux continues to dominate the Web-server world but the desktop is another matter. Windows has an iron grip on desktops, the battleground where Linux has to prove itself to be viewed as a serious alternative. Though the frequent complaints and not uncommon unhappiness about Windows' performance favour Linux in this regard, the future for Linux appears to be one of co-existence with Windows, emerging more as an alternative to Unix rather than Windows. Windows is so globally entrenched in implementation, skills, standards and applications that unless there is a major paradigm shift in computing architecture (which negates Windows' advantages), Linux can only play second fiddle to Windows particularly in office and home client machines.

8.2 Linux Adoption: Reasons and Issues
The research shows that adoption of Linux in Singapore is slow. Adoption has occurred mainly for servers, especially for hosting Web sites. In both case studies, implementation of Linux was for production systems. Other server migrations in Singapore include Zuji.com, Schenker Asia Pacific and Housing Development Board (IBM, 2006), but such migrations for production systems are still uncommon.

Despite an increase in Linux's user friendliness, organizations have been slow to embrace Linux for desktops (Martens, 2005). IDC forecasts that by 2008, 9% of desktops worldwide would be Linux-based. Even if this prediction becomes real, Linux would still be a distant second to Windows. One reason for this slow adoption could be that Linux requires one to be more tech-savvy than for Windows. There is also the issue that most IT users do not know of any other OS other than Windows. As long as it does not pose any

major problem and functions reasonably well, they tend to stick to what they are familiar with (in this case Windows). Notwithstanding its slow progress in the desktop**,** Linux is proving itself in niche areas requiring lean computing - it is being increasingly used in embedded devices and research and development (see http://wiki.lugs.org.sg/OpenSourceUsers).

Organizations which adopt Linux for production work do so not only for cost reasons but also because it presents a solution to prevailing performance and security problems and legacy infrastructure issues. Upon closer examination of this finding, it is clear that today's organizations are driven more by IT's functionality and less by its cost. Thus, Linux implementations driven largely by cost and less by other factors could have adverse outcomes, such as disruption to business. For example, Cendant Travel Distribution Services' implementation of Linux proved costly when a slowdown of the system resulted in agents being unable to access the company's critical reservation application (Koch, 2005).

8.3 Benefits of Linux Adoption
The evidence from the experts and the two case studies suggest that Linux is superior in performance and more stable and secure than Windows for servers. These are significant advantages for organizations demanding secure and high-performance IT services and 24/7 system availability. GV and NLB have done so and are benefiting from the switch to Linux.

The research has also noted that Linux has lower TCO than Windows. However, the low-TCO argument favouring Linux might not always hold for every business as TCO can differ according to the nature of the business operations and implemented applications. TCO comparisons also often fail to consider the dynamic changes in hardware and software costs and support expenses. Organizations should therefore move beyond TCO and focus on strategic and operational fits when assessing Linux for adoption.

The research has also found software openness to be a significant benefit of Linux. From a strategic perspective, Linux's open source nature is good for businesses as it provides flexibility, scalability, portability, customisation and control in the development and operation of the necessary IT infrastructure. Businesses can avoid vendor lock-in and implement solutions that best suit their needs. Organizations are also appreciating the opportunities provided by Linux for prolonging the life span of their legacy systems, as GV did with its legacy databases and old hardware.

8.4 Challenges of Linux Adoption
Of all the challenges faced by Linux, the top three identified by this research are: lack of applications, inadequate vendor support, and scarcity of Linux skills. Lack of applications, or rather the relatively small set of applications compared to the warehouse of applications available for Windows, is the top-most challenge for Linux; this fact has also been noted by Martens (2005) and Rosenberg (2006). In particular, development of applications for Linux platform is particularly slow for the desktops. Development of new applications for the Linux platform has to go beyond the web and move into

mainstream production and desktop services. The Linux community and vendors need to actively promote the development and migration of popular applications for this platform.

Microsoft Windows is pervasive. Skills and capabilities are readily available to support this ubiquitous OS. The same cannot be said about Linux. Linux implementations are more of an exception when compared to Windows implementations. As a consequence, demand for Linux skills is low and there is only minimal education and training for Linux in Singapore. Even the tertiary institutions have not included Linux, though a futuristic technology, in any significant way in their IT curricula. The Infocomm Development Authority of Singapore (IDA) has recognized this dilemma and is beginning to address the deficiency in Linux skills. The establishment of the InfoComm Club by IDA with Novell in schools in 2006 [IDA, 2005] is a significant event. Novell is a major vendor supporting Linux, and the OS can be expected to feature in IT education in the local schools. Novell's participation also appears to suggest that the government has recognised Linux's significance for Singapore.

Vendor support for Linux is a major challenge and big names such as IBM, Redhat and Novell and smaller local vendors such as Resolvo and Cxrus are beginning to address this challenge. The support for Linux, however, is far from that available for Windows. The required support spans from advice, training and technical support to the provision of necessary drivers for peripherals and plug-and-play devices such as PDAs and digital cameras. While many of these support requirements for Linux are being progressively addressed, the lack of device drivers has continued to be an issue (Rosenberg, 2006). Vendors such as Novell and Redhat have been making steady progress in this matter and drivers for common peripherals are now available. Lack of vendor support is slowly changing from a real to a perceived problem for Linux. NLB and GV appear to have recognized this change in the state of vendor support for Linux when they decided to adopt this OS.

Linux User Groups (LUGs) are a significant factor in Linux adoptions in many countries but the same cannot be said for Singapore's LUG - our research indicates that their support is at best minimal. This state of Singapore's LUG should not be a major factor affecting decisions on Linux adoption as the collective effort of the global Linux community is very robust and comprehensive and is readily available to all Linux users regardless of geographical location.

8.5 The Future of Linux in Singapore
For the short to mid-term, industry experts predict a slow and gradual adoption of Linux in Singapore. They attribute this to the risk-averse nature of Singapore businesses. Furthermore, the outcome of Linux adoption and efforts from vendors and other interested parties to promote Linux have not been compelling. The government could help in the latter matter.

The Singapore government is a major user and early adopter of technological innovations (IDA, 2005). As stated by Ms. Toh from IDA, the government makes its technology procurement and adoption decisions based on value-for-money and fit-for-purpose. On

the basis of this principle, IDA is neutral towards Linux and has remained unfazed by the constant interactions within the industry and the global trend of organizations and governments adopting Linux. The government positions itself as a business customer and allows market forces to determine the outcome of Linux adoption in Singapore. IDA's argument is that a neutral stance is required to maintain an open free market economy.

The public sector is seen as a pioneer in technology adoption in Singapore – the Inland Revenue, Port of Singapore Authority and Land Transport Authority are good examples in this regard. The private sector often looks for cues and takes advantage of the public sector's experience when embracing new technologies. Government agencies such as NLB are just beginning to implement Linux, and these implementations are for servers. To make a more significant impact on Linux adoption in Singapore at large, Linux implementations in the public sector should be more aggressive and should extend to desktops. The private sector will, as in the past, look at what is happening to Linux in the public sector before acting.

9. Conclusion

Linux is here to stay – that is the research evidence and what the literature says. Notwithstanding any inroads made by Linux in the near future, the foreseeable future is a scenario of Linux co-existing with Windows. Linux on desktops will happen. New clients, especially mobile/wireless and embedded devices, are likely to be enabled by Linux as they would require a lean OS, but Windows will remain prominent if not dominant in IT infrastructure. The sheer size of implementation and huge investments will ensure Windows' dominance, unless there is a major paradigm shift in computer architecture whereby Windows becomes irrelevant or inappropriate and Linux or another OS becomes the right complement.

Linux continues to grow as an alternative OS for servers, particularly for the Web. This trend will continue due to the enhancements and improvements to Linux, and should make a difference to the current snail-pace adoption for desktops in the future. Linux is maturing and concerns about lack of applications and supporting system software, non-availability of device drivers and the issue of inadequate support are being addressed by the growing number of vendors. Organizations should therefore be more prepared to look at Linux favourably, not only for Web servers but also for production system servers and desktops and other clients.

Though the TCO factor may favour Linux against Windows, the critical factor that should tilt any decision on OS should be strategic and operational fit to an organization's business. In this regard, Linux appears to have potential for gaining the advantage. From a technological perspective, Linux (lean and open OS with loosely coupled components offering flexibility, scalability, performance and security and opportunities for innovation and advancement of OS) is a better fit than Windows to fulfil an organization's OS needs for servers as well as desktops as the organization progresses into the future. Provided that concerns about lack of applications, supporting software, device drivers and support are effectively addressed, who would argue against enjoying greater flexibility,

scalability, portability, security and performance in the IT infrastructure of an organization via Linux?

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