TWO RESEARCH CONTRIBUTIONS IN 64-BIT COMPUTING: TESTING AND APPLICATIONS

The combined results and analysis for two papers

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Abstract

Following the release of Windows 64-bit and Redhat Linux 64-bit operating systems (OS) in late April 2005, this is the one of the first 64-bit OS research projects completed in a British university. The objective is to investigate (1) the increase/decrease in performance compared to 32-bit computing; (2) the techniques used to develop 64-bit applications; and (3) how 64-bit computing should be used in IT and research organizations to improve their work. This paper summarizes research discoveries for this investigation, including two major research contributions in (1) testing and (2) application development. The first contribution includes performance, stress, application, multiplatform, JDK and compatibility testing for AMD and Intel models. Comprehensive testing results reveal that 64-bit computing has a better performance in application performance, system performance and stress testing, but a worse performance in compatibility testing than the traditional 32-bit computing. A 64-bit dual-core processor has been tested and the results show that it performs better than a 64-bit single-core processor, but only in application that requires very high demands of CPU and memory consumption. The second contribution is .NET 1.1 64-bit implementations. Without additional troubleshooting, .NET 1.1 does not work on 64-bit Windows operating systems in stable ways. After stabilizing .NET environment, the next step is the application development, which is a dynamic repository with functions such as registration, download, login-logout, product submissions, database storage and statistical reports. The technology is based on Visual Studio .NET 2003, .NET 1.1 Framework with Service Pack 1, SQL Server 2000 with Service Pack 4 and IIS Server 6.0 on the Windows Server 2003 Enterprise x64 platform with Service Pack 1.

1. Introduction

32-bit computing was first introduced in 386 models in 1985 but a surge of high demands began after the launch of Windows operating systems since the mid-1990s [12]. 32-bit computing revolutionized the world in science and technology, and also changed our life styles and career options [19]. Higher software and hardware demands for visualizations, performance, speed, security, interoperability, usability, database integration and easy connections to the internet have been required since the 1990s [1, 2, 8, 11, 12, 16]. The Intel 64-bit Itanium release in late 2001 made the first-step-forward for high performance computing; however 32-bit software applications were unable to work on Itanium. This bug was fixed until the release of Itanium 2 in 2003 [10]. In September 2003, AMD launched its first 64-bit computing Athlon and Operon models. Compared with Itanium, software applications built on 32-bit computing were able to run smoothly on the AMD Athlon 64-bit computers [2]. However due to the lack of support of 64-bit operating systems, AMD found it difficult to release more 64-bit computing models.

With the release of 64-bit Linux and Windows operating systems between 2004 and mid-2005, many more 64-bit computers were manufactured. Two major 64-bit desktop/server models are AMD Athlon 64 and Intel EM 64T. Each model has its own distinctive features, and it is hard to judge the winner, however the lower price for the AMD chip is a bonus. The term “bit” refers to the amount of data the computer can manipulate as a single slot. A 32-bit processor can perform operations on slots of data of up to 32 ones and zeros, and a 64-bit processor can handle slots of data up to 64 digits. In terms of memory storage and allocation, the 64-bit memory can allow 2^{64} allocations and combinations in the memory compared to 32-bit memory can allow 2^{32} allocations and combinations in the memory. As a result, a 32-bit computer can accommodate up to 4 GB of virtual memory but a 64-bit computer can accommodate up to 16 TB of virtual memory [14]. This suggests that a 64-bit model is several times as powerful as the identical 32-bit model, and the testing results in the Section 2 of this paper can justify this assumption.

There is another new feature known as “dual-core” processing ability on some 64-bit processors, and two major desktop/server dual-core models are AMD Athlon 64 X2 and Intel Extreme Edition. A dual-core CPU is designed to have the capabilities for two normal CPUs. In other words, a dual-core 64-bit processor can run nearly twice faster than the ordinary 64-bit processors [3]. This new technology leads to a new research area: Application and performance testing: whether the application and performance on a dual-core processor is twice better than the single-core processor.

Currently Redhat Enterprise Linux 4 x64, Windows XP Professional x64 and Server 2003 x64 platforms are supporting the 64-bit demands. Using several testing guidelines and scenarios, the hardware and software performance on these platforms were fully tested. The results are discussed in the latter part of this paper.

2. Comprehensive Testing

Several types of testing were carried out including system performance, stress, application multiplatform and JDK. Each test was described in a different scenario. Due to the availability of more Windows-based applications and test tools, the majority of performance testing was carried out on the Windows XP Professional x64. The criteria chosen to test the performance included (1) speed to execute the programs or perform particular functions (scenario 1); (2) compatibility between the operating system and software applications (scenario 3); (3) multiplatform testing, which included relative performance for applications running between XP Professional x64 and Redhat ES 4 x64 (scenario 4); (4) Java Development Kit (JDK) testing, which was based on the top of multi-platform testing, and in addition of taking considerations of different JDK versions and postgres database (scenario 5); and finally (5) stress testing, which include (a) the relative CPU and memory performance after 24 hours and 120 hours, and (b) the relative application performance after 24 hours and 120 hours (scenario 6). There is another scenario describing the application and performance testing: single-core 64-bit model vs. dual-core 64-bit model (scenario 2).

(1) Scenario 1: Application and performance testing of an AMD 64-bit model and an Intel 64-bit model, and their relative performance against their 32-bit counter-parts.

(a) Speed to execute the programs or perform particular functions

Two types of test machines were built: The first was based on AMD Athlon 64 3400+ on an AMD-pro motherboard, and the other was Intel EM 64T 3.4 GHz on an Intel-Pro motherboard. 1GB of DDR memory, a 160 GB hard-disk and a 256 MB Graphic card were also attached for each system, which 64-bit Windows Professional x64 was installed. Their relative performance was compared to another two existing machines based on AMD Athlon +3400 and Intel 3.4 GHz, which had the same hardware configurations except CPU, and had 32-bit Windows installed.

The choices for application testing included video/DVD (movies), image processing (Photoshop and Corel Draw), static multimedia (media player and Flash), dynamic multimedia (3D modeling or visualisation), publishing (Office 2003), compiler (C++), Java (JDK 1.4.2_04), servers (IIS and Tomcat), database (SQL Server and MySQL), Developer platform (Visual Studio .NET 2003 and Eclipse), UNIX (Cygwin and SSH Client), antivirus scan (Norton and Sophos), registry or spyware scan (Ad Aware and Registry Mechanics) and calculations (Visual C++ and 3D plots). Each software tool was running on each machine at each time with the same task to perform, and in this case the purpose was to test the duration for a single job to be completed, which included three main steps: (a) time to start up the program; (b) time to complete a job, or time to perform the task and (c) time to end the task. Total time taken and any observations were recorded, and the results were based on three sets of testing. As the title suggests, time taken is the major factor.

Results for this set of tests are summarized below:

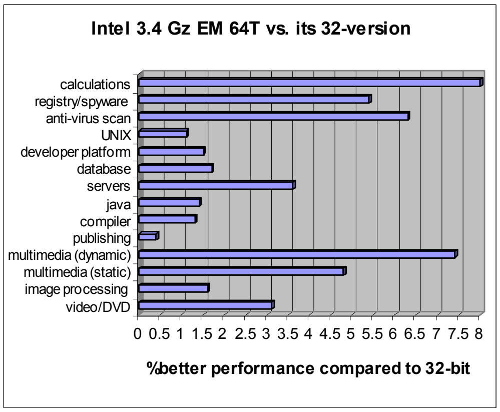

Figure 1A: Intel mode l: % better performance compared to 32-bit

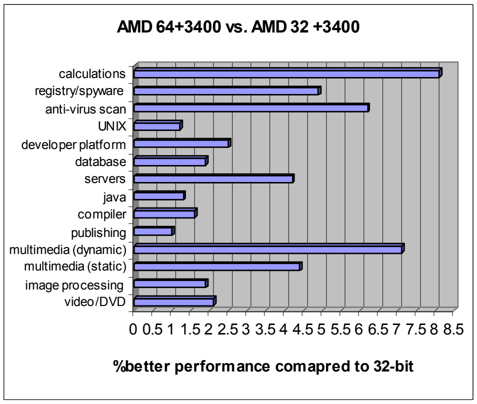

Figure 1B: AMD mode l: % better performance compared to 32-bit

These results confirm two theories. Firstly, 64-bit computing is suitable for high performance computing in areas such as dynamic multimedia and calculations, where more CPU and memory utilizations are demanded. Secondly, 64-bit computing has a better performance than 32-bit computing. However the percentage for better performance is only between 0.4 % (publishing, Intel) and 8.1% (calculations, AMD), which are less than expected. The likely reason is that the current software is based on 32-bit programming and it relies on the operating system or CPU processor or compilers to convert the 32-bit application into 64-bit application, which takes additional time and CPU consumption [9, 13, 14, 15]. This situation can only be improved when 64-bit software is available.

(2) Scenario 2: Application and performance testing: single-core 64-bit model vs. dual-core 64-bit model

A new AMD Athlon 64 3500+ socket 939 was used for single-core processor. Since price factors were taken into considerations, a 64-bit 4200+ AMD X2 was selected, which was expected to have about 1.4 times better performance than a 64 3500+ model according to the information from AMD. The testing focus was on the performance of application software as in scenario 1.

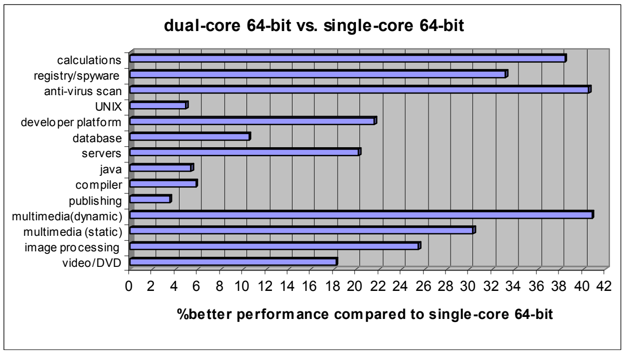

Figure 2: dual-core 64-bit vs. single-core 64-bit and the better performance

This result confirms that a dual-core processor has a better performance than a single-core processor, but for applications that have very high demands on CPU and memory consumption. These high-demand applications include dynamic multimedia, calculations and anti-virus scan, and they are having 30% - 41% better performance on the dual-core processor than the single-core processor.

(3) Scenario 3: Compatibility testing between a 64-bit computing and 32-bit computing

Definitions for “compatibility” vary between different institutions. They are two definitions close to the definition in this paper. The first is “capability of existing or performing in harmonious congenial combination” [6]. The second is “two or more items or components of equipment or material existing or functioning in the same system or environment without mutual interference” [7].

At the beginning of testing, it was discovered that some software and programming languages were unstable on the 64-bit Windows because of the incompatibility between the application and operating system (OS). Hence, 32-bit Windows was used as the benchmark, and the application and OS performance of 64-bit Windows was used to test against 32-bit. The areas to assess “compatibility” include (a) easy installations; (b) stability of the application or languages (particularly .NET and Java for web services); (c) ability for self-updates if applicable, or the level of difficulties for manual updates.; (d) whether additional troubleshooting is required and (e) whether an application interferes with others, and causing malfunctioning of an application or the operating system. The application software is based on Figure 1A and Figure 1B.

(a) Easy installations: Software installations on Windows OS have no differences on 32-bit and 64-bit, except the latter is between 0 - 30% faster, and scores an overall 5% improved performance at the end.

(b) Stability of the application or programming languages: Currently for Java, there is no Sun 1.4.2 64-bit Java for AMD models and Intel EE models, however there are 1.5.0 versions for 64-bit applications. There are stability problems for .NET and details are mentioned in the “Application” part of the paper. Compiling .NET and Java had no major problems during the process of testing. In the area of anti-virus software, both Norton and Sophos anti-virus do not function well largely due to incompatibility between itself and the 64-bit OS. This confirms that a number of software is unstable on 64-bit OS. Thus, the overall score is -30% improved performance.

(c) Self-updates / manual updates: Majority of anti-virus software had problems with automatic updates because of factor (b) above, all the software with the functionality for self-updates or manual updates had no problems in doing so. This includes Windows updates, security updates, registry updates, anti-virus updates and spyware updates. 0% implies no differences.

(d) Additional troubleshooting: Point (b) above has mentioned some of these. For applications with high complexity, additional troubleshooting was required. The final score is -10% based on the overall outcomes.

(e) Interference / malfunction: On Server 2003 Enterprise x64, the OS regularly reported system errors, despite the fact that troubleshooting was successful. It did not cause major malfunctions on the OS and software, but slowed down the speed of starting up Server 2003 x64 initially. Minor incompatibility of security updates and anti-virus might cause malfunctions. However there was no such problem on XP Professional x64. Based on these factors, the overall score -10%.

(4) Scenario 4: Multiplatform testing

The purpose of this scenario is to test whether applications can work across the different platforms that most of the 32-bit and 64-bit computers can support. The software for multi-platform testing is OMII_2 version 2.0.0 (OMII_2.0.0). OMII_2.0.0 is a collection of tested, documented and integrated software components that provide a standard platform for integrating e-Science middleware as well as a simple, secure web service-based Grid infrastructure for new e-Science users [13]. However due to the fact that no 64-bit servers were available, the OMII_2.0.0 client was installed on the client-side 64-bit machines (XP Professional x64, Redhat Enterprise Linux 4 x64) and OMII_2.0.0 servers were installed on the server-side 32-bit machines (Redhat Enterprise Linux 3 and SuSE 9.0). Currently there are only Linux versions for server-side applications.

The test procedure included creating an account on the server, obtaining the account approval and ensuring the job submission done was completed. It required a security certificate such as omii or e-science certificates for authorization and personal detail checks. During this process, it exercised the account service, job service, database service and the resource allocation service of the OMII_2.0.0 server on the client side. Upon successful job completion, there was a message stating “Build successful”. In this testing, Sun JDK 1.4.2_08 was chosen as the default JDK for 64-bit Windows and Redhat clients.

The testing results showed positive outcomes for Windows client platforms, as there was no problem for a 64-bit client to communicate with the 32-bit server. The account was accredited and four services were working smoothly. On Redhat platforms, the 64-bit Redhat client was able to interact with 32-bit Redhat and SuSE servers regardless of the certificate type. Figure 3 below shows the four successful combinations for multiplatform testing.

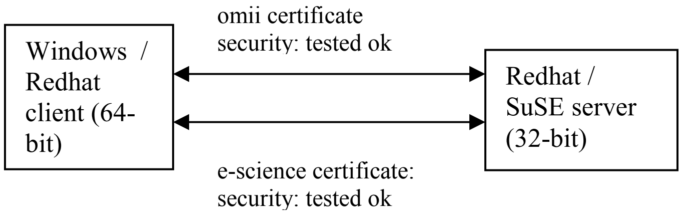

Figure 3: multiplatform testing

(5) Scenario 5: Java Development Kit (JDK) Testing

The JDK testing was based on the top of multi-platform testing, except the difference was, taking into consideration of (a) different JDK versions: Sun 1.4.2 (04 – 08), Sun 1.5.0_02 and IBM JDK 1.4.2.1.0.4 (IBM Java142-2) and (b) postgres database 7 and 8 to test OMII_2.0.0. Before proceeding to carry out this testing, a matrix of different combinations of JDKs, certificates, databases and platforms was drawn. There was a total of 64 combinations, out of which 14 combinations were selected for JDK testing. The OMII_2.0.0 application, also known as Cauchy, was the core component used to test whether JDK testing was successful, because it took all the considerations of Tomcat, Axis and OMII_2.0.0 server-side components such as “Base/Extension” and “Services”. Upon the successful running of this application, it prompted for PlotWS services, which plotted the graph from the requested job. There was a new feature, Graphical User Interfaced Cauchy (GUI-Cauchy), which simplified the entire process with a few clicks on the GUI-Cauchy itself. In order to test Cauchy and GUI-Cauchy, both clients Cauchy/GUI-Cauchy and server-side Cauchy need to be installed, and at least one account needs to be open on the client and server side. Among the 14 scenarios for testing, the results showed positive outcomes, both Cauchy and GUI-Cauchy are running successfully.

(6) Scenario 6: Stress testing

The scenario was exactly the same as scenario 1. The only exception was to run two visualisation or 3-D applications that consumed high CPU and memory usages on a 32-bit machine and a 64-bit machine running for 24 hours, 48 hours, 72 hours, 96 hours and 120 hours respectively. There were two aspects of measurements derived from the system logs and third-party software: (a) The relative CPU and memory performance against time and (b) the software performance against time. The relative performance for these two entities was then plotted on the same graph.

The results confirm that the application that consumes a high CPU and memory usage is more suited to running on 64-bit machines, with their performance not likely to be affected during stress tests. Comparing this result with results from scenarios 1 to 5, the current distinct advantage for 64-bit machines is only deployed during stress testing.

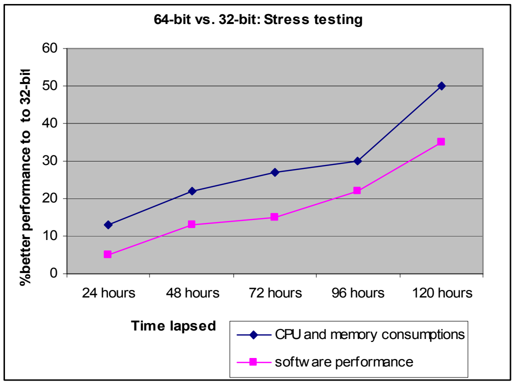

Figure 4: better performance in stress testing

3. Application development on 64-bit computing

The technology is based on Visual Studio .NET 2003, .NET 1.1 Framework with Service Pack 1, SQL Server 2000 with Service Pack 4 and IIS Server 6.0 on the Windows Server 2003 Enterprise x64 platform with Service Pack 1. Additional troubleshooting, ranging from 1 hour to three days in the author's experiences, is required when setting up this developer environment and stabilizing IIS with .NET Framework. The application is based on a dynamic repository that has functions such as registration, download, login-logout, product submissions, database storage and statistical reports. The functionality and technology-behind this, are described in Section 3.1 and 3.2 of this paper.

3.1 Functionality and implementations

.NET ASP.NET 1.1, VB.NET and SQL queries are the main development languages. The coding technique is one static ASP.NET in-front and one dynamic VB.NET code-behind. Programming, compiling and testing can be taken place at the same place on the same platform – Visual Studio 2003. The term "repository" refers to dynamic pages that are presented as a browser-interface to the real database. The following is the description of the repository functionality.

(a) Registration: This is the first-step for all users. The three java-scripts on the client side check whether the right information and all the "blanks" have been filled. On the server-side, each blank represents the data property for each entity, which is then processed by the dynamic .NET code upon submission. Upon successful registration, all the blanks are saved and stored into the database table "registered users" of SQL Server, and each entity on the database table has its own properties and permission. The .NET codes are separated into static and dynamic codes. The static code is the interface and the dynamic code creates a .NET function known as "register", and can be configured or compiled in the Visual Studio .NET 2003.

The process of registration is divided into two stages, for which the earlier description refers to stage one. In stage two, another .NET function known as "registerok", checks the status of the registration and recommends what users should do next based on the registration status. For successful registration, an email with a randomly-generated password is then sent to the user via SMTP protocol and recommends the user to login to the secure site. For unsuccessful registration, the repository asks for re-registration, or to receive a new password again.

(b) Login-logout: This technique is different than most .NET applications, because there is no .NET function dedicated to this. A .NET-authenticated directory, known as "repository" is created. All the .NET pages that require authentication are all stored safely under this directory. .NET authentication is achieved by configuring the "web.conf" file, which specifies which web directory is password-protected under the IIS server and .NET Framework. Security can be further enhanced by selecting "Integrated Security", comprising both .NET authentication and Windows authentication, under the control panel of the IIS server. There is a "Sign-out" method, which is a specific .NET function that can get all the .NET pages to logout the authenticated server instantly. However this is a two-step process. The first process requires the users to confirm logging out, and the second process then executes the logging-out functions.

(c) Downloads: This is the most critical part of the repository because registered users can download the latest software releases before August 2005. Each release is dedicated to a .NET page, which has ASP.NET as the code-in-front and VB.NET as the code-behind. All the release .NET pages are stored within the repository directory, which has the integrated security turned on. When users request for downloads via browsers, the repository prompts for the password authentication. Upon providing a username and password, the .NET page checks whether this information matches with the password in the database table of the SQL Server. If the user does not provide the right information, the .NET page then responds back. If this fails more than twice, the .NET page provides an option to go to the "forget password" functionality, which then finds the users in the database and sends them their new password.

After a successful login, the user can select to download software, which has the .gz and .zip files as the standard format. The IIS Server has a list of files for integrated security, which also include .gz and .zip formats. The size for downloads is not restricted.

(d) Product submission: This is for registered users who wish to submit their software product. On the submission page, the users provide information about their software and the public URLs to download it from. There are four fields for this page, and each field is equivalent to an entity of a database table. The .NET page can also check whether the information provided matches the required properties. Upon submission, the users are asked to accept the organizational terms and conditions. Whether the submission is successful or not, the .NET page can inform the user online about their submission status. For unsuccessful submission, the .NET page can get into the SQL server, retrieve the error message and display error message online. For successful submission, the submission information is safely stored in the database table and displays each submission status on another .NET page, which can only been seen and managed by the administrator. The administrator can choose to accept or reject the submission without downloads. If it is decided to download the software, the software is then downloaded on a directory called "Quarantine", which is then checked by anti-virus software to ensure its safety. Upon successful checking, the software is then passed to the right person for further evaluation, which is an internal process within the organization.

(e) Database storage: SQL Server 2000 is the default database and its Service Pack 4 has 64-bit database application. There are three database tables created to facilitate the needs for (a)-(d), and one table holds all the information for the registered users, which can be obtained by performing SQL queries within SQL server. There are also four "Stored Procedures" (SP) to enhance authentication and database queries. SP are used to encapsulate a set of operations or queries to execute on a database server [5].

```
dbconn = OpenOMIIDatabase()  'Now Open the database and
check the password
sqlcmd = New SqlCommand("CheckPassword", dbconn)
sqlcmd.CommandType = CommandType.StoredProcedure
sqlcmd.Parameters.Add("@password",
SqlDbType.NVarChar).Value=password
sqlcmd.Parameters.Add("@email", SqlDbType.NVarChar).Value
= user
```

```
CREATE PROCEDURE [CheckPassword]
            (@Email [nvarchar](50),
            @Password    [nvarchar](8))
AS SELECT * FROM
[OMII].[dbo].[RegisteredUsers] WHERE Email
LIKE @Email AND [Password]=@Password
GO
```

(f) Statistical reports: The IIS server generates daily reports, which record information on the visitors' online activities. Cygwin is used to retrieve the required information, and it is then summarized into a log file. Two software applications are used to generate website reports. The first is Analog, which is useful to generate the overall report that displays the visited files, domains and IP of the users and also browsers/OS used by the users. The second is WebLog Expert, which is particularly helpful in dealing with dynamic applications. It can track down the users' IP/domains, files to download, number of downloads, periods of downloads, dates/times of visits and reports any abnormal activities.

3.2 The entire flow and architecture for the dynamic .NET pages

The figure below shows the entire flow and architecture for the dynamic .NET pages. All the .NET applications and developer platforms can be installed on a 64-bit laptop and can function well without connecting to the internet, similar to a mobile server. Details of implementations including how .NET applications on 64-bit computing can work in harmony will be demonstrated during the presentation.

3.3 .NET Implementation on .NET 2.0 Framework and Visual Studio .NET 2005

The next stage is to investigate the possibility of implementing .NET applications based on the latest Microsoft technologies. This includes Visual Studio .NET 2005, SQL Server 2005, .NET Framework 2.0 and IIS Server 6.0 on the Server 2003 Enterprise x64 platform with Service Pack 1. This level of troubleshooting is very challenging due to incompatibility of Visual Studio .NET 2005, IIS Server 6.0 and .NET Framework 2.0 on the Server 2003 Enterprise x64, and that is why they are known as beta versions. Unlike 32-bit platform, conversions between .NET 1.1 and .NET 2.0 on 64-bit platform are extremely difficult and highly likely to result in the instability of the entire IIS, .NET Framework and 64-bit operating system. Hence the implementations cannot begin unless (1) the developer and OS platforms on 64-bit computing become more stable and robust; and (2) software to support 64-bit computing become widely available and bug-free. However, this combination of technologies can function on the current 32-bit Windows Server 2003 [4].

4. Discussions and conclusion

Several issues are worthy of discussions. Firstly, backward compatibility is not possible. This means that any 64-bit .NET implementations do not work on 32-bit machines. It also means that 64-bit operating systems do not work on 32-bit machines, and error messages can instantly appear if trying to do so. Hence, it is recommended for the programmers to develop their software on the 32-bit platforms and to develop software that can be converted into 64-bit applications. Currently there are approximately 90% - 95% of applications and machines built on 32-bit versions. Therefore it may not be a wise decision to move the entire hardware and software into 64-bit computing, but incremental upgrades should be more applicable.

Secondly, 64-bit computing does not perform as well as what theories and manufacturers claim. The main reason is that presently applications are not built based on 64-bit computing but are “converted” into 64-bit computing, or relying on the 64-bit operating systems to run lower-end 32-bit applications, and this phenomenon is very obvious in current 64-bit applications and Windows OS [9, 13, 14, 15]. 64-bit Linux such as Redhat ES 4 has overcome this problem by upgrading its kernel version but this version of the kernel is very unstable, because it had been re-installed on the author’s machines more than ten times in order to maintain multiple-boot system stability.

The third issue is about how 64-bit computing should be used in the research and IT organizations. It may not make major differences for office desktop uses such as publishing and video, but it may have a better performance in areas that consume high levels of CPU and memory uses, particularly for stress tests. However due to the limitations of testing scenarios, some forms of stress tests and application tests are not applicable but the results in this paper favour the assumption: 64-bit computing is suitable for stress tests (including concurrent jobs) and application tests that consume high CPU and memory.

The fourth discussion is about the future of computing, and the current direction from Intel, AMD, Microsoft, Redhat, Novell (SuSE), Sun, IBM and SAP favour the 64-bit computing as evident from their recent 64-bit releases. One example is the report from SAP, which confirms their SAP-SD 2-Tier performance has improved from 597 to 1017 concurrent users [13]. However, it may take some time before the next generation of IT systems arrive. The second example is about the collaborations between IBM UK and the University of Southampton for a £1.2 million supercomputing project. This partnership enables further improvements of the existing e-science applications such as web services and engineering. The infrastructure is an IRIDIS supercomputer, made up of a cluster of AMD +64 Opteron processors [18].

To expand the fourth discussion, the implications for the organizations were under part of the research. Instead of quantitative-based research for testing and applications as described, this part of the research was based on qualitative research methodology. In order to carry on this, several top academic or practitioners in the related field were interviewed either face-to-face or via email or phone. The summary is as followed:

(1) Why 64-bit computing should be used?: There must be distinctive reasons for going into 64-bit computing, and three of which include (a) providing high computing power; (b) running applications that require high consumptions of CPU and memory and (c) preparing for next-generation computing.

(2) Is 64-computing better than 32-bit computing?: At this stage, it is difficult to judge the winner, because each has its own distinctive advantages. The current disadvantages that 64-bit computing have, are largely related to unsupported drivers, platforms and software, thus making its performance lower than the expectations. However in the next few years, the situation will be changed.

(3) Stability issues: 80% of the system administrators think that current 64-bit operating systems are unstable, thus not recommending any uses. However, one of them suggested that the “Gentoo” Linux is the most stable 64-bit OS and the preliminary testing results favoured this. In fact and in reality the “stability” concern is the combination of troubleshooting and usability issues: Even if with successful troubleshooting, it is difficult to justify in what ways the 64-bit OS can perform the better tasks. However in this paper, the author has demonstrated how this can be achieved.

The final discussion is related to middleware research: Middleware is defined as "the software and hardware infrastructure to support model of computation and information utilities on demand" [5]. In this paper, 64-bit computing is considered as a middleware, in which both hardware performance testing and software implementations were successfully completed. Furthermore, the testing results and development techniques were presented and analysed, and this was a break-through in the current usability issue (obtained from approximately 100 surveys) – which is related to "not sufficiently knowing how to properly make uses of 64-bit computing". In the next coming paper, the author would present how a cluster of eight 64-bit machines can handle the equivalent work for 100 CPUs or more, as well as the fact of improving the current usability issue for 64-bit computing.

In conclusion, this paper has presented the two major research contributions in testing and application of the 64-bit computing. Comprehensive testing results reveal that 64-bit computing has a better performance in application performance, system performance and stress testing, and the latter is a bonus for the IT and research organizations. However, 64-bit computing has a worse performance in compatibility testing than 32-bit computing, and the software and hardware manufacturers should focus on improving this. A 64-bit dual-core processor performs better than a 64-bit single-core processor, but only in application that requires very high demands of CPU and memory consumption. The second contribution is .NET 1.1 64-bit implementations, including the techniques to develop 64-bit applications. There are four minor contributions discussed: (a) the correct combinations for developer platforms; (b) the programming techniques; (c) functionality for dynamic repository; and finally (d) integrations and interoperability between .NET, SQL Server and IIS Server are presented. The dynamic repository can be easily customized into a mobile server without connecting to the internet, and techniques and implementations can be demonstrated in the conference.

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