An Introduction to 64-bit Computing

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Introduction
The current trend in the market towards 64-bit computing on desktops has sparked interest in the industry for 64-bit computers. Intel and AMD have already released their 64-bit processors suitable for desktops and servers. However, 64-bit computers are not new; companies have been using 64-bit systems on high-end servers for years and they still do. What is new is the interest in 64-bit computing for desktops. Microsoft’s Vista operating system is expected to give a much needed fillip to the popularization of 64-bit architectures.

With the advent of 64-bit versions of Linux and Windows operating systems, there comes a huge challenge of porting applications and device drivers. Is it necessary to port all applications? What kind of applications require 64-bit computing horsepower and why? Can 32-bit applications work on the 64-bit platforms? This paper tries to explore the benefits of 64-bit to applications and answer some of the questions posed above.

What is 64-bit Computing?
“64-bit” computing implies computing on a 64-bit processor. Simply put, the labels "16-bit," "32-bit", "64-bit", etc., characterize a processor’s data stream. 64-bit wide memory buses imply that the address lines are 64 bit wide and virtual addressing mechanisms use 64 bit sized pointers. Although we hear the term "64-bit code," it actually refers to code that operates on 64-bit data. It also implies that by special instructions (or modes) one can access the 64-bit registers or computing capability.

Figure:1 depicts a simplistic view of a processor and the blocks that have to be 64-bit wide to be called a 64-bit processor.

![Processor Block Diagram](image-url)
The following table shows the different standards and the differences between them.

<table>
<thead>
<tr>
<th>DATA TYPE</th>
<th>SIZE IN VARIOUS STANDARDS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LP64</td>
</tr>
<tr>
<td>char</td>
<td>8</td>
</tr>
<tr>
<td>short</td>
<td>16</td>
</tr>
<tr>
<td>int</td>
<td>32</td>
</tr>
<tr>
<td>long</td>
<td>64</td>
</tr>
<tr>
<td>long long</td>
<td>64</td>
</tr>
<tr>
<td>pointer</td>
<td>64</td>
</tr>
</tbody>
</table>

**Figure 2: Standards**

LP64 also known as 4/8/8 implies that *long* variable and pointers are of 64 bits or 8 Bytes.

ILP64 also known as 8/8/8 implies that *int, long* variables and pointers are of 64 bits or 8 Bytes.

LLP64 also known as 4/4/8 implies that *long long* variable and pointers are 64 bits or 8 Bytes.

The current distributions of Linux on 32 bit based architecture conform to the ILP32 standard. The upcoming Linux 64 bit systems will conform to LP64 standard, while MS Windows Vista is LLP64 compliant.

**Why 64-bit?**

This question is often not answered completely and cannot be answered very quantitatively. Several factors determine if 64-bit architecture will improve the performance of generic and everyday applications or not. 64-bit architecture will definitely benefit those applications that have one or more of requirements mentioned in this section.

**Memory**

A 32-bit machine utilizes 32 bits of virtual addressing. It translates to a total virtual memory of $2^{32}$ bytes which is 4 GB. Often out of the 4 GB process address space, some space is reserved for the use by the Operating System\(^1\). While 2 GB may be sufficient in many cases, corporate databases have indexes that are definitely larger. Graphic applications such as CAD, gaming applications, multimedia and video editing software quickly consume RAM. With the advent of DVD and HD_DVD and beyond, file sizes of 2 GB and more are becoming common. Such huge file sizes cannot be supported easily in current 32 bit systems (without performance penalties).

Simple applications like Web servers can also gain significant performance improvements by loading static content into memory rather than on slower disks. Performance of the 32 bit machine can be hindered owing to the frequent swapping between the processes, when several processes (with large memory requirements) execute concurrently.

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\(^1\)Windows uses a space of 2 GB for OS use but it is not so in Linux. Effectively a process gets only 2 GB for its own use in Windows.
Listed below are some applications that require high memory:

- **Graphic editors (CAD):** Graphic editing software is known to be memory hungry. Applications like Panorama Factory (photo editing software) are found to perform much better under higher virtual memory provided by 64-bit processors.

- **Video and multimedia editing software:** The video and audio editing software need higher memory because of the complex operations they perform on a large data. 64-bit architecture helps these types of applications with higher memory and processing power.

- **Databases:** Large organizations have large data to be handled and higher memory provided by 64-bit architecture, most certainly helps databases as they can store more information in memory compared to a 32-bit platform. This will result in higher performance databases.

The theoretical limit of memory in 64-bit systems is $2^{64}$ bytes which is 16 EB. Although systems with such a huge amount of memory will be prohibitively expensive, the current systems provide 40 bits of physical address space or 48 bits of virtual address space.

**Large-number math**

Large-number math is an obvious advantage offered by a 64-bit processor. A 32-bit processor can handle the integer range of -2.1 billion to +2.1 billion (approximately). However, it is not to say that a 32-bit processor cannot handle a 64-bit number today. A number larger than 32-bits can be stored in multiple memory locations as lower and higher 32-bits and the software can be programmed to treat it as a single 64-bit number (long long). But these are at best workarounds and are not fast. On the other hand, a 64-bit processor will be able to handle bigger numbers without having to resort to the workarounds and hence are inherently faster.

This capability of the processor to handle larger numbers helps the following cases:

- **Large financial systems:** These systems will work with large numbers and 64-bit processor’s ability to work with larger numbers comes in handy.

- **Computer simulations:** Computer simulations used in medical field are extremely complex and require high performance processors. 64-bit processor with its mathematical ability with higher numbers.
• **Graphics rendering (3D gaming):** Computer programs like Crafty (an open-source, high performance chess program) have shown 47% improvement when run under 64-bit mode over 32-bit mode on AMD Athlon processors.

• **Compression, Cryptography (Encryption):** Most of the digital security systems are based on the algorithm used to encrypt the data and the size of the keys (for encryption) used in the process. Larger keys are safer and are harder to break. With 32-bit processors, 256-bit key will need 8 addresses in memory \((8 \times 32 = 256\text{ bit})\) and will involve more mathematical computations. A 64-bit processor will store the same encryption key in 4 addresses in memory and will significantly speed up the encryption process.

**Date Format**
The current Date format is a 32-bit signed integer which will expire soon\(^2\), hence the format has to be changed to 64 bit signed integer. It is said that in Microsoft Windows environment a process cannot run for more than 49.7 days. This is due to the limitation of 32 bit time format. The system clock is used to evaluate the elapsed time (in milliseconds from the inception) and this turns negative after 49.7 days.

**What about normal applications?**
It is quite obvious that applications written to exploit 64-bit architectures can gain from faster access to data, availability of 64-bit resources like 64-bit and 128 bit registers, 64-bit pointers and larger data types. Applications can also have larger file caches and map large process data in virtual address space and can support larger files using standard system library calls, etc.
Categorically it cannot be stated that 64-bit systems are better off for all scenarios, in certain cases the gains are not significant (but they do measure up to 32 bit counterparts).

**To port or not to port?**
The big question still remains unanswered and ambiguous. The effort for porting all applications can be quite high and must be balanced with a return-on-investment assessment. To ease the problems of existing applications, most 64-bit architectures (operating system and processor) operate in 2 modes – 64-bit mode and compatibility mode. 32-bit applications can work without recompilation in the compatibility mode albeit with some performance penalties. It is however advisable to port device drivers and other performance sensitive applications to 64-bit and optimize the application to make use of the enhancements provided by the 64-bit architecture.

\(^2\)2038 A.D. to be exact. This is valid for Linux machines only.
Figure 3 shows what we foresee as the evolution path for applications. Legacy 16-bit and 32-bit applications will continue to exist. Some applications will just be compiled in 64-bit mode to benefit from a few obvious advantages, while few others will be enhanced to exploit the features of the 64-bit architecture. Within the next 2-3 years we will see a lot more proliferation of 64-bit desktop applications as 64-bit desktops and operating systems, specifically from Microsoft appear and become popular in the market.

MindTree’s Experience

MindTree has a team of engineers working on 64-bit software and hardware platforms as well as migration of applications and device drivers. MindTree has developed a porting tool called CodeMigrate.

CodeMigrate helps to identify potential 64-bit porting issues automatically. The tool takes in the user source code (C source code) as the input and then suggests the changes required to enable clean porting to 64bit system. The tool specifies exactly where the code needs to be changed so that it can be easily migrated to 64bit system. The tool acts as an enabler and can be used for semi-automating the process of migration of (legacy) source codes to 64 bit systems. The tool can be easily customized for specific needs and coding standards. MindTree is using this tool to port a large and complex server application to 64-bit Linux operating system running on AMD hardware.
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