*Comparative study of 32-bit and 64-bit architecture models*

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***Abstract*—***A 32-bit system is the one that can access 232 memory addresses, i.e 4 GB of RAM or physical memory. while 64-bit system can access 264 memory addresses, i.e actually 18-Quintillion GB of RAM. The 64-bit model, although introduced two-decades ago, still has not been able to successfully replace the 32-bit model. Back in the 1990s and early 2000s, all low-end systems were based on 32-bit architecture, while 64-bit architecture was specific to high-end servers. For instance, 64-bit processors including Alpha and SPARC have powered high-end,*

*SMP servers. However, recently, small servers using Intel Itanium,*

*AMD Athlon64 and Opteron, and IBM PowerPC G5 have appeared. As the available RAM space increased, microcomputers and workstations based on 64-bit architecture were introduced. Introducing a 64-bit model to general use meant that a larger primary memory was available to the system and the producers also introduced larger physical memory to the system in form of drives and discs.* *But, since everything as a 64-bit code now, memory units that needed lesser space would still use up 64-bits of the register. And while a 64-bit system is way better than a 32-bit system, but it has several problems in the modern x86 architecture model although most of them are legacy issues, they still need work. We try to explore changes that are based on memory allocation, compatibility and addressability.*

***Keywords****: architecture, WoW64, registers, processor ,Operating system, addressability, compatibility, memory, file size, x86, DLL, emulator, NTFS, virtual memory, LFS, Hard-link, context switching, pool size, paging*

1. **Method Employed**

While most of the results and observations are based on experiments and results, some are purely of theoretical construct. The verification of the theoretical results in case of MS-Office has been done by using the Microsoft office documentation available on the official website of Microsoft. And NovaBench is a public database and the information is hence used for the purpose of comparison.

The tools used for the results have been mentioned with each observation.

1. **Available RAM Memory**

Number of addressable units and hence the theoretical maximum size of RAM allowed in a 32 bit and 64 bit architectures are (Table 1) :

|  |  |
| --- | --- |
|  | **Maximum size of RAM supported(Theoretically)** |
| **32 –bit architecture** | 4 GB |
| **64-bit architecture** | 18 Quintillion GB |

**Table 1**

1. **Paging Size Allowed**

Now, on a 32-bit system, each page table entry is about 4 bytes. And so, assuming a page-frame size to be about 4 KB (Just for calculation), we come to a result that about 220 page frames are allowed. However, for a 64-bit architecture, the same specifications become 252 page-frames. However, there is always some experimental error. For eg. A 4 GB RAM may have only about 1.8 GB to 3 GB of actual free space while a 8 GB RAM may have about 6.5 GB to 7.5 GB of free space.

And the following documentation available at Microsoft official documentations only prove the mathematical observations. The amount in which 64-bit systems enhance memory is tremendous (Table 2).

|  |  |
| --- | --- |
|  | **Supported Page Pool Size** |
| **Windows 2007 and earlier** | 470 MB |
| **Windows 2010 and later** | 128 GB |

**Table 2**

1. **Compatibility**

* No clear preference found except for the fact that 64-bit architecture is a pressing need keeping in mind the increasing reliance on software to hold databases and the increase in complexity in scientific computing. Most 32 bit softwares are compatible to 64-bit system but the opposite is not true.
* Some OS like Windows have some specific file formats to be used in different architectures. So, in windows while ntfs is incompatible with 32 bit architecture, FAT is 32-it specific and FAT-ex can run on both architectures.
* 64-bit software clearly has an edge in security features, smoothness of functioning and data handling when run on 64-bit architecture.
* However, not all 32-bit softwares give enhanced performance in a 64-bit environment. For instance, a 32-bit process with a virtual memory need of say 2 GB is run on a system with a 4GB RAM (as stated, which is about 3 GB in reality), the same process on a 64-bit RAM will consume about 4-5 GB virtual memory due to add-ons or due to the fact that in a 64-bit register, every process has about double the allocation in a 32-bit architecture and thus the thread stack size doubles. So, if here a 64-bit system has yet a 4 GB RAM, the process will not proceed and system will terminate it.
* Windows uses WoW64 to run x86 programs on a x86-64 system. This helps the OS in rapid context switching and slows the processor less than other OS where generally an emulator program runs 32 bit programs thereby increasing the number of threads being simultaneously processed.

1. **Some Examples**
2. **Microsoft Office –** Microsoft Office 2007 has only one version – 32 bit version (Table 3).

|  |  |  |
| --- | --- | --- |
| **Name** | **Office – 2007** | **Office 2010 and beyond** |
| Access | Supports VBA libraries but big number entries may have errors | 2010 VBA supports big numbers |
| Excel | The number of cells and other specifications are fairly similar. No comparison made. | * 32 bit : 2 GB virtual Address space * 64-bit: No hard limit * 64 bit offer about 32kbytes of internal formula length, double the 32-bit version. |

**Table 3**

In fact, Visual Basic based software is generally backward compatible. And VB 2015 supports all applications up to VB 2009.

1. **Python 3.**7 –

Before Python 3.8, the generic python IDLE was al 32 bit program. The reasons being:

1. The data to process is generally not very large if scientific libraries are not being used.
2. Since dll files are themselves usually 32-bit based, turns out a 32-bit python interpreter is better if it is not to handle very large data.

So, 32-bit becomes the preferred choice to avoid compatibility problems. To handle large databases, some standard scientific distribution such as Spyder IDE with anaconda package can be used.

1. **Chrome –**

**Note:** CPU usage and memory consumed determined using task Manger(Table 4 and 5).

|  |  |  |  |
| --- | --- | --- | --- |
|  | **CPU Usage** | **Memory** | **Security** |
| **32 bit** | **No big difference** | **60 MB**  **(upto Windows 7)** | **Standard features.**  **Encryption limited by memory available** |
| **64 bit** | **No big difference** | **111.7 MB**  **(Windows 8)** | **Enhanced Encryption**  **Windows x86-64 provided increased security and because the server had increased processing capacity, lesser crashes.** |

**Table-4**

**Average results of tests on 32-bit and 64-bit Google Chrome software:**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| **TESTS** | **HTML 5.0 SUPPORT** | **CSS SUPPORT** | **OCTANE 2.0 SCORE** | **MOTIONMARK 1.0** | **JETSTREAM 1.0** | **BASEMARK SCORE** | **PAGE LOAD RESPONSE** |
| **32 – bit** | **96.58%** | **57.05%** | **19760** | **100.5** | **175.62** | **156.05** | **89%** |
| **64-bit** | **97%** | **58%** | **20804** | **109.2445**  **(max recorded: 239.06,**  **Min recorded: 33.20)** | **183.51** | **281.34** | **95%** |

**Table 5**

The generalised observations are (Jetstream, MotionMark, Octane and Basemark are all benchmarking tools):

1. HTML 5 has fairly the same support in both chromes.
2. The JetStream 1.1 and Jetstream 2, both indicate that Chrome 64 bit is slightly faster (about 5% on average)
3. Using Motionmark1.1 , we found that Chrome 64-bit has better graphics than Chrome 32-bit and it is naturally a result of increased availability of data transfer and memory for more pixel support. (Chrome 64-bit is about 8.75% better than Chrome-32 bit)
4. Using octane 2.0(an open source Google benchmarking app), we found that the Java performance of a 32-bit and 64-bit Chrome varied by about 5%.
5. However, as Chrome 64-bit consumes more memory, low-end systems cannot use it effectively.

Our results were fairly similar with other browsers such as Mozilla Firefox (by default 32-bit) (stored in program files(x86)) and Chromium browser.

1. **Games with high software requirements–**

* No actual comparison needed.
* PubG and GTA5 are examples of software applications with very high resource requirements. They are both 64-bit only games and as per specifications of the games, must be played on a system with at least 8 GB RAM, a strong GPU and a large virtual memory which are not found in any 32-bit architecture machine.
* However, if played on a 32-bit OS with 64-bit hardware architecture, the system crashes.
* Thus, for games with high CPU usage, the 32-bit systems do not have much to offer and 64-bit systems are clear winners.

1. **Computer OS and processor**

Here, the tests were more than just software applications but to analyse how hardware, processors and their types have been affected with the growth of ISA from 32 to 64 bit. Using Novabench, benchmarking software for processors and systems, we have tried to understand the same.

Note: For this experiment, we stuck to 64-bit systems. The systems used are microcomputers manufactured between 2011 to 2019. This ensured that we had systems to examine from the introduction of a 64-bit OS (the Windows 7) to the latest microcomputer processors and OS. The results were (Table 6):

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| **SYSTEMS** | **NOVABENCH SCORE** | **CPU SCORE** | **RAM SCORE** | **GPU SCORE** | **Year of Manufacture** |
| 1. Intel i3-2310M(2.1 GHz) core with intel HD graphic family) | 578 | 334 | 124 (4GB) | 99 | 2012 |
| 1. Intel i3-4010U(1.7 GHz) core with Intel HD graphic family | 575 | 232 | 178 (8 GB) | 139 | 2017 |
| 1. Intel i5-8250U(3.2 GHz) core with Intel UHD graphics 620 | 1239 | 793 | 166(8 GB DDR4) | 251 | 2018 |
| 1. Intel i5-8250U(3.38GHz) core with UHD Graphics 620 | 1491 | 880 | 205(8 GB) | 379 | 2018 |

Table 6

Further, Novabench maintains an online directory of the results which allows the comparison of systems with similar cores.

The average scores for Pentium III processor series from Nova-Bench Database is about 290 (highest by Intel Pentium III Xeon with 307) while average score of Pentium II was 277.

Clearly, the introduction of 64-bit architecture helped push forward processor capacities (as can be seen in the figure).

1. **Theoretical Limit of Cache memory**

Since the cache memory is very small when compared to physical memory and the idea that a 64-bit architecture increases addressable units by a factor of 232 or by 4294967296 times:

* If data sets are very large, the cache doesn’t work very well –low locality of reference.
* If cache works well – locality of reference is very high – cache is idle most of the time.

1. **Observation**

A 64-bit architecture and OS are clear winners in most cases.

1. **Conclusion**

64-bit architecture is better than 32-bit architecture on most fronts while still facing many compatibility issues. Additionally, RAM size limits software performance and so, a 64-bit system needs to have a RAM of more than 4-5 GB in order to provide optimal support to software applications.

1. **Further areas of study**

* High Power Wastage in a multi-core system (Turing Lecture 2019 points out that about a fifth of energy is wasted).
* Instruction wastage in a high scale architecture (As we already pointed out – a 64-bit system consumes double memory than a 32-bit system as visible in the Chrome example)
* If data sets are very large, the cache doesn’t work very well –low locality of reference. If cache works well – locality of reference is very high – cache is idle most of the time.
* Mobiles focused on improved security, performance and die size.
* However, they were modelled on existing processor models for general purpose CPUs.
* Open Source codes have become a reality and there is a pressing need for new Instruction set Architectures that cater to them in the same way they cater producer-specific programs

1. **Abbreviations**
2. ISA: Instruction Set Architecture
3. FAT: File Allotment Table
4. NTFS: NT File System/New Technology File System
5. RAM: Random Access Memory
6. DLL: dynamic linked libraries
7. OS: Operating System
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