

## Paper Summary – Xen and the Art of Virtualization – Shawn Anderson

This paper outlines Xen, a virtual machine managing platform that was created in 2003. The goals of Xen were to provide a high performance, lightweight, virtualization option that would support multiple OS's. Xen was made to support OS's such as Linux, BSD, and Windows XP; with the intention of being able to run up to 100 VM's on a single server. Xen is built on an x86 instruction set. In 2003 x86 had no support for full virtualization, thus OS augmentation was required for OS's to be ported to Xen.

Xen is implemented in the fashion of paravirtualization, which means that the guest OS's are aware that they are running on virtual hardware. Guests are permitted to speak directly to hardware in any case that they have permissions to do so. Otherwise, a context switch to Xen is required.

Memory management was a particular hurdle for Xen and for virtualization attempts in general. To aid in memory management, Xen utilizes the x86 protection ring, a hierarchical permissions system ranging from 0 to 3 where 0 is the highest privilege. In the case of context switches to Xen, the Translation Lookaside Buffer (TLB) is not flushed as it is in the case of a normal context switch. Avoiding expensive TLB flushes is one of the ways that Xen was able to achieve such high performance over its peer systems.

Xen handles exceptions and traps in a straightforward manner, the only exception being the page fault handler. Xen uses an asynchronous I/O ring and both real and virtualized time to accomplish virtual address translation. Xen implements a balloon driver to lend resources from one guest OS to another in the case that there is an excess of resources with one OS, and a demand for resources in another OS. Xen provides virtual networking services such as a virtual firewall-router.

Xen outperforms its peer systems such as VMware Workstation 3.2 and User-Mode Linux. Xen enables a wide range of computing capabilities; from application mobility, to distribution of web services. This has been proven by the wide spread use of Xen, especially in the case of Amazon EC2.