The *Xen* of Virtualization

Assignment for CLC-MIRI

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March 4, 2013

Outline

Why Virtualization?

- Excess resources
  - Most tasks are limited by I/O not CPU
  - Similar to time sharing for multi-tasking
- Isolation
  - Security: Private memory for each process
  - Performance: A process shouldn't hang the whole system
- Heterogeneity
  - Multiple OS on a single hardware

Approaches to Virtualization

- Multiple Processes on standard OS
  - Performance Isolation is hard
  - System administration is difficult
- Full Virtualization
  - Provides complete abstraction of underlying hardware
  - Pros: No modification to host OS
  - Cons: Performance overhead
  - Limitation: Lack of hardware support in x86 architecture
  - Limitation: Difficult memory management

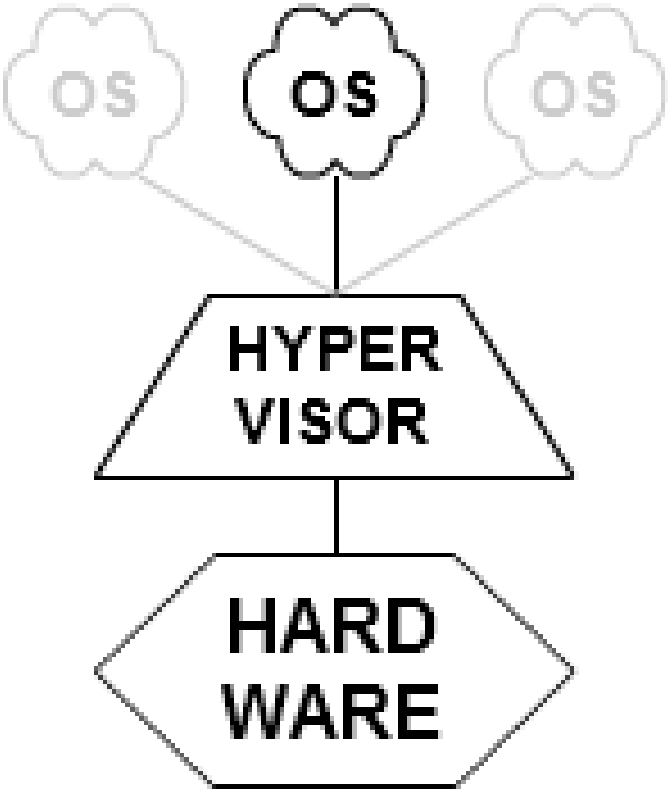
Paravirtualization

- Guest OS has *partially* direct access to physical hardware
- Better Performance (even without virtualization support in hardware)
- No need to emulate all hardware, so simpler to manage
- Pros: User applications can be executed without modifications
- Cons: Guest OS needs to be modified

History

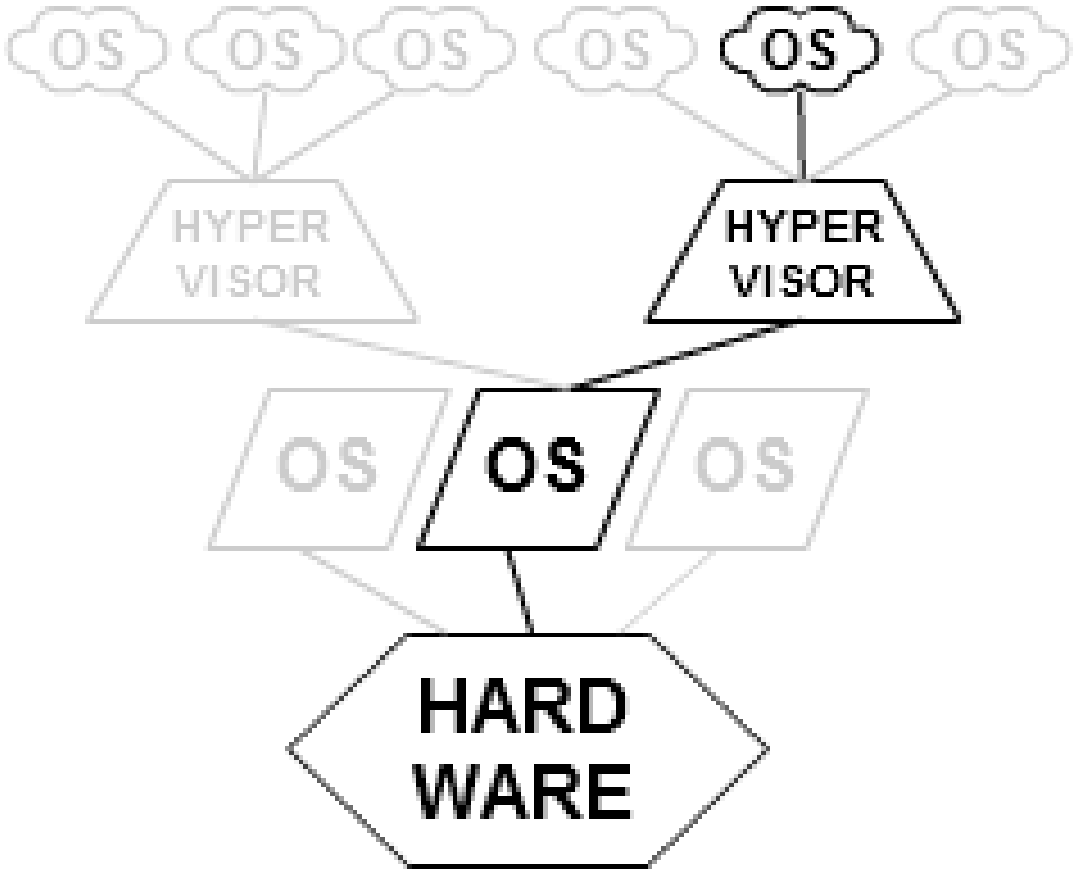
- Xen a breakthrough when no virtualization support in hardware
- Developed at University of Cambridge Computer Laboratory
- Supported by Microsoft. Windows XP's code was provided as well!
- Successful commercially, was acquired by Citrix Systems
- Commercial Products: Citrix XenServer, Oracle VM, Xen.org

Xen: Bare-Metal Hypervisor



TYPE 1

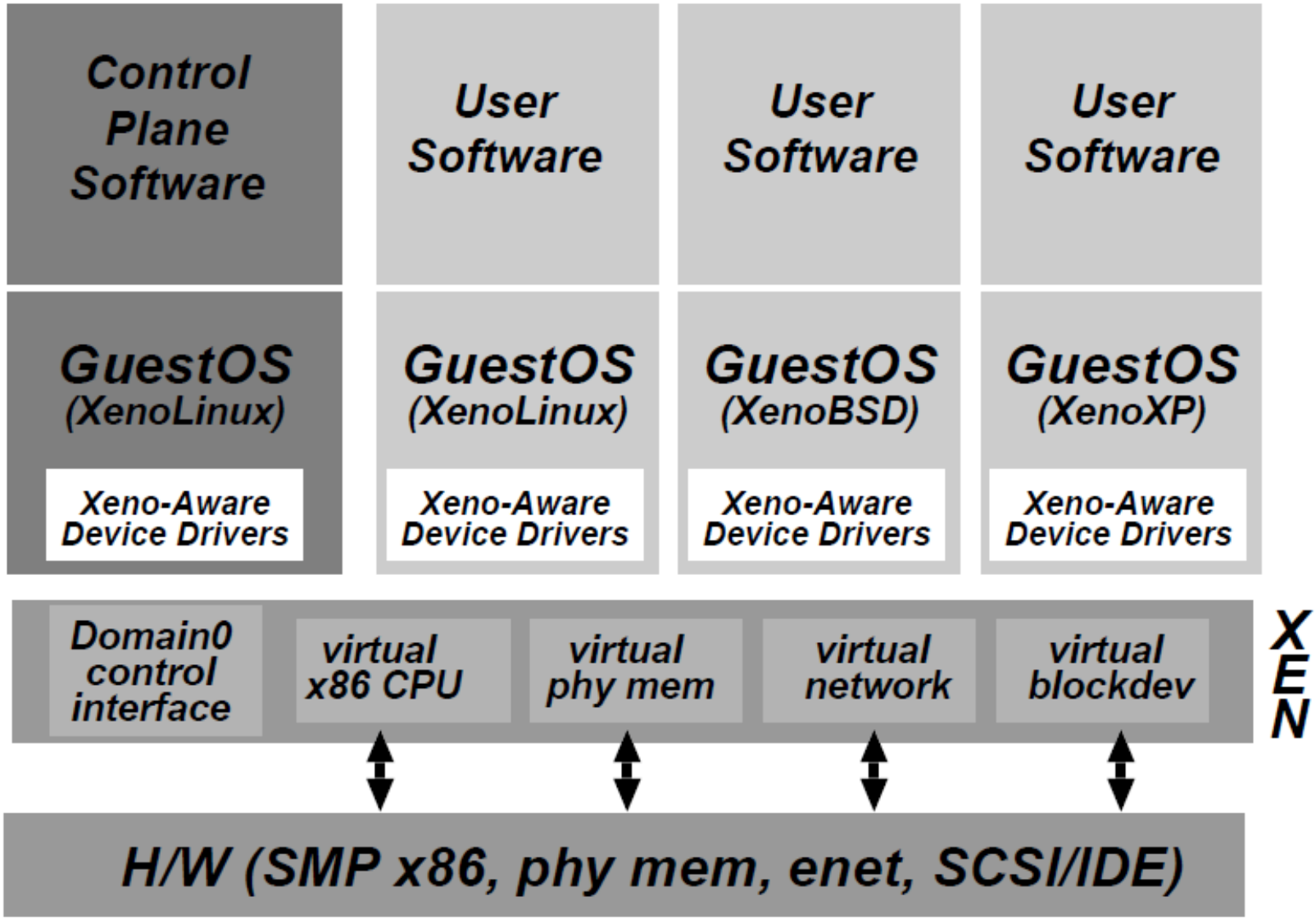
native
(bare metal)



TYPE 2

hosted

Xen Architecture



Xen Virtual Machine Interface: Memory

- Virtualizing memory is hard!
- x86 doesn't have software-managed or tagged translation lookaside buffer (TLB)
- TLB maps virtual memory seen from a process address space to physical memory
- Xen gives control to guest OS to manage page tables for its processes

Xen Virtual Machine Interface: CPU

- Privilege levels, ring 0, 1, 2 and 3 in x86
- OS runs in separate address space and with higher privilege
- Xen hypervisor in ring 0, guest OS in ring 1, user processes in ring 3
- This requires modification to guest OS
- System calls efficiently handled as guest OS directly installs handler
- Page faults are slow as delivered through Xen

Xen Virtual Machine Interface: I/O

- Hardware devices are not emulated, just abstracted
- Data is transferred via Xen efficiently
- Uses shared-memory, asynchronous buffer-descriptor rings
- Light-weight event delivery mechanism to notify guest OS

Asynchronus I/O Handling

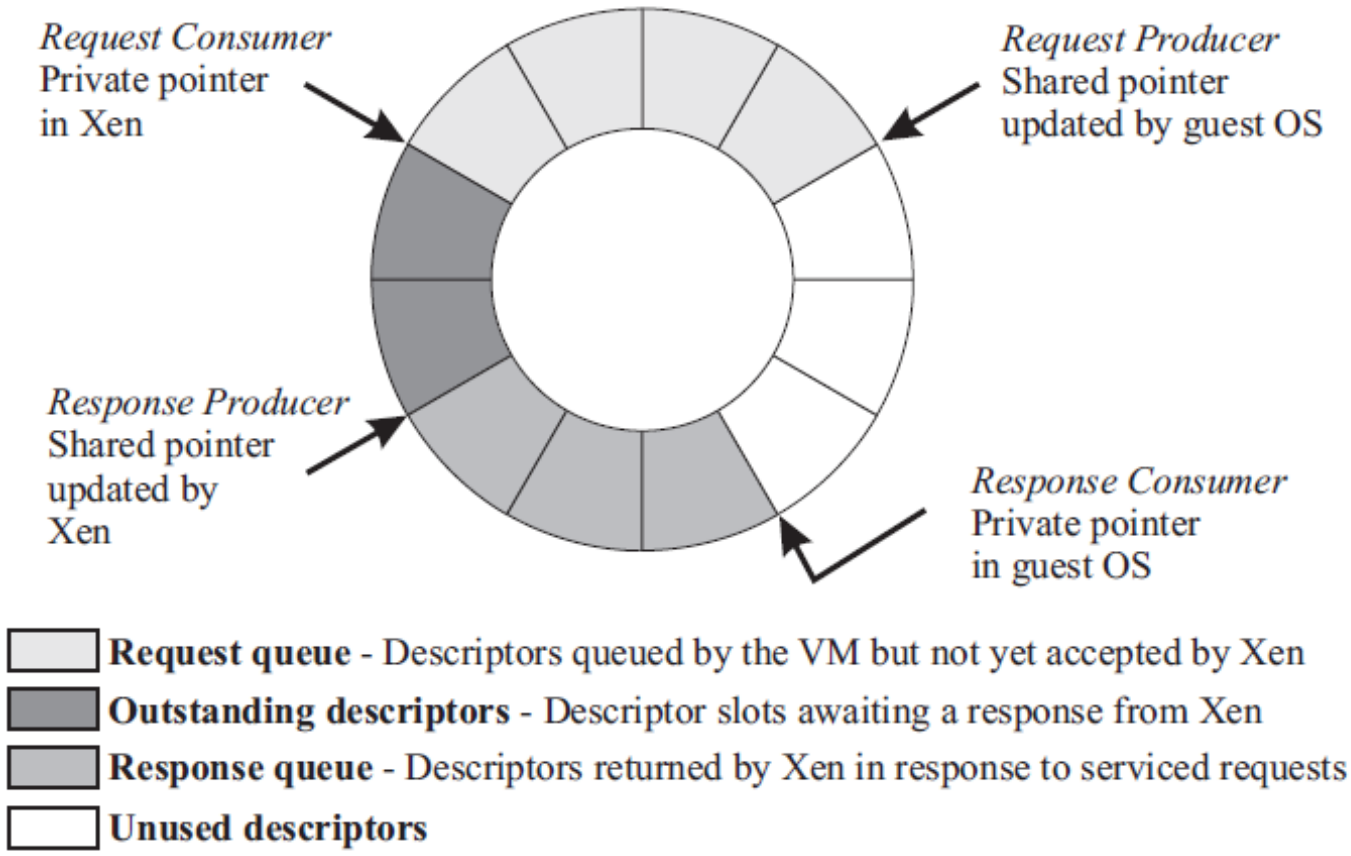


Figure 2: The structure of asynchronous I/O rings, which are used for data transfer between Xen and guest OSes.

Xen Virtual Machine Interface: Timers

- Real time: Nanoseconds since machine boot
- Virtual Time: Only advances when guest OS is executing
- Wall-clock Time: Off-set from current real time
- Guest OS can use pair of alarm timers, real and virtual

Performance Relative to Native Linux, VMWare, UML

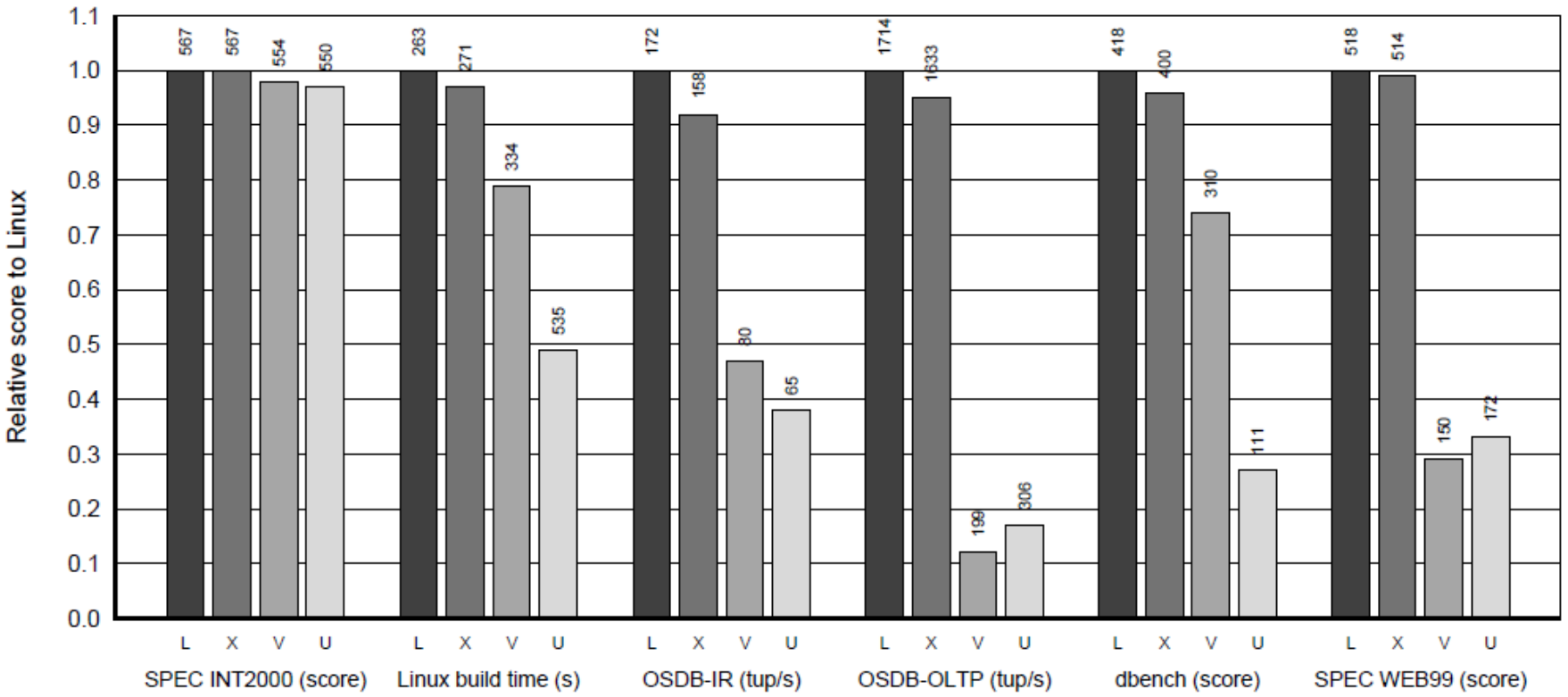


Figure 3: Relative performance of native Linux (L), XenoLinux (X), VMware workstation 3.2 (V) and User-Mode Linux (U).

Operating Systems Benchmarks

Config	null call	null I/O	stat	open closeTCP	slct	sig inst	sig hndl	fork proc	exec proc	sh proc
L-SMP	0.53	0.81	2.10	3.51	23.2	0.83	2.94	143	601	4k2
L-UP	0.45	0.50	1.28	1.92	5.70	0.68	2.49	110	530	4k0
Xen	0.46	0.50	1.22	1.88	5.69	0.69	1.75	**198**	**768**	**4k8**
VMW	0.73	0.83	1.88	2.99	11.1	1.02	4.63	874	2k3	10k
UML	24.7	25.1	36.1	62.8	39.9	26.0	46.0	21k	33k	58k

Table 3: `lmbench`: Processes - times in μs

Config	2p 0K	2p 16K	2p 64K	8p 16K	8p 64K	16p 16K	16p 64K
L-SMP	1.69	1.88	2.03	2.36	26.8	4.79	38.4
L-UP	0.77	0.91	1.06	1.03	24.3	3.61	37.6
Xen	**1.97**	**2.22**	**2.67**	**3.07**	**28.7**	**7.08**	39.4
VMW	18.1	17.6	21.3	22.4	51.6	41.7	72.2
UML	15.5	14.6	14.4	16.3	36.8	23.6	52.0

Table 4: `lmbench`: Context switching times in μs

Config	0K File create	0K File delete	10K File create	10K File delete	Mmap lat	Prot fault	Page fault
L-SMP	44.9	24.2	123	45.2	99.0	1.33	1.88
L-UP	32.1	6.08	66.0	12.5	68.0	1.06	1.42
Xen	32.5	5.86	68.2	13.6	**139**	1.40	**2.73**
VMW	35.3	9.3	85.6	21.4	620	7.53	12.4
UML	130	65.7	250	113	1k4	21.8	26.3

Table 5: `lmbench`: File & VM system latencies in μs

Network Performance

	TCP MTU 1500		TCP MTU 500	
	TX	RX	TX	RX
Linux	897	897	602	544
Xen	897 (-0%)	897 (-0%)	516 (-14%)	467 (-14%)
VMW	291 (-68%)	615 (-31%)	101 (-83%)	137 (-75%)
UML	165 (-82%)	203 (-77%)	61.1(-90%)	91.4(-83%)

Table 6: `ttcp`: Bandwidth in Mb/s

Concurrent Virtual Machines

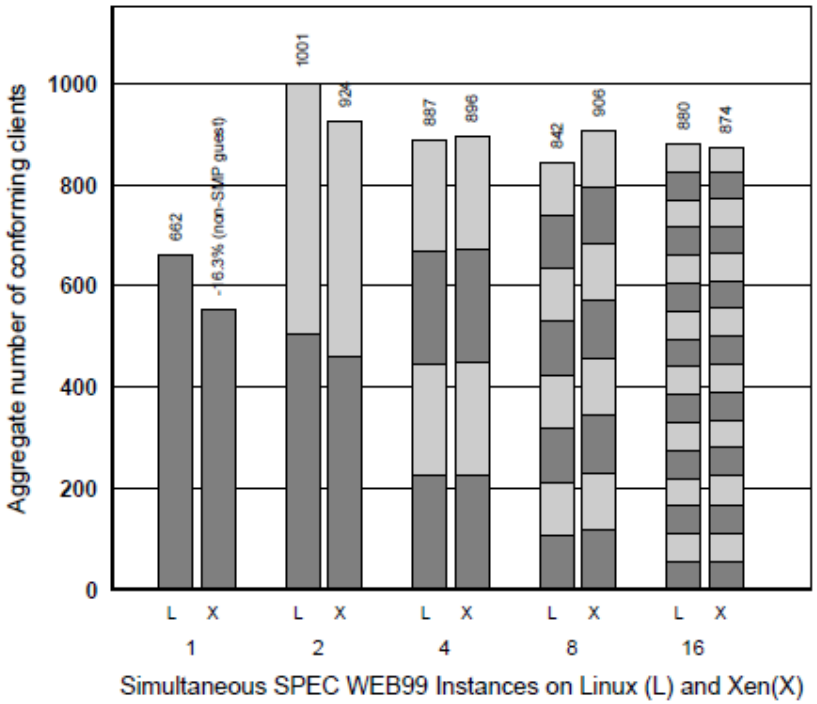


Figure 4: SPEC WEB99 for 1, 2, 4, 8 and 16 concurrent Apache servers: higher values are better.

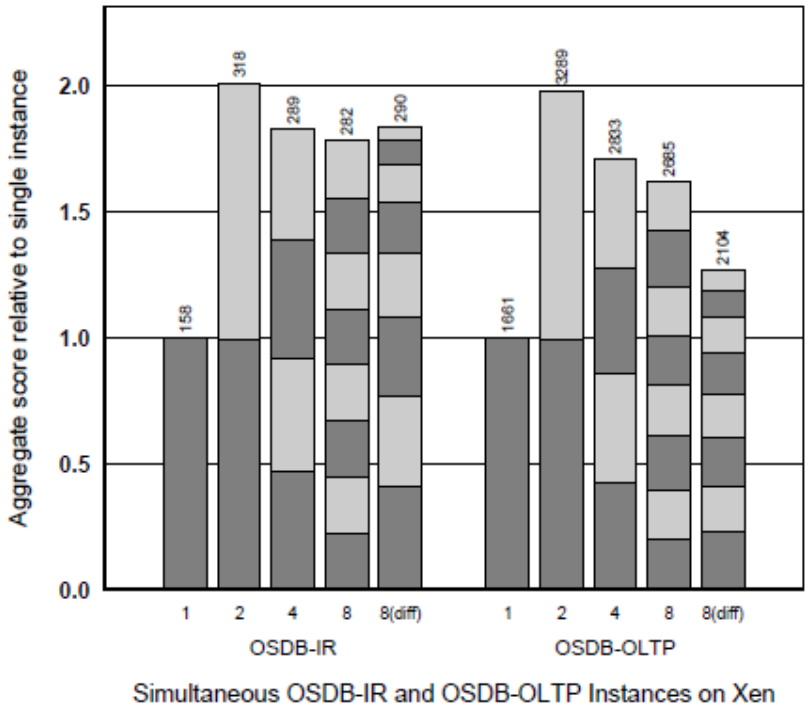


Figure 5: Performance of multiple instances of PostgreSQL running OSDB in separate Xen domains. 8(diff) bars show performance variation with different scheduler weights.

Scalability

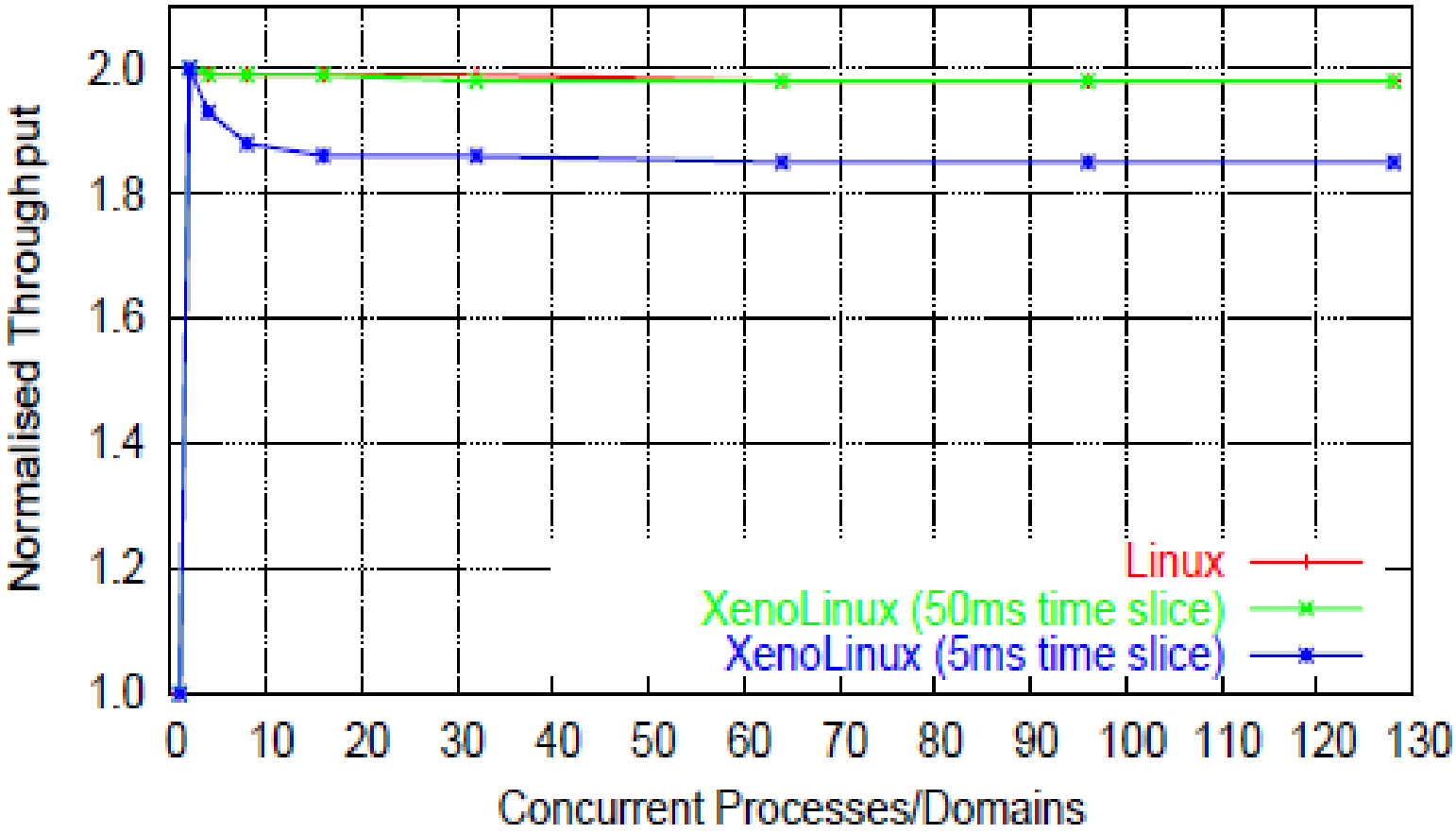


Figure 6: Normalized aggregate performance of a subset of SPEC CINT2000 running concurrently on 1-128 domains

Conclusion

- Supports Paravirtualization with modified guest OS
- Hardware-assisted virtualization, allowing for unmodified guest OS
- Virtual machine migration
- Available as dedicated virtualization platform
- Available as optional configuration for Unix, Linux, and Solaris systems
- QubeOS uses Xen for desktops to provide *Security by Isolation*