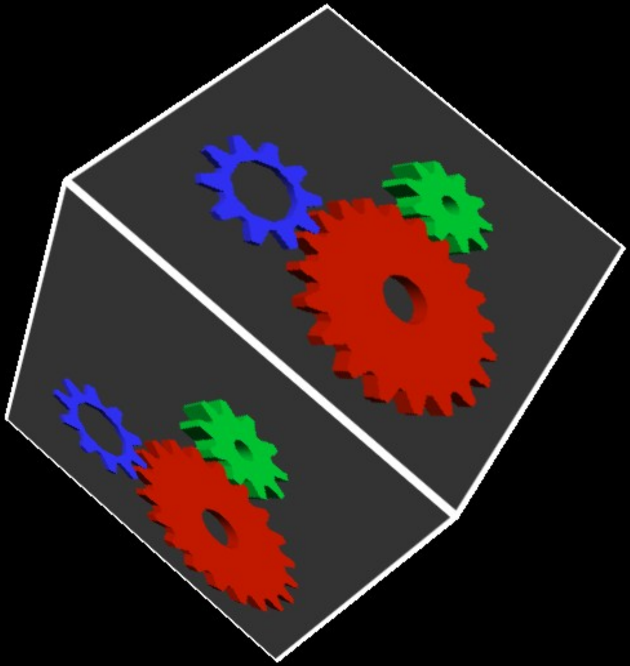
VMM-Independent Graphics Acceleration



H. Andrés Lagar-Cavilla, U of Toronto
andreslc@cs.toronto.edu
Niraj Tolia (CMU), Eyal de Lara (Toronto),
M. Satyanarayanan (CMU)

Why Virtualize 3D Acceleration?

Two simultaneous trends

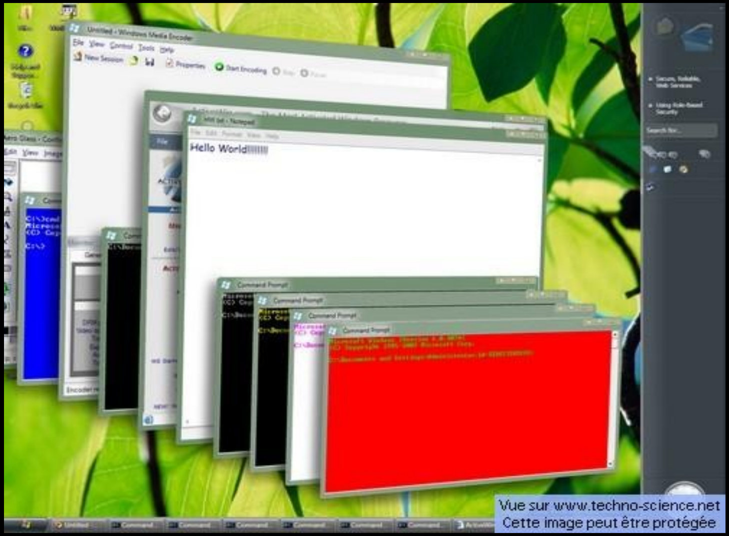
- VMs out of the server room
- Client apps going 3D

And we only have software rendering (Mesa)

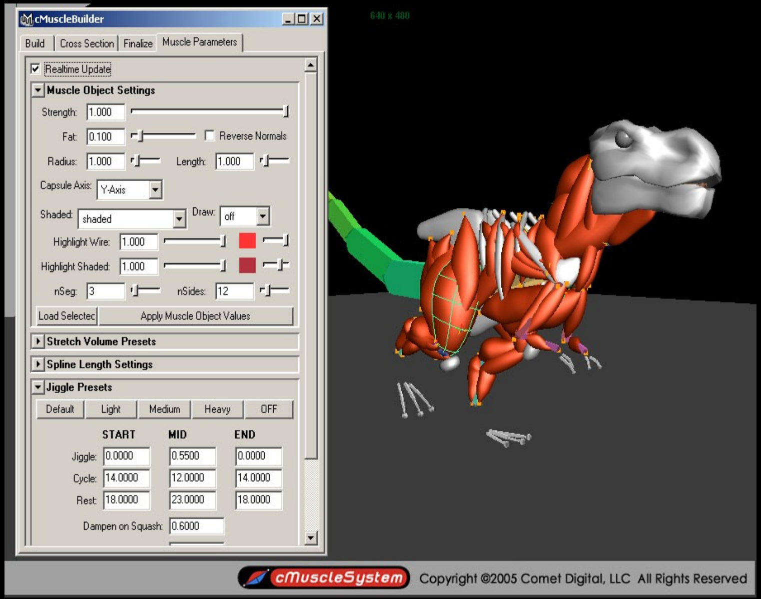
Virtualization of Client Apps

- Soulpads
- The Collective
- Internet Suspend/Resume
- Virtual Appliances
- Moka5, MojoPac, BlackDog, ...

The World Is Going 3D


Hello World!!!!!!
Vue sur www.techno-science.net
Cette image peut être protégée

Ubuntu Dapper 6.06 (TEST)
Support XCB, a modern replacement for the old Xlib: http://xcb.freedesktop.org/



☑ Realtime Update

Muscle Object Settings

Strength: 1.000

Fat: 0.100 □ Reverse Normals

Radius: 1.000 Length: 1.000

Capsule Axis: Y-Axis

Shaded: shaded Draw: off

Highlight Wire: 1.000

Highlight Shaded: 1.000

nSeg: 3 nSides: 12

Jiggle Presets

	START	MID	END
Jiggle:	0.0000	0.5500	0.0000
Cycle:	14.0000	12.0000	14.0000
Rest:	18.0000	23.0000	18.0000

Dampen on Squash: 0.6000

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Why Is 3D Virtualization Hard?

3D vendors compete through HW diversity

- Lack of unifying hardware abstraction
- Closed specs

Open HW abstractions simplify virtualization:

- Network -> Ethernet Frame
- Block Devices -> BIO request
- SCSI drives -> SCSI command packet
- ....

How could we ever write 3D applications?

3D Rendering APIs

De facto unifying software abstraction
Developer gets vendor independence

Two main APIs

- OpenGL
- Direct3D

OpenGL

- Cross-platform

VMGL: Virtualizing OpenGL

Provides 3D HW acceleration to applications running inside virtual machines

- GPU independent
- VMM independent
- Guest OS independent
- Suspend and resume capable

- 87% or better of native HW acceleration
- Two orders of magnitude better than Mesa

VMGL Design

API virtualization

- GPU vendor independence

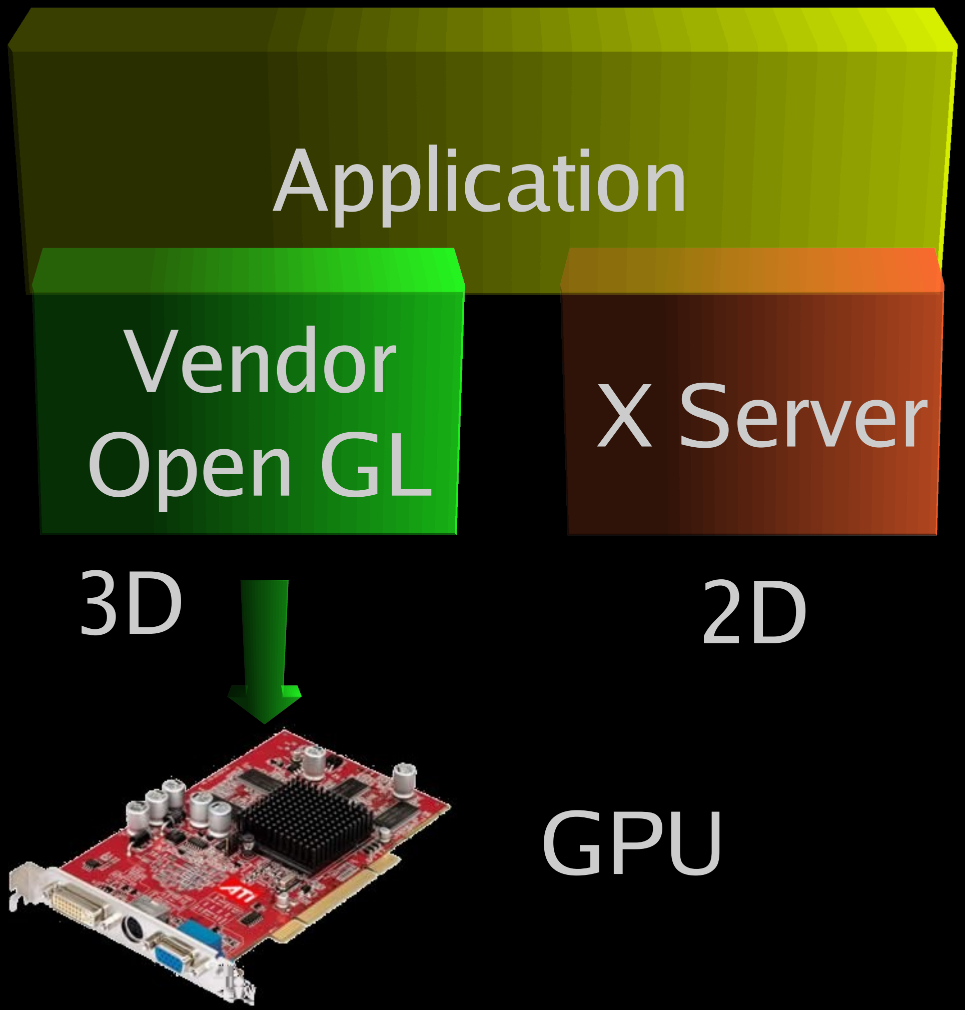
OpenGL: cross-platform API

- Guest OS independence

Network Communication

- VMM independence

OpenGL Apps In X11 Systems



Application

Vendor Open GL

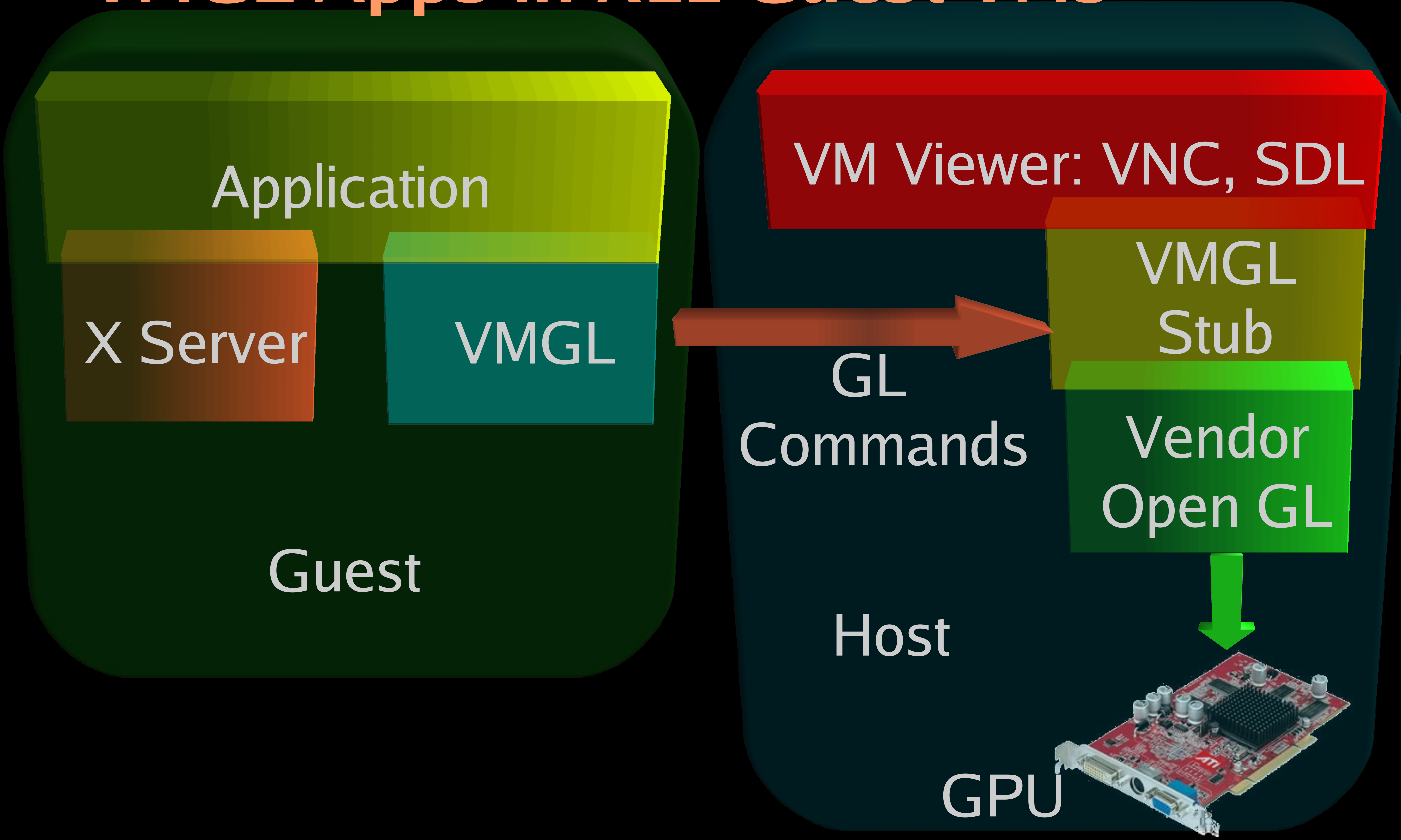
X Server

3D

2D

GPU

VMGL Apps in X11 Guest VMs



Implementation Aspects

- OpenGL API v1.5
  - Shaders through extensions
- Efficient GL network transport
- 3D and 2D output composing in VM viewer
- Suspend/Resume implementation
- Xen-specific: Domain 0 drivers

Implementation Aspects

- OpenGL API v1.5
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- Xen-specific: Domain 0 drivers

Efficient GL Transport

Transport over network

- VMM Independence

WireGL / Chromium

- Intended for tiled rendering

Only send updates that “matter”

- glTextureXY only when texture visible

Combine, reorder and buffer commands

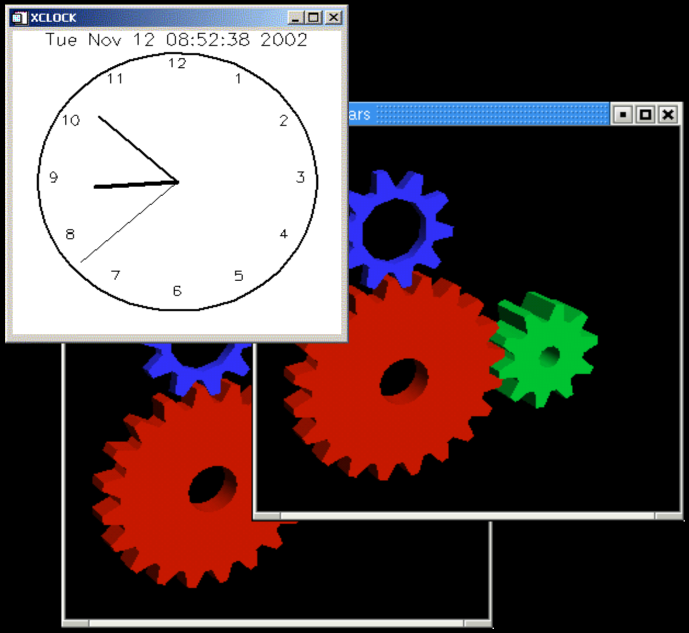
- glRotate + glTranslate ->
  Single matrix transformation

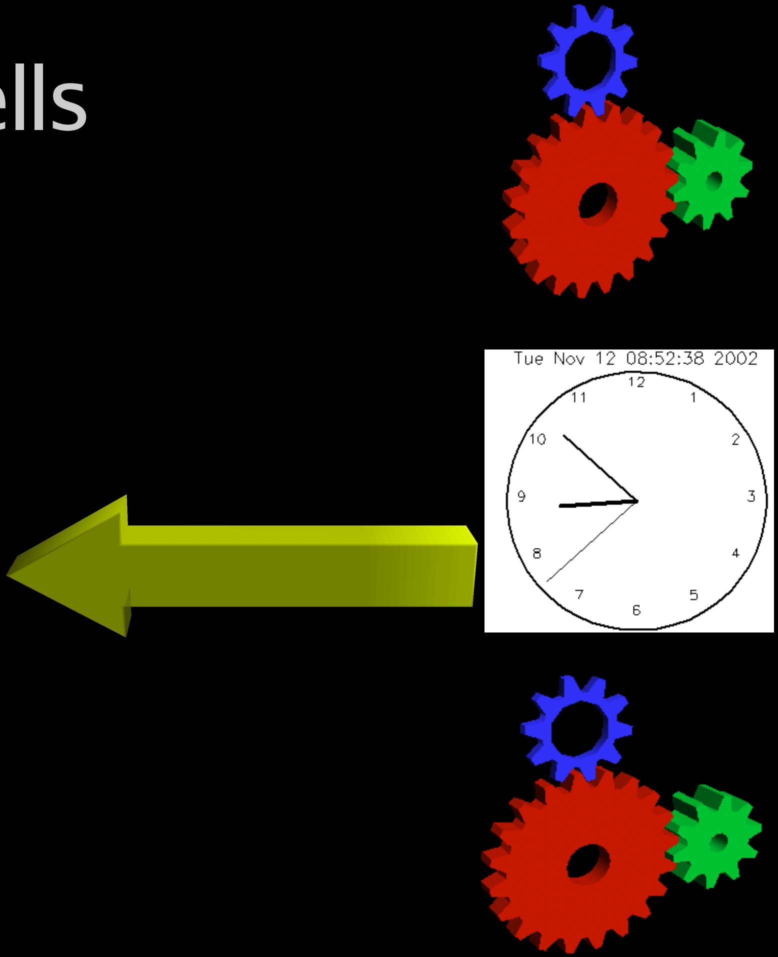
Output Composing in VM Viewer

3D & 2D output coming from different sources

Extension in VM's X server tells viewer about 3D windows

- Position
- Size
- Clipping





Suspend / Resume

Think each GL app as a GL device

- Runtime: keep track of OpenGL state
- Suspend: “freeze”G L device (trivial)
- Resume: flush state to new GL stub

OpenGL state is GPU independent

- Suspend/resume across different GPUs

OpenGL state is bounded

- See experiments

VMGL Suspend / Resume State

Windows

- Visual bits
- Binding to window manager extension

GL Contexts

- Context data: fog, transformations...
- Textures: pixmap, clamp mode
- Display Lists: verbatim unrolling

VMGL Evaluation

VMGL: OpenGL Virtualization

VMMs

- Xen – Paravirtual (results unless otherwise noted)
- Xen – HVM
- VMware Workstation

OSs

- Linux 2.6.16.29
- OpenSolaris 10 rel 06/06
- FreeBSD rel 6.1

Hardware

- ATI X600, Intel Dual Core 2.4 GHz, VT, 2GB Ram

Workloads

Quake 3

thewhiteguy played with fire

wjc was killed by Plinny's Garand

Mr T connected

[3dc]Leonidas WAS KILLED BY TEAMMATE DocNartman

DocNartman was killed by Niners's Thompson

DEMO CONTROLS

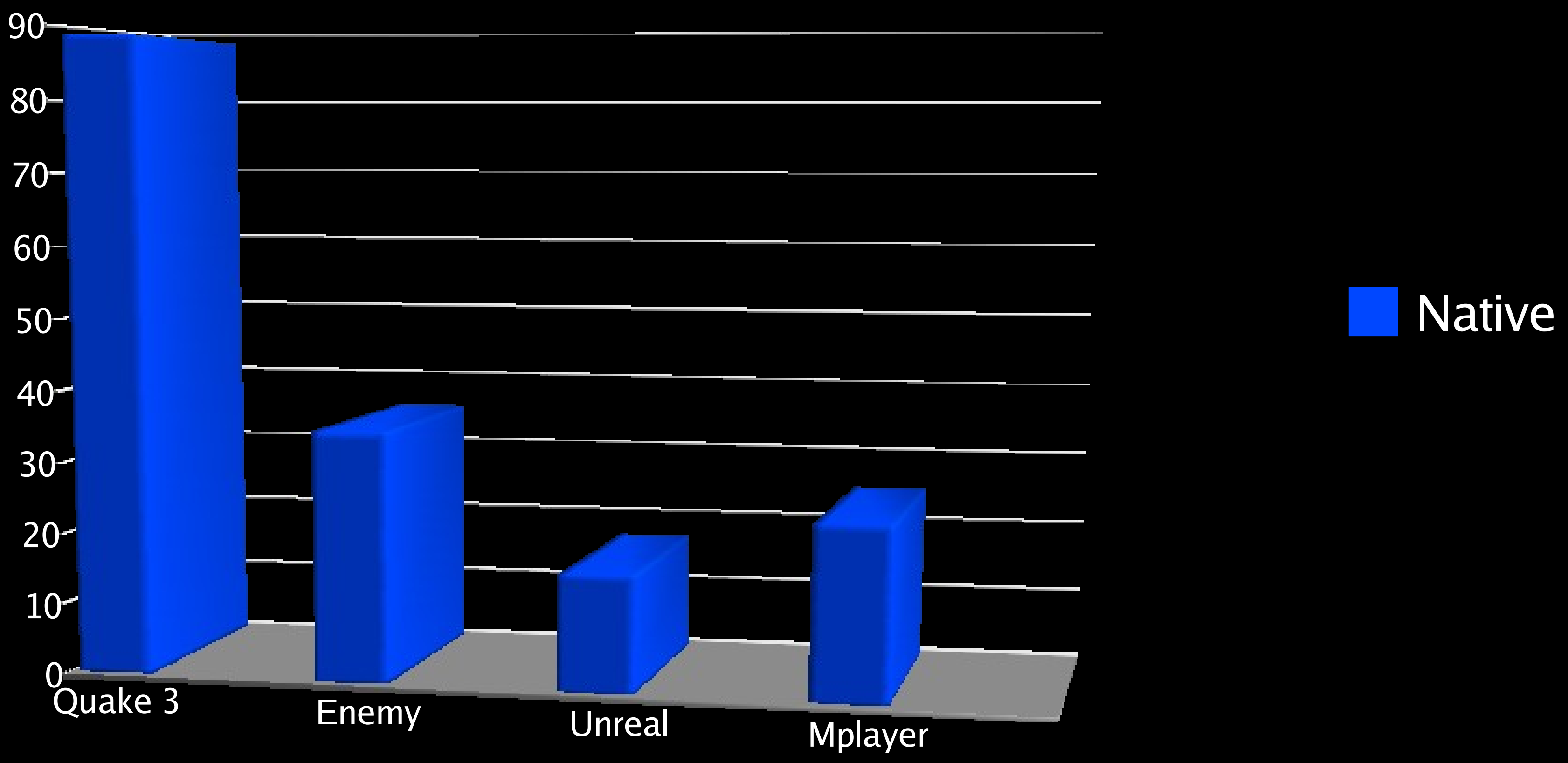
TAB	scores
F1-F5	avidemo record
F11-F12	screenshot
KP_DOWN	slow down (--)
KP_LEFT	slow down (-)
KP_UP	speed up (++)
KP_RIGHT	speed up (+)
SPACE	normal speed
ENTER	External view
LFT/RGHT	Change angle
UP/DOWN	Move in/out
BACKSPACE	help on/off

Enemy Territory

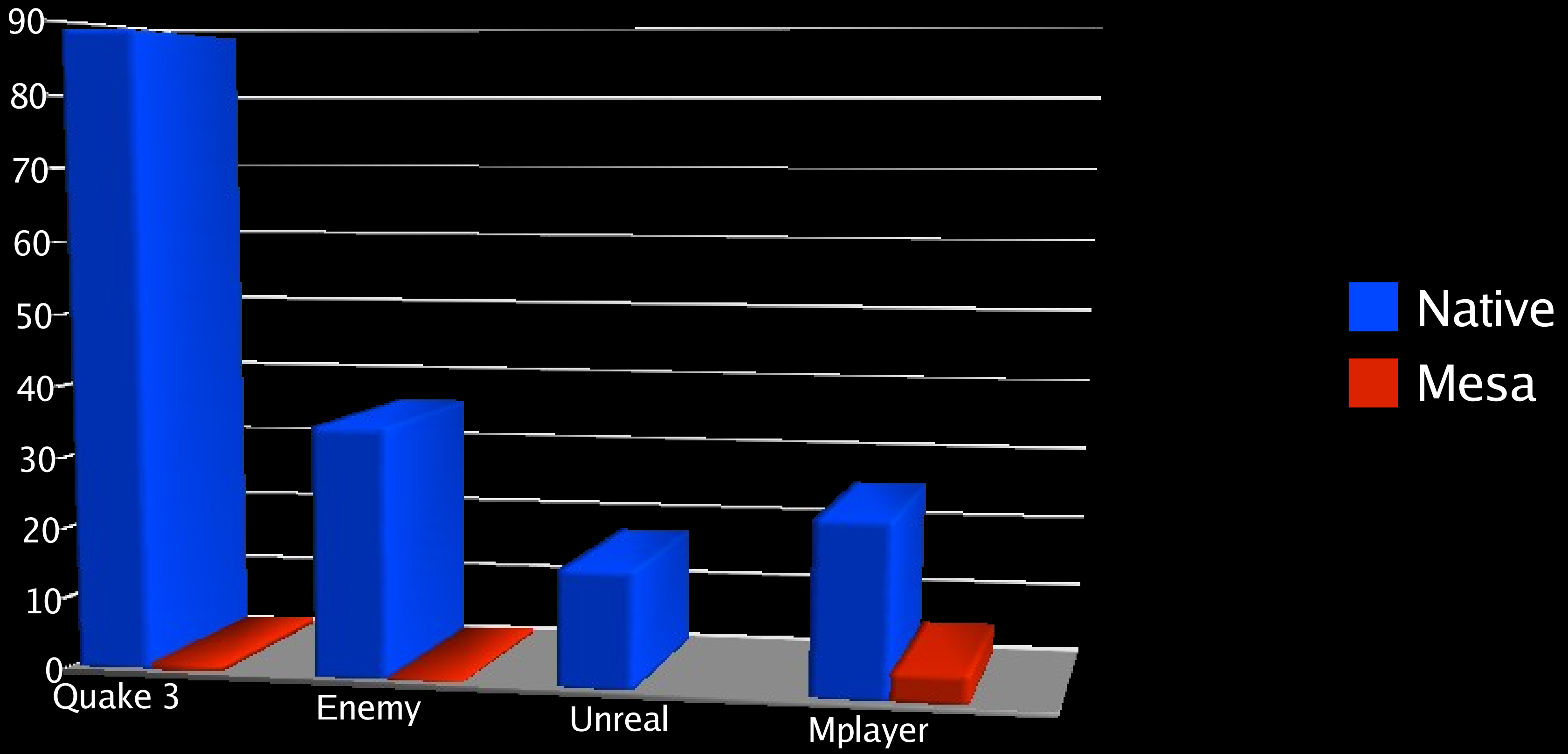
Unreal 2004

Mplayer

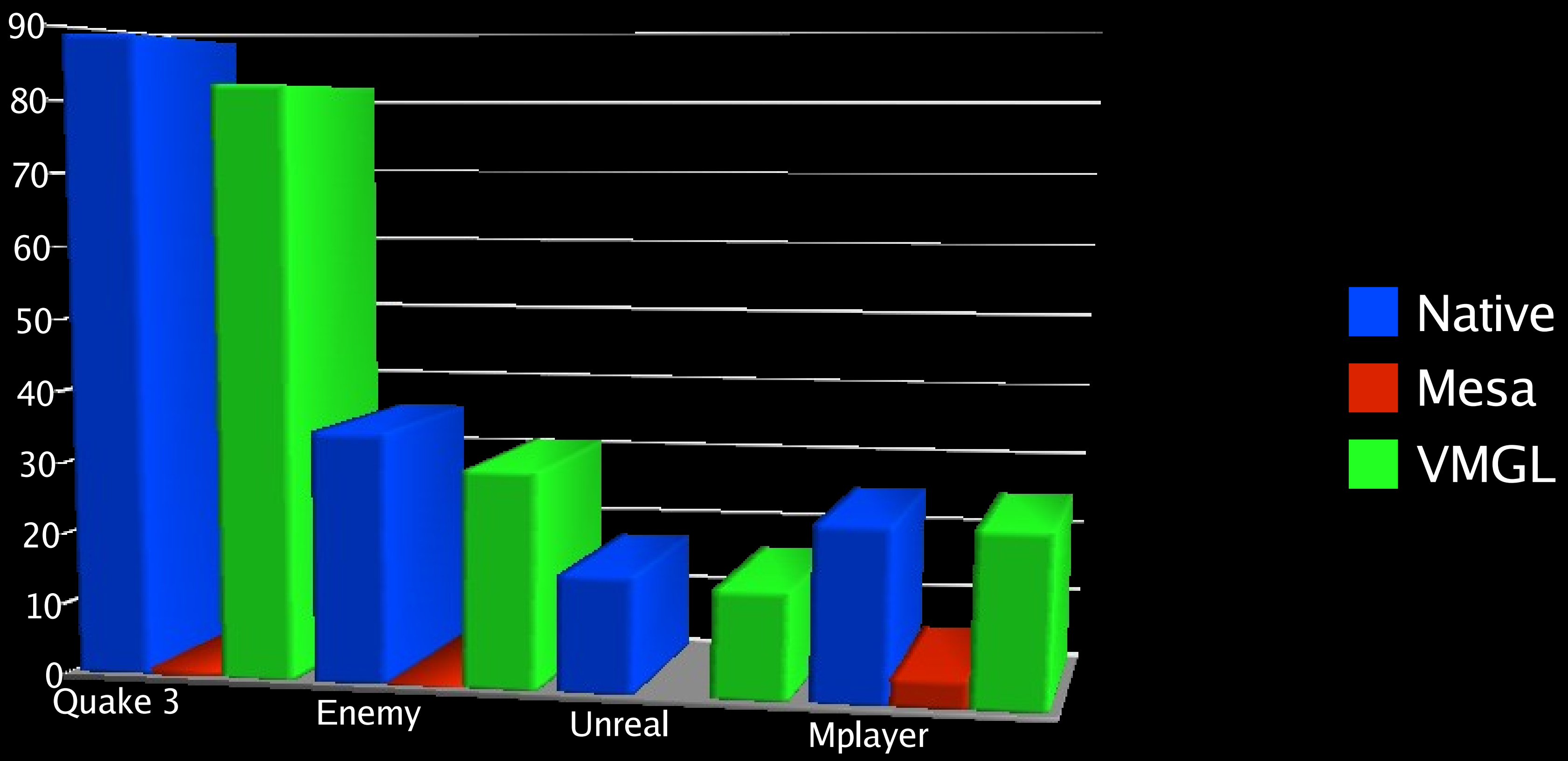
Performance (FPS)



Performance (FPS)

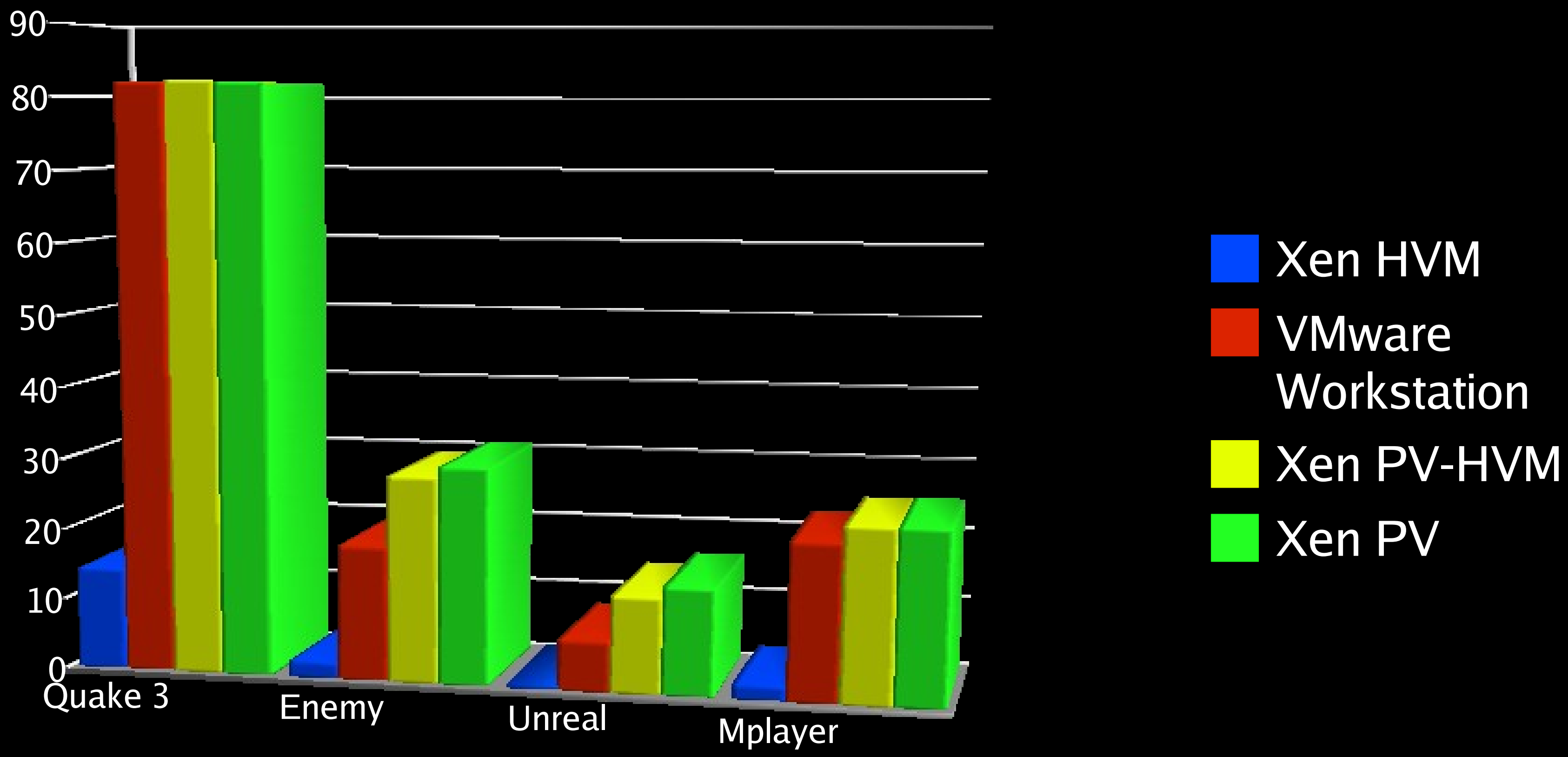


Performance (FPS)



- 87% or better of native performance

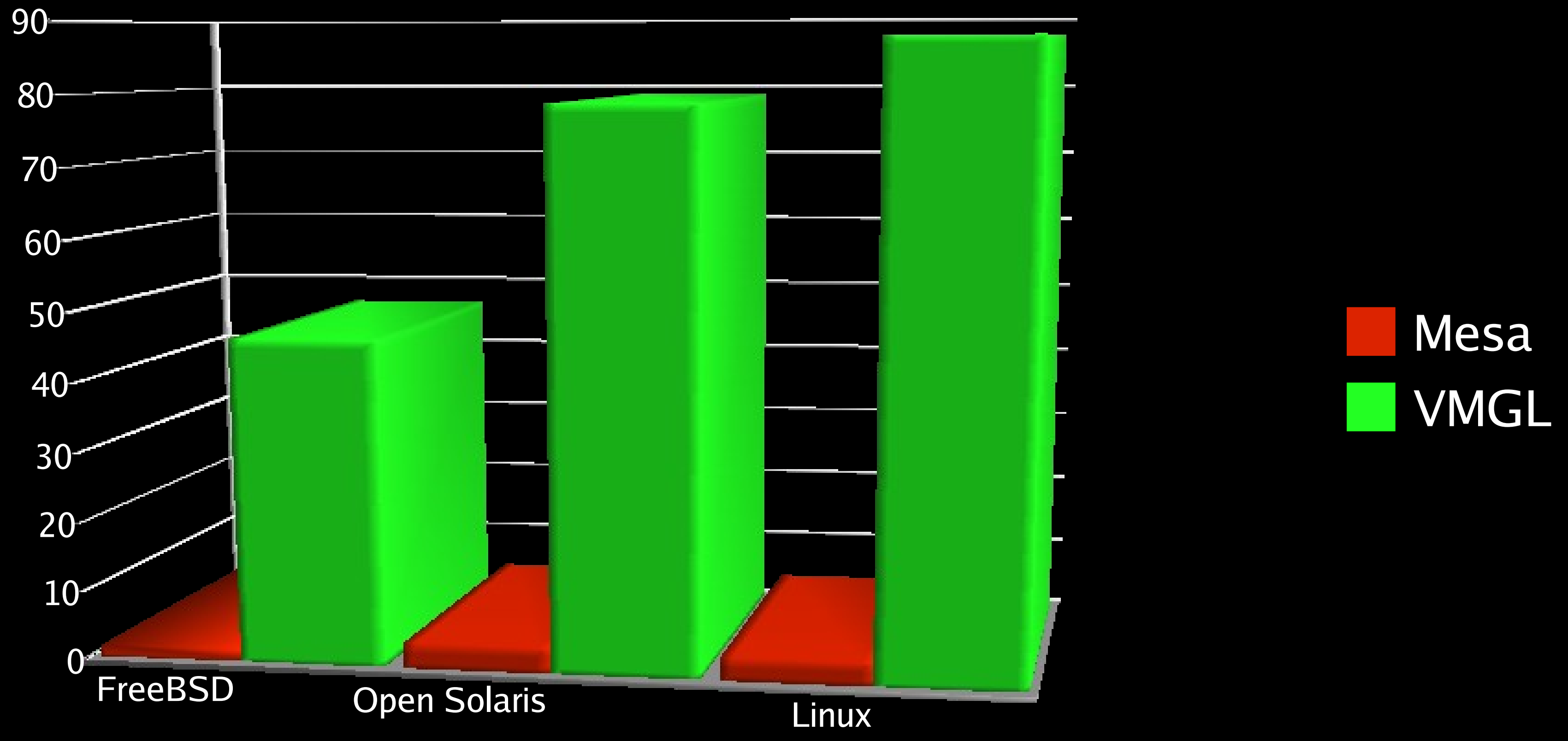
VMM Portability (FPS)



- VMM and VM type independent

Guest OS Portability (FPS)

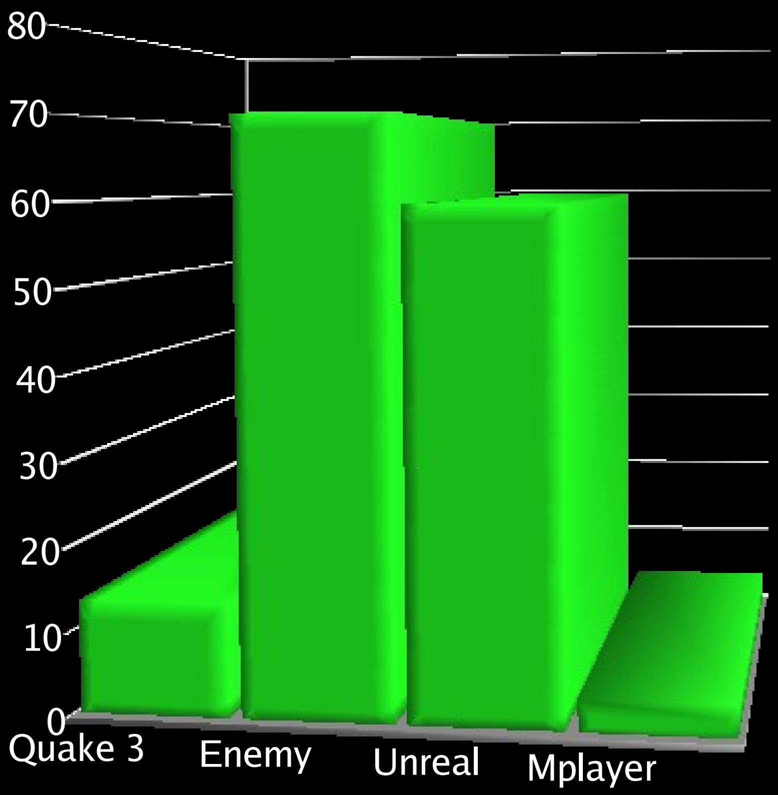
Quake 3 on VMware Workstation



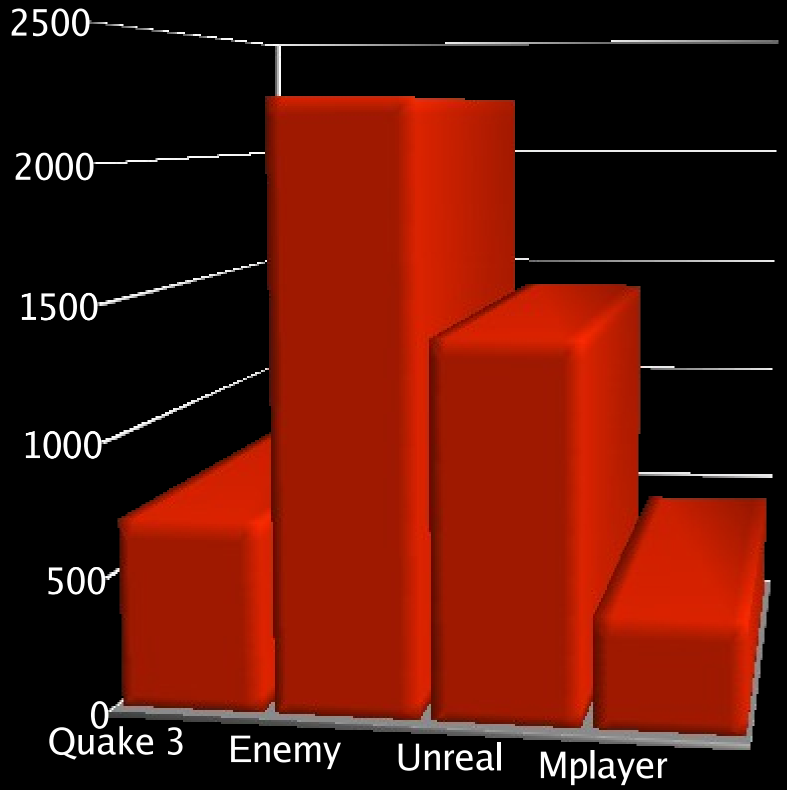
- VMGL easily ported to other X11-based OSs

Suspend Resume Performance

State Size(MBs)



Resume Time (ms)



- State size bounded
- Also across GPUs from different vendors

Wrapping UP

VMGL: OpenGL virtualization

Enable intersection of two growing trends

- Virtualization
- 3D Graphics

GPU/vendor independence
VMM independence
Guest OS independence

More eval & details in paper

TODO

VMM-specific improvements

- Shared memory transport

Windows

- Code porting
- Window Manager hooks
- Direct3D support via translation layers

THANKS

Demo

Q&A

2549 Downloads and counting:

www.cs.toronto.edu/~andreslc/vmgl/

andreslc@cs.toronto.edu

BACKUP

Xen Domain 0 GPU Drivers

ATI & Nvidia:

- GPU Mem mapping in user-space GL lib

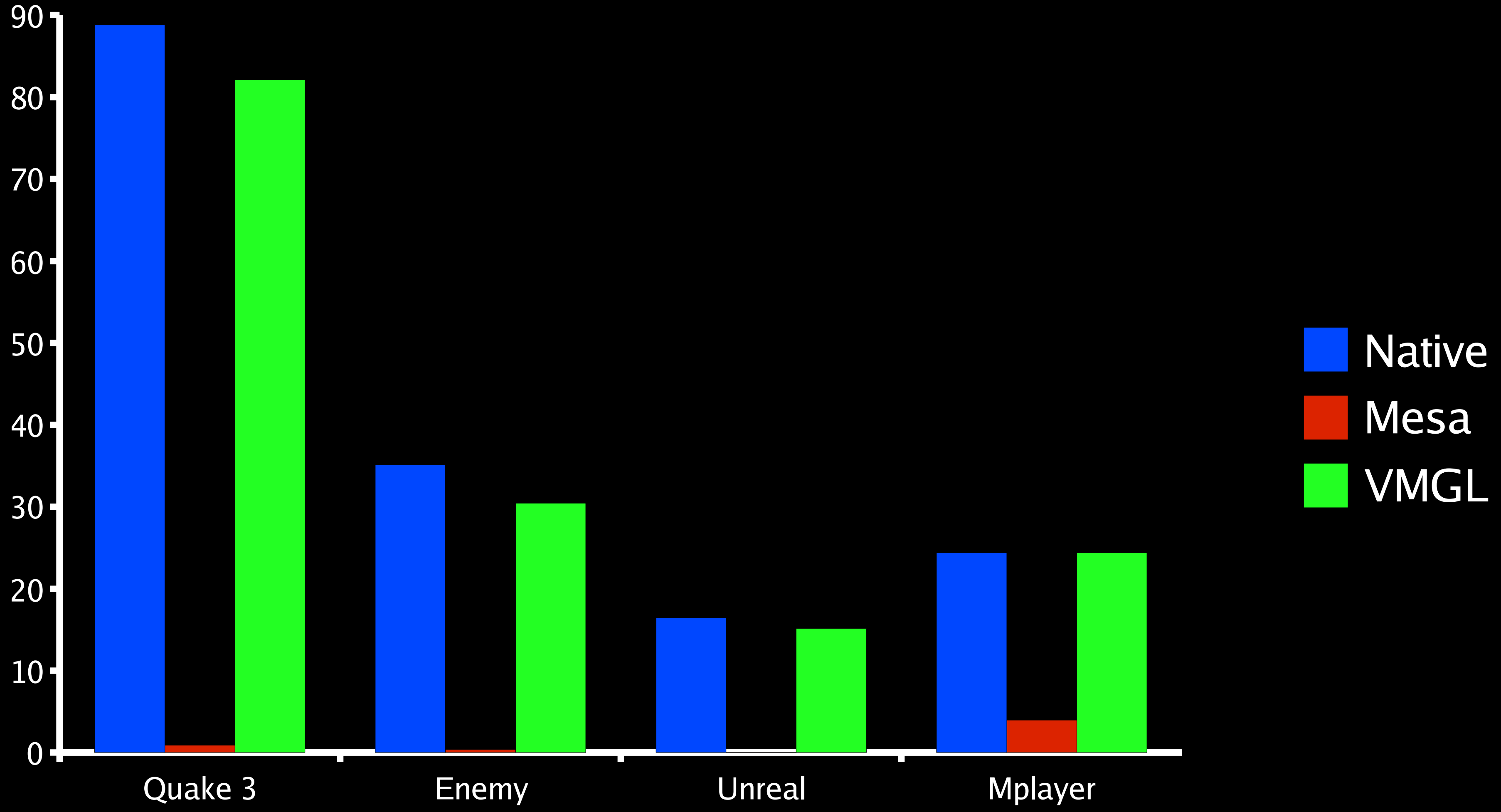
Oblivious to Xen additional indirection

- Virtual -> Physical (VM) -> Machine
- Even for domain 0

Fix open source portion of driver

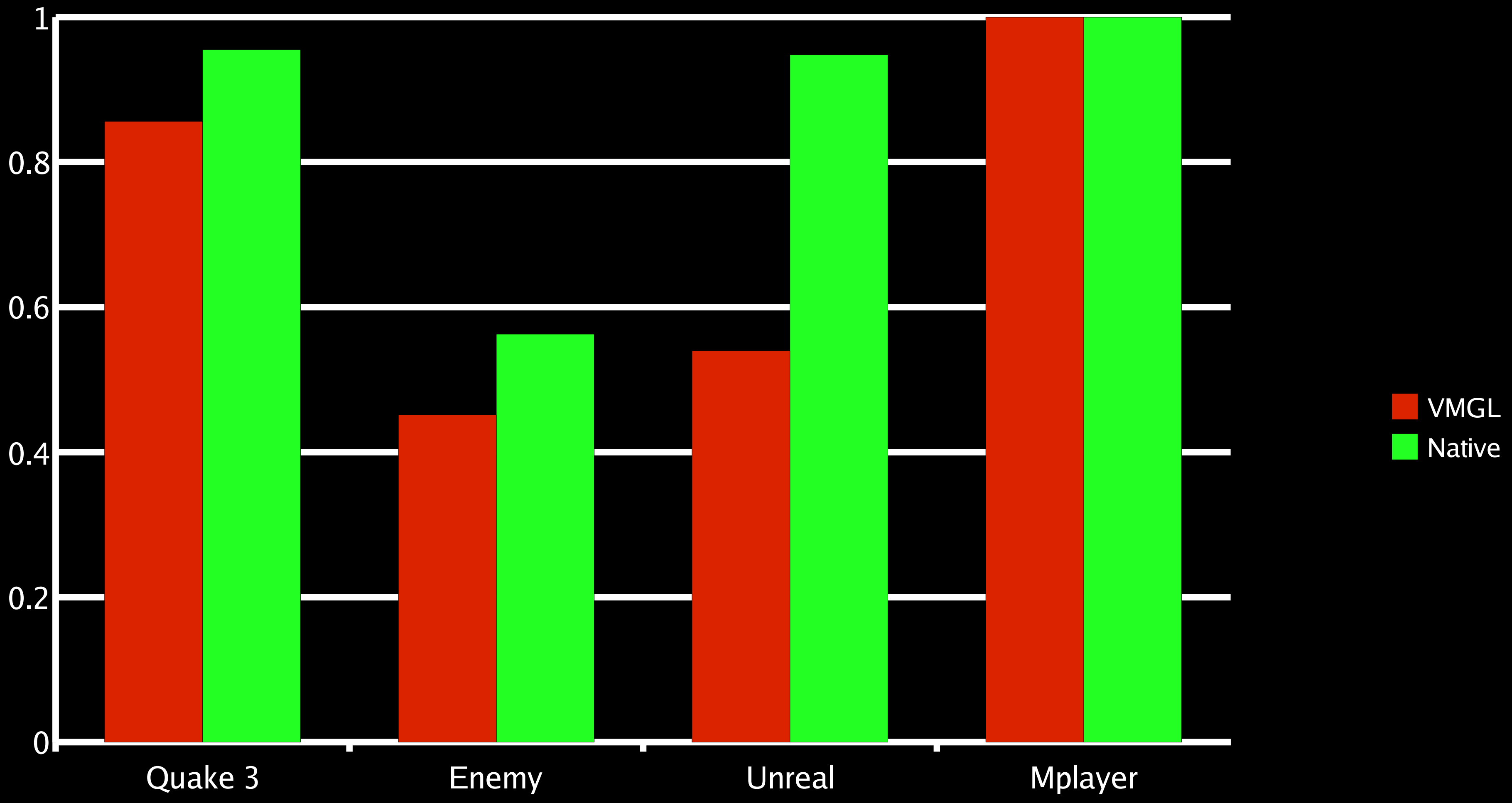
Use Xen-paravirt mem mapping functions

Performance (FPS)

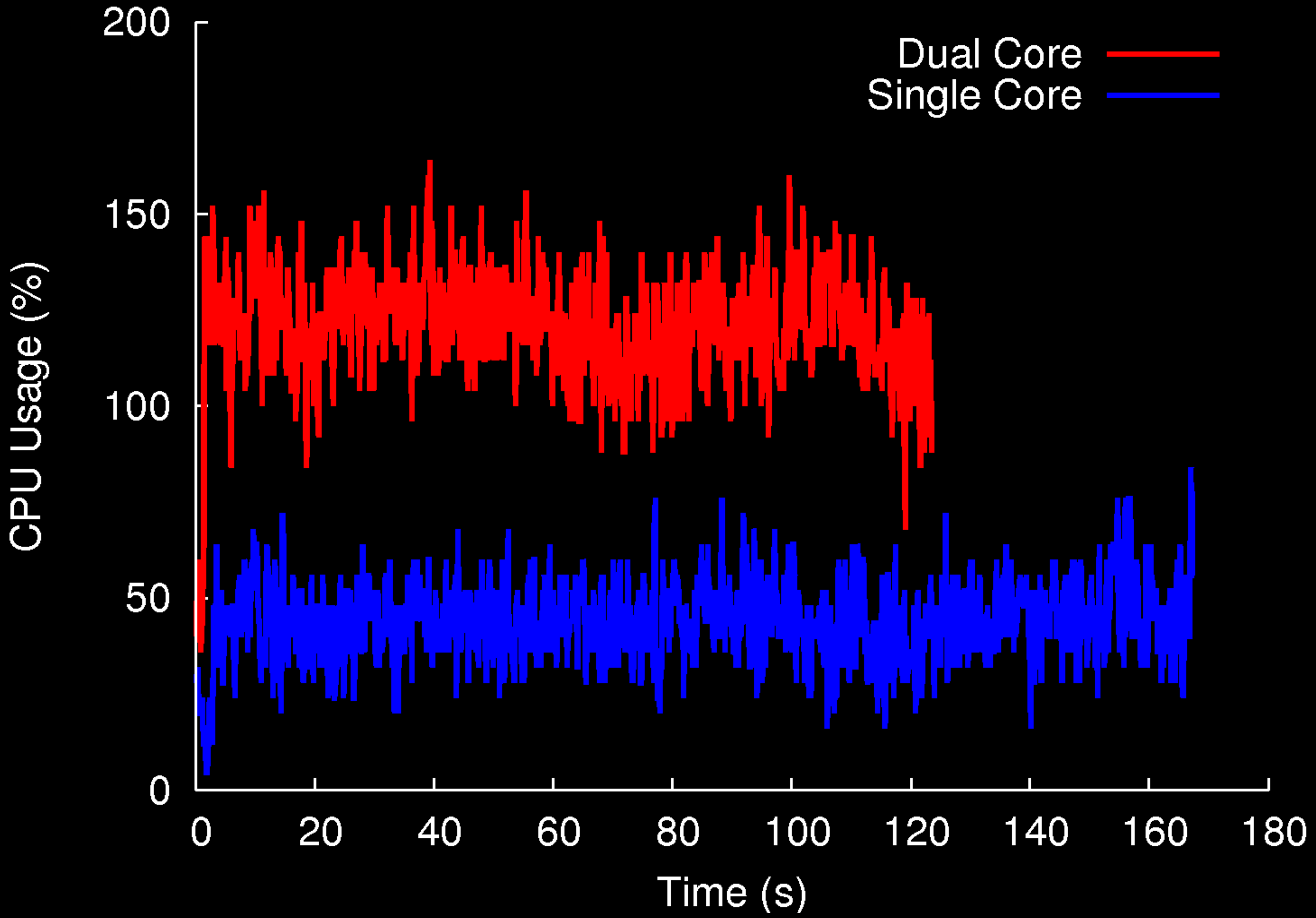


- 87% or better of native performance

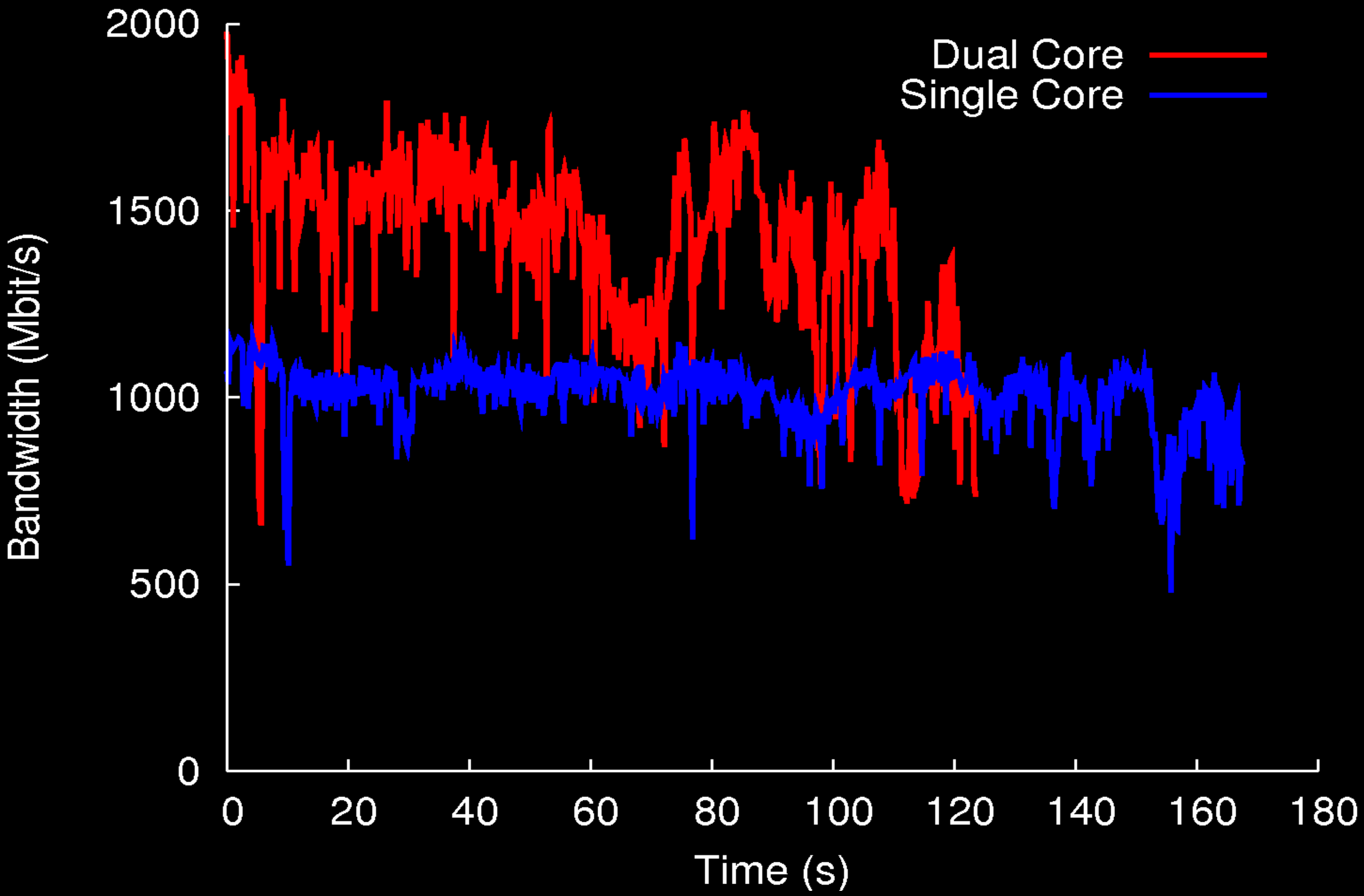
Concurrent Execution



CPU Consumption - Unreal



Bandwidth Consumption - Unreal


Dual Core
Single Core
Bandwidth (Mbit/s)
Time (s)