MULTI-USER VR SOLUTIONS FOR ENTERPRISE DEPLOYMENT

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AGENDA

Background and Motivation

Virtual Reality Meets Virtualization

Enterprise VR

Use Cases
Business Needs
Proposed Solution

Building a Multi-User Virtualized VR System

Design Requirements
Hardware
Software

Initial Results

Future Research

Q&A
BACKGROUND
What was our Motivation?

Location Based Entertainment
- Density problem
- Management of multiple PCs across separate venues

Our own tradeshow setup experience
- Multiple Rooms and Demo Staff,
- Long Setup times, cabling complexity, space required, keeping multiple systems in Sync with latest updates,
VIRTUAL REALITY MEETS VIRTUALIZATION

Why not push pixels over the network?

Multiple full-featured VR experiences on one server?

NVIDIA GeForce NOW

Games streaming From Global Datacenters
VIRTUAL REALITY MEETS VIRTUALIZATION

Latency... the silent killer

Latency demands of VR - 20ms

NVIDIA GeForce GRID Latency - up to 150ms
VIRTUAL REALITY MEETS VIRTUALIZATION

GPU Pass-Through to the rescue

NVIDIA GRID Technology

GPU Pass-Through

Hypervisor Support for Quadro

Bypass the Pixel streaming

Direct output from Quadro display connector to VR HMD
QUADRO PASCAL
Next Generation Quadro VR-Ready Platform
ENTERPRISE VR
ENTERPRISE VR MARKET

Anticipating Growth

Experimenting
Finding valid uses for VR

Struggling with deployment

• Scalable
• Practical
• Reliable
• Maintainable
• Affordable
VR USE CASE CATEGORIES

HMDs

SINGLE-HMD

MULTI-HMD

PHYSICAL SPACE

PLAYERS

VIRTUAL SPACE

SINGLE-PLAYER

MULTI-PLAYER

SINGLE-PLAYER

MULTI-PLAYER
## VR USE CASES

<table>
<thead>
<tr>
<th>SINGLE-HMD SINGE-PLAYER</th>
<th>SINGLE-HMD MULTI-PLAYER</th>
<th>MULTI-HMD SINGLE-PLAYER</th>
<th>MULTI-HMD MULTI-PLAYER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Individual HMD in one Physical Location</td>
<td>Individual HMDs at each of several physical Locations</td>
<td>Multiple HMDs within tether range of each other</td>
<td>Multiple HMDs within tether range of each other</td>
</tr>
<tr>
<td>One user playing a Single-Player VR Game or Experience</td>
<td>Multiple Players competing or collaborating in a shared VR Environment</td>
<td>Each user playing a separate Single-Player VR Game or Experience</td>
<td>Multiple Players competing or collaborating in a shared VR Environment</td>
</tr>
<tr>
<td>Examples:</td>
<td>Examples:</td>
<td>Examples:</td>
<td>Examples:</td>
</tr>
<tr>
<td>Single-Player Gaming, Self Training, Experience, Designer/Developer</td>
<td>Multi-Player Gaming, Instructor Led Training, Team Meetings, Collab Design/Review</td>
<td>Gamers at an event, Self Training Center, VR Theater, Designers/Developers</td>
<td>Team Gaming, Team Training, Group Experience, Collab Design/Review</td>
</tr>
</tbody>
</table>

* Excluding Mobile Smartphone-based solutions due to power and positional tracking limitations
MULTI-USER TEMPORARY DEPLOYMENTS

Setup / Teardown - cycle can be time consuming

4 users in 4 single room scale volume configuration at a single location

* Image provided courtesy of Mass Virtual

Source: © Mass Virtual, Used by Permission
DEPLOYMENT PLATFORM OPTIONS

PC or Mobile VR

HW Platform

# VR Rigs

Use Case

Single PC

Multiple PCs

Single-HMD Single-Player
Single-HMD Multi-Player
Multi-HMD Single-Player
Multi-HMD Multi-Player

Deployment Platforms
DEPLOYMENT PLATFORM OPTIONS

Solving the VR at Scale Problem

<table>
<thead>
<tr>
<th>HW Platform</th>
<th>PC</th>
<th>Multi-User VR System</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single PC</td>
<td></td>
<td>1:4 (1:8)</td>
</tr>
<tr>
<td>Single-HMD Single-Player</td>
<td>Multi-HMD Single-Player</td>
<td>Multi-HMD Multi-Player</td>
</tr>
<tr>
<td>Single-HMD Multi-Player</td>
<td>Multi-HMD Multi-Player</td>
<td>Multi-HMD Multi-Player</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th># VR Rigs</th>
<th>Using Case</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single PC</td>
<td>Single-Player</td>
</tr>
<tr>
<td>Multi-PCs</td>
<td>Multi-Player</td>
</tr>
<tr>
<td>Multi-PCs</td>
<td>Multi-HMD Single-Player</td>
</tr>
<tr>
<td>Multi-PCs</td>
<td>Multi-HMD Multi-Player</td>
</tr>
</tbody>
</table>
Premium VR Headsets such as the HTC Vive, include a lot of parts to setup.

For multi-user Enterprise uses in temporary locations, setup time can be considerable.
# CONSUMER VS ENTERPRISE

## VR CHARACTERISTICS

<table>
<thead>
<tr>
<th>CONSUMER</th>
<th>ENTERPRISE</th>
</tr>
</thead>
<tbody>
<tr>
<td>VR Inside the Home</td>
<td>VR outside the Home, <strong>VR at Scale</strong></td>
</tr>
<tr>
<td>Single VR rig remains fixed in a Dedicated Space</td>
<td>Multiple VR rigs setup in Dedicated Spaces or moved in and out of Multi-Purpose Shared-Use Collaborative Meeting Spaces</td>
</tr>
<tr>
<td>Single User is also Owner, Maintainer and Operator who controls facility access.</td>
<td>No specific user, Company-Owned, Remote IT-Management, shared access to VR equip.</td>
</tr>
<tr>
<td>No User or Content conflict</td>
<td>Multiple Simultaneous Users in limited volumes. Possible Tracking interference.</td>
</tr>
<tr>
<td>No Tracking System interference</td>
<td>Integrated cable management, complexity reduction, design for rapid setup/teardown</td>
</tr>
<tr>
<td>Parts and cable management designed for one-time setup of single systems.</td>
<td></td>
</tr>
</tbody>
</table>
ENTERPRISE VR BUSINESS NEEDS:

VR Platform Requirements

1. **Multiple Users** in a common shared physical space
2. **High Density** - small footprint consuming minimal floorspace
3. **Rapid Setup / Teardown** by users with minimal knowledge of VR equipment
4. **Rugged/Relocatable/Shippable** - self contained as much as possible
5. **Remotely Manageable** by Enterprise IT
6. **Logically Identical** to Individual Networked PCs
7. **Performance Equivalence** (or better) to standalone PCs
Separate PCs or VR Notebooks introduce additional recurring costs when relocated.

TOTAL COST OF OWNERSHIP
Setup / Teardown Time... Recurring Expense on Every Deployment

• **Total Cost** - more than just the cost of Hardware

• **Setup Time** - manpower cost
  - loss of room
  - idled systems
  - SW update time

• **Inaccessible Venues** - which are unusable due to limited setup time?

• **Maintenance and Troubleshooting** - lost or damaged parts, incorrect hookups, accidental OS changes, on-site IT staff

• **Spares Cost** - higher failure rates
PROPOSED CONCEPT
Multi-User Virtualized Virtual Reality System

Rapidly Deployable Multi-User VR systems could service more users over their lifetime than the comparable number of standalone VR-Ready Notebooks
CENTRALIZED IT-MANAGEMENT

Virtualization technologies enable IT management savings
PROPOSED SOLUTION: Highly Integrated Packaging

Integrated Base Stations mounts

Integrated Power Distribution, Network, Charging, Storage

Integrated PC - Link Box cabling inside case

Requires only a single external power receptacle

(Optional) Integrated Optical Isolation (Pipe & Drape)
Field Replaceable Units and Spares

Integrated Hand Controller Charging Station
Designed into Shipping Container

Field Replaceable HMD/Link Box combo,
Front-Loading, Integrated Tether Strain Relief
PROPOSED PACKAGING:
Density, Mobility, Simplicity - Varies by Use Case

Shippable tradeshow rackmount cases on wheels

2-man portable ruggedized stackable hard cases for remote locations

Non-shippable rolling half-racks for deployment between conference rooms within office buildings
MULTI-USER VR CONCEPT

Virtual reality content software

- Vive hardware concept
- 4 users
- Shared single VR experience
- 4 room scale volume configuration

Source: © Mass Virtual, Used by Permission
MULTI-USER LOCAL COLLABORATION

- Vive hardware
- 4 users
- Single VR experience

4 users in a single room scale volume configuration
MULTI-USER DISTANCE COLLABORATION

4 Users at location:
Tampa, Florida

1-4 Users at location:
Little Rock, Arkansas

Source: © Mass Virtual, Used by Permission
ADDITIONAL CONCEPT HARDWARE CONFIGURATION

4 users in 4 single room scale volume configuration at a single location

Source: © Mass Virtual, Used by Permission
VIRTUAL ATTAIN MULTI-USER DEMONSTRATOR

Helicopter Pilot
PC Station 1

Instructor View
PC Station 3

Marshaller
PC Station 2

Source: © Mass Virtual, Used by Permission
MULTI-USER VR IN LIMITED SPACE

Source: © Mass Virtual, Used by Permission
ENTERPRISE VR

Source: © HTC Vive, Used by Permission
THE MOST AWARDED VR SYSTEM ON THE MARKET

Source: © HTC Vive, Used by Permission
ABOUT VIVE

BUILT TO SCALE

Seated  Standing  Room-scale

Source: © HTC Vive, Used by Permission
FLEXIBLE TRACKING

Multi-user Seated or Standing Configurations

Source: © HTC Vive, Used by Permission
EDUCATION LAYOUT

Source: © HTC Vive, Used by Permission
VIVE Consumer Edition

- 2160 x 1200, 90fps, 110 degree fov
- Comfortable Head-strap
- Eye Relief
- IPD Adjustment
- Built-In Microphone
- Front Facing Camera
- Narrow | Wide Gasket Cushion

$799

VIVE Business Edition

- Deluxe Audio Strap
- 5 Meter HMD Cable Extension
- 2 Additional Wide and Narrow Face Plates
- Commercial Warranty
- Enterprise EULA
- Dedicated Phone Line Support
- Software distribution & management utilities

$1,200
A NEW ECO SYSTEM OF TRACKABLE DEVICES

Source: © HTC Vive, Used by Permission
EYE TRACKING
US/EMEA Availability Q3
WIRELESS IS COMING

AVAILABLE Q3, 2017
Business Edition
4-6 Users Single Environment

Source: © HTC Vive, Used by Permission
ULTIMATE DEVELOPER PLAYGROUND

MULTI-USER DISTANCE COLLABORATION

4 Users at location: Tampa, Florida

1-4 Users at location: Little Rock, Arkansas

Lets build the future of VR together!

Source: © Mass Virtual, Used by Permission
BUILDING A MULTI-USER VR SYSTEM
MULTI-USER VR
MACHINE DESIGN REQUIREMENTS
Specific to the Machine

Two or more HMDs connected to a single machine. Target 4 HMDs from a 4U machine.

DisplayPort 1.2 and/or HDMI 2.0/2.1 video output capable of 4K resolution at 90 FPS delivered to each HMD

USB 3.0 root hub data interconnect to each HMD

HMD agnostic (enough USB ports to handle different HMDs and Tracking Systems)

3200W redundant power limit (two 110 or 220 kVA circuits to maintain redundancy)

Run Independent of Monitors
HARDWARE
CHASSIS AND MOTHERBOARD
Supermicro 4028GR-TR Barebones Server

4U Chassis, Two CPU Sockets

Eight Doublewide x16 PCIe slots distributed evenly between CPU Sockets to isolate PCIe traffic and reduce latency.

Room for Four Virtual Machines (4 Users).
2 slots needed per VM (GPU + USB 3.0 card)
CHASSIS AND MOTHERBOARD

Supermicro 4028GR-TR PCIe Slot Layout

QUADRO P6000
USB 3.0
QUADRO P6000
USB 3.0

QUADRO P6000
USB 3.0
QUADRO P6000
USB 3.0

PCIe

CPU1

PCIe g3 x16

PCIe g3 x16

CPU2

Image Source: © SUPERMICRO Superserver 4028GR-TR User Guide
QUADRO PROFESSIONAL GPUS
Enterprise Grade Reliability and Features

Must dedicate one physical GPU to each VR user

Quadro GPUs support NVIDIA Multi-OS technology which allows them to operate in passthrough mode on a Virtual Machine.

Quadro VR-Ready Driver runs on each Virtual Machine to ensure compatibility with standard VR Software

Quadro supports Forced EDID function to let the Windows OS believe there is a monitor attached to the primary display out. This allows Multi-User VR system to run with headset displays only.

Quadro is designed to run continuously at lower power.
# QUADRO GPU OPTIONS

Different sizes to meet cost, performance, and density goals

## GPU Comparison

<table>
<thead>
<tr>
<th>GPU</th>
<th>Family</th>
<th>CUDA Parallel-Processor Cores</th>
<th>GPU Memory</th>
<th>Max Power Consumption</th>
<th>VM System Memory</th>
</tr>
</thead>
<tbody>
<tr>
<td>QUADRO GP100</td>
<td>Pascal</td>
<td>3584</td>
<td>16 GB</td>
<td>235 W</td>
<td>24GB</td>
</tr>
<tr>
<td>QUADRO P6000</td>
<td>Pascal</td>
<td>3840</td>
<td>24 GB</td>
<td>250 W</td>
<td>24GB</td>
</tr>
<tr>
<td>QUADRO P5000</td>
<td>Pascal</td>
<td>2560</td>
<td>16 GB</td>
<td>180 W</td>
<td></td>
</tr>
<tr>
<td>QUADRO P4000</td>
<td>Pascal</td>
<td>1792</td>
<td>8 GB</td>
<td>105 W</td>
<td></td>
</tr>
<tr>
<td>QUADRO M6000* 24GB</td>
<td>Maxwell</td>
<td>3072</td>
<td>24 GB</td>
<td>250 W</td>
<td></td>
</tr>
<tr>
<td>QUADRO M6000</td>
<td>Maxwell</td>
<td>3072</td>
<td>12 GB</td>
<td>250 W</td>
<td></td>
</tr>
<tr>
<td>QUADRO M5000</td>
<td>Maxwell</td>
<td>2048</td>
<td>8 GB</td>
<td>150 W</td>
<td></td>
</tr>
</tbody>
</table>
USB 3.0 CONTROLLERS
Key to Low Latency

With current Hypervisors, each Virtual Machine requires passthrough of a dedicated USB 3.0 card to meet latency requirements.

Some VR Headsets require multiple USB ports per user.

CAUTION: USB PCIe Controller cards are not currently on the hardware support list for VMware vSphere ESXi or Citrix XenServer.

Our sample build uses the Inateck KTU3FR-5021 5-Port USB 3.0 PCIe Controller Card
MEMORY AND STORAGE

Recommended System Memory per virtual machine >= GPU memory
Hypervisor needs it’s own System Memory as well.

Our Sample build uses 256GB of DDR4 1600Mhz ECC SDRAM installed
48GB per Virtual Machine (1.5x Quadro P6000 memory capacity)
64GB left for Hypervisor.

Storage for our sample build consists of
one 256 GB disks for cache and boot
four 256 GB disks each dedicated to a single VM guest machine.

For enterprise builds that depend on fault tolerance it would be important to
combine drives into a RAID5 array for VM storage and separate 256GB SSD RAID0
Mirror set to serve as the system boot drive.
POWER

Redundant Power Supplies

Our sample system has four 1600W redundant power supplies, only two power supplies are required to operate the system at full power with four HMDs in session. This provides a fully redundant power configuration that is enterprise ready and fault tolerant.

It also helps keep noise levels down as the power supplies need not run at full capacity during normal operation.

Opportunities exist to further refine each system by powering internal integrated HTC link boxes from the system power supplies. With internal USB ports on Inateck USB PCIe cards, it is possible to keep most of the HTC wiring inside the chassis.

External power may still be desired to allow selective power-cycling of link boxes via remote controlled power distribution devices.
# SYSTEM COMPONENT SUMMARY:
## Sample System As Built

<table>
<thead>
<tr>
<th>Item</th>
<th>QTY</th>
<th>Manufacturer</th>
<th>Mfg Part Number</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>System</td>
<td>1</td>
<td>SuperMicro</td>
<td>4028GR-TR or 4028GR-TRT</td>
<td>SuperMicro SuperServer Barebones X10DRG-O+-CPU Motherboard, X9DRG-O-PCIE Daughter Board in CSE-418GTS-R3200B Chassis with redundant 1600W power supplies</td>
</tr>
<tr>
<td>CPU</td>
<td>2</td>
<td>Intel</td>
<td>BX80660E52640V4</td>
<td>Xeon E5-2640 2.4 GHz v4 10-core LGA 2011 Processor</td>
</tr>
<tr>
<td>Memory</td>
<td>2</td>
<td>Kingston</td>
<td>KVR21R15D4K4/64</td>
<td>Kingston 64GB RAM Kit (4x16GB) 2133MHz DDR4 ECC Reg CL15 DIMM DR x 4 with TS Server Memory</td>
</tr>
<tr>
<td>128GB total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SSD Drives</td>
<td>4</td>
<td>Samsung</td>
<td>MZ-7KE1T0BW</td>
<td>Samsung 850 PRO - 1TB - 2.5-Inch SATA III Internal SSD, usable with Linux.</td>
</tr>
<tr>
<td>GPU</td>
<td>4</td>
<td>NVIDIA</td>
<td></td>
<td>Quadro M6000, P4000, P5000, or P6000</td>
</tr>
<tr>
<td>USB Cards</td>
<td>4</td>
<td>Inateck</td>
<td>KTU3FR-5O2U</td>
<td>7-port USB 3.0 controller (2 ports are internal facing)</td>
</tr>
</tbody>
</table>
INITIAL RESULTS
RESULTS
Anecdotal Qualification

Successful Tradeshow deployments with VMware

• No user complaints
• Multi-User Single-Player mode

Tested by several VR software developers

Demos available in the GTC Exhibit Hall

• HTC Vive booth 700 MonsterVR 4 user collaborative +1
• CAVRNUS booth 934 CAVRNUS 4 user collaborative
• Super Micro Computer booth 111 Static System

Give it a try and tell us what you think.
## MULTI-USER VR SYSTEM

<table>
<thead>
<tr>
<th>STRENGTHS</th>
<th>LIMITATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dense, Tight Packaging possible</td>
<td>Currently limited to a Single GPU per User. VR-SLI not supported.</td>
</tr>
<tr>
<td>Rapid Setup</td>
<td>Commercial Hypervisors do not officially support USB passthrough</td>
</tr>
<tr>
<td>4-Users per 4U system (6U Rack)</td>
<td>Tethers</td>
</tr>
<tr>
<td></td>
<td>Density limited by USB passthrough requirement</td>
</tr>
</tbody>
</table>
FUTURE RESEARCH
FUTURE WORK
Additional Areas of Research

Expanded Configurations:
- 2-way workstation
- 8-way P4000 dense system.

Varied Topologies:
- Shared & Separate gaming areas
- Stacked systems working together
- Theater Row Seating

Wireless Multi-User solutions such as TPCAST (see demo at NVIDIA VR Village)

Multiple Hypervisors: VMware ESXi, Citrix Xenserver, ???
FUTURE WORK
Additional Areas of Research

IT management scenarios
  Cloned Virtual Machines
  Remote System management
  Shared Storage

Packaging concepts optimized for:
  Datacenter Density
  Ruggedized Portability,
  Self-containment
  Rapid setup.
MORE INFORMATION

Useful Links

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Fred Devoir Sr. Solution Architect, NVIDIA    fdevoir@nvidia.com
Sean Wagstaff Enterprise Tech Marketing, NVIDIA    swagstaff@nvidia.com
Frank Black Director of Enterprise Sales, HTC-Vive    Frank_Black@htc.com

Session: S7171 - MULTI-USER VIRTUAL REALITY SOLUTIONS FOR ENTERPRISE DEPLOYMENT

Slides: PDF version of Presentation (Access limited to GTC attendees for 30 days)

Blog    If You Build It, They Will Come: Multi-User VR Environment Showcased at GTC
REQUEST THE BUILD GUIDE
System Integrators and Partners

http://info.nvidia.com/vrsystem.html
QUESTIONS?