Virtio-and friends GENIVI AMM Munich
Matti Möll, OpenSynergy GmbH
Outline

• Platform Standardization
• Looking at Virtualized platforms
• Comparing techniques
• Virtio
  - What it does
  - How it works
• Summary
Platform Standardization (so far)

- **Defacto standard for personal computers „IBM PC“ and „PC Compatible“**
  - Hardware and software interface
  - BIOS
  - Peripheral standards (ISA, ATA)
  - Platform design became the x86 Architecture

- **PXE**
  - Preboot Execution Environment
  - Early execution environment for Extension ROMs and Netboot

- **UEFI**
  - PXE + BIOS + Bootloader
  - Extensible preboot and runtime environment
  - Provides services and HALs
Virtualized Platforms

• **Desktop Virtualization (early days)**
  - Almost all x86
  - Replicate desktop system
  - Emulated IDE controller, Intel Network card, VGA graphics, etc.
  - Drivers exist, interfaces already standardized
  - Vendor specific device models

• **Server Virtualization**
  - x86 (and a couple of mainframes)
  - Vendor Specific device models
  - Mostly network and storage

• **Cloud Virtualization**
  - Vendor specific
  - Virtio based models
  - Almost only network and storage
Challenges of virtualized environments

• Virtualized IO devices are available for desktop and cloud applications because everyone uses standardized interfaces (virtio, xen, vmware)
  • Disk
  • Network
• Embedded devices lack the ecosystem that cloud providers build upon
• Challenges for virtualized IO devices in automotive
  • High effort of SoC specific device virtualization
  • Multimedia device virtualization
  • Low amount of reusable virtual devices
Standardizing Hypervisor APIs

- Mechanisms
- Where do we cut?
- COTS or domain specific?
- Strict requirements or rough consensus?

Focus on I/O, virtual/shared devices and drivers
## Mechanisms for device virtualization

### in Hypervisor

- **driver**
- **device**
- **SoC**

- Only used for UART (optionally)
- not recommended for other devices as the Hypervisor is minimalistic.

Example: UART

### device with virtualization support

- **driver**
- **SoC**
- **virtdev1**
- **virtdevN**

- COQOS supports this when the SoC hardware supports virtualized devices
- Recommended wherever the hardware supports it, as it tends to give the best performance and separation

Example: GPU on RCAR-H3

### low-level client-server

- **vdriver**
- **sharing driver**
- **IPC**
- **SoC**
- **device**

- Single driver in VM that acts as "server"
- Driver-specific sharing logic is needed.
- Other VMs use "virtual driver".
- Compromise between performance and flexibility

Example: shared block device

### distributed frameworks over Guest IPC

- **framework**
- **IPC**
- **driver**

- Allows reuse of existing frameworks for distributed applications in a virtualized environment over VNET.
- Supports complex sharing semantics at the cost of more overhead

Example: NFS
### Device Virtualization Technologies

<table>
<thead>
<tr>
<th>Technology</th>
<th>Description</th>
<th>Reusability</th>
<th>Platform independence</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard library (or layer)</strong></td>
<td>Implement hypervisor specific standard libraries</td>
<td>As long as the same hypervisor is used</td>
<td>As good as vendor interface</td>
</tr>
<tr>
<td>virtualization (OpenGL, DRM,</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Android HAL …)</td>
<td></td>
<td></td>
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<tr>
<td><strong>Virtio</strong></td>
<td>Implement virtio based devices that follow either existing standards or</td>
<td>Virtio support is available in Linux, Android and</td>
<td>Builds upon the kernel-userspace interface of</td>
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<td></td>
<td>specify new ones</td>
<td>many other operating systems</td>
<td>Linux and allows large flexibility because the</td>
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<td></td>
<td></td>
<td></td>
<td>devices themselves make no assumption about the</td>
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<td></td>
<td></td>
<td></td>
<td>hardware</td>
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<td><strong>HV vendor custom</strong></td>
<td>Develop virtual devices optimized to be used with a particular hypervisor</td>
<td>As long as the same hypervisor is used</td>
<td>Implementation specific</td>
</tr>
</tbody>
</table>

**Trade-off between development effort, reusability, platform independence, availability and maturity**
Let’s assume virtio
Introduction to virtio

- Virtio “De-Facto Standard For Virtual I/O Devices” [Russel 2008]
- Formally standardized since March 2016 (OASIS VIRTIO-v1.0)
- Virtio provides interfaces for many devices
  - Block Storage
  - Network
  - Console
  - GPU
  - Input (hid)
  - Crypto device
  - vSock
  - File Server (9pfs)
  - Many more in development (vIOMMU, etc.)
- For the complete Android experience there are still missing pieces
  - Audio
  - Sensors
  - Media Acceleration Offload (VPU)
Talking about virtio

- **Device** refers to the implementation of the virtual/para-virtual device, also known as Backend or Server
- **Driver** refers to the guest driver, also known as Frontend or Client
- **Device Host** is the guest that provides the Device to other guests
- **Device Guest** is the consumer of a Device
- **Guest** is a partition or virtual machine
Shared device Architecture with Virtio

Hypervisor System

Device Emulation Framework

Linux/Android user space

Linux kernel space

Subsystem

Virtio-<device>

virtio

Plumbing

Client VM Memory

Hardware

SG list

Buffer

VQ

VQ=Virt Queue

SG=Scatter Gather

Virtio Support

Open Source

Hypervisor Vendor
A Note on Memory allocation

- The driver decides where memory is allocated
  - Drivers define allocation policy
  - Pooling possible but not needed
  - No Bounce buffers, no wasted memories if system requirements allow this
Why Virtio?

• Standardized
• Proven in Use
  - Well tested device models
• Established community
  - IBM, Red Hat, Siemens, Huawei, Oracle, ARM, Intel
• Efficient and performant
• Diverse operating system support
  - Linux, BSD, Windows, UEFI
  - Driver maintenance done upstream
• Supported by many VMMs and Clouds
  - Qemu, kvm-tool, Foundation model
  - ARM Foundation model/ Fast model
  - Google Compute Cloud, DigitalOcean, OHV
Summary

- Creating platforms with multiple independent providers has fueled innovation in the past
- PC, Servers, Cloud
- Proposal: Standardize on virtio for I/O devices
- What already exists and how does virtio work
- Virtio is standardized and designed to allow interoperable and independent implementations
Discussion
Discussion

• Can virtio provide the I/O interfaces we need?
• What’s missing?
• Level of standardization?
• What’s next?
OpenSynergy GmbH

Rotherstraße 20
D-10245 Berlin
Germany

Phone +49 30 60 98 540-0
E-Mail info@opensynergy.com
Web www.opensynergy.com

OpenSynergy GmbH

Starnberger Str. 22
D-82131 Gauting / Munich
Germany

Phone +49 89 89 34 13-33
E-Mail bluetooth@opensynergy.com

OpenSynergy, Inc. (USA)

765 East 340 South
Suite 106
American Fork, Utah 84003

Phone +1 619 962 1725
E-Mail bluetooth@opensynergy.com

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