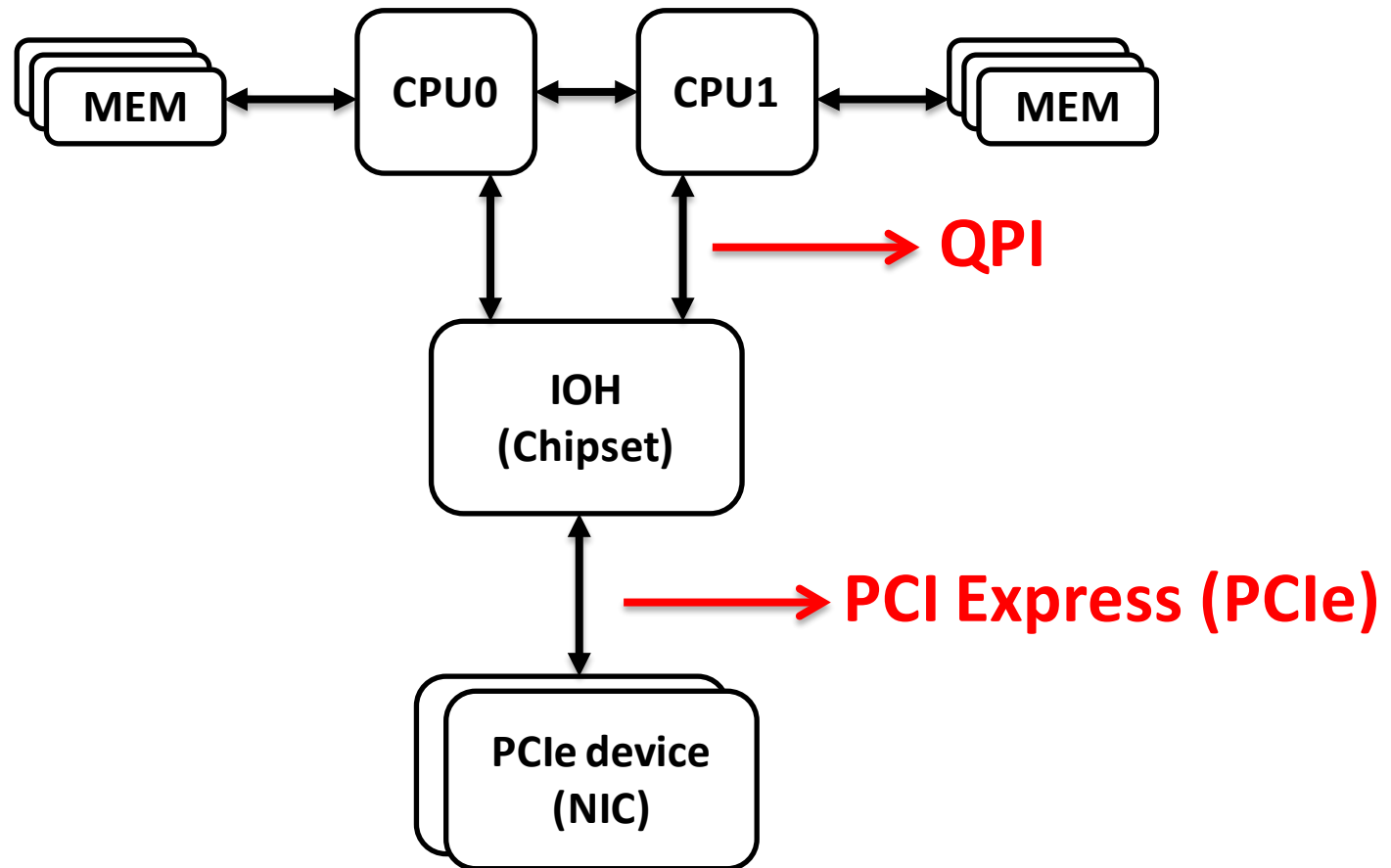


パケット転送を支える技術

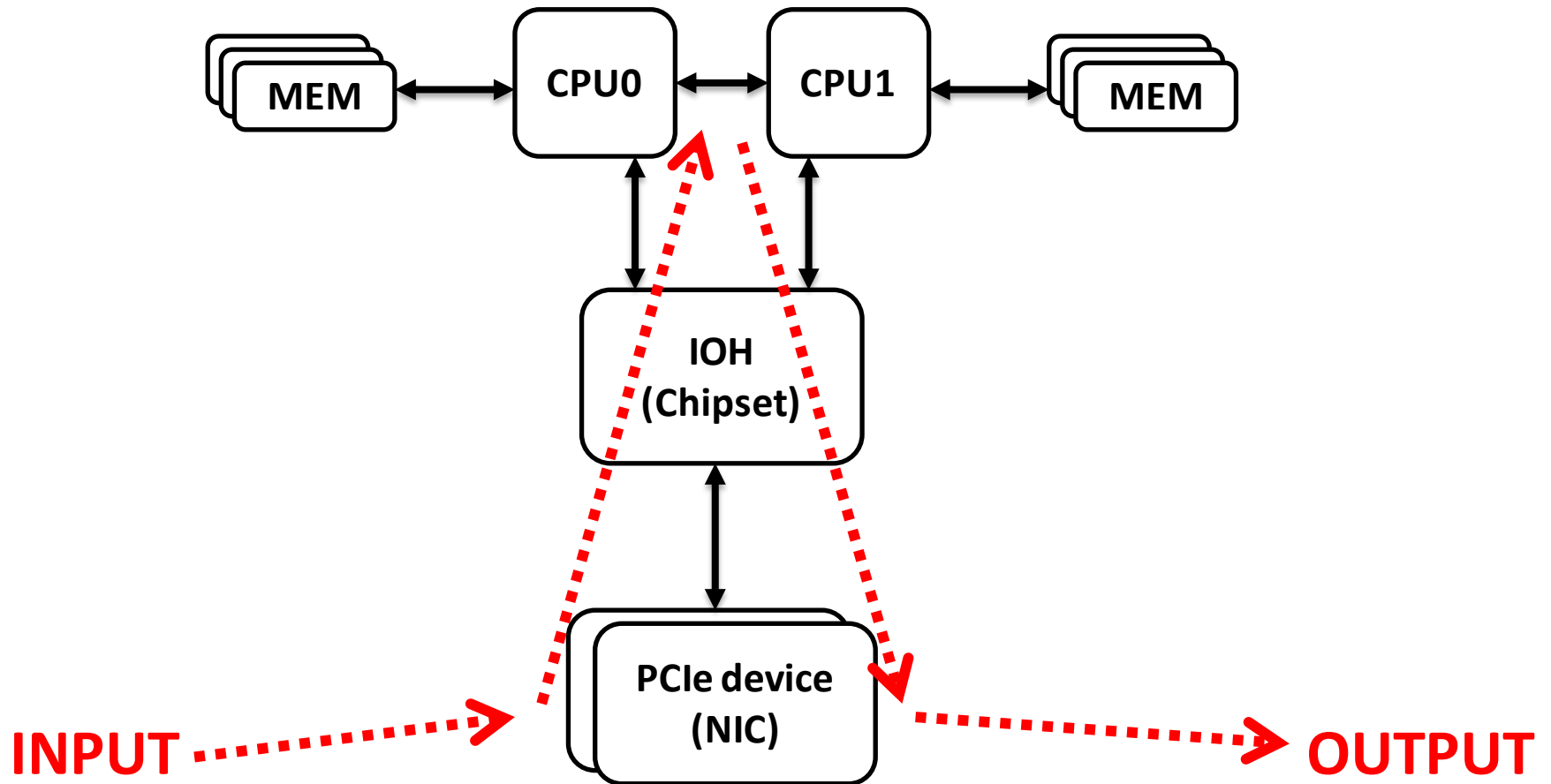
海老澤 健太郎 @ パラレルス株式会社

Twitter: @ebiken

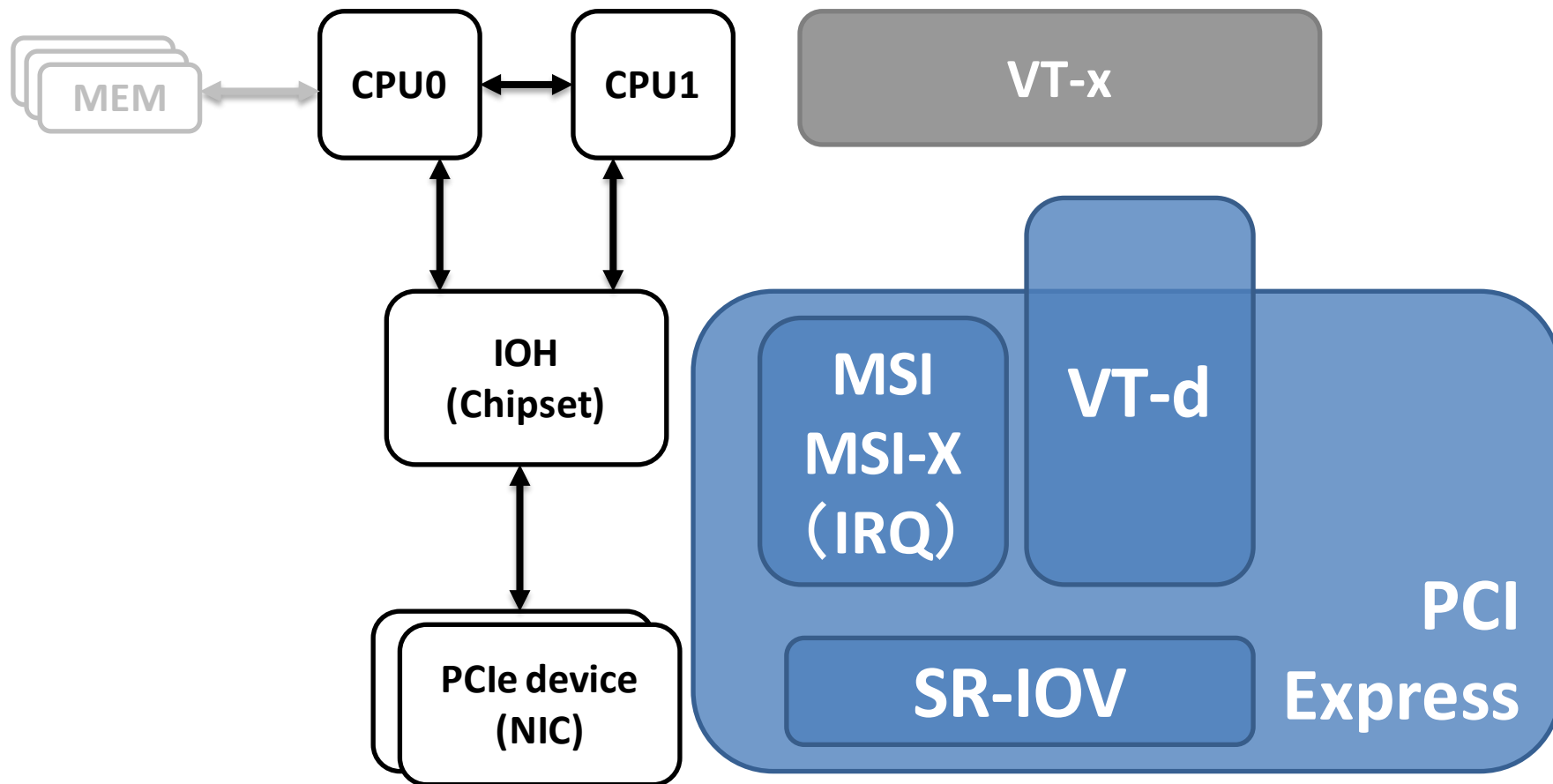
サーバーの物理構造



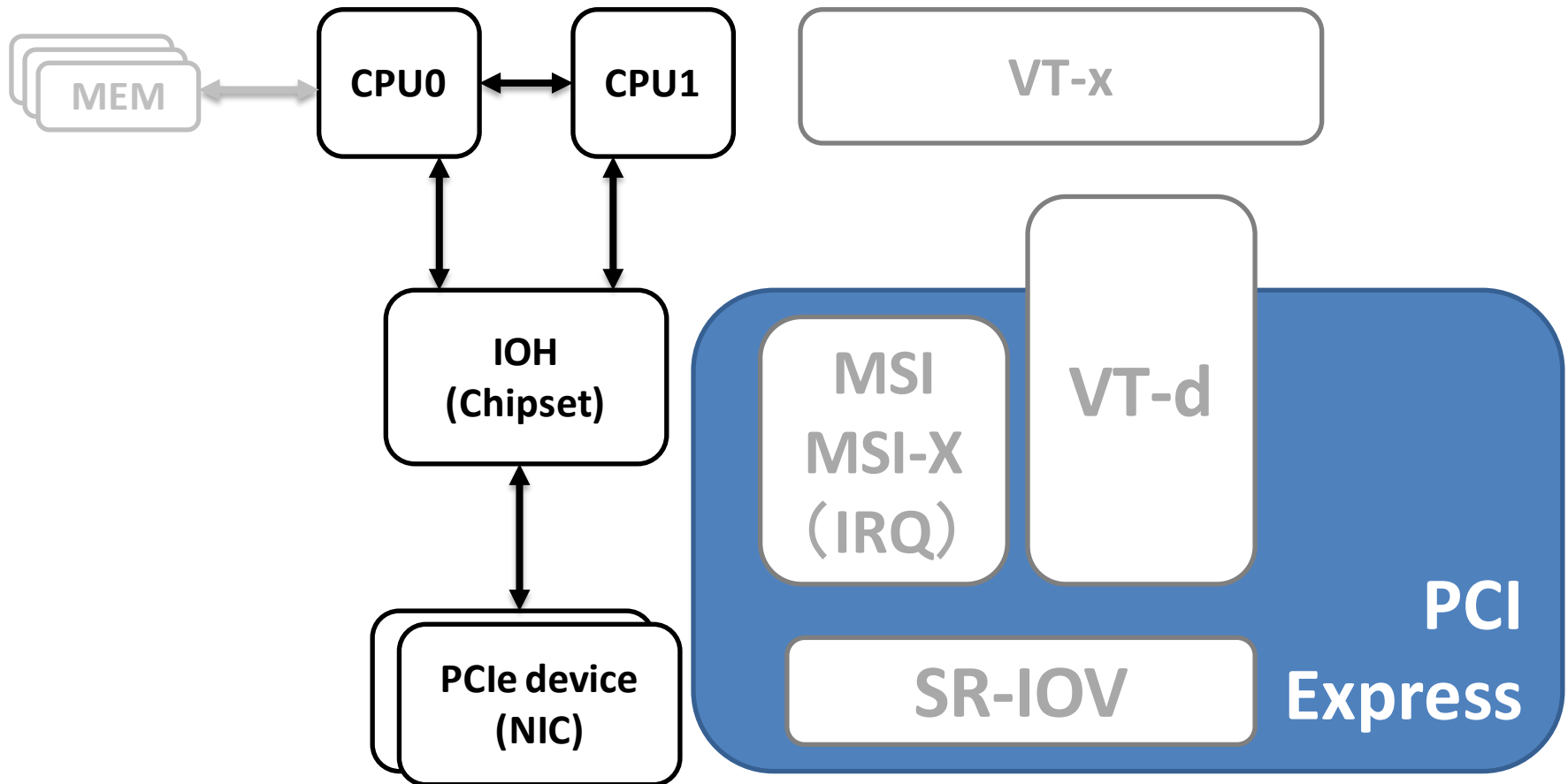
パケットの流れ



仮想化 & パケット転送 技術マップ



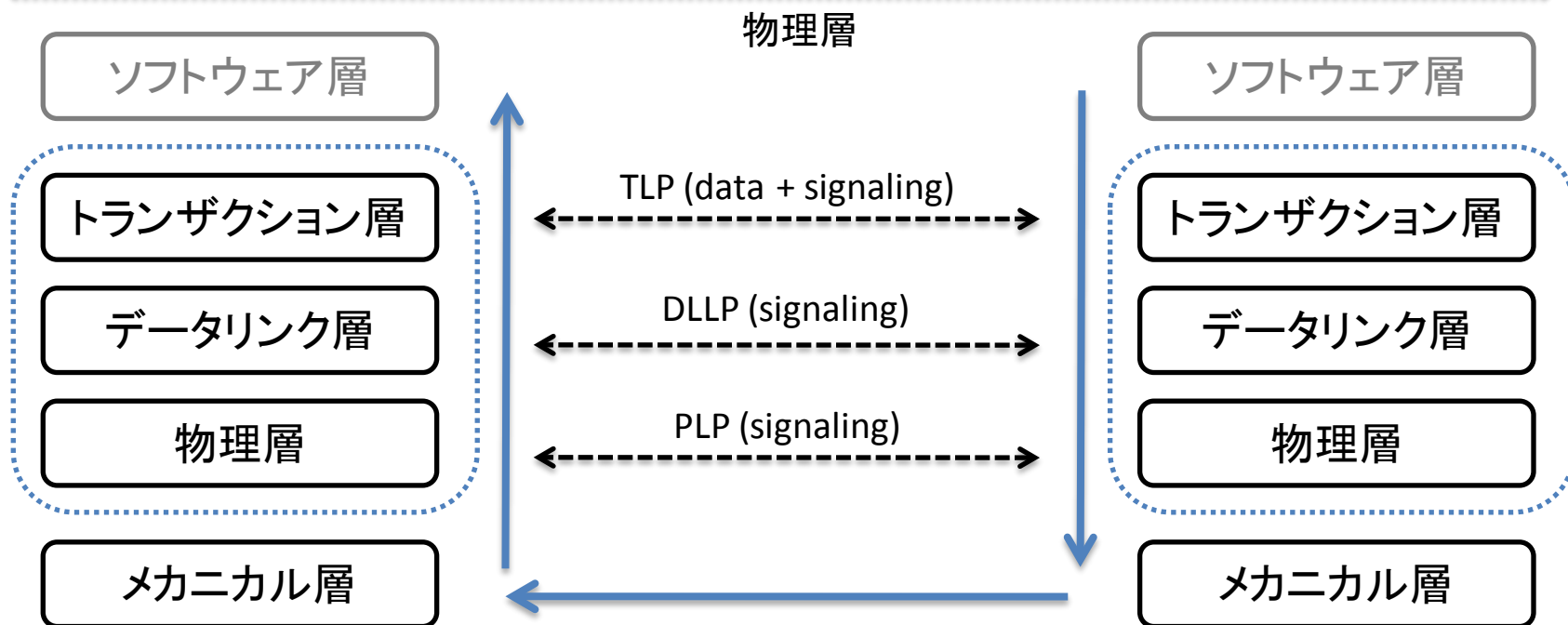
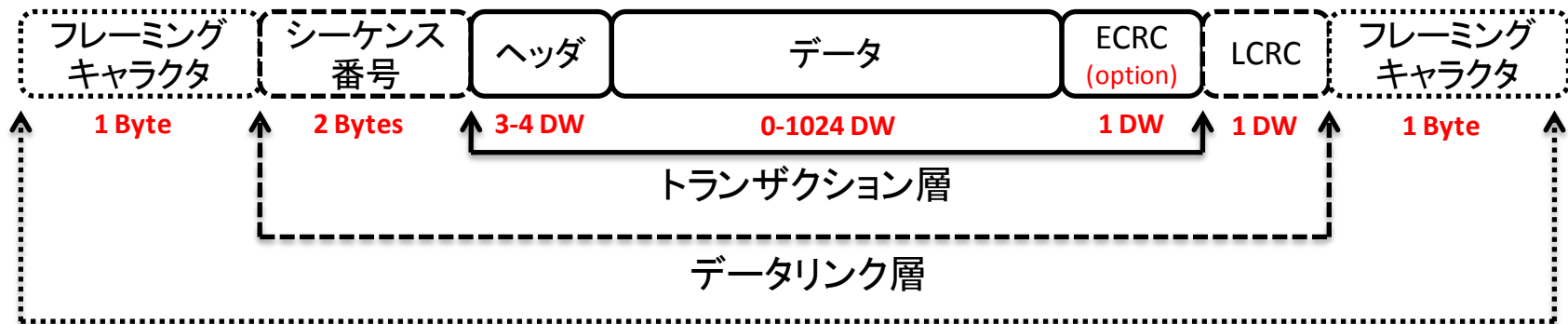
PCI Express - PCIe



PCI Express - PCIe とは？

- 「パケットベース」のプロトコル
- CRCやデータコーディングによるエラー検出
 - 8b10bエンコーディングオーバーヘッドに考慮(20%)
- point-to-point接続のシリアル通信
 - リンク(バス)をスイッチで繋ぐツリー構造
 - ポート速度を処理するのに十分なバス幅を確保

パケット構造



PCIe の帯域

	伝送速度	実効速度 (8b10b考慮)
PCIe 1.1 x 4	10Gbps x 2	8Gbps x 2
PCIe 1.1 x 8	20Gbps x 2	16Gbps x 2
PCIe 2.0 x 4	20Gbps x 2	16Gbps x 2
PCIe 2.0 x 8	40Gbps x 2	32Gbps x 2

10Gbps x 2 port x Full Duplex には
PCIe 2.0 x 8 Lane 必要

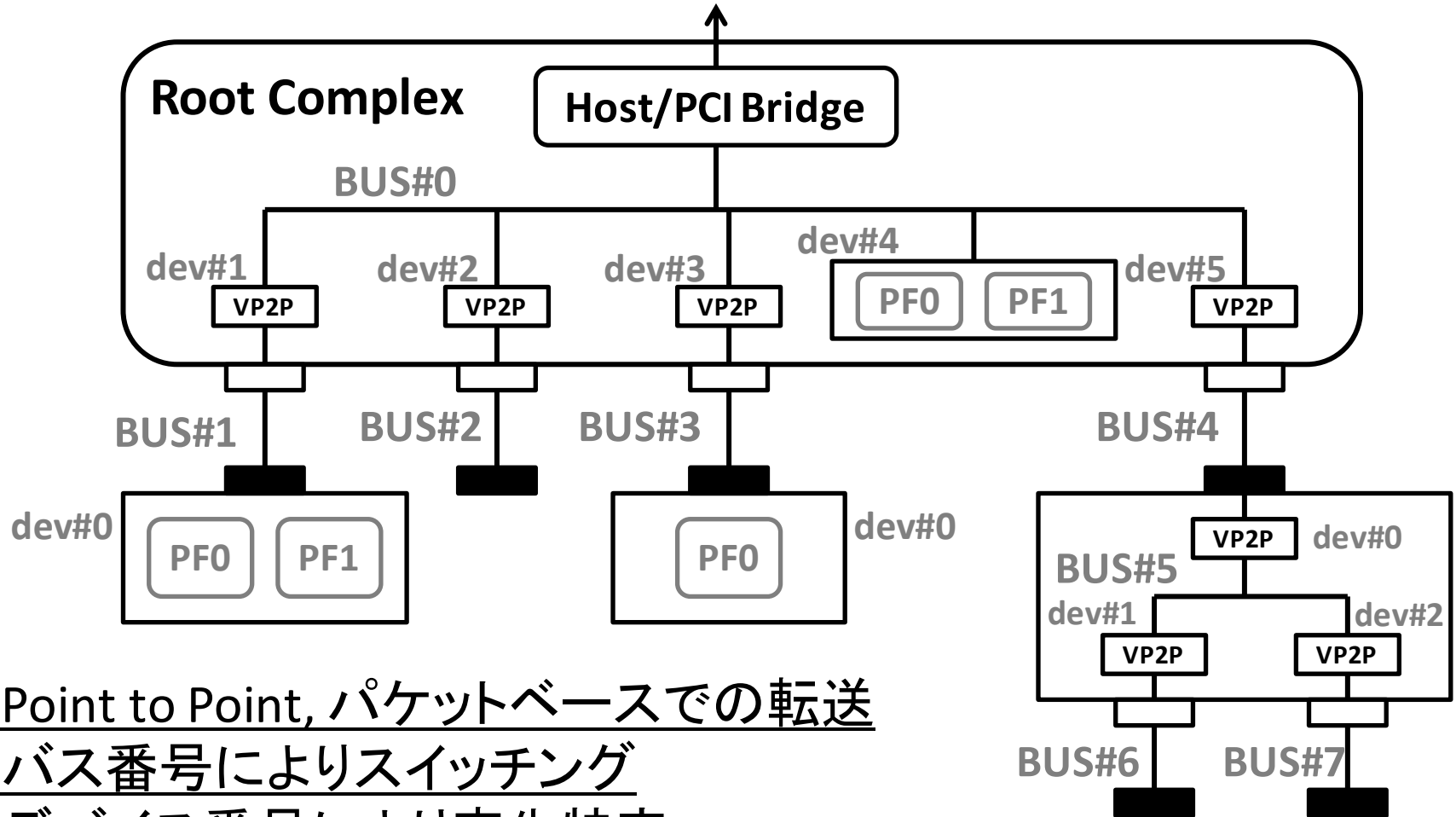
PCIe デバイスをLinuxから見てみる

```
[ebiken@iwpf01 ~]$ lspci
... snip ...
01:00.0 Ethernet controller: Broadcom Corporation NetXtreme II
01:00.1 Ethernet controller: Broadcom Corporation NetXtreme II
03:00.0 Ethernet controller: Intel Corporation 82599EB 10-Gigab
03:00.1 Ethernet controller: Intel Corporation 82599EB 10-Gigab
```

BUS:Device.Function で認識

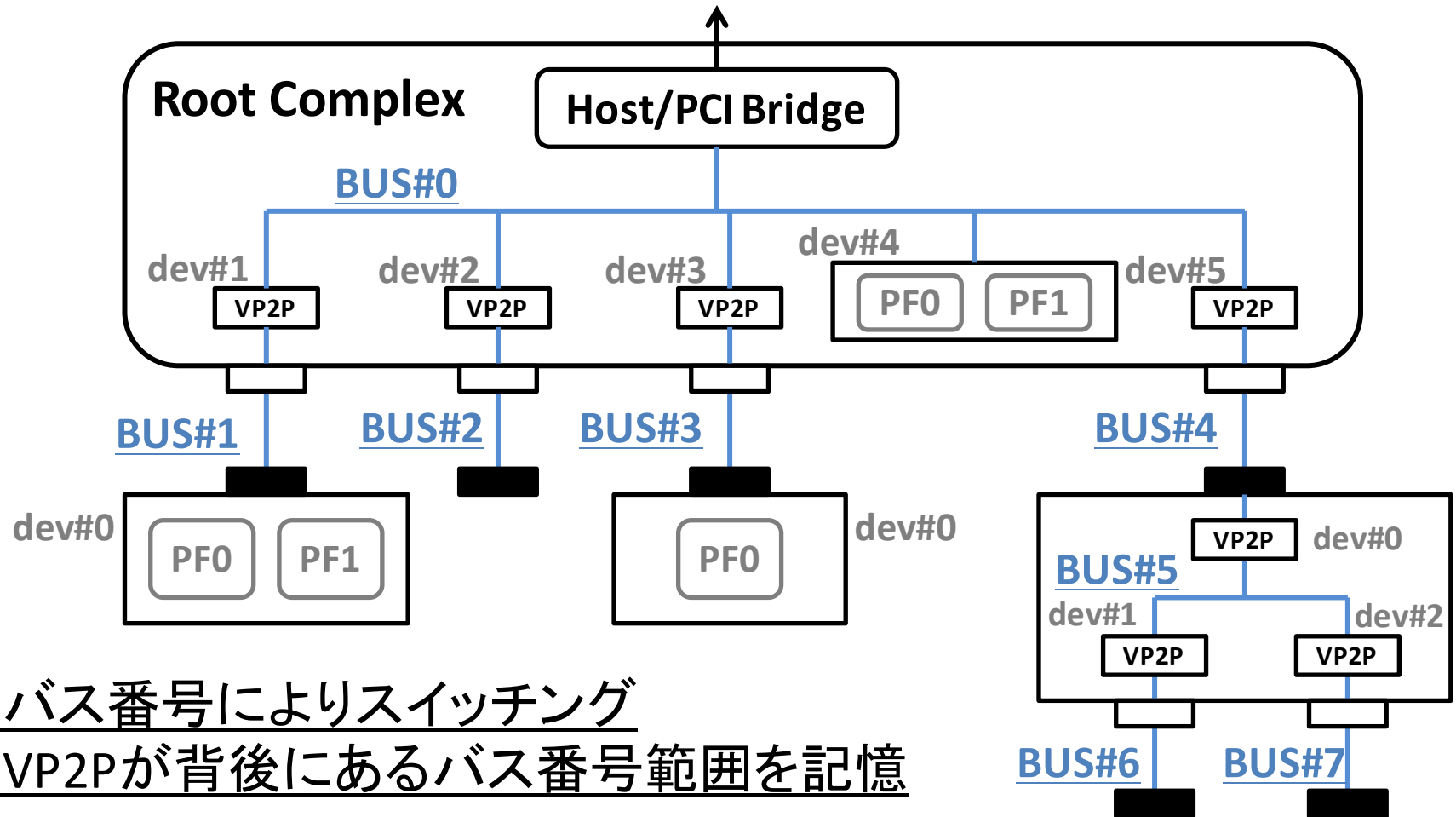
```
[ebiken@iwpf01 ~]$ lspci
... snip ...
01:00.0 Ethernet controller: Broadcom Corporation NetXtreme II BCM5716 Gigabit Ethernet (rev 20)
01:00.1 Ethernet controller: Broadcom Corporation NetXtreme II BCM5716 Gigabit Ethernet (rev 20)
03:00.0 Ethernet controller: Intel Corporation 82599EB 10-Gigabit SFI/SFP+ Network Connection (rev 01)
03:00.1 Ethernet controller: Intel Corporation 82599EB 10-Gigabit SFI/SFP+ Network Connection (rev 01)
```

PCIe Topology – 物理配線



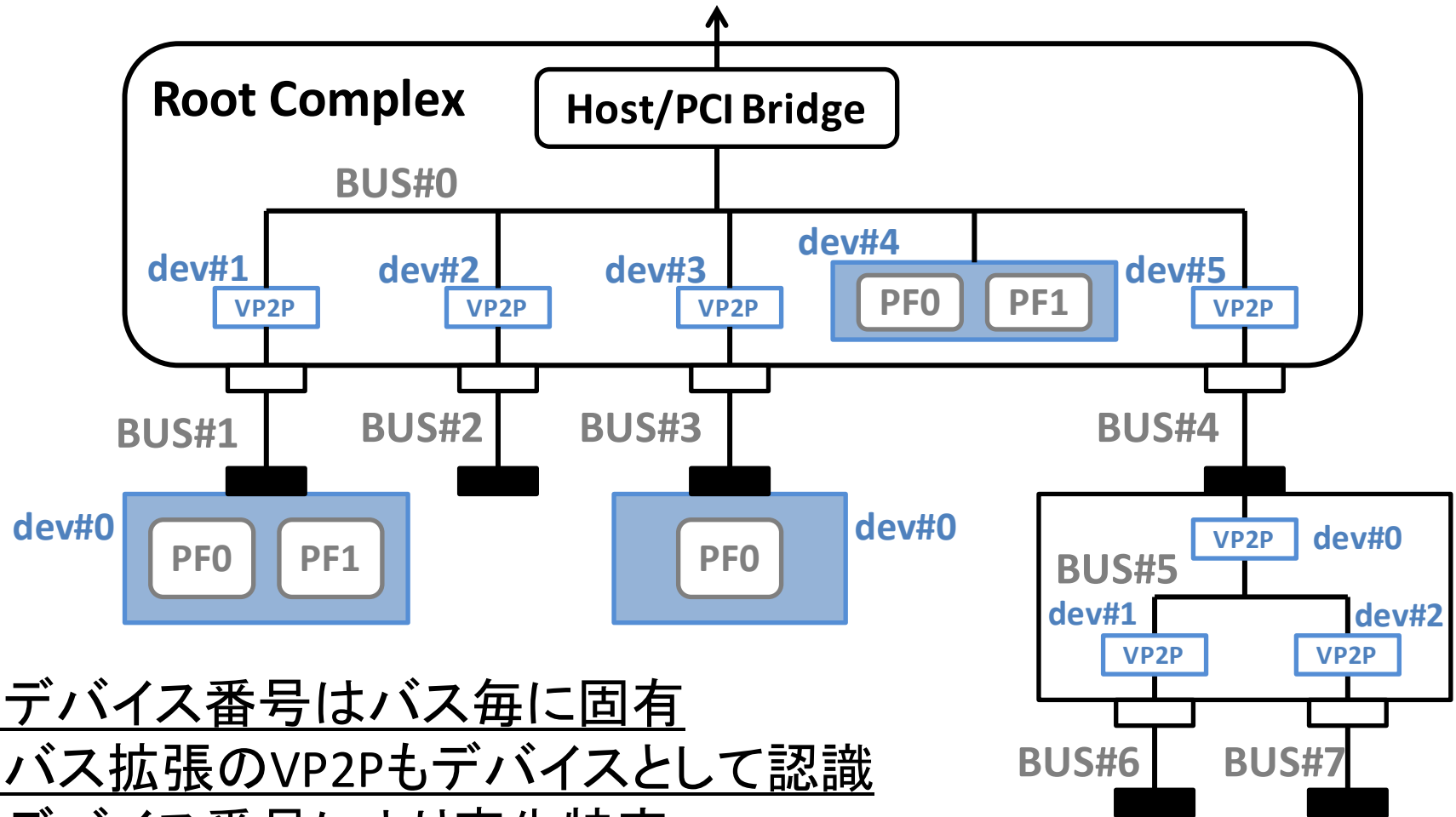
- Point to Point, パケットベースでの転送
- バス番号によりスイッチング
- デバイス番号により宛先特定

PCIe Topology - BUS:Device:Function



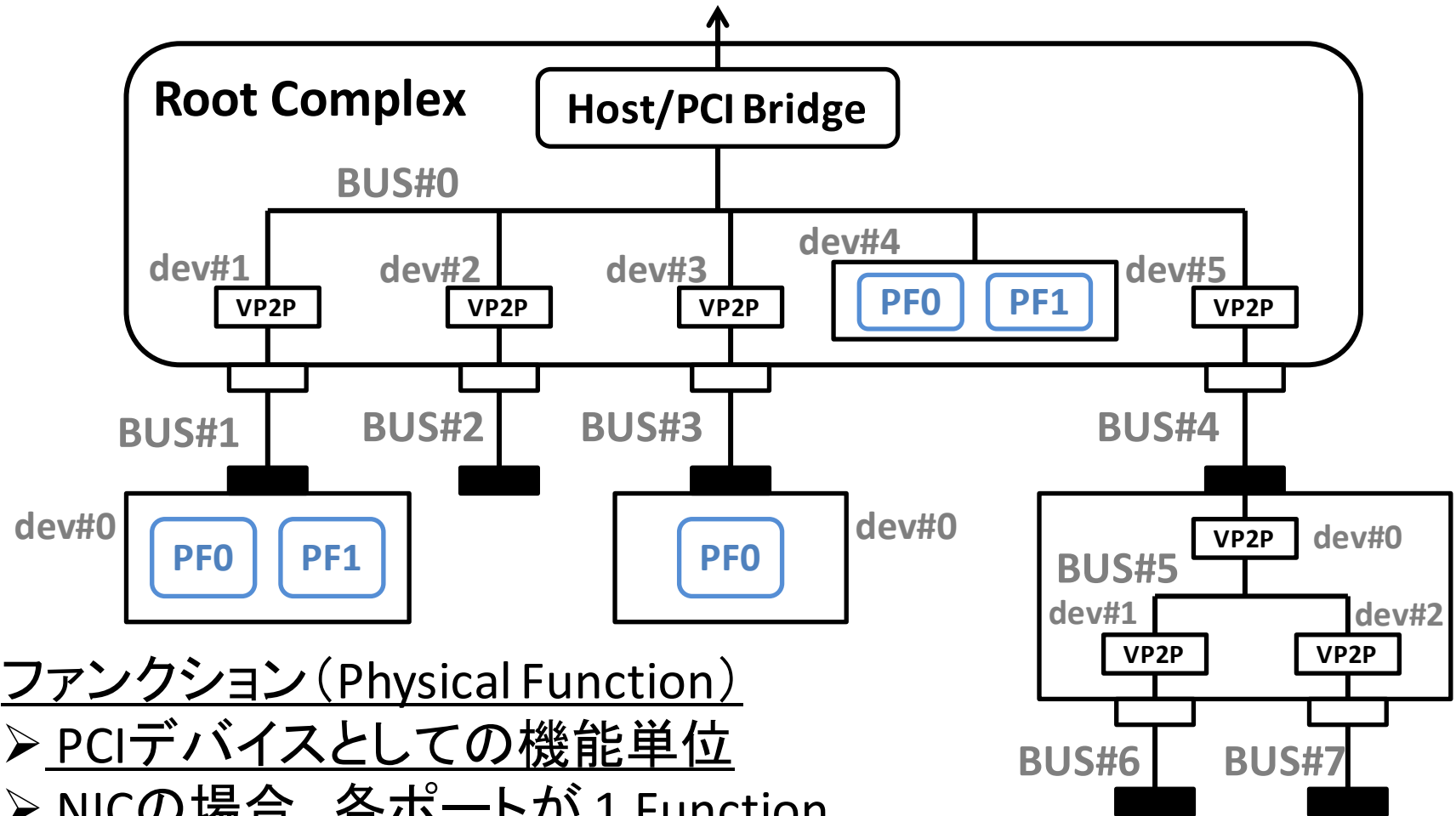
- バス番号によりスイッチング
- VP2Pが背後にあるバス番号範囲を記憶

PCIe Topology - BUS:Device:Function



- デバイス番号はバス毎に固有
- バス拡張のVP2Pもデバイスとして認識
- デバイス番号により宛先特定

PCIe Topology - BUS:Device:Function




ファンクション (Physical Function)

- PCIデバイスとしての機能単位
- NICの場合、各ポートが 1 Function
- Sound+VideoカードならそれぞれがFunction

PCIe トポロジをOSから見てみる

```
[ebiken@iwpf01 ~]$ lspci -tv
... snip ...
¥-[0000:00]--+-00.0 Intel Corporation 5500 I/O
      +-01.0-[01]--+-00.0 Broadcom Corp
      |                    ¥-00.1 Broadcom Corp
      +-03.0-[02]--
      +-07.0-[03]--+-00.0 Intel Corpora
      |                    ¥-00.1 Intel Corpora
```



```
[ebiken@iwpf01 ~]$ lspci -tv
... snip ...
¥-[0000:00]--+-00.0 Intel Corporation 5500 I/O Hub to ESI Port
      +-01.0-[01]--+-00.0 Broadcom Corporation NetXtreme II BCM5716 Gigabit Ethernet
      |                    ¥-00.1 Broadcom Corporation NetXtreme II BCM5716 Gigabit Ethernet
      +-03.0-[02]--
      +-07.0-[03]--+-00.0 Intel Corporation 82599EB 10-Gigabit SFI/SFP+ Network Connection
      |                    ¥-00.1 Intel Corporation 82599EB 10-Gigabit SFI/SFP+ Network Connection
      +-14.0 Intel Corporation 5520/5500/X58 I/O Hub System Management Registers
      +-14.1 Intel Corporation 5520/5500/X58 I/O Hub GPIO and Scratch Pad Registers
```

PCIe トポロジをOSから見てみる

```
[ebiken@iwpf01 ~]$ lspci -tv
... snip ...
¥-[0000:00]-+-00.0 Intel Corporation 5500 I/O
      +-01.0-[01]--+-00.0 Broadcom Corp
      |                    ¥-00.1 Broadcom Corp
      +-03.0-[02]--
      +-07.0-[03]--+-00.0 Intel Corpora
      |                    ¥-00.1 Intel Corpora
```

バス番号 : デバイス番号 : ファンクション番号

※ ファンクション × 2 = 2ポート

デバイスの機能を確認

```
[ebiken@iwpf01 ~]$ lspci -v -s 03:00.0
```

```
03:00.0 Ethernet controller: Intel Corporation 82599EB 10-Gigabit  
SFI/SFP+ Network Connection (rev 01)
```

```
Subsystem: Intel Corporation Ethernet Server Adapter X520-2
```

```
Flags: bus master, fast devsel, latency 0, IRQ 38
```

```
Memory at d9900000 (64-bit, prefetchable) [size=512K]
```

```
I/O ports at fcc0 [size=32]
```

```
Memory at d98f8000 (64-bit, prefetchable) [size=16K]
```

```
Capabilities: <access denied>
```

```
Kernel driver in use: ixgbe
```

```
Kernel modules: ixgbe
```



root権限必要

[ebiken@iwpcf01 ~]\$ ***sudo lspci -v -s 03:00.0***

03:00.0 Ethernet controller: Intel Corporation 82599EB 10-Gigabit SFI/SFP+ Network Connection (rev 01)

Subsystem: Intel Corporation Ethernet Server Adapter X520-2

Flags: bus master, fast devsel, latency 0, IRQ 38

Memory at d9900000 (64-bit, prefetchable) [size=512K]

I/O ports at fcc0 [size=32]

Memory at d98f8000 (64-bit, prefetchable) [size=16K]

Capabilities: [40] Power Management version 3

Capabilities: [50] MSI: Enable- Count=1/1 Maskable+ 64bit+

Capabilities: [70] MSI-X: Enable+ Count=64 Masked-

Capabilities: [a0] Express Endpoint, MSI 00

Capabilities: [100] Advanced Error Reporting

Capabilities: [140] Device Serial Number 00-1b-21-ff-ff-74-5a-f8

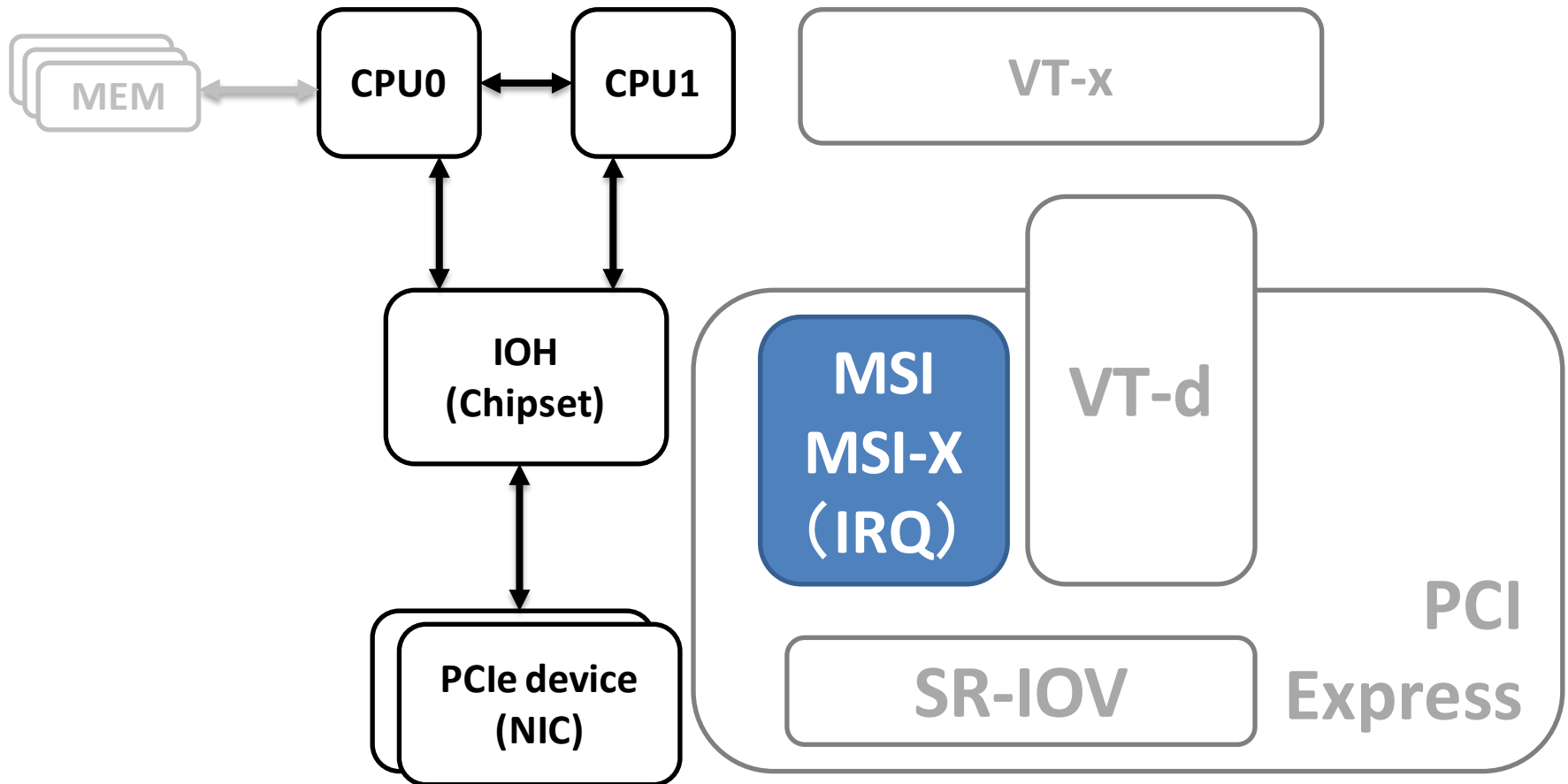
Capabilities: [150] Alternative Routing-ID Interpretation (ARI)

Capabilities: [160] Single Root I/O Virtualization (SR-IOV)

Kernel driver in use: ixgbe

Kernel modules: ixgbe

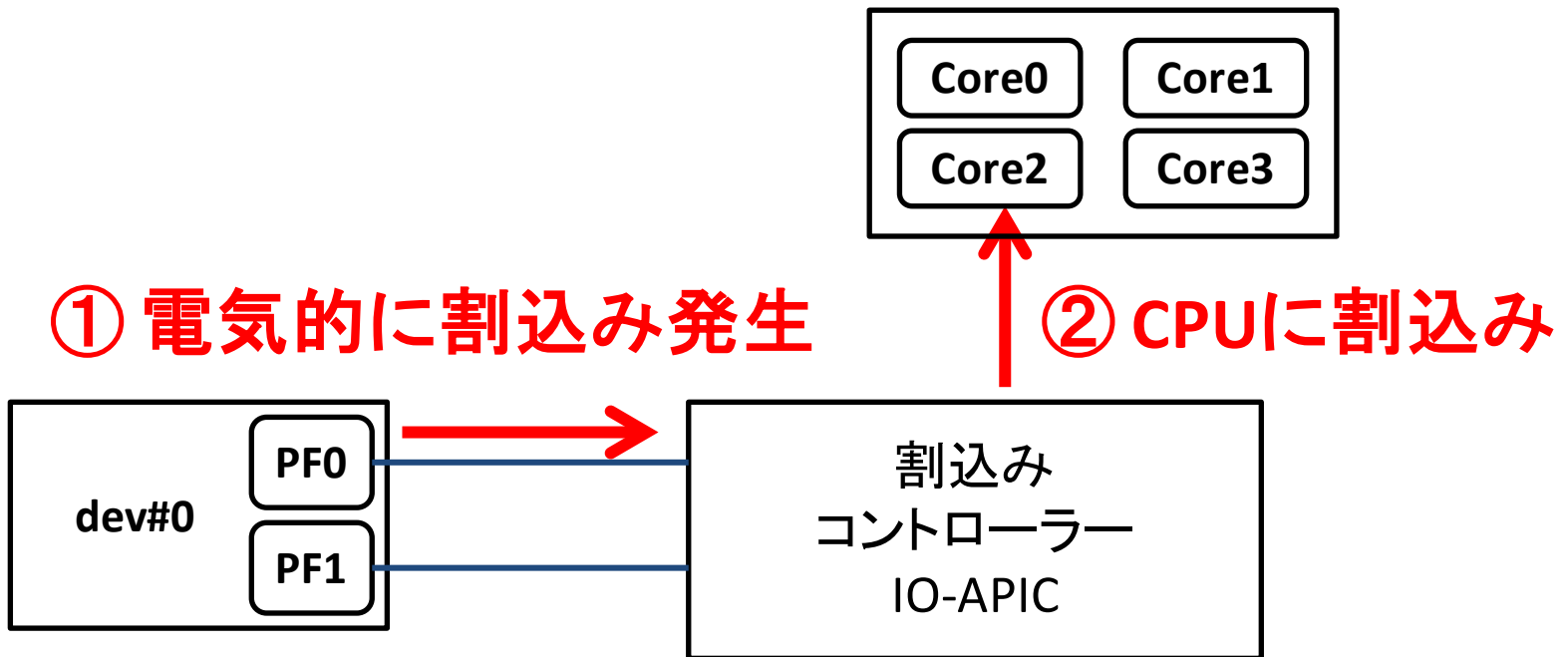
割込み：MSI / MSI-X



割り込み : Pin Based Interrupt(Legacy)

割り込み線 = 1ファンクション1本

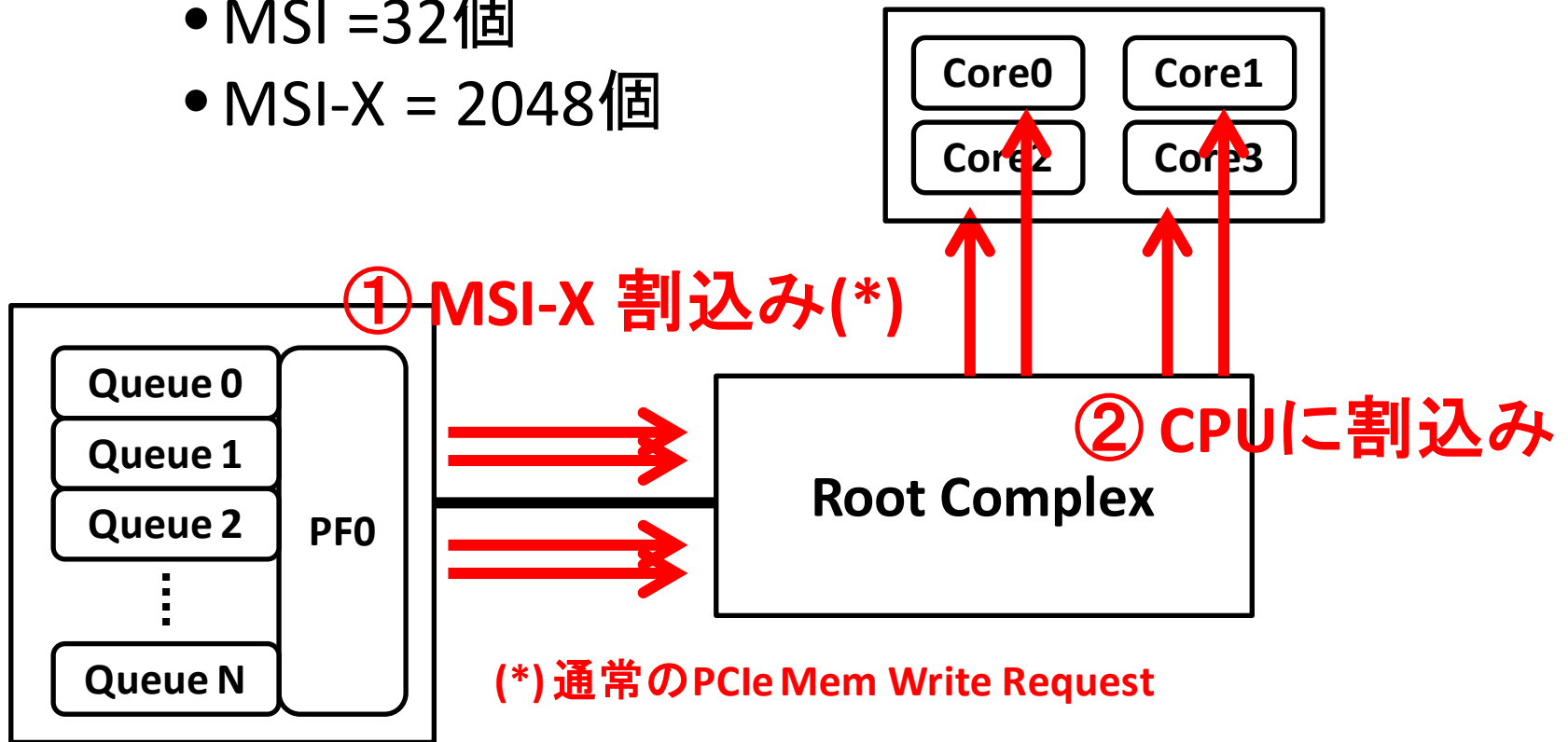
Portで送受信した割り込みは同じCPU(Core)に割り込み



割り込み : MSI / MSI-X

MSI = Message Signaled Interrupt
Queue毎に割り込むCPU(Core)を変更可能

- MSI = 32個
- MSI-X = 2048個

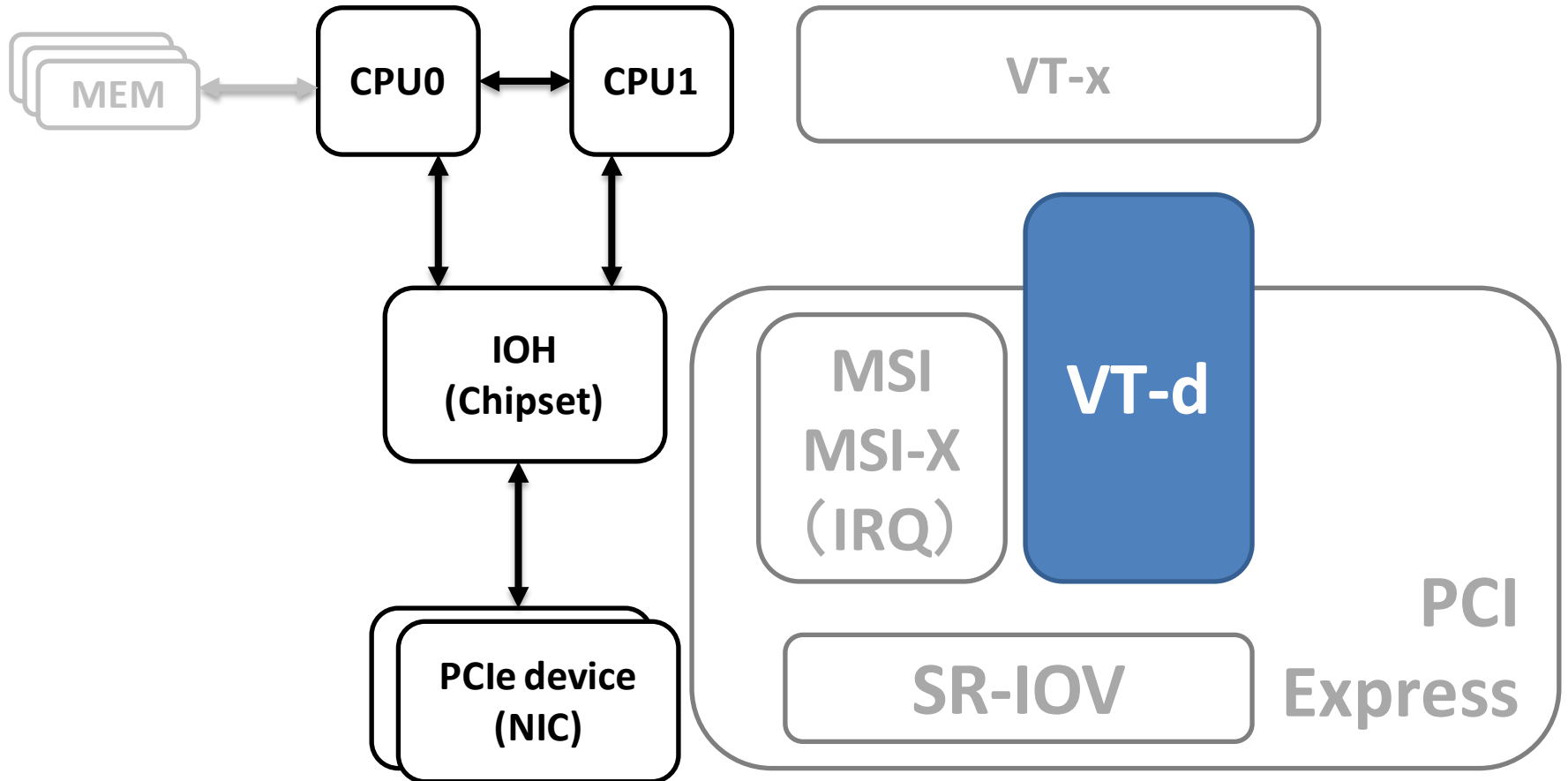


割込み : IRQ, MSI/MSI-X

```
[ebiken@iwpf01 ~]$ cat /proc/interrupts
```

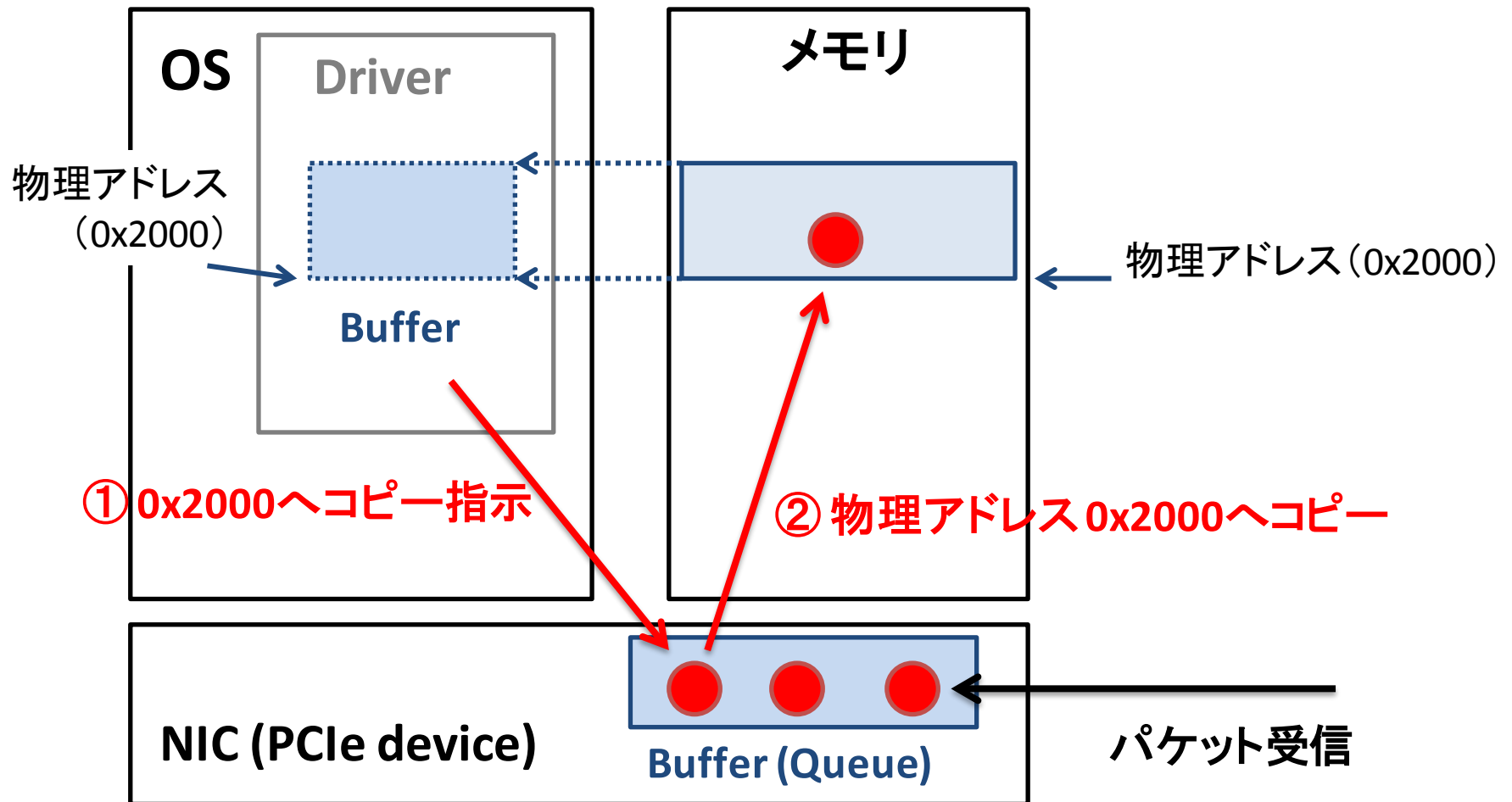
	CPU0	CPU1	CPU2	CPU3	CPU4	CPU5	CPU6	CPU7			
... snip ...											
83:	153048		0	0	0	0	0	0	0	PCI-MSI-edge	p1p1-TxRx-0
84:	158095		34	0	0	0	0	0	0	PCI-MSI-edge	p1p1-TxRx-1
85:	88240		0	34	0	0	0	0	0	PCI-MSI-edge	p1p1-TxRx-2
86:	156169		0	0	44	0	0	0	0	PCI-MSI-edge	p1p1-TxRx-3
87:	155602		0	0	0	34	0	0	0	PCI-MSI-edge	p1p1-TxRx-4
88:	168235		0	0	0	0	34	0	0	PCI-MSI-edge	p1p1-TxRx-5
89:	195289		0	0	0	0	0	34	0	PCI-MSI-edge	p1p1-TxRx-6
90:	163879		0	0	0	0	0	0	34	PCI-MSI-edge	p1p1-TxRx-7
91:	4		0	0	0	0	0	0	0	PCI-MSI-edge	p1p1:lsc
92:	171226		0	0	0	0	0	0	0	PCI-MSI-edge	p1p2-TxRx-0
93:	196258		34	0	0	0	0	0	0	PCI-MSI-edge	p1p2-TxRx-1
94:	175363		0	34	0	0	0	0	0	PCI-MSI-edge	p1p2-TxRx-2
95:	24	878678		0	44	0	0	0	0	PCI-MSI-edge	p1p2-TxRx-3
96:	172140		0	0	0	34	0	0	0	PCI-MSI-edge	p1p2-TxRx-4
97:	152054		0	0	0	0	34	0	0	PCI-MSI-edge	p1p2-TxRx-5
98:	163481		0	0	0	0	0	34	0	PCI-MSI-edge	p1p2-TxRx-6
99:	88243		0	0	0	0	0	0	34	PCI-MSI-edge	p1p2-TxRx-7
100:	4		0	0	0	0	0	0	0	PCI-MSI-edge	p1p2:lsc

Virtualization Technology for directed I/O

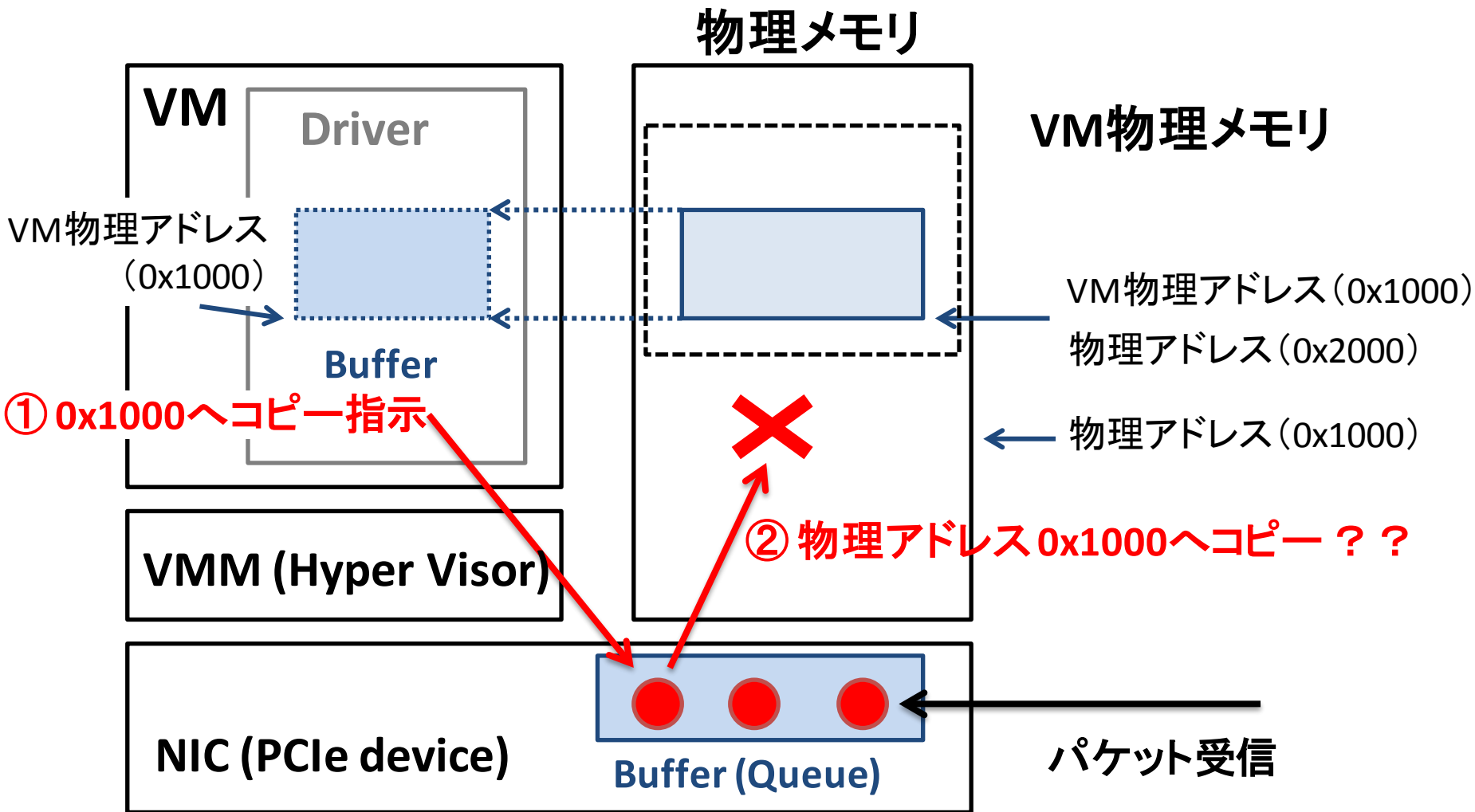


DMA : Direct Memory Access

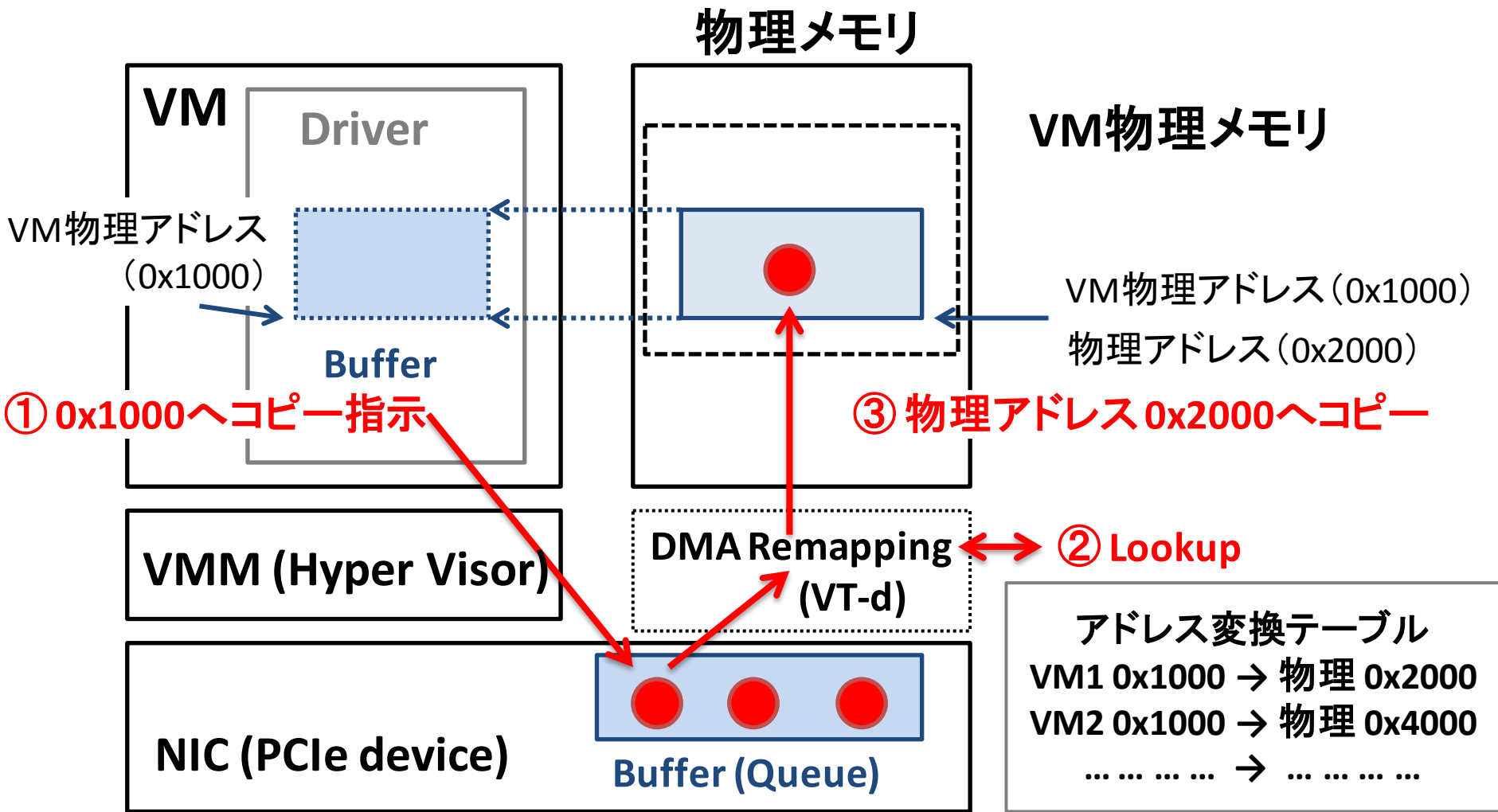
CPUを介さずパケットをコピー



仮想環境 (VM) の場合



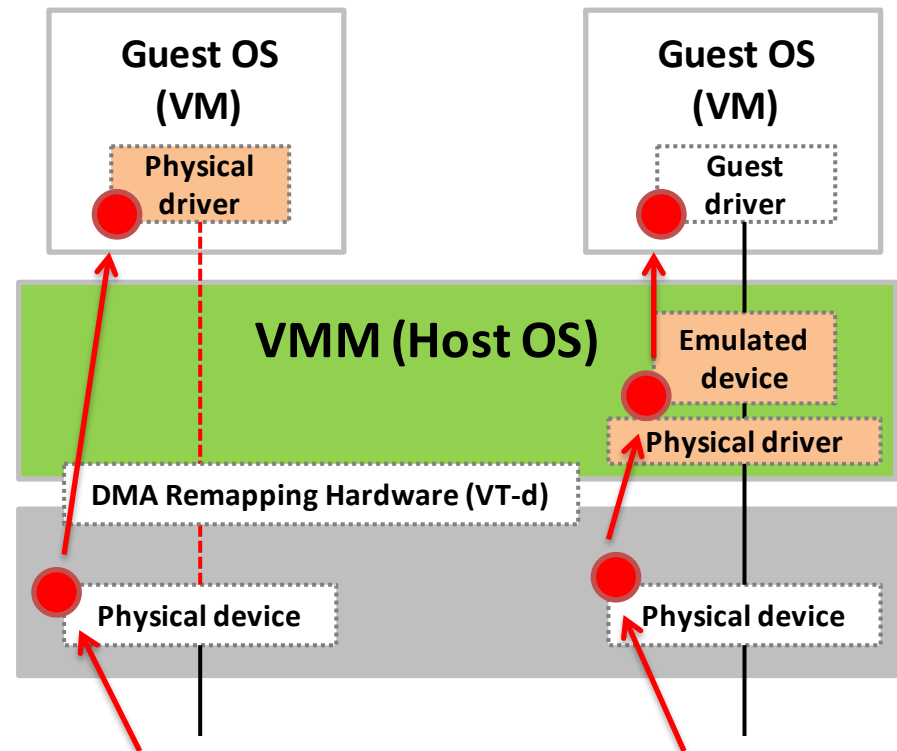
仮想環境 (VM) + VT-d サポート



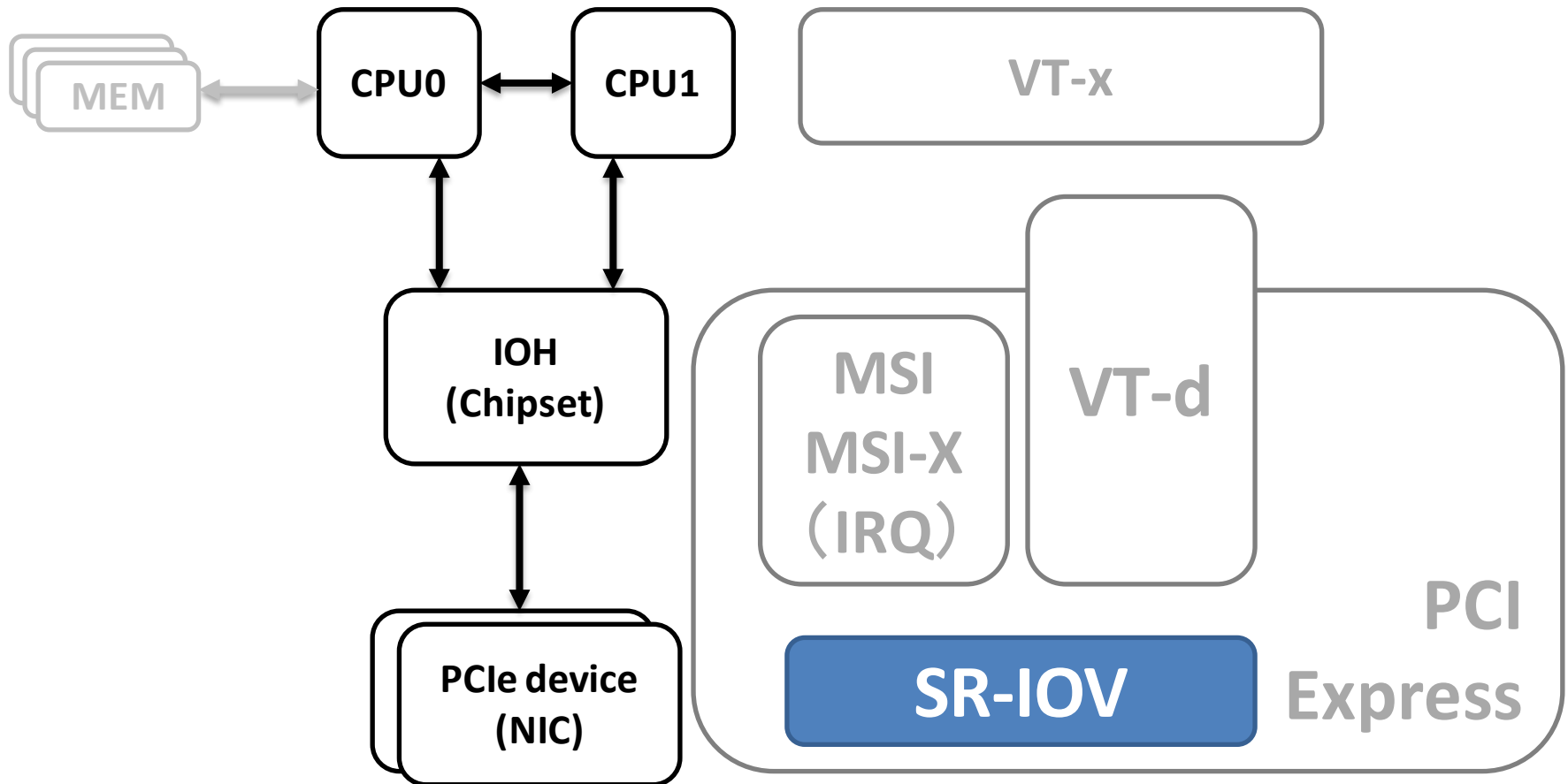
VT-d によるI/O デバイス割り当て

- 物理デバイス(NIC)を VMに割り当て
- VMから直接見える(割込みのみVMM経由)
- パケットをDMA転送
- オーバーヘッド=極小

1ポート(※)に1VMのみ
(※) 1 PCIe Function



SR-IOV : Single Root - IO Virtualization



SR-IOV & Virtual Function

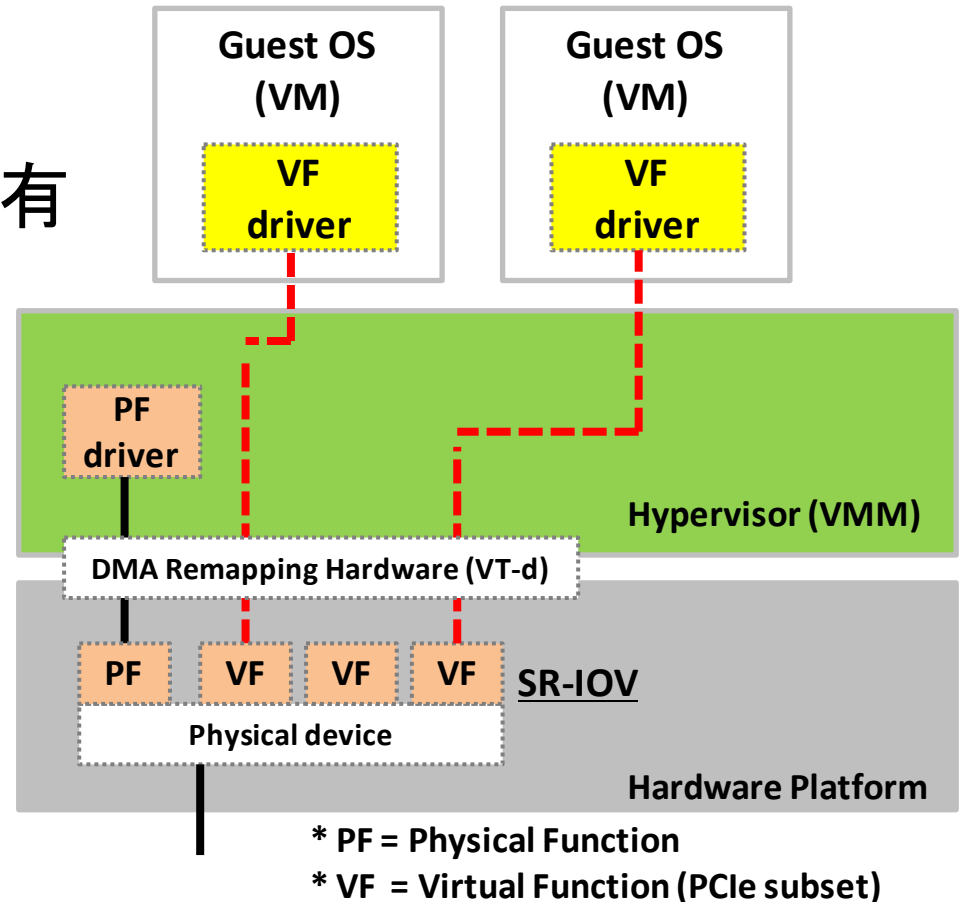
- SR-IOV = Single Root - IO Virtualization
- PCIe Device (NIC) 機能
- Virtual Function = Physical Functionのサブセット
 - 設定はPhysical Function経由
 - データ送受信は Virtual Function <-> Driver 直接

I/O デバイス割り当て + 共有 (SR-IOV)

物理デバイス (NIC) を VM に割り当て + 共有
オーバーヘッド = 極小

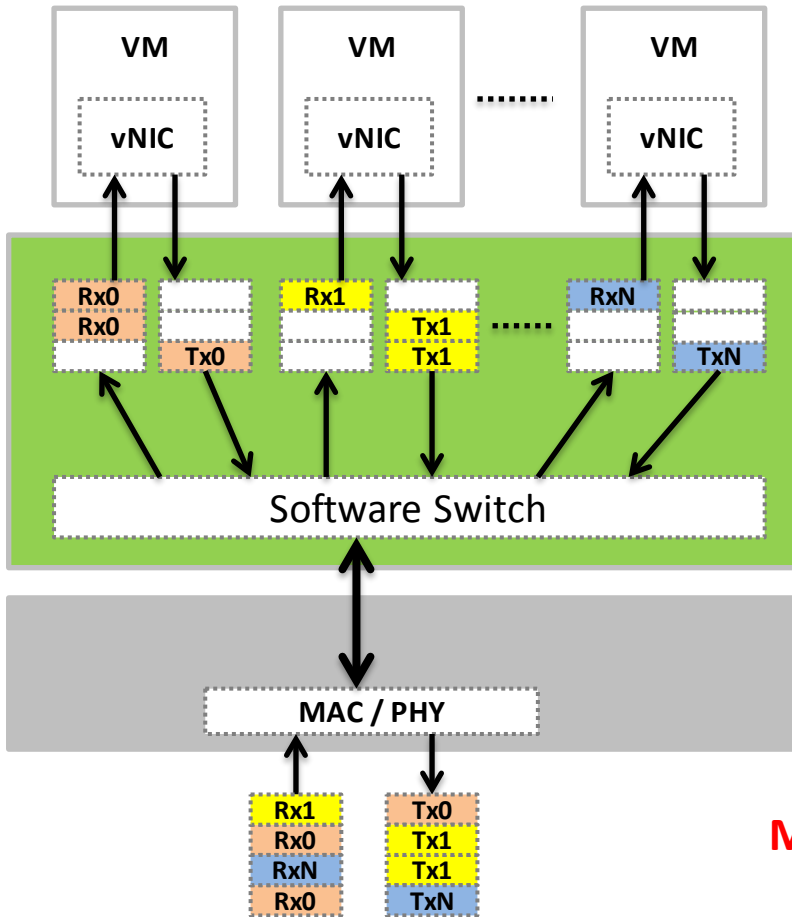
複数 VM での物理ポート共有

VM からは VF = NIC (Port) に見える

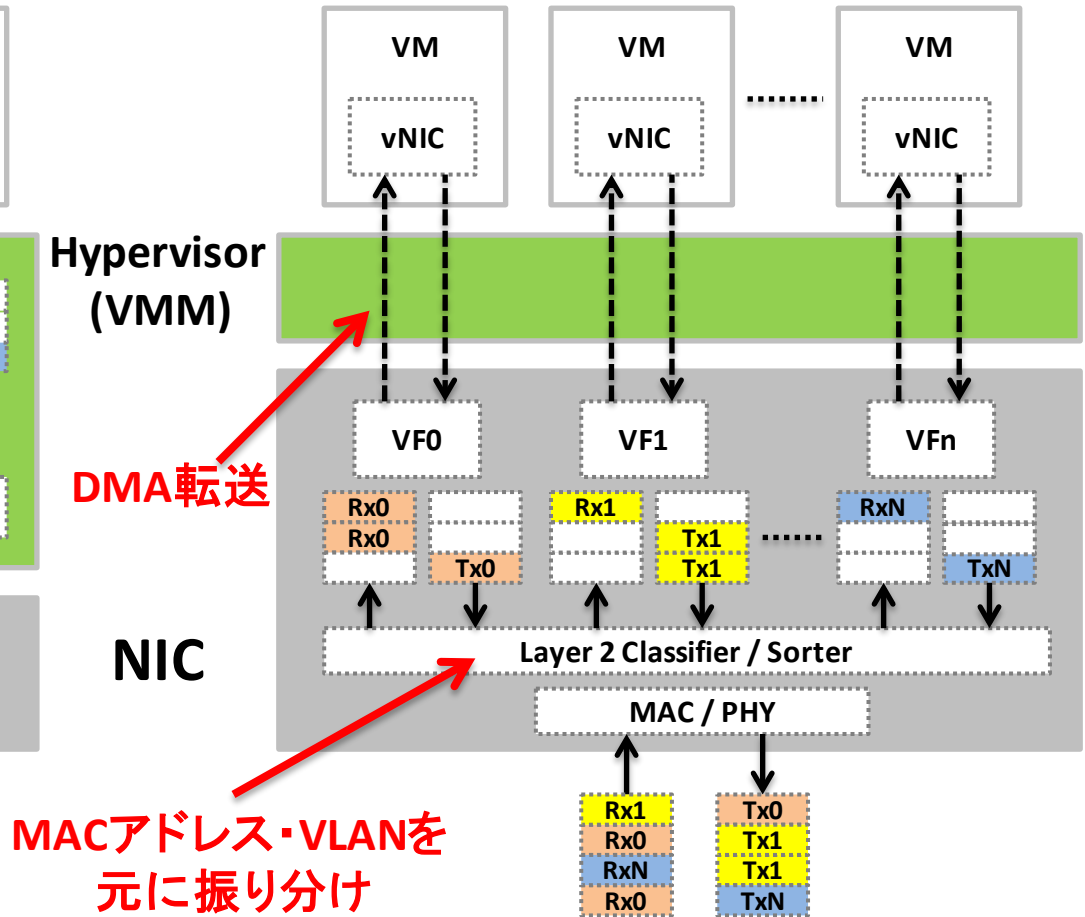


SR-IOV パケットフロー

SR-IOV 無し: VMMがパケット振り分け



SR-IOV 有り: NICがパケット振り分け
VMMはパス・スルー



SR-IOV : lspci -tv @ VMM (Host)

```
[ebiken@iwpf01 ~]$ lspci -tv
```

```
¥-[0000:00]--00.0 Intel Corporation 5500 I/O Hub to ESI Port
  +-01.0-[01]---00.0 Broadcom Corporation NetXtreme II BCM5716 Gigabit Ethernet
  |                   ¥-00.1 Broadcom Corporation NetXtreme II BCM5716 Gigabit Ethernet
  +-03.0-[02]--
  +-07.0-[03]---00.0 Intel Corporation 82599EB 10-Gigabit SFI/SFP+ Network Connection
  |                   ¥-00.1 Intel Corporation 82599EB 10-Gigabit SFI/SFP+ Network Connection
  +-14.0 Intel Corporation 5520/5500/X58 I/O Hub System Management Registers
```

```
[ebiken@iwpf01 ~]$ sudo modprobe -r ixgbe
```

```
[ebiken@iwpf01 ~]$ sudo modprobe ixgbe max vfs=2,2
```

SR-IOV設定

```
[ebiken@iwpf01 ~]$ lspci -tv
```

```
¥-[0000:00]--00.0 Intel Corporation 5500 I/O Hub to ESI Port
  +-01.0-[01]---00.0 Broadcom Corporation NetXtreme II BCM5716 Gigabit Ethernet
  |                   ¥-00.1 Broadcom Corporation NetXtreme II BCM5716 Gigabit Ethernet
  +-03.0-[02]--
  +-07.0-[03]---00.0 Intel Corporation 82599EB 10-Gigabit SFI/SFP+ Network Connection
  |                   ¥-00.1 Intel Corporation 82599EB 10-Gigabit SFI/SFP+ Network Connection
  |                   +-10.0 Intel Corporation 82599 Ethernet Controller Virtual Function
  |                   +-10.1 Intel Corporation 82599 Ethernet Controller Virtual Function
  |                   +-10.2 Intel Corporation 82599 Ethernet Controller Virtual Function
  |                   ¥-10.3 Intel Corporation 82599 Ethernet Controller Virtual Function
```

BUS [03] に Device 10 (Virtual Function) 生成

SR-IOV : lspci -tv @ VM (Guest)

```
[root@dutvm-sriov ~]# lspci -tv
-[0000:00]--00.0 Intel Corporation 440FX - 82441FX PMC [Natoma]
+-01.0 Intel Corporation 82371SB PIIX3 ISA [Natoma/Triton II]
+-01.1 Intel Corporation 82371SB PIIX3 IDE [Natoma/Triton II]
+-01.2 Intel Corporation 82371SB PIIX3 USB [Natoma/Triton II]
+-01.3 Intel Corporation 82371AB/EB/MB PIIX4 ACPI
+-02.0 Cirrus Logic GD 5446
+-03.0 Intel Corporation 82559 Ethernet Controller Virtual Function
+-04.0 Red Hat, Inc Virtio block device
+-05.0 Red Hat, Inc Virtio memory balloon
\--06.0 Intel Corporation 82559 Ethernet Controller Virtual Function
```



BUS [00] : device 06 . function 0

Intel Corporation 82559 Ethernet Controller Virtual Function

Virtual Functionが直接見えている

VF Capabilities @ VMM (Host)

PF依存情報
は[virtual]

```
[ebiken@iwpf01 ~]$ sudo lspci -v -s 3:10.0
03:10.0 Ethernet controller: Intel Corporation 82599 Ethernet Controller Virtual Function (rev 01)
Subsystem: Intel Corporation Device 0003
Flags: bus master, fast devsel, latency 0
[virtual] Memory at c0000000 (64-bit, non-prefetchable) [size=16K]
[virtual] Memory at c0100000 (64-bit, non-prefetchable) [size=16K]
Capabilities: [70] MSI-X: Enable+ Count=3 Masked-
Capabilities: [a0] Express Endpoint, MSI 00
Capabilities: [100] Advanced Error Reporting
Capabilities: [150] Alternative Routing-ID Interpretation (ARI)
Kernel driver in use: ixgbevf
Kernel modules: ixgbevf
```

Capabilitiesに
SR-IOV無し

driver, modules は ixgbevf (not ixgbe)

VF Capabilities @ VM (Guest)

PCI Physical Function として見えている
([virtual] 無し)

```
[root@dutvm-sriov ~]# lspci -v -s 00:06.0
00:06.0 Ethernet controller: Intel Corporation 82559 Ethernet Controller Virtual
Function (rev 01)
Subsystem: Intel Corporation Device 0003
Physical Slot: 6
Flags: bus master, fast devsel, latency 0
Memory at f202c000 (32-bit, non-prefetchable) [size=16K]
Memory at f2030000 (32-bit, non-prefetchable) [size=16K]
Capabilities: [a0] Express Endpoint, MSI 00
Capabilities: [70] MSI-X: Enable+ Count=3 Masked-
Kernel driver in use: ixgbevf
Kernel modules: ixgbevf
```

VM側でもixgbevf 使用

CapabilitiesにPF機能無し

[100] Advanced Error Reporting
[150] Alternative Routing-ID Interpretation (ARI)

/proc/interrupts @ VMM (Host)

```
[ebiken@iwpf01 ~]$ cat /proc/interrupts
```

```
      CPU0  CPU1  CPU2  CPU3  CPU4  CPU5  CPU6  CPU7
... snip ...
 84:      0      0      0      0      0      0      0      0  PCI-MSI-edge p1p1-TxRx-0
 85:      0      0      0      0      0      0      0      0  PCI-MSI-edge p1p1
 86:      0      0      0      0      0      0      0      0  PCI-MSI-edge p1p2-TxRx-0
 87:      0      0      0      0      0      0      0      0  PCI-MSI-edge p1p2

 88:      0      0      0      0      0      0      0      0  PCI-MSI-edge kvm:0000:03:10.0
 89:      0      0      0      0      0      0      0      0  PCI-MSI-edge kvm:0000:03:10.0
 90:      0      0      0      0      0      0      0      0  PCI-MSI-edge kvm:0000:03:10.0
 94:      0      0      0      0      0      0      0      0  PCI-MSI-edge kvm:0000:03:10.1
 95:      0      0      0      0      0      0      0      0  PCI-MSI-edge kvm:0000:03:10.1
 96:      0      0      0      0      0      0      0      0  PCI-MSI-edge kvm:0000:03:10.1
```

PFの割込み

↑

PCI-MSI-edge p1p1-TxRx-0
PCI-MSI-edge p1p1
PCI-MSI-edge p1p2-TxRx-0
PCI-MSI-edge p1p2

PCI-MSI-edge kvm:0000:03:10.0
PCI-MSI-edge kvm:0000:03:10.0
PCI-MSI-edge kvm:0000:03:10.0
PCI-MSI-edge kvm:0000:03:10.1
PCI-MSI-edge kvm:0000:03:10.1
PCI-MSI-edge kvm:0000:03:10.1

↓

VF割込み

/proc/interrupts @ VM (Guest)

```
42:          4          7 PCI-MSI-edge eth0-rx-0
43:          5         12 PCI-MSI-edge eth0-tx-0
44:          4          4 PCI-MSI-edge eth0:mbx
45:          8          3 PCI-MSI-edge eth1-rx-0
46:         11          6 PCI-MSI-edge eth1-tx-0
47:          4          3 PCI-MSI-edge eth1:mbx
```

- eth0, eth1 として認識
- eth0:mbx, eth1:mbx = PF/VF間通信に使用

VT-x, VT-d, SR-IOV サポート確認方法

Intel CPU VT-x, VT-d サポート確認方法

http://ark.intel.com/

The screenshot shows the Intel ARK website interface. The top navigation bar includes the Intel logo, a menu, and search options. The main content area is divided into sections for Desktop Products, Desktop Processors, and a list of processor categories. A red box highlights the link for "2nd Generation Intel® Core™ i7 Processors". A red arrow points from the text "1) Click !!" to this link. Below this, another red arrow points from the text "2) Click !!" to the "Intel® Core™ i7-2600S Processor (8M Cache, 2.80 GHz)" entry in a table of processor specifications.

Product Specs ▾

Desktop Products

Desktop Processors

2nd Generation Intel® Core™ i7 Processors

2nd Generation Intel® Core™ i5 Processors

2nd Generation Intel® Core™ i3 Processors

Previous Generation Intel® Core™ i7 Extreme Processor

Intel® Celeron® Desktop Processor

2nd Generation Intel® Core™ i7 Processors (Desktop) [See All](#)

Intel Inside
CORE i7

2nd Generation Intel® Core™ i7 Processors (Desktop)
Click on a product name to see detailed specifications

Show spec, stepping, ordering, and socket details







Compare Select: All None	Product Name	Status	Embedded Options Available	Max TDP	Recommended Channel Price	Gr
Select	Intel® Core™ i7-2600S Processor (8M Cache, 2.80 GHz)	Launched	No	65 W	\$294.00	Inte Graphi
Select	Intel® Core™ i7-2600K Processor (8M Cache, 3.40 GHz)	Launched	No	95 W	\$317.00	Inte Graphi
Select	Intel® Core™ i7-2600 Processor (8M Cache, 3.40 GHz)	Launched	Yes	95 W	\$294.00	Inte Graphi

1) Click !!

2) Click !!

Intel CPU VT-x, VT-d サポート確認方法

VT-x **VT-d**

Advanced Technologies		
Intel® Turbo Boost Technology		2.0
Intel® vPro Technology		Yes
Intel® Hyper-Threading Technology		Yes
Intel® Virtualization Technology (VT-x)		Yes
Intel® Virtualization Technology for Directed I/O (VT-d)		Yes
Intel® Trusted Execution Technology		Yes
AES New Instructions		Yes
Intel® 64		Yes
Idle States		Yes
Enhanced Intel SpeedStep® Technology		Yes
Thermal Monitoring Technologies		Yes
Intel® Fast Memory Access		Yes
Intel® Flex Memory Access		Yes
Execute Disable Bit		Yes

Click !!

Intel CPU VT-x, VT-d サポート確認方法

<http://ark.intel.com/search/advanced/?s=t&VTX=true&VTD=true>

Advanced Search Export

Filters Applied: Intel® Virtualization Technology (VT-x) | true Intel® Virtualization Technology for Directed I/O (VT-d) | true

Compare Now (0)

115 Matching Products

MODIFY FILTERS

Clear Filters Search

Compare
Select: All | None

Essentials

Family

Select

Processor Number

Code Name

Product Name	Launch Date	Processor Number	# of Cores	# of Threads	Clock Speed	Max Turbo Frequency	Cache	System Bus	Instruction Set	Embedded Options Available	Max TDP	Recommended Channel Price	VT-x	VT-d
Intel® Core™ i7-2640M Processor (4M Cache, 2.80 GHz)	Q4'11	i7-2640M	2	4	2.8 GHz	3.5 GHz	4 MB	5 GT/s	64-bit	No	35 W	\$346.00	Yes	Yes
Intel® Core™ i7-2760QM Processor (6M Cache, 2.40 GHz)	Q4'11	i7-2760QM	4	8	2.4 GHz	3.5 GHz	6 MB	5 GT/s	64-bit	No	45 W	\$378.00	Yes	Yes
Intel® Core™ i7-2860QM Processor (8M Cache, 2.50 GHz)	Q4'11	i7-2860QM	4	8	2.5 GHz	3.6 GHz	8 MB	5 GT/s	64-bit	No	45 W	\$568.00	Yes	Yes
Intel® Core™ i7-2960XM														

Intel® Virtualization Technology (VT-x) Options Available



Intel® Virtualization Technology for Directed I/O (VT-d)



Product Name

Launch Date

Processor Number

Intel® Core™ i7-2640M Processor (4M Cache, 2.80 GHz)

Q4'11

i7-2640M

Intel® Core™ i7-2760QM Processor (6M Cache, 2.40 GHz)

Q4'11

i7-2760QM

Intel® Core™ i7-2860QM Processor (8M Cache, 2.50 GHz)

Q4'11

i7-2860QM

Intel® Core™ i7-2960XM

VT-x

VT-d

Yes

Yes

Yes

Yes

Yes

Yes

SR-IOVサポートする Intel NIC一覧

<http://www.intel.com/support/network/adapter/pro100/sb/CS-031492.htm>

Intel® Server Adapters

FAQs: Using SR-IOV with Intel® Ethernet Server Adapters

Which Intel® Ethernet Adapters support SR-IOV?

- Intel® Ethernet Server Adapter X520-DA2
- Intel® Ethernet Server Adapter X520-SR1
- Intel® Ethernet Server Adapter X520-SR2
- Intel® Ethernet Server Adapter X520-LR1
- Intel® Ethernet Server Adapter X520-T2
- Intel® Gigabit ET Dual Port Server Adapter
- Intel® Gigabit EF Dual Port Server Adapter
- Intel® Gigabit ET2 Quad Port Server Adapter

Which hypervisors support SR-IOV on Intel® Ethernet Adapters?

Xen Hypervisor*

KVM* (Kernel Based Virtual Machine)

Which operating systems and distributions include virtual function driver support for guests?

Virtual Function (VF) drivers for guest operating systems are available for:

- Windows Server 2008 R2*
- Windows Server 2008*, 32-bit and 64-bit
- Linux* 2.6.30 kernel or later
- Red Hat Enterprise Linux* 5.4
- Red Hat Enterprise Linux 5.5
- SUSE Linux Enterprise Server* 11 SP1

Intel NIC VT-d, SR-IOV サポート確認方法

<http://www.intel.com/products/ethernet/resource.htm>

Controllerの型番からデータシートや参考資料が入手可能

The screenshot shows the Intel Ethernet Resource Center interface. It features three filter menus: 'Select Category' with options 'All', '10 Gigabit Ethernet', '10/100', and 'Gigabit Ethernet'; 'Select Product' with options '82580EB/82580DB', '82583V', '82598EB', '82599EB/ES', and 'I350'; and 'Select Resource Type' with options 'All', 'Application note', 'Datasheet', 'Design checklist', and 'Design guide'. Below these is a 'Keyword Search' field and a 'Tool Tips' link. A pagination control shows '<< < 1 > >>' and a dropdown set to '25'. The main content is a table with the following data:

Product	Category	Resource Link	Resource Type
82599EB/ES	10 Gigabit Ethernet	Intel® 82599 SR-IOV Driver Companion Guide, 1.0	Application note
82599EB/ES	10 Gigabit Ethernet	PCI-SIG SR-IOV Primer: An Introduction To SR-IOV Technology, 2.5	Application note
82599EB/ES	10 Gigabit Ethernet	Intel® 82599 10 GbE Controller Datasheet, 2.71	Datasheet
		Assigning Interrupts to Processor Cores	Application note
		Avoiding New Design Errors When Using Intel® Ethernet Controllers	Application note
		Manageability - Intel® Sideband Technology	Application note
		PCI Express* whitepaper	Application note
		Boot Agents for BIOS Engineers	Application note

参考文献

- Books

- PCI Express 設計の基礎と応用 (CQ出版社)
 - ISBN 978-4-7898-4641-7
- PCI Express System Architecture (MINDSHARE)
 - ISBN 978-0-321-15630-3
- Linux デバイスドライバプログラミング (ソフトバンククリエイティブ株式会社)
 - ISBN 978-4-7973-4642-8
- Understanding The Linux Kernel (O'REILLY)
 - ISBN 978-0-596-00565-8

- PCI-SIG

- PCI Express Base Specification, Revision 2.1, March 4, 2009
- Single Root I/O Virtualization and Sharing Specification, Revision 1.0, September 11, 2007

- Intel

- Intel Virtualization Technology for Directed I/O, Architecture Specification, Revision: 1.3
- Intel 82599 10 GbE Controller Datasheet, Revision Number: 2.7
- Intel 82599 SR-IOV Driver Companion Guide, Revision 1.00, May 2010
- PCI-SIG SR-IOV Primer, An Introduction to SR-IOV Technology, Revision 2.5, January 2011
- Product Specs from <http://ark.intel.com/>

予備スライド