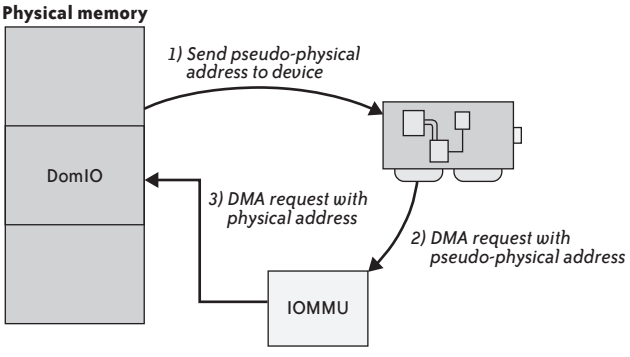

FIGURE 7-9. Direct device access using an IOMMU

Enhancing the memory management hardware can also remove the need for shadow page tables.* Both AMD and Intel have technology (respectively, Rapid Virtualization Indexing and Enhanced Page Tables) which perform the translation between pseudophysical addresses and physical addresses. Therefore there is no need for the hypervisor to create shadow page tables, as the whole translation occurs in hardware.

Of course, a far cheaper solution is to take the lessons learned from paravirtualization and apply them to unmodified guest operating systems. Although it is not possible to change core parts of the operating system, we can add device drivers, and moreover, Xen can modify the virtual hardware on which the operating system runs. To this end, the emulated hardware provides a *Xen platform device*, which appears as a PCI device to unmodified guest operating systems and provides access to the virtual platform. It is then possible to write frontend devices for the unmodified operating systems, which operate in the same way as frontends in paravirtualized operating systems. By doing this, we achieve I/O performance in hardware virtual machines that is comparable to the paravirtualized case.

When we introduced paravirtualization earlier in this chapter, we said that the only ways to get a commodity operating system running as a paravirtualized guest would be by doing it ourselves or by convincing the developers of a proprietary operating system that they should do it. As a testament to the success of paravirtualization, Microsoft has included *enlightenments* in Windows Server 2008, which improve the performance of memory management when running in a virtual machine. These enlightenments are equivalent to paravirtualized operations, as they rely on hypercalls to inform the hypervisor of the current operation.

* It should be noted that Xen's shadow page table implementation is highly optimized, and achieves competitive performance, but still has some overhead when compared with paravirtualized page tables.