cloud system is usually based on Virtual Desktop Infrastructure (VDI) solutions [7]. The foundation of virtual desktop solutions is server virtualization. Hypervisor is the core of the most popular virtualization technologies. We can use it to create a customized virtual desktop (VD). Administrator in cloud side deploys the operating system and a variety of applications for each user. Cloud terminal is connected to virtual desktop through the IP network, and then visits the virtual desktop via desktop displays protocol.

TABLE III. EXPERIMENTAL MACHINE INFORMATION

Type	Cloud Terminal	VDs in Cloud Side
CPU	Samsung S5PV210 (ARMCortex-A8)	QEMU Virtual CPU (cpu64-rhel6)
Clock	600MHz-1GHz	2.26GHz
Memory	312M	1G
Operating System	Debian6.0.4 (linux-2.6.35.7)	Ubuntu11.04(linux-3.0.0-16) Windows XP SP3 Windows 7 Ultimate SP1

TABLE IV. EXPERIMENT RESULTS

Device Information	Virtual Desktop in Cloud Side					
	Linux		Windows XP		Windows 7	
U-Disk Data Size	**Read and Write Speed (MB/s)**					
	Read	Write	Read	Write	Read	Write
10M	3.107	2.875	2.728	2.457	2.835	2.594
50M	2.665	2.491	2.564	2.347	2.474	2.378
100M	2.653	2.488	2.471	2.354	2.476	2.367
500M	2.493	2.407	2.378	2.212	2.439	2.198
1G	2.458	2.386	2.382	2.079	2.382	2.127
5G	2.336	2.277	2.263	2.106	2.338	2.083
Printer	**I/O Operations Performance**					
Printing	OK		OK		OK	
Copying	OK		OK		OK	
Scanning	OK		OK		OK	
Sound Card	**I/O Operations Performance**					
Audio In	OK		OK		OK	
Audio Out	OK		OK		OK	

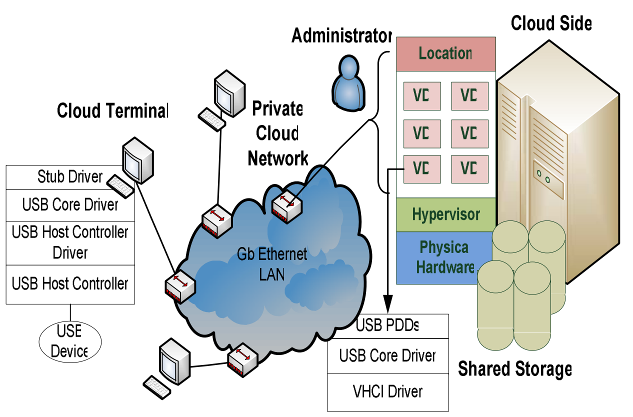

Figure 4. Architecture of Desktop Cloud System

Figure 4 builds the experimental environment for USB device redirection approach. Table Ⅲ shows machine information of cloud terminal and virtual desktop. Cloud terminal visits virtual desktop via spice [8], an open source desktop displays protocol. USB Devices to be evaluated include three types: storage, control and audio. We choose Teclast Coolflash USB3.0 U-disk as storage device, capacity for 8G and USB2.0 compatible. The control device we select is a Samsung SCS-4x20 series PCL6 multi-function printer. Audio device is a sound card, 7.1 Channel Sound. Table Ⅳ shows the evaluation results.

B. *Results and Conclusion*

By the experiments, we show that it is reasonable to expand the peripheral bus over an IP network to implement USB device redirection in desktop cloud system. We can functionally use various remote USB devices and different operating systems can access remote redirected devices without any modification. Furthermore, the I/O performance of remote USB devices in LAN is sufficient for actual usage.

As far as USB device redirection mechanism works properly, it still has the following drawbacks. First, since device redirection is implemented in a lower layer of an operating system and the raw device functions are being shared, it is unable to provide concurrent access to a remote USB device. Second, as the proposed approach is sensitive to IP network, issues such as network delay and jitters will influence usage of remote redirected devices. Third, USB device redirection mechanism has only been widely applied in LAN environment at present.

In future work, with the application of network lock mechanism, concurrent access to a remote redirected device will be realized. Meanwhile, the rapid progress of networking technologies will alleviate problems of network delay and jitters. Besides, we will continue to improve the USB device technology to support various network environments efficiently, such as a wireless network and a wide area network (WAN).

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