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USB-BASED NETWORKING AND I/O HUB

Background of the Invention

1. Field of the Invention

The present invention generally relates to computer system networks, and more particularly to networked personal computer systems. Still more particularly, this application relates to the use of Universal Serial Bus based communications for computer networking.

2. Description of the Prior Art

Computer networking is, and has been for some years, common in the industry. The ability to connect many computer systems in a network, whether as server/client or peer-to-peer, has become an indispensable tool to business, and has recently begun to enter users' homes. To make computer networking available to as many people as possible, it is desirable to make these networks as easy to set up and operate as possible.

Current networking equipment generally consists of a network interface card (NIC), which is installed in each computer system, then connected to other computer systems. Even the installation of the NIC is beyond the abilities of most computer users, since it generally entails actually opening the computer system chassis and physically installing the NIC on the system board.

Each NIC must then be connected either to a network hub, which allows many systems to be networked in a "hub and spoke" arrangement, or directly to one or more other systems

in a daisy-chain arrangement. Each system must then be configured to communicate with each other system, using appropriate operating-system drivers. Other equipment, such as a printer, may then be attached to the network, and shared between the computer systems on that network.

Because of the relative complexity of setting up a computer network, it is beyond the ability of most individuals or small businesses, unless they are willing and able to take on the cost of hiring a technician to do the installation. It would therefore be desirable to achieve a means of networking computer systems and equipment that is as easy as possible.

The Universal Serial Bus (USB) specification describes a cable bus that supports data exchange between a host computer and a wide range of simultaneously accessible peripherals. The bus allows peripherals to be attached, configured, used, and detached while the host and other peripherals are in operation, i.e., the peripherals are "hot swappable." Because most personal computer systems now include an installed USB port, users are able to simply plug in any number of peripherals to the host computer system, allowing a wide range of devices to be easily attached and detached.

The host computer system is the system where the USB Host Controller is installed. This includes the host hardware platform (CPU, bus, etc.) and the operating system in use; this is generally the only actual computer system present, with all other attached USB devices being either USB hubs or peripheral devices for that computer system. It

is important to note that the USB specification, available at <http://www.usb.org> and hereby incorporated by reference, requires that only one host be present in any USB system.

A USB system has three primary types of devices, the USB host, described above; one or more USB devices, such as printers, scanners, and modems; and the USB interconnect, which is the manner in which USB devices are connected to and communicate with the host. The interconnect includes the Bus Topology, the Inter-layer Relationships, Data Flow Models, and the USB Schedule. The details of the interconnect, and device and host requirements, may be found in the USB specification, and is not of concern to the average user.

Because of the ease of using USB connections and devices for the average user, it is a preferred means of implementing many communications between computer systems and devices. Since the USB specification requires that there is only one USB host in any system, however, USB has not been available for use in networking multiple computer systems. Therefore, it would be desirable to provide a means for combining the ease-of-use of a USB system into a computer networking system, to provide an improved computer networking system that is technically accessible to most users.

Summary of the Invention

It is therefore one object of the present invention to provide an improved computer system network.

It is another object of the present invention to provide an improved system and method for personal computer networking.

It is yet another object of the present invention to provide an improved system and method for personal computer networking utilizing Universal Serial Bus based communications.

There is therefore provided a system and method for providing network communications between personal computer systems using USB communications. The disclosed USB networking hub allows multiple hosts to exist in a USB-based network. The networking hub includes an integrated virtual network adapter, which provides for communications among and between multiple hosts.

The above as well as additional objectives, features, and advantages of the present invention will become apparent in the following detailed written description.

Brief Description of the Drawings

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, however, as well as a preferred mode of use, further objectives, and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

Figure 1 is a block diagram of a data processing system in accordance with the preferred embodiment of the present invention;

Figure 2A depicts a block diagram of a networking hub in accordance with the preferred embodiment of the present invention;

Figure 2B depicts a block diagram of a networking hub in accordance with an alternate embodiment of the present invention;

Figure 3 is a more detailed block diagram of a virtual network adapter in accordance with a preferred embodiment of the present invention;

Figure 4 depicts a flowchart of the initialization process of the virtual network adapter in accordance with a preferred embodiment of the present invention; and

Figure 5 is a flowchart of a data transmission routine in accordance with a preferred embodiment of the present invention.

Description of the Preferred Embodiment

The following description details the operation and features of several preferred embodiments of the present invention, but it will be understood by those of skill in the art that the scope of the invention is defined only by the issued claims, and not by any description herein.

With reference now to the figures, and in particular with reference to **Figure 1**, a block diagram of a data processing system in which a preferred embodiment of the present invention may be implemented is depicted. Data processing system **100** may be, for example, one of the desktop models of personal computers available from International Business Machines Corporation of Armonk, New York. Data processing system **100** includes processors **101** and **102**, which in the exemplary embodiment are each connected to level two (L2) caches **103** and **104**, respectively, which are connected in turn to a system bus **106**.

Also connected to system bus **106** is system memory **108** and Primary Host Bridge (PHB) **122**. PHB **122** couples I/O bus **112** to system bus **106**, relaying and/or transforming data transactions from one bus to the other. In the exemplary embodiment, data processing system **100** includes graphics adapter **118** connected to I/O bus **112**, receiving user interface information for display **120**. Peripheral devices such as nonvolatile storage **114**, which may be a hard disk drive, and keyboard/pointing device **116**, which may include a conventional mouse, a trackball, or the like, are connected via an Industry Standard Architecture (ISA) bridge **121** to I/O bus **112**. PHB **122** is also connected to PCI slots **124** and USB controller **126** via I/O bus **112**.

The exemplary embodiment shown in **Figure 1** is provided solely for the purposes of explaining the invention and those skilled in the art will recognize that numerous variations are possible, both in form and function. For instance, data processing system 100 might also include a compact disk read-only memory (CD-ROM) or digital video disk (DVD) drive, a sound card and audio speakers, and numerous other optional components. All such variations are believed to be within the spirit and scope of the present invention. Data processing system 100 and the exemplary networking hubs described below are provided solely as examples for the purposes of explanation and are not intended to imply architectural limitations.

Referring now to **Figure 2A**, the networking hub 200 includes multiple sub-hubs, 202,204,206, each of which has an associated virtual network adapter (VNA) 210,212,214, respectively. Each sub-hub is connected to a single upstream host at host connections 220,222,224, and is connected to one or more USB devices on ports 230,232,234. It is noted that the USB specification refers to USB peripheral devices as "functions," and the terms "device" and "function" will be used interchangeably here. Each sub-hub allows communications, in a conventional manner, between its respective upstream host and devices attached to its ports. Although, in this exemplary diagram, only one port is shown attached to each sub-hub, those of skill in the art will realize that each sub-hub can support multiple ports.

The respective VNAs 210,212,214 of each sub-hub are interconnected over logical interconnect 240 to provide for communications among and between each sub-hub. By communicating over the VNA system, communications are

provided between the multiple hosts. Each sub-hub can accommodate a single upstream connection, a single VNA, and one or more downstream connections. It should be noted that upstream connections 220,222,224, need not be directly connected to a host, but may be connected, for example, over a series of interconnected USB hubs.

The VNA system is provided to overcome one limitation of the USB specification, which requires that only one host can connect to each USB system. The VNA 210,212,214 appears to each host, in the preferred embodiment, as an ethernet adapter attached to its respective sub-hub 202,204,206. Each host therefore is able to communicate with each other sub-hub, and with the nodes and devices attached to the other sub-hubs, by communicating over the VNAs of the respective sub-hubs.

With reference now to **Figure 2B**, an alternate networking hub 250 is provided, in which a single VNA controller 260 manages communications between each sub-hub 252,254,256. This embodiment, which appears to the hosts and USB devices to be functionally identical to the embodiment of Figure 2A, reduces needless duplication of logic by combining the functions of multiple VNA controllers 210,212,214 into a single VNA controller 260. The single VNA appears to each sub-hub as its own dedicated network device.

This system operates as above, allowing hosts on upstream attachments 270,272,274 communicate via sub-hubs 252,254,256, respectively, to USB devices on ports 280,282,284. VNA 250 allows communications between the sub-hubs, so that each host can effectively communicate with other hosts. Inter-VNA module 286 and inter-hub VNA

connection 288 allow multiple networking hubs to be interconnected.

Referring now to **Figure 3**, a more detailed block diagram of an exemplary VNA 300 is shown. VNA 300 is a single VNA with multiple sub-hub inputs, as shown in Figure 2A. USB I/F blocks 330, 340, 350 are USB interface connections for the USB sub-hubs which the VNA interconnects. These are connected to microcontroller 310, which manages VNA communications. The VNA firmware 370 is preferably stored in a non-volatile FLASH memory. Random access memory 360 is used as a buffer and scratchpad memory.

The inter-VNA port 380 is an optional port used to connect directly to another VNA. In the preferred embodiment, communications over this port are standard serial communications, and a standard null-modem cable can be used to connect multiple VNAs. Of course, if a higher bandwidth is desired, this port can be implemented with any number of high-speed interconnects.

The USB I/F (VNA) block 320 is an optional dedicated USB port for the VNA to act as a USB "function" or device. This may be used for a USB host to communicate directly with the VNA, for example to update the VNA firmware.

In reference to **Figure 4**, a flowchart detailing the initialization sequence of the network hub is shown. Upon startup (**step 410**), the VNA microcontroller initializes and enables the USB interfaces to be recognized and attached by any attached sub-hubs (**step 420**). The connected sub-hubs then recognize the VNA and attach it as a USB function (**step 430**). After this, when the host queries the sub-hub over its USB upstream connection (**step 440**), the sub-hub indicates the VNA as an attached USB function (**step 450**).

The host then attaches the VNA as a USB/Network function (step 460), since it sees the VNA as a network adapter attached to the USB sub-hub. The host then loads an appropriate network driver for the VNA (step 470), and the initialization routine ends (step 480).

With reference now to Figure 5, a flowchart showing the VNA data transport routine is shown. When the system is operating (step 510), the VNA microcontroller will receive a data packet from a host via the sub-hub over one of its USB interfaces (step 520). This data packet is buffered in the VNA RAM (step 530), then sent out to the destination sub-hub (step 540). It should be noted that when the data packet is resent out, the VNA controller will rebroadcast this packet only to the non-originating USB interfaces; this prevents the originating sub-hub from receiving the resent packet broadcast. Next, if the inter-VNA port is enabled (step 550), the data packet is also sent out over the inter-VNA connection (step 560). Finally, when all broadcasts have completed, the VNA RAM buffer is cleared (step 570) and the routine ends (step 580).

While the invention has been particularly shown and described with reference to a preferred embodiment, it will be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the spirit and scope of the invention. For example, while the above description discusses is specifically drawn to the Universal Serial Bus specification, the disclosed networking system and virtual network adapter can be modified to any number of communications standards and different computer architectures and systems. Other variations are certainly

within the ability of one skilled in the art, and are expected to fall within the scope of the claims.

**CLAIMS:**

1. A computer system network, comprising:
a plurality of computer systems each having a communications port;
a device hub connected to each of said communications ports; and
at least one peripheral device connected to said device hub;
wherein said device hub appears to each computer system as a hub with an attached network adapter.
2. The network of claim 1, wherein said device hub has a plurality of sub-hubs, each sub-hub connected to a respective one of said computer systems.
3. The network of claim 1, wherein said device hub comprises a microprocessor system which emulates a dedicated network adapter for each of said computer systems.
4. The network of claim 1, wherein said computer systems communicate with said device hub according to the universal serial bus specification.
5. The network of claim 1, wherein said communications port is a USB port.
6. The network of claim 1, wherein said computer systems communicate with each other over said device hub.
7. The network of claim 1, wherein computer systems each may operate at least one of said peripheral devices.



8. A communications hub, comprising:
a plurality of host connections, each operatively connected to communicate with a host computer system;
a plurality of sub-hubs, each connected to a respective one of said host connections; and
a virtual network adapter, connected to each of said sub-hubs,
wherein said virtual network adapter emulates a network adapter connected to each sub-hub, and enables communications between said sub-hubs.
9. The hub of claim 8, wherein said host computer systems communicate with said communications hub according to the universal serial bus specification.
10. The hub of claim 8, wherein said host connections are USB ports.
11. The hub of claim 8, wherein said host computer systems communicate with each other over said communications hub.
12. The hub of claim 8, wherein each sub-hub is configured to communicate with at least one peripheral device.
13. A communications hub, comprising:
a plurality of host connections, each operatively connected to communicate with a host computer system;
a plurality of sub-hubs, each connected to a respective one of said host connections; and
a plurality of virtual network adapters, each connected to a respective one of said sub-hubs,



wherein each of said virtual network adapters emulates a network adapter connected to its respective sub-hub, and are inter connected to enable communications between said sub-hubs.

14. The hub of claim 13, wherein said host computer systems communicate with said communications hub according to the universal serial bus specification.

15. The hub of claim 13, wherein said host connections are USB ports.

16. The hub of claim 13, wherein said host computer systems communicate with each other over said communications hub.

17. The hub of claim 13, wherein each sub-hub is configured to communicate with at least one peripheral device.

18. A communications hub, comprising:

- a plurality of host connections, each operatively connected to communicate with a host computer system;

- a plurality of sub-hubs, each connected to a respective one of said host connections; and

- a virtual network adapter, connected to each of said sub-hubs,

wherein said virtual network adapter performs the steps of:

- receiving data from a first host computer system, over a first one of said sub-hubs; and

- sending said data to all other said sub-hubs, but not to said first one of said sub-hubs.



19. The hub of claim 18, wherein said host computer systems communicate with said communications hub according to the universal serial bus specification.

20. The hub of claim 18, wherein said host connections are USB ports.

21. The hub of claim 18, wherein said host computer systems communicate with each other over said communications hub.

22. The hub of claim 18, wherein each sub-hub is configured to communicate with at least one peripheral device.

22. The hub of claim 18, wherein said virtual network adapter can be connected to the virtual network adapters of other hubs, allowing host communications therebetween.