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**PCIE TUNNELING THROUGH SAS**CROSS REFERENCE TO RELATED  
APPLICATIONS

This document claims priority to U.S. Provisional Patent Application No. 61/836,282 (filed on Jun. 18, 2013) entitled PCIE TUNNELING THROUGH SAS, which is hereby incorporated by reference.

## FIELD OF THE INVENTION

The invention generally relates to tunneling Peripheral Component Interconnect Express (PCIe) traffic through Serial Attached Small Computer System Interface (SAS) connections of a SAS domain via the PCIe protocol.

## BACKGROUND

Numerous storage device interfaces exist and continually challenge traditional SAS domains. For example, PCIe-based storage devices are now being configured in parallel with traditional SAS domains. These PCIe storage devices may be required to transfer data to and from upstream SAS storage controllers, where the data can then be placed on a native PCIe interface. But, PCIe is a packet based, connectionless transfer protocol and SAS is an end-to-end, connection based protocol that does not provide for connectionless transfers, making interworking particularly challenging.

## SUMMARY

Systems and methods presented herein provide for tunneling PCIe traffic through a SAS domain comprising a topology of one or more PCIe capable SAS expanders, one or more traditional SAS expanders, and one or more PCIe capable SAS controllers. The tunneling of PCIe traffic allows PCIe target devices (e.g., SCSI-Over-PCIe (SOP) devices, Non-Volatile Memory Express (NVMe) devices, and Serial AT-Attachment Express (SATAexpress) devices) in the SAS topology to be connected to a PCIe-based host system through a SAS domain, including SAS expanders and a SAS controller. In one embodiment, a data system includes a Serial Attached Small Computer System Interface expander, a Peripheral Component Interconnect Express target device coupled to the expander, and a Serial Attached Small Computer System Interface controller communicatively coupled to a host system and the expander. The controller is operable to open a SAS connection with the expander via the Serial Attached Small Computer System Interface protocol, and to transport packet data between the target device and the host system through the connection via the Peripheral Component Interconnect Express protocol. For example, the controller and the expander may be operable to buffer packets of data in the connection. The controller may issue a number of the data packets to be transferred in the connection. Then, the issued number of data packets are transported between the target device and the host system through the SAS connection via the Peripheral Component Interconnect Express protocol.

The various embodiments disclosed herein may be implemented in a variety of ways as a matter of design choice. For example, the embodiments may take the form of computer hardware, software, firmware, or combinations thereof. Other exemplary embodiments are described below.

## BRIEF DESCRIPTION OF THE FIGURES

Some embodiments of the present invention are now described, by way of example only, and with reference to the

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accompanying drawings. The same reference number represents the same element or the same type of element on all drawings.

FIG. 1 is a block diagram of an exemplary data system that tunnels PCIe data through a SAS domain.

FIG. 2 is a flowchart of an exemplary process for tunneling PCIe data through a SAS domain.

FIG. 3 is an exemplary block diagram of SAS links that are operable to establish SAS connections between SAS components in a SAS domain and tunnel PCIe data packets.

FIG. 4 is a block diagram of exemplary PCIe tunneling through a SAS domain.

FIG. 5 is another block diagram of exemplary PCIe tunneling through a SAS domain.

FIG. 6 is a block diagram of an exemplary PCIe capable SAS expander.

FIG. 7 is a block diagram of an exemplary PCIe target aggregator of the PCIe capable SAS expander of FIG. 6.

FIG. 8 is a block diagram of an exemplary PCIe capable SAS controller.

FIG. 9 is a block diagram of an exemplary PCIe/SAS interworking initiator of the PCIe capable SAS controller of FIG. 8.

FIG. 10 is a block diagram of an exemplary computing system in which a computer readable medium provides instructions for performing methods herein.

## DETAILED DESCRIPTION OF THE FIGURES

The figures and the following description illustrate specific exemplary embodiments of the invention. It will thus be appreciated that those skilled in the art will be able to devise various arrangements that, although not explicitly described or shown herein, embody the principles of the invention and are included within the scope of the invention. Furthermore, any examples described herein are intended to aid in understanding the principles of the invention and are to be construed as being without limitation to such specifically recited examples and conditions. As a result, the invention is not limited to the specific embodiments or examples described below.

FIG. 1 is a block diagram of an exemplary data system that tunnels PCIe data through a SAS domain **100**. In this embodiment, the SAS domain **100** is configured with a PCIe capable SAS expander (PCIe/SAS expander **101**), a traditional SAS expander **102**, and another PCIe capable SAS expander (PCIe/SAS expander **103**) coupled to a PCIe host system **105** through a PCIe capable SAS controller (PCIe/SAS controller **104**). The expander **102** is coupled between the expanders **101** and **103** and is operable to connect to a plurality of SAS target devices **110** via the SAS protocol. The PCIe/SAS expanders **101** and **103** are both operable to connect and communicate with PCIe target devices **111** via the PCIe protocol and SAS target devices **110** (as well as other SAS expanders **102**) via the SAS protocol. The combination of the PCIe/SAS controller **104** and a PCIe/SAS expander **101/103** allows the data system **100** to transfer PCIe packet communications between the PCIe host system **105** and PCIe target devices **111** through the SAS domain **100** by tunneling the PCIe packet data through the SAS protocol. The PCIe/SAS controller **104** also translates PCIe data to SAS to route data from the PCIe host system **105** to the appropriate SAS target device **110**. In one embodiment, a number of PCIe target devices **111** are directly attached to the PCIe/SAS controller **104** in a manner that allows PCIe packets to flow through a port layer and a PCIe/SAS interworking initiator (explained