

To: T10 Technical Committee  
 From: Steven Fairchild, HP ([steve.Fairchild@hp.com](mailto:steve.Fairchild@hp.com))  
 Date: 4 September 2003  
 Subject: SAS Discover Algorithm Modification

The purpose for this proposal is to correct the existing Discover process algorithm example in Appendix J. The algorithm in Appendix J does not match the text in section 4.6.7. It implemented a maximal descent algorithm and the text describes the proper level descent algorithm. For small topologies, the results are equivalent. However for topologies with more than two levels of edge expander devices in an edge expander device set, the existing example is incorrect. The example has been corrected and the text for Appendix J is included in this proposal.

- **The first recommendation is to accept the Discover process example code changes to appendix J outlined for inclusion in the SAS 1.1 specification.**

This proposal also introduces a Discover process route table optimization that reduces the memory requirements for route tables in configurable expander devices. The Discover process optimization is to qualify the SAS address for entry into the route table by following this set of rules;

- a) SAS addresses referencing the expander device being configured (self-referencing addresses) shall be excluded from the expander device route table.
- b) SAS addresses directly connected to the expander device being configured shall be excluded from the expander device route table.
- c) The first instance of a SAS address shall be inserted in the configured expander device route table. Subsequent instances of a SAS address shall be excluded from the configured expander device route table.
- d) Discovered phys with a DIRECT route attribute shall be inserted in the expander device route table even if the end device is currently not attached and a SAS address is not available. If a SAS address is not available a zero value shall be inserted and the DISABLE EXPANDER ROUTE ENTRY bit for the entry shall be set to one in the SMP CONFIGURE ROUTE INFORMATION function (see 10.4.3.9).

The result of the Discover process route table optimization is to improve the efficiency of the limited memory resource that exists in edge expander devices and fanout expander devices. Otherwise, the memory required to support edge expander device sets with 3 or more levels exceeds the practical limits on ASIC designs.

The Discover process route table optimization also reduces the number of SMP commands required to configure expander devices; which reduces the bandwidth and time impact for doing the Discover process.

The unfortunate impact of this change is to make the Discover process algorithm defined in SAS 1.0 incompatible with the Discover process route table optimization described, because the location of the route table entries in the configurable route table of configurable expander devices will not be consistent. The diagrams at the end of this proposal illustrate the change in the route table entry layout.

- **The second recommendation is to accept the text and example code changes outlined to implement the Discover route table optimization for inclusion in the SAS 1.1 specification.**

## Changes to correct the Discover process algorithm in Appendix J.

The following corrections to the example Discover process algorithm are appropriate to have the example follow the existing text in the Expander device routing section (4.6.7).

**Substitute the contents of J.2 for (changes are highlighted, code that is related to the Discover route table optimization is indicated in blue);**

```
// SASDiscoverSimulation.h

// assume the maximum number of phys in an expander device is 128
#define MAXIMUM_EXPANDER_PHYS 128

// assume the maximum number of indexes per phy is 128
#define MAXIMUM_EXPANDER_INDEXES 128

// limit to 8 initiators for this example
#define MAXIMUM_INITIATORS 8

// defines for address frame types
#define ADDRESS_IDENTIFY_FRAME 0x00
#define ADDRESS_OPEN_FRAME 0x01

// defines for SMP frame types
#define SMP_REQUEST_FRAME 0x40
#define SMP_RESPONSE_FRAME 0x41

// defines for SMP request functions
#define REPORT_GENERAL 0x00
#define REPORT_MANUFACTURER_INFORMATION 0x01
#define DISCOVER 0x10
#define REPORT_PHY_ERROR_LOG 0x11
#define REPORT_PHY_SATA 0x12
#define REPORT_ROUTE_INFORMATION 0x13
#define CONFIGURE_ROUTE_INFORMATION 0x90
#define PHY_CONTROL 0x91

// defines for the protocol bits
#define SATA 0x01
#define SMP 0x02
#define STP 0x04
#define SSP 0x08

// defines for open responses, arbitrary values, not defined in the spec
#define OPEN_ACCEPT 0
#define OPEN_REJECT_BAD_DESTINATION 1
#define OPEN_REJECT_RATE_NOT_SUPPORTED 2
#define OPEN_REJECT_NO_DESTINATION 3
#define OPEN_REJECT_PATHWAY_BLOCKED 4
#define OPEN_REJECT_PROTOCOL_NOT_SUPPORTED 5
#define OPEN_REJECT_RESERVE_ABANDON 6
#define OPEN_REJECT_RESERVE_CONTINUE 7
#define OPEN_REJECT_RESERVE_INITIALIZE 8
#define OPEN_REJECT_RESERVE_STOP 9
#define OPEN_REJECT_RETRY 10
#define OPEN_REJECT_STP_RESOURCES_BUSY 11
#define OPEN_REJECT_WRONG_DESTINATION 12

// definitions for discovery algorithm use
enum
{
    SAS_SIMPLE_LEVEL_DESCENT = 0,
    SAS_UNIQUE_LEVEL_DESCENT
};
```

```

// definitions for SMP function results
enum SMPFunctionResult
{
    SMP_FUNCTION_ACCEPTED = 0,
    SMP_UNKNOWN_FUNCTION,
    SMP_FUNCTION_FAILED,
    SMP_INVALID_REQUEST_FRAME_LENGTH,
    SMP_PHY_DOES_NOT_EXIST = 0x10,
    SMP_INDEX_DOES_NOT_EXIST,
    SMP_PHY_DOES_NOT_SUPPORT_SATA,
    SMP_UNKNOWN_PHY_OPERATION
};

// DeviceTypes
enum DeviceTypes
{
    NO_DEVICE = 0,
    END_DEVICE,
    EDGE_EXPANDER_DEVICE,
    FANOUT_EXPANDER_DEVICE
};

// RoutingAttribute
enum RoutingAttribute
{
    DIRECT = 0,
    SUBTRACTIVE,
    TABLE
};

// RouteFlag
enum DisableRouteEntry
{
    ENABLED = 0,
    DISABLED
};

// PhyLinkRate(s)
enum PhysicalLinkRate
{
    RATE_UNKNOWN = 0,
    PHY_DOES_NOT_EXIST,
    PHY_DISABLED,
    PHY_FAILED,
    SPINUP_HOLD_OOB,
    GBPS_1_5 = 8,
    GBPS_3_0
};

// PhyOperation
enum PhyOperation
{
    NOP = 0,
    LINK_RESET,
    HARD_RESET,
    DISABLE,
    CLEAR_ERROR_LOG = 5,
    CLEAR_AFFILIATION
};

// provide the simple type definitions
typedef unsigned char byte;
typedef unsigned short word;
typedef unsigned long dword;
typedef unsigned _int64 quadword;

```

```

// the structures assume a char bitfield is valid, this is compiler
// dependent defines would be more portable, but less descriptive

// the Identify frame is exchanged following OOB, for this
// code it contains the identity information for the attached device
// and the initiator application client
struct Identify
{
    // byte 0
    byte AddressFrame:4;           // ADDRESS_IDENTIFY_FRAME
    byte DeviceType:3;             // END_DEVICE
    //

    byte RestrictedByte0Bit7:1;

    // byte 1
    byte RestrictedByte1;

    // byte 2
    union
    {
        struct
        {
            byte RestrictedByte2Bit0:1;
            byte SMPInitiator:1;
            byte STPInitiator:1;
            byte SSPInitiator:1;
            byte ReservedByte2Bit4_7:4;
        };
        byte InitiatorBits;
    };

    // byte 3
    union
    {
        struct
        {
            byte RestrictedByte3Bit0:1;
            byte SMPTarget:1;
            byte STPTarget:1;
            byte SSPTarget:1;
            byte ReservedByte3Bit4_7:4;
        };
        byte TargetBits;
    };

    // byte 4-11
    byte RestrictedByte4_11[8];

    // byte 12-19
    quadword SASAddress;

    // byte 20
    byte PhyIdentifier;

    // byte 21-23
    byte RestrictedByte20_23[3];

    // byte 24-27
    byte ReservedByte24_27[4];

    // byte 28-31
    dword CRC;
};

// the Open address frame is used to send open requests
struct OpenAddress
{

```

```

// byte 0
byte AddressFrame:4;           // ADDRESS_OPEN_FRAME
byte Protocol:3;              // SMP
                               // STP
                               // SSP

byte Initiator:1;

// byte 1
byte ConnectionRate:4;        // GBPS_1_5
                               // GBPS_3_0

byte Features:4;

// byte 2-3
word InitiatorConnectionTag;

// byte 4-11
quadword DestinationSASAddress;

// byte 12-19
quadword SourceSASAddress;

// byte 20
byte CompatibleFeatures;

// byte 21
byte PathwayBlockedCount;

// byte 22-23
word ArbitrationWaitTime;

// byte 24-27
byte MoreCompatibleFeatures[4];

// byte 28-31
dword CRC[4];
};

// request specific bytes for a general input function
struct SMPRequestGeneralInput
{
    // byte 4-7
    dword CRC;
};

// request specific bytes for a phy input function
struct SMPRequestPhyInput
{
    // byte 4-7
    byte IgnoredByte4_7[4];

    // byte 8
    byte ReservedByte8;

    // byte 9
    byte PhyIdentifier;

    // byte 10
    byte IgnoredByte10;

    // byte 11
    byte ReservedByte11;

    // byte 12-15
    dword CRC;
};

// the ConfigureRouteInformation structure is used to provide the

```

```

// expander route entry for the expander route table, it is intended
// to be referenced by the SMPRequestConfigureRouteInformation struct
struct ConfigureRouteInformation
{
    // byte 12
    byte IgnoredByte12Bit0_6:7;
    byte DisableRouteEntry:1;    // if a routing error is detected
                                // then the route is disabled by
                                // setting this bit

    // byte 13-15
    byte IgnoredByte13_15[3];

    // byte 16-23
    quadword RoutedSASAddress;    // identical to the AttachedSASAddress
                                // found through discovery

    // byte 24-35
    byte IgnoredByte24_35[12];

    // byte 36-39
    byte ReservedByte36_39[4];
};

// request specific bytes for SMP ConfigureRouteInformation function
struct SMPRequestConfigureRouteInformation
{
    // byte 4-5
    byte ReservedByte4_5[2];

    // byte 6-7
    word ExpanderRouteIndex;

    // byte 8
    byte ReservedByte8;

    // byte 9
    byte PhyIdentifier;

    // byte 10-11
    byte ReservedByte10_11[2];

    // byte 12-39
    struct ConfigureRouteInformation Configure;

    // byte 40-43
    dword CRC;
};

// the PhyControlInformation structure is used to provide the
// expander phy control values, it is intended
// to be referenced by the SMPRequestPhyControl struct
struct PhyControlInformation
{
    // byte 12-31
    byte IgnoredByte12_31[20];

    // byte 32
    byte IgnoredByte32Bit0_3:4;
    byte ProgrammedMinimumPhysicalLinkRate:4;

    // byte 33
    byte IgnoredByte33Bit0_3:4;
    byte ProgrammedMaximumPhysicalLinkRate:4;

    // byte 34-35
    byte IgnoredByte34_35[2];
};

```

```

// byte 36
byte PartialPathwayTimeoutValue:4;
byte ReservedByte36Bit4_7:4;

// byte 37-39
byte ReservedByte37_39[3];
};

// request specific bytes for SMP Phy Control function
struct SMPRequestPhyControl
{
    // byte 4-7
    byte IgnoredByte4_7[4];

    // byte 8
    byte ReservedByte8;

    // byte 9
    byte PhyIdentifier;

    // byte 10
    byte PhyOperation;

    // byte 11
    byte UpdatePartialPathwayTimeoutValue:1;
    byte ReservedByte11Bit1_7:7;

    // byte 12-39
    struct PhyControlInformation Control;

    // byte 40-43
    dword CRC;
};

// generic structure referencing an SMP Request, must be initialized
// before being used
struct SMPRequest
{
    // byte 0
    byte SMPFrameType; // always SMP_REQUEST_FRAME

    // byte 1
    byte Function;
    // REPORT_GENERAL
    // REPORT_MANUFACTURER_INFORMATION
    // DISCOVER
    // REPORT_PHY_ERROR_LOG
    // REPORT_PHY_SATA
    // REPORT_ROUTE_INFORMATION
    // CONFIGURE_ROUTE_INFORMATION
    // PHY_CONTROL

    // byte 2-3
    byte ReservedByte2_3[2];

    // bytes 4-n
    union
    {
        struct SMPRequestGeneralInput ReportGeneral;
        struct SMPRequestGeneralInput ReportManufacturerInformation;
        struct SMPRequestPhyInput Discover;
        struct SMPRequestPhyInput ReportPhyErrorLog;
        struct SMPRequestPhyInput ReportPhySATA;
        struct SMPRequestPhyInput ReportRouteInformation;
        struct SMPRequestConfigureRouteInformation ConfigureRouteInformation;
        struct SMPRequestPhyControl PhyControl;
    } Request;
};

```



```

};

// request specific bytes for SMP Report General response, intended to be
// referenced by SMPResponse
struct SMPResponseReportGeneral
{
    // byte 4-5
    word ExpanderChangeCount;

    // byte 6-7
    word ExpanderRouteIndexes;

    // byte 8
    byte ReservedByte8;

    // byte 9
    byte NumberOfPhys;

    // byte 10
    byte ConfigurableRouteTable:1;
    byte Configuring:1;
    byte ReservedByte10Bit2_7:6;

    // byte 11
    byte ReservedByte11;

    // byte 12-15
    dword CRC;
};

// request specific bytes for SMP Report Manufacturer Information response,
// intended to be referenced by SMPResponse
struct SMPResponseReportManufacturerInformation
{
    // byte 4-7
    byte IgnoredByte4_7[4];

    // byte 8
    byte ReservedByte8;

    // byte 9-10
    byte IgnoredByte9_10[2];

    // byte 11
    byte ReservedByte11;

    // byte 12-19
    byte VendorIdentification[8];

    // byte 20-35
    byte ProductIdentification[16];

    // byte 36-39
    byte ProductRevisionLevel[4];

    // byte 40-59
    byte VendorSpecific[20];

    // byte 60-63
    dword CRC;
};

// the Discover structure is used to retrieve expander port information
// it is intended to be referenced by the SMPResponseDiscover structure
struct Discover
{
    // byte 12

```

```

byte ReservedByte12Bit0_3:4;
byte AttachedDeviceType:3;
byte IgnoredByte12Bit7:1;

// byte 13
byte NegotiatedPhysicalLinkRate:4;
byte ReservedByte13Bit4_7:4;

// byte 14
union
{
    struct
    {
        byte AttachedSATAHost:1;
        byte AttachedSMPInitiator:1;
        byte AttachedSTPInitiator:1;
        byte AttachedSSPInitiator:1;
        byte ReservedByte14Bit4_7:4;
    };
    byte InitiatorBits;
};

// byte 15
union
{
    struct
    {
        byte AttachedSATADevice:1;
        byte AttachedSMPTarget:1;
        byte AttachedSTPTarget:1;
        byte AttachedSSPTarget:1;
        byte ReservedByte15Bit4_7:4;
    };
    byte TargetBits;
};

// byte 16-23
quadword SASAddress;

// byte 24-31
quadword AttachedSASAddress;

// byte 32
byte AttachedPhyIdentifier;

// byte 33-39
byte ReservedByte33_39[7];

// byte 40
byte HardwareMinimumPhysicalLinkRate:4;
byte ProgrammedMinimumPhysicalLinkRate:4;

// byte 41
byte HardwareMaximumPhysicalLinkRate:4;
byte ProgrammedMaximumPhysicalLinkRate:4;

// byte 42
byte PhyChangeCount;

// byte 43
byte PartialPathwayTimeoutValue:4;
byte IgnoredByte36Bit4_6:3;
byte VirtualPhy:1;

// byte 44
byte RoutingAttribute:4;
byte ReservedByte44Bit4_7:4;

```

```

// byte 45-49
byte ReservedByte45_49[5];

// byte 50-51
byte VendorSpecific[2];

// byte 52-55
dword CRC;
};

// response specific bytes for SMP Discover, intended to be referenced by
// SMPResponse
struct SMPResponseDiscover
{
    // byte 4-7
    byte IgnoredByte4_7;

    // byte 8
    byte ReservedByte8;

    // byte 9
    byte PhyIdentifier;

    // byte 10
    byte IgnoredByte10;

    // byte 11
    byte ReservedByte11;

    // byte 12-55
    struct Discover Result;
};

// response specific bytes for SMP Report Phy Error Log, intended to be
// referenced by SMPResponse
struct SMPResponseReportPhyErrorLog
{
    // byte 4-7
    byte IgnoredByte4_7;

    // byte 8
    byte ReservedByte8;

    // byte 9
    byte PhyIdentifier;

    // byte 10
    byte IgnoredByte10;

    // byte 11
    byte ReservedByte11;

    // byte 12-15
    dword InvalidDwordCount;

    // byte 16-19
    dword DisparityErrorCount;

    // byte 20-23
    dword LossOfDwordSynchronizationCount;

    // byte 24-27
    dword PhyResetProblemCount;

    // byte 28-31
    dword CRC;
};

```

```

};

// this structure describes the Register Device to Host FIS defined in the
// SATA specification
struct RegisterDeviceToHostFIS
{
    // byte 24
    byte FISType;

    // byte 25
    byte ReservedByte25Bit0_5:6;
    byte Interrupt:1;
    byte ReservedByte25Bit7:1;

    // byte 26
    byte Status;

    // byte 27
    byte Error;

    // byte 28
    byte SectorNumber;

    // byte 29
    byte CylLow;

    // byte 30
    byte CylHigh;

    // byte 31
    byte DevHead;

    // byte 32
    byte SectorNumberExp;

    // byte 33
    byte CylLowExp;

    // byte 34
    byte CylHighExp;

    // byte 35
    byte ReservedByte35;

    // byte 36
    byte SectorCount;

    // byte 37
    byte SectorCountExp;

    // byte 38-43
    byte ReservedByte38_43[6];
};

// response specific bytes for SMP Report Phy SATA, intended to be
// referenced by SMPResponse
struct SMPResponseReportPhySATA
{
    // byte 4-7
    byte IgnoredByte4_7;

    // byte 8
    byte ReservedByte8;

    // byte 9
    byte PhyIdentifier;

```

```

// byte 10
byte IgnoredByte10;

// byte 11
byte AffiliationValid:1;
byte AffiliationsSupported:1;
byte ReservedByte11Bit2_7:6;

// byte 12-15
byte ReservedByte12_15[4];

// byte 16-32
quadword STPSASAddress;

// byte 24-43
struct RegisterDeviceToHostFIS FIS;

// byte 44-47
byte ReservedByte44_47[4];

// byte 48-55
quadword AffiliatedSTPInitiatorSASAddress;

// byte 56-59
dword CRC;
};

struct ReportRouteInformation
{
    // byte 12
    byte IgnoredByte12Bit0_6:7;
    byte ExpanderRouteEntryDisabled:1;

    // byte 13-15
    byte IgnoredByte13_15[3];

    // byte 16-23
    quadword RoutedSASAddress;

    // byte 24-35
    byte IgnoredByte24_35[12];

    // byte 36-39
    byte ReservedByte36_39[4];
};

// response specific bytes for SMP Report Route Information, intended to be
// referenced by SMPResponse
struct SMPResponseReportRouteInformation
{
    // byte 4-5
    byte IgnoredByte4_5;

    // byte 6-7
    word ExpanderRouteIndex;

    // byte 8
    byte ReservedByte8;

    // byte 9
    byte PhyIdentifier;

    // byte 10
    byte IgnoredByte10;

    // byte 11
    byte ReservedByte11;

```

```

    // byte 12-39
    struct ReportRouteInformation Result;

    // byte 40-43
    dword CRC;
};

// response specific bytes for SMP Configure Route Information,
// intended to be referenced by SMPResponse
struct SMPResponseConfigureRouteInformation
{
    // byte 4-7
    dword CRC;
};

// response specific bytes for SMP Phy Control,
// intended to be referenced by SMPResponse
struct SMPResponsePhyControl
{
    // byte 4-7
    dword CRC;
};

// generic structure referencing an SMP Response, must be initialized
// before being used
struct SMPResponse
{
    // byte 0
    byte SMPFrameType;                // always 41h for SMP responses

    // byte 1
    byte Function;

    // byte 2
    byte FunctionResult;

    // byte 3
    byte ReservedByte3;

    // bytes 4-n
    union
    {
        struct SMPResponseReportGeneral ReportGeneral;
        struct SMPResponseReportManufacturerInformation
            ReportManufacturerInformation;
        struct SMPResponseDiscover Discover;
        struct SMPResponseReportPhyErrorLog ReportPhyErrorLog;
        struct SMPResponseReportPhySATA ReportPhySATA;
        struct SMPResponseReportRouteInformation ReportRouteInformation;
        struct SMPResponseConfigureRouteInformation ConfigureRouteInformation;
        struct SMPResponsePhyControl PhyControl;
    } Response;
};

// this structure is how this simulation obtains it's knowledge about the
// initiator port that is doing the discover, it is not defined as part of
// the standard...
struct ApplicationClientKnowledge
{
    quadword SASAddress;
    byte NumberOfPhys;
    byte InitiatorBits;
    byte TargetBits;
};

```

```

// the TopologyTable structure is the summary of the information gathered
// during the discover process, the table presented here is not concerned
// about memory resources consumed, production code would be more concerned
// about specifying necessary elements explicitly
struct TopologyTable
{
    // pointer to a simple list of expanders in topology
    // a walk thru this link will encounter all expanders in
    // discover order
    struct TopologyTable *Next;

    // simple reference to this device, primarily to keep identification of
    // this structure simple, otherwise, the only place the address is
    // located is within the Phy element
    quadword SASAddress;

    // information from REPORT_GENERAL
    struct SMPResponseReportGeneral Device;

    // information from DISCOVER
    struct SMPResponseDiscover Phy[MAXIMUM_EXPANDER_PHYS];

    // list of route indexes for each phy
    word RouteIndex[MAXIMUM_EXPANDER_PHYS];

    quadword RouteTable[MAXIMUM_EXPANDER_PHYS][MAXIMUM_EXPANDER_INDEXES];

    //
    // in production code there would also be links to the necessary device
    // information like end device; vendor, model, serial number, etc.
    // the gathering of that type of information is not done here...
    //
};

```

**Substitute the contents of J.3 for the following (there are too many changes to highlight assume a complete substitution, code that is related to the Discover process routing table optimization is indicated in blue);**

```
// SASDiscoverSimulation.cpp
//
// this is a simple simulation and code implementation of the initiator
// based expander discovery and configuration

// there is no attempt to handle phy errors, arbitration issues, etc.
// production level implementation would have to handle errors appropriately

// structure names used are equivalent to those referenced in the
// SAS document

// basic assumptions
//
// 1. change primitives will initiate a rediscovery/configuration sequence
// 2. table locations for SASAddresses are deterministic for a specific
//    topology only, when the topology changes, the location of a SASAddress
//    in an ASIC table cannot be assumed
// 3. a complete discovery level occurs before the configuration of the
//    level begins, multiple passes are required as the levels of expanders
//    encountered between the initiator and the end devices is increased
// 4. configuration of a single expander occurs before proceeding to
//    subsequent expanders attached
// 5. the Attached structure is filled in following OOB and is available
//    from the initialization routines
// 6. the Iam structure is provide by the application client

#include <malloc.h>
#include <memory.h>

// include the SAS structures
#include "SASDiscoverSimulation.h"

// this defines the type of algorithm used for discover
int DiscoverAlgorithm = SAS_SIMPLE_LEVEL_DESCENT;

// loaded by the application client, in this simulation it is provided
// in a text file, SASDeviceSetExample.ini
struct ApplicationClientKnowledge Iam[MAXIMUM_INITIATORS] = { 0 };

// obtained following OOB from the attached phy, in this simulation
// it is provided in a text file, SASDeviceSetExample.ini
struct Identify Attached[MAXIMUM_INITIATORS] = { 0 };

// buffers used to request and return SMP data
struct SMPRequest SMPRequestFrame = { 0 };
struct SMPResponse SMPResponseFrame = { 0 };

// resulting discover information will end up in this table
struct TopologyTable *SASDomain[MAXIMUM_INITIATORS] = { 0 };

// this is the function used to send an SMPRequest and get a response back
extern byte SMPRequest(byte PhyIdentifier,
                      quadword Source,
                      quadword Destination,
                      struct SMPRequest *SMPRequestFrame,
                      struct SMPResponse *SMPResponseFrame,
                      byte *OpenStatus,
                      byte Function,
                      ...);

// this function is used to output error information, it mimics fprintf
// functionality to an open trace file
```



```

extern int TracePrint(char *String, ...);

// this function gets the report general and discover information for
// a specific expander, the discover process should begin at the subtractive
// boundary and progress downstream
static struct TopologyTable *DiscoverExpander(byte PhyIdentifier,
                                              quadword SourceSASAddress,
                                              quadword DestinationSASAddress)
{
    struct TopologyTable *expander = 0;
    byte phyCount = 0;
    int error = 1;

    byte openStatus = OPEN_ACCEPT;

    // get the report general information for the expander
    SMPRequest(PhyIdentifier,
               SourceSASAddress,
               DestinationSASAddress,
               &SMPRequestFrame,
               &SMPResponseFrame,
               &openStatus,
               REPORT_GENERAL);

    // don't worry about too much in the 'else' case for this example,
    // production code must handle
    if((openStatus == OPEN_ACCEPT) &&
        (SMPResponseFrame.FunctionResult == SMP_FUNCTION_ACCEPTED))
    {
        if(SMPResponseFrame.Response.ReportGeneral.NumberOfPhys <=
            MAXIMUM_EXPANDER_PHYS)
        {
            // allocate space to retrieve the expander information
            expander = (struct TopologyTable *)
                calloc(1,
                      sizeof(struct TopologyTable));

            // make sure we only do this if the allocation is successful
            if(expander)
            {
                // save the address of this expander
                expander->SASAddress = DestinationSASAddress;

                // copy the result into the topology table
                memcpy((void *)&(expander->Device),
                      (void *)&SMPResponseFrame.Response.ReportGeneral,
                      sizeof(struct SMPResponseReportGeneral));

                // now walk through all the phys of the expander
                for(phyCount = 0;
                    (phyCount < expander->Device.NumberOfPhys);
                    phyCount++)
                {
                    // get the discover information for each phy
                    SMPRequest(PhyIdentifier,
                               SourceSASAddress,
                               DestinationSASAddress,
                               &SMPRequestFrame,
                               &SMPResponseFrame,
                               &openStatus,
                               DISCOVER,
                               phyCount);

                    // don't worry about the 'else' case for this example,
                    // production code must handle
                    if((openStatus == OPEN_ACCEPT) &&
                        (SMPResponseFrame.FunctionResult == SMP_FUNCTION_ACCEPTED))

```

```

{
    // clear the error flag
    error = 0;

    // copy the result into the topology table
    memcpy((void *)&(expander->Phy[phyCount]),
           (void *)&SMPResponseFrame.Response.Discover,
           sizeof(struct SMPResponseDiscover));
}
else
{
    // if we had a problem on this link, then don't bother
    // to do anything else, production code, should be more
    // robust...
    // for this simulation example, the addresses are
    // described as strings, so we can print them out...
    // not true for production code...
    TracePrint("\n"
               "discover error, %02Xh at %s\n",
               SMPResponseFrame.FunctionResult,
               (char *)&DestinationSASAddress);

    // something happened so just bailout on this expander
    error = 1;

    // release the memory we allocated for this...
    free(expander);
    expander = 0;
    break;
}
}

// the assumptions we made were exceeded, need to bump simulation
// limits...
else
{
    TracePrint("\n"
               "report general error"
               ", NumberOfPhys %d exceeded limit %d on %s\n",
               expander->Device.NumberOfPhys,
               MAXIMUM_EXPANDER_PHYS,
               (char *)&DestinationSASAddress);
}
}
else
{
    // if we had a problem getting report general for this expander,
    // something is wrong, can't go any further down this path...
    // production code, should be more robust...
    // for this simulation example, the addresses are
    // described as strings, so we can print them out...
    // not true for production code...
    TracePrint("\n"
               "report general error, open %02Xh result %02Xh at %s\n",
               openStatus,
               SMPResponseFrame.FunctionResult,
               (char *)&DestinationSASAddress);
}

// the expander pointer is the error return, a null indicates something
// bad happened...
return(expander);
}

```

```

// this routine searches upstream for the subtractive boundary that defines
// the edge expander device set
static struct TopologyTable *FindBoundary(byte PhyIdentifier,
                                         quadword SourceSASAddress,
                                         struct TopologyTable *Expander,
                                         struct TopologyTable **DeviceSet)
{
    struct TopologyTable *expander = Expander;
    struct TopologyTable *nextExpander;

    struct Discover *discover;

    byte phyCount;

    int error = 0;
    int foundSubtractivePort = 0;

    quadword subtractiveSASAddress;
    byte attachedPhyIdentifier;

    // make sure the device set link is initialized
    *DeviceSet = 0;

    // the outer loop searches for subtractive phys and finds the SAS addresses
    // connected to them, it validates that the subtractive phys all resolve
    // to the same expander address, then moves upstream searching for the
    // edge expander device set boundary
    do
    {
        // initialize the subtractive address, a zero value is not valid
        subtractiveSASAddress = 0;
        attachedPhyIdentifier = 0;

        // walk through all the phys of this expander
        for(phyCount = 0;
            (phyCount < expander->Device.NumberOfPhys);
            phyCount++)
        {
            // this is just a pointer helper
            discover = &(expander->Phy[phyCount].Result);

            // look for phys with edge or fanout devices attached...
            if((discover->RoutingAttribute == SUBTRACTIVE) &&
                ((discover->AttachedDeviceType == EDGE_EXPANDER_DEVICE) ||
                 (discover->AttachedDeviceType == FANOUT_EXPANDER_DEVICE)))
            {
                // make sure all the subtractive phys point to the same address
                // when we are connected to an expander device
                if(!subtractiveSASAddress)
                {
                    subtractiveSASAddress = discover->AttachedSASAddress;
                    attachedPhyIdentifier = discover->AttachedPhyIdentifier;
                    foundSubtractivePort = 1;
                }
                // the addresses don't match... problem...
                else if(subtractiveSASAddress !=
                        discover->AttachedSASAddress)
                {
                    // production code needs to deal with this better, for this
                    // example, the SASAddresses are assumed to strings
                    // so just print out the error information
                    TracePrint("\n"
                               "topology error, diverging subtractive phys"
                               ", '%s' != '%s' \n",
                               (char *)&subtractiveSASAddress,
                               (char *)&discover->AttachedSASAddress);

                    error = 1;
                }
            }
        }
    }
}

```

```

        break;
    }
}

// if no error, then decide if we need to go upstream or stop
if(!error)
{
    // if we have a subtractive address then go upstream to see
    // if it is part of the edge expander device set
    if(subtractiveSASAddress)
    {
        // get the discover information
        nextExpander = DiscoverExpander(PhyIdentifier,
                                        SourceSASAddress,
                                        subtractiveSASAddress);

        // if we successfully got the information from the next
        // expander then proceed upstream...
        if(nextExpander)
        {
            struct Discover *discover;

            // this is just a pointer helper
            discover = &(nextExpander->Phy[attachedPhyIdentifier].Result);

            // check to see if we are connected to the subtractive
            // port of the next expander, if we are then we have two
            // expander device sets connected together, stop here
            // and save the address of next expander in device set,
            // the return will be expander
            if(discover->RoutingAttribute == SUBTRACTIVE)
            {
                *DeviceSet = nextExpander;
                break;
            }
            // go ahead and continue upstream looking for the boundary
            else
            {
                // release the memory we allocated for this
                free(expander);

                // move upstream to the next expander
                expander = nextExpander;
            }
        }
        // if there are no more upstream expanders stop here...
        else
        {
            break;
        }
    }
    // if we did not get a subtractive address this time around then stop
    else
    {
        // if we did find a subtractive port on a previous pass,
        // then return with expander pointing to the last device
        // with the subtractive port
        if(foundSubtractivePort)
        {
            break;
        }
        // if we never found a subtractive port, then return with a
        // null indicating there are no subtractive phys, don't free
        // the memory, because it is still in use by the calling routine
        else

```

```

        {
            expander = 0;
        }
    }
}
// if there was an error make sure we return a null expander pointer
else
{
    // to get here, we had to see more than one subtractive phy that
    // connect to different SAS addresses, this is a topology error
    // do cleanup on any memory allocated if necessary
    if((expander != Expander) &&
        (expander != *DeviceSet))
    {
        // release the memory we allocated for this and make sure
        // we return a null
        free(expander);
        expander = 0;
    }
}
}
while(!error &&
    expander &&
    subtractiveSASAddress);

// on return expander should contain the subtractive boundary expander
// or a null indicating there were no subtractive phys,
// or a null indicating there was an error
return(expander);
}

// find the table structure associated with a specific SAS address
static struct TopologyTable *FindExpander(struct TopologyTable *Expander,
                                         quadword SASAddress)
{
    // walk the list of expanders, when we find the one that matches, stop
    while(Expander)
    {
        // do the SASAddresses match
        if(SASAddress == Expander->SASAddress)
        {
            break;
        }

        Expander = Expander->Next;
    }

    return(Expander);
}

// this routine searches the subtractive phys for the upstream expander address
static int UpstreamExpander(struct TopologyTable *Expander,
                           quadword *SASAddress,
                           byte *PhyIdentifier)
{
    struct Discover *discover;

    byte phyCount;

    int found = 0;

    // walk through all the phys of this expander, searching for subtractive
    // phys return the SASAddress and PhyIdentifier for the first subtractive
    // phy encountered, they should all be the same if they have anything
    // attached
    for(phyCount = 0;
        (phyCount < Expander->Device.NumberOfPhys);

```

```

        phyCount++)
    {
        // this is just a pointer helper
        discover = &(Expander->Phy[phyCount].Result);

        // look for phys with edge or fanout devices attached...
        if((discover->RoutingAttribute == SUBTRACTIVE) &&
            ((discover->AttachedDeviceType == EDGE_EXPANDER_DEVICE) ||
             (discover->AttachedDeviceType == FANOUT_EXPANDER_DEVICE)))
        {
            *SASAddress = discover->AttachedSASAddress;
            *PhyIdentifier = discover->AttachedPhyIdentifier;
            found = 1;
            break;
        }
    }

    return(found);
}

// this routine determines whether a SAS address is directly attached to
// an expander
static int DirectAttached(struct TopologyTable *Expander,
                        quadword SASAddress)
{
    int direct = 0;
    byte phyCount;

    for(phyCount = 0;
        phyCount < Expander->Device.NumberOfPhys;
        phyCount++)
    {
        // did we find the address attached locally
        if(SASAddress ==
            Expander->Phy[phyCount].Result.AttachedSASAddress)
        {
            direct = 1;
            break;
        }
    }

    return(direct);
}

// this routine determines whether the SAS address, can be optimized out
// of the route table
static int QualifiedAddress(struct TopologyTable *Expander,
                        byte PhyIdentifier,
                        quadword SASAddress,
                        byte RoutingAttribute,
                        byte *DisableRouteEntry);

{
    int qualified = 1;
    word routeIndex;

    if(DiscoverAlgorithm == SAS_UNIQUE_LEVEL_DESCENT)
    {
        // leave in any entries that are direct routing attribute, assumes
        // that they are slots that will be filled by end devices, if
        // it is not direct, then filter out any empty connections,
        // connections that match the expander we are configuring
        // and connections that are truly direct attached
        if(SASAddress &&
            (SASAddress != Expander->SASAddress) &&
            (!DirectAttached(Expander,
                            SASAddress)))
    }
}

```

```

    {
        if(RoutingAttribute == DIRECT)
        {
            // if this is a phy that is has a direct routing attribute
            // then, have it consume an entry, it may be filled in
            // at any time
        }
        else
        {
            for(routeIndex = 0;
                routeIndex < Expander->Device.ExpanderRouteIndexes;
                routeIndex++)
            {
                if(Expander->RouteTable[PhyIdentifier][routeIndex] ==
                    SASAddress)
                {
                    qualified = 0;
                    break;
                }
            }
        }
        else if(!SASAddress &&
            (RoutingAttribute == DIRECT))
        {
            // if a 0 address that is direct routing, then assume it is an
            // empty slot that can be filled at any time, this keeps things
            // positionally stable for most reasonable topologies
            *DisableRouteEntry = DISABLE;
        }
        else
        {
            qualified = 0;
        }
    }

    return(qualified);
}

// this function is the configuration cycle from the current expander to
// the hub expander
static int ConfigureExpander(byte PhyIdentifier,
    quadword SourceSASAddress,
    struct TopologyTable *HubExpander,
    struct TopologyTable *ThisExpander)
{
    struct TopologyTable *thisExpander = ThisExpander;
    struct TopologyTable *expander = ThisExpander;
    struct TopologyTable *configureExpander;

    struct Discover *discover;

    quadword upstreamSASAddress = 0;
    byte upstreamPhyIdentifier = 0;

    byte phyIndex;
    word routeIndex;
    byte openStatus = OPEN_ACCEPT;

    int error = 0;

    do
    {
        // move upstream from here to find the expander table to configure with
        // information from "thisExpander"
        if(!UpstreamExpander(thisExpander,
            &upstreamSASAddress,

```

```

        &upstreamPhyIdentifier))
    {
        break;
    }

    if(upstreamSASAddress)
    {
        // get the expander associated with the upstream address
        configureExpander = FindExpander(HubExpander,
                                         upstreamSASAddress);

        // if we found an upstream expander, then program it's route
        // table
        if(configureExpander)
        {
            byte disableRouteEntry = ENABLED;

            for(phyIndex = 0;
                phyIndex < configureExpander->Device.NumberOfPhys;
                phyIndex++)
            {
                if(configureExpander->Phy[phyIndex].Result.AttachedSASAddress ==
                    thisExpander->SASAddress)
                {
                    // loop through all the phys of the attached expander
                    for(routeIndex = 0;
                        ((routeIndex <
                            thisExpander->Device.NumberOfPhys) &&
                            (configureExpander->RouteIndex[phyIndex] <
                                configureExpander->Device.ExpanderRouteIndexes));
                        routeIndex++)
                    {
                        discover = &(expander->Phy[routeIndex].Result);

                        // assume the route entry is enabled
                        disableRouteEntry = ENABLED;

                        // check to see if the address needs to be configured
                        // in the route table, this decision is based on the
                        // optimization flag
                        if(QualifiedAddress(configureExpander,
                                           phyIndex,
                                           discover->AttachedSASAddress,
                                           discover->RoutingAttribute,
                                           &disableRouteEntry))
                        {
                            word index = configureExpander->RouteIndex[phyIndex];

                            // configure the route indexes for the expander
                            // with the attached address information
                            SMPRequest(PhyIdentifier,
                                       SourceSASAddress,
                                       configureExpander->SASAddress,
                                       &SMPRequestFrame,
                                       &SMPResponseFrame,
                                       &openStatus,
                                       CONFIGURE_ROUTE_INFORMATION,
                                       index,
                                       phyIndex,
                                       disableRouteEntry,
                                       discover->AttachedSASAddress);

                            if((openStatus != OPEN_ACCEPT) ||
                                (SMPResponseFrame.FunctionResult !=
                                 SMP_FUNCTION_ACCEPTED))
                            {
                                error = 1;

```



```

        break;
    }

    // add the address to the internal copy of the
    // route table, if successfully configured
    configureExpander->RouteTable[phyIndex][index] =
        discover->AttachedSASAddress;

    // increment the route index for this phy
    configureExpander->RouteIndex[phyIndex]++;
}
}
}
}
}

// move upstream
thisExpander = configureExpander;

} while(!error &&
        upstreamSASAddress);

return(error);
}

// this discovers then configures as necessary the expanders it finds
// within the SAS domain that are "downstream"
struct TopologyTable *DiscoverAndConfigure(byte PhyIdentifier,
                                          quadword SourceSASAddress,
                                          struct TopologyTable *HubExpander)
{
    struct TopologyTable *currentExpander = HubExpander;
    struct TopologyTable *nextExpander;

    struct Discover *currentDiscover;

    quadword sasAddress;
    byte phyIndex;

    int error = 0;

    // this is a level descent traversal with a configuration stage
    // at each transition to a new level, if a configuration is required
    // by the expander

    // the discover process moves forward through the topology, but the
    // configuration process stays anchored at the hub of the
    // topology, meaning the fanout expander, or the top most subtractive
    // edge expander device
    // this ensures that as each new expander is added to the
    // topology table list, it is in the configuration chain

    while(!error &&
        currentExpander)
    {
        // start at phy 0
        phyIndex = 0;

        // walk through all the phys of the current expander looking for
        // new expanders to add to the topology table
        do
        {
            // this is just a pointer helper
            currentDiscover = &(currentExpander->Phy[phyIndex].Result);

            // look for phys with edge or fanout devices attached...

```

```

if((currentDiscover->RoutingAttribute == TABLE) &&
    ((currentDiscover->AttachedDeviceType == EDGE_EXPANDER_DEVICE) ||
     (currentDiscover->AttachedDeviceType == FANOUT_EXPANDER_DEVICE)))
{
    struct TopologyTable *thisExpander = currentExpander;
    struct TopologyTable *previousExpander = currentExpander;

    // check to see if we already have the address information
    // in our expander list
    while(thisExpander)
    {
        // if we do, then stop here
        if(currentDiscover->AttachedSASAddress ==
            thisExpander->SASAddress)
        {
            break;
        }

        // setup the pointer references
        previousExpander = thisExpander;
        thisExpander = thisExpander->Next;
    }

    // if we did not have the expander in our list, then get
    // the information
    if(!thisExpander)
    {
        // discover all the details about the attached expander
        // and insert into the master list
        thisExpander =
            DiscoverExpander(PhyIdentifier,
                            SourceSASAddress,
                            currentDiscover->AttachedSASAddress);

        // if we got the discover information, then add it to the
        // list
        if(thisExpander)
        {
            previousExpander->Next = thisExpander;

            // go through the configure cycle progressively ascending
            // to each expander starting at "thisExpander"
            ConfigureExpander(PhyIdentifier,
                              SourceSASAddress,
                              HubExpander,
                              thisExpander);
        }
    }

    // move to the next phy on this expander
    phyIndex++;
} while(phyIndex <
        currentExpander->Device.NumberOfPhys);

// cycle to the next expander to discover
currentExpander = currentExpander->Next;
}

// return the top of expander list
return (HubExpander);
}

// this routine will append the leaf to the tree domain
void ConcatenateDomains(struct TopologyTable *Tree,
                        struct TopologyTable *Leaf)

```

```

{
    while(Tree)
    {
        if(Tree->Next == 0)
        {
            Tree->Next = Leaf;
            break;
        }

        Tree = Tree->Next;
    }
}

// the application client for the initiator device would make a call to
// this function to begin the discover process...
// to simplify the setup for the simulation, the DiscoverProcess will get
// the Initiator number to allow multiple initiators...
void DiscoverProcess(byte Initiator,
                    byte PhyIdentifier)
{
    // check to see if an expander is attached
    if((Attached[Initiator].DeviceType == EDGE_EXPANDER_DEVICE) ||
        (Attached[Initiator].DeviceType == FANOUT_EXPANDER_DEVICE))
    {
        struct TopologyTable *connectedExpander;

        // get some local variables to keep things simple
        quadword sourceSASAddress = Iam[Initiator].SASAddress;
        quadword destinationSASAddress = Attached[Initiator].SASAddress;

        // expander is attached, so begin by getting the information about
        // the connected expander
        connectedExpander = DiscoverExpander(PhyIdentifier,
                                            sourceSASAddress,
                                            destinationSASAddress);

        // make sure we get the information from the expander
        if(connectedExpander)
        {
            struct TopologyTable *thisDeviceSet;
            struct TopologyTable *attachedDeviceSet = 0;

            // go upstream on the subtractive phys until we discover that we are
            // attached to another subtractive phy or a fanout expander
            // then begin the discover process from that point, this works
            // because any new address that we find will naturally move upstream
            // due to the subtractive addressing method
            // if during the discover cycle, it is determined
            // that there are two device sets connected, then a second discover
            // and configuration cycle is required for the other device set
            thisDeviceSet = FindBoundary(PhyIdentifier,
                                        sourceSASAddress,
                                        connectedExpander,
                                        &attachedDeviceSet);

            // set the root for the domain as the subtractive boundary
            if(thisDeviceSet)
            {
                // output a little information about the subtractive boundary
                TracePrint("subtractive boundary at %s\n",
                          (char *)&thisDeviceSet->SASAddress);

                SASDomain[Initiator] = thisDeviceSet;
            }
            // if there was no subtractive boundary, then the root is the
            // expander connected to the initiator
            else

```

```

{
    // output a little information about the subtractive boundary
    TracePrint("connected expander at %s\n",
        (char *)&connectedExpander->SASAddress);

    SASDomain[Initiator] = connectedExpander;
}

// begin the discover and configuration cycle
DiscoverAndConfigure(PhyIdentifier,
    sourceSASAddress,
    SASDomain[Initiator]);

// if two device sets are connected, then the attached device set
// has to be discovered and configured
if(attachedDeviceSet)
{
    // output a little information about the attached device set
    TracePrint("attached device set at %s\n",
        (char *)&attachedDeviceSet->SASAddress);

    // discover and configure the attached device set
    DiscoverAndConfigure(PhyIdentifier,
        sourceSASAddress,
        attachedDeviceSet);

    // put the domains together
    ConcatenateDomains(SASDomain[Initiator],
        attachedDeviceSet);
}
}
}
}

```

## Changes to implement the Discover process route table optimization.

To document the Discover process route table optimization the following sections should be changed.

### Section 4.6.7.4

**From:**

If the management application client detects an expander route entry that references the SAS address of the expander device itself (i.e., self-reference), it shall disable the expander route entry by setting the DISABLE EXPANDER ROUTE ENTRY bit to one in the SMP CONFIGURE ROUTE INFORMATION function (see 10.4.3.9).

**To:**

Delete, this should not be possible with the optimized algorithm.

**From:**

Annex I contains an example algorithm used by an application client to perform the discover process.

**To:**

Annex J contains an example algorithm used by an application client to perform the discover process.

### Section 4.6.7.5

**From:**

The expander route table for each expander phy shall be configured starting from expander route index 0 by level (i.e., all level 1 entries first, then all level 2 entries, then all level 3 entries, etc.) up to the value of the EXPANDER ROUTE INDEXES field reported by the SMP REPORT GENERAL function (see 10.4.3.3).

Assuming the level 1 edge expander device has N expander phys, the first N entries shall be used for the level 1 edge expander device's expander phy 0 through expander phy N. If an expander phy is attached to a device other than the level 0 expander device (i.e., attached to a level 2 device), the corresponding expander route entry shall contain the SAS address of the level 2 device. Otherwise (e.g., if the expander phy is not attached to any device, or the expander phy is attached to the level 0 expander device), the corresponding expander route entry shall be disabled.

For each of the level 2 devices that:

- a) is an edge expander device with M expander phys; and
- b) is attached to an expander phy in the level 1 edge expander device with the table routing attribute,

the next M entries shall be used for the level 2 edge expander device's expander phy 0 through expander phy M. If an expander phy is attached to a device other than the level 1 expander device (i.e., attached to a level 2 device), the corresponding expander route entry shall contain the SAS address of the level 3 device. Otherwise (e.g., if the expander phy is not attached to any device, or the expander phy is attached to the level 1 expander device), the corresponding expander route entry shall be disabled.

This process shall repeat for all levels of edge expander devices in the edge expander device set.

**To:**

The expander route table for each expander phy shall be configured starting from expander route index 0 by level (i.e., all level 1 entries first, then all level 2 entries, then all level 3 entries, etc.) up to the value of the EXPANDER ROUTE INDEXES field reported by the SMP REPORT GENERAL function (see 10.4.3.3).

Discovered SAS addresses shall be qualified for insertion into the expander device route table by the following;

- a) Discovered SAS addresses referencing the expander device being configured (self-referencing addresses) shall be excluded from the expander device route table.
- b) Discovered SAS addresses directly connected to the expander device being configured shall be excluded from the expander device route table.
- c) The first instance of a discovered SAS address shall be inserted in the configured expander device route table. Subsequent instances of a discovered SAS address shall be excluded from the configured expander device route table.
- e) Discovered phys with a DIRECT route attribute shall be inserted in the expander device route table even if the end device is currently not attached and a SAS address is not available. If a SAS address is not available a zero value shall be inserted and the DISABLE EXPANDER ROUTE ENTRY bit for the entry shall be set to one in the SMP CONFIGURE ROUTE INFORMATION function (see 10.4.3.9).

Assuming the level 1 edge expander device has N qualified SAS addresses attached to its phys, the first N entries shall be used for the level 1 edge expander device's qualified SAS addresses in expander phy order. If an expander phy is attached to a device other than the level 0 expander device (i.e., attached to a level 2 device), the subsequent expander route entries shall contain the qualified SAS addresses of the level 2 device. Otherwise (e.g., if the expander phy is not attached to any device, or the expander phy is attached to the level 0 expander device), the subsequent expander route entries shall be disabled.

For each of the level 2 devices that:

- c) is an edge expander device with M qualified SAS addresses attached to its phys; and
- d) is attached to an expander phy in the level 1 edge expander device with the table routing attribute,

the next M entries shall be used for the level 2 edge expander device's qualified SAS addresses in expander phy order. If an expander phy is attached to a device other than the level 1 expander device (i.e., attached to a level 2 device), the subsequent expander route entries shall contain the qualified SAS addresses of the level 3 device. Otherwise (e.g., if the expander phy is not attached to any device, or the expander phy is attached to the level 1 expander device), the subsequent expander route entries shall be disabled.

This process shall repeat for all levels of edge expander devices in the edge expander device set.

## Figure 38 and 39, notations

### From:

Entries for ...

### To:

Qualified SAS Addresses for ...

## Table 16 changes;

**Table 16 — Expander route table levels for edge expander device R or fanout expander device R**

**Expander route index Expander route entry contents**

### Level 1 (from device R) entries

- 0 First qualified SAS address of the port attached to edge expander device N
- 1 Second qualified SAS address of the port attached to edge expander device N
- ... ..additional qualified SAS addresses of the ports attached to edge expander device N
- n Last qualified SAS address of the port attached to edge expander device N

### Level 2 (from device R) entries

- n + 1 First qualified SAS address of the port attached to edge expander device U
- ... ..additional qualified SAS addresses of the ports attached to edge expander device U...
- n + 1 + u Last qualified SAS address of the port attached to edge expander device U
- ... ..additional qualified SAS addresses of the ports attached to devices at level 2 (from device R)...
- First qualified SAS address of the port attached to edge expander device V

... ..additional **qualified SAS addresses of the ports attached to** edge expander device V  
**Last qualified** SAS address of the port attached to edge expander device V  
**Level 3 (from device R) entries**  
**First qualified** SAS address of the port attached to edge expander device W  
... ..additional **qualified SAS addresses of the ports attached to** edge expander device W  
**Last qualified** SAS address of the port attached to edge expander device W  
... ..additional **qualified SAS addresses of the ports attached to** devices at level 3 (from device R)...  
**Last qualified** SAS address of the port attached to edge expander device Z  
... ..additional **qualified SAS addresses of the ports attached to** edge expander device Z  
**Last qualified** SAS address of the port attached to edge expander device Z  
**Entries for additional levels**  
... ..

**Table 17 changes;**

**Table 17 — Expander route table levels for edge expander device N**

**Expander**  
**route index Expander route entry contents**  
**Level 1 (from device N) entries**  
0 **First qualified** SAS address of the port attached to edge expander device U  
... ..additional **qualified SAS addresses of the ports attached to** edge expander device U  
u **Last qualified** SAS address of the port attached to edge expander device U  
**Level 2 (from device N) entries**  
u + 1 **First qualified** SAS address of the port attached to edge expander device W  
... ..additional **qualified SAS addresses of the ports attached to** edge expander device W  
u + 1 + w **Last qualified** SAS address of the port attached to edge expander device W  
... ..additional **qualified SAS addresses of the ports attached to** devices at level 2 (from device N)...  
**First qualified** SAS address of the port attached to edge expander device X phy 0  
... ..additional **qualified SAS addresses of the ports attached to** phys in edge expander device Z  
**Last qualified** SAS address of the port attached to edge expander device X  
**Entries for additional levels**  
... ..

**Table 18 changes;**

**Table 18 — Expander route entries for edge expander E0 phy 0**

**Expander**  
**route index Expander route entry contents**  
**Level 1 entries**  
0 SAS address (e.g., D11) of the device attached to phy 1 of edge expander device E1  
1 SAS address (e.g., D12) of the device attached to phy 2 of edge expander device E1  
... ..  
Y SAS address (e.g., D1Y) of the device attached to phy N of the attached edge expander device E1  
**Level 2: no entries since all devices attached to E1 through EN, except for E0, are end devices**

**Table 19 changes;**

**Table 19 — Expander route entries for fanout expander device F phy 0**

**Expander**  
**route index Expander route entry contents**  
**Level 1 entries**  
0 SAS address (e.g., E1) of the device attached to phy 1 of edge expander device E0  
1 SAS address (e.g., E2) of the device attached to phy 2 of edge expander device E0  
... ..  
N SAS address (e.g., EN) of the device attached to phy N of the attached edge expander device E0  
**Level 2 entries**  
N + 1 SAS address (e.g., D11) of the device attached to phy Y of the edge expander device E1  
... ..

N + 1 + Y SAS address (e.g., D1Y) of the device attached to phy Y of the edge expander device E1

... ..

... ..

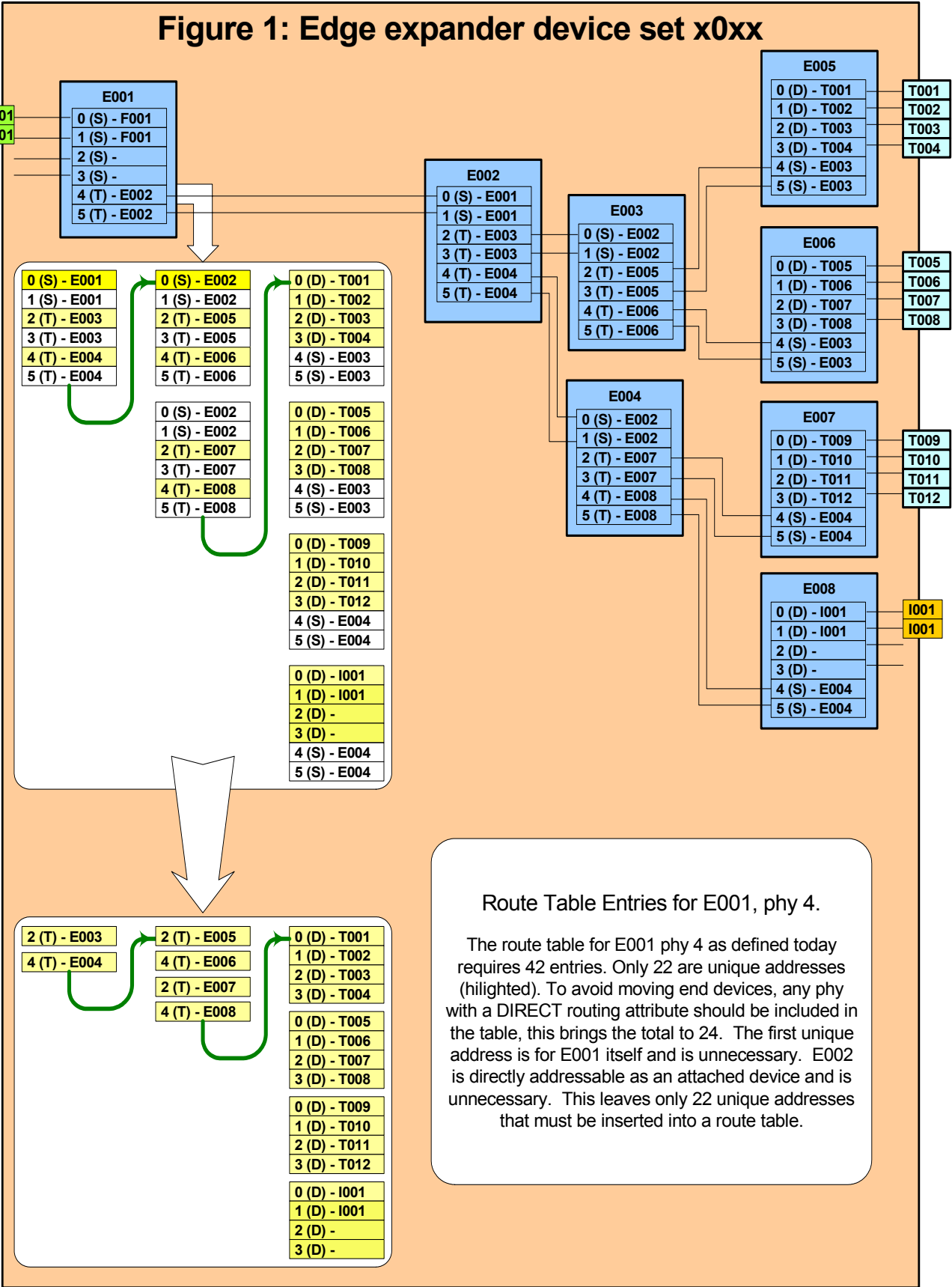
SAS address (e.g., DNZ) of the device attached to phy Z of the edge expander device EN

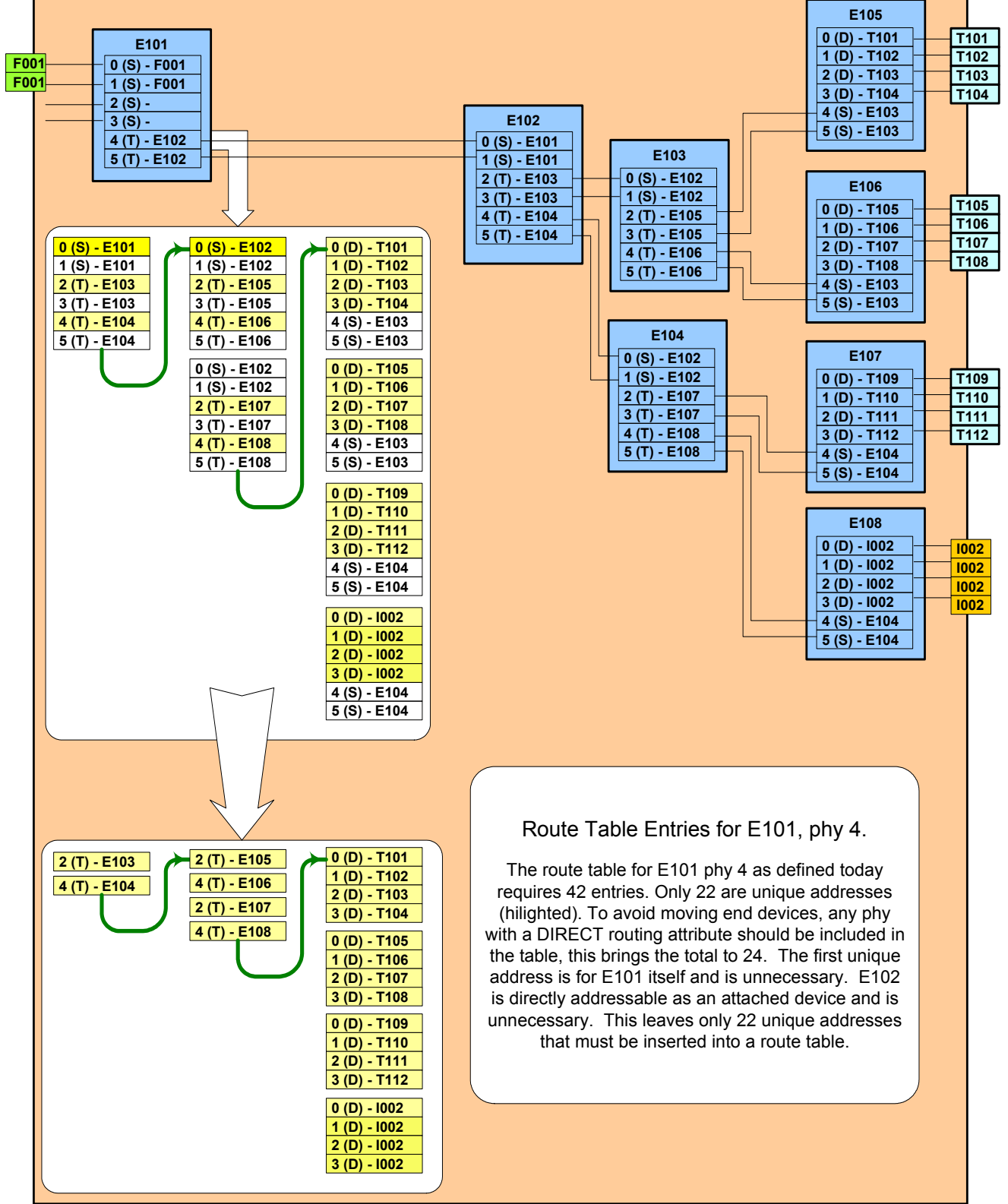
**Level 3 entries: none since all devices attached to E1 through EN, except for E0, are end devices**



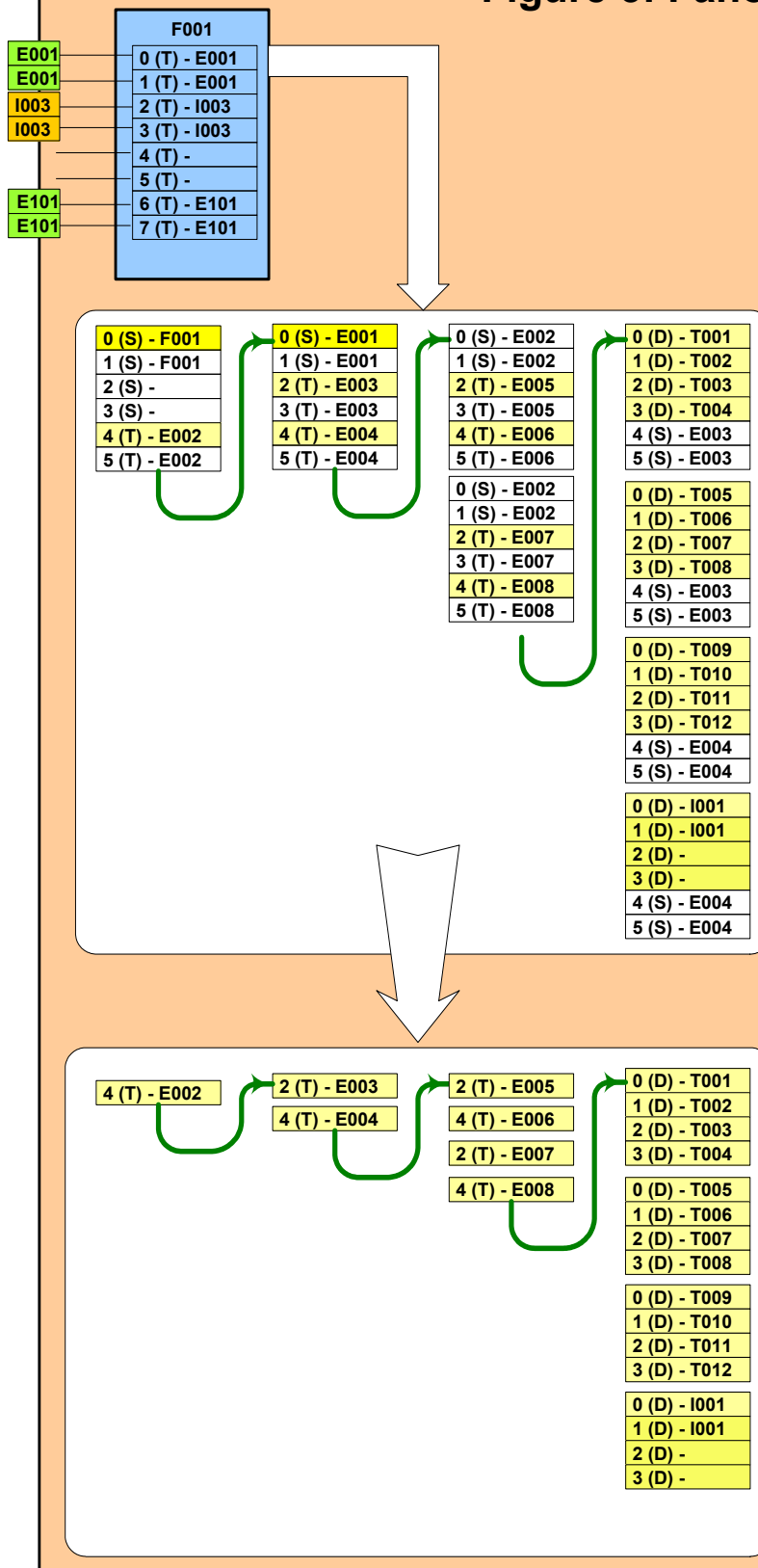
**Clarifying diagrams for the Discover process route table optimization.**

Figures 1, 2 and 3 describe a topology that has two, edge expander device sets connected with a fanout expander. Each figure shows the original route table contents and the optimized route table contents.



**Figure 2: Edge expander device set x1xx**

### Figure 3: Fanout



### Route Table Entries for F001, phy 0.

The route table for F001 phy 2 requires 48 entries. Only 22 are unique addresses (highlighted). To avoid moving end devices, any phy with a DIRECT routing attribute should be included in the table, this brings the total to 25. The first unique address is for F001 itself and is unnecessary. E001 is directly addressable as an attached device and is unnecessary. This leaves only 23 unique addresses that must be inserted into a route table.