



# SuperSpeed USB Developers Conference

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# Streams

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# Agenda

- Background
  - Features
  - Example
- General Stream State Machine
  - IN Streams
  - OUT Streams

# Background



- Streams driven by existing Mass Storage Class (MSC) issues
  - Serious MSC performance bottlenecks
  - Only one disk command may be outstanding at a time
  - Device Class intervention required for each stage of command processing
  - Software copy required for data transfers
- Next generation Mass Storage Class Definition
  - USB Attached SCSI Protocol (UASP)
  - Goals
    - SAM-4 Compliant protocol
    - Support Command Queuing
      - 512 or greater per MSC device
    - Direct DMA of Data to/from user/process address space (First Party DMA)
    - Support core Targeting of Completion Status
    - FS, HS, and SS USB support

# Features



- Up to 64K Streams supported
- Built on top of SuperSpeed Bulk protocol
  - Requires Stream ID (SID) field in DPH and ACK TP
  - Available on IN and OUT pipes
  - Transfer level multiplexing of data streams
  - Minimize device and host hardware requirements
- Usage
  - Device ability to set the Current Stream in the host
    - Host may reject a request if it has no buffers/data for the stream
  - Host ability to inform device of buffer/data availability
    - The host does not initially identify specific stream availability
      - Initial stream availability through an out-of-band mechanism, e.g. on separate pipe to the device
    - The host may inform the device of the renewed availability the previously selected stream
  - Host or Device may truncate a Stream transfer
    - If buffers/data are exhausted
    - Device may need to schedule another (e.g. higher priority) stream

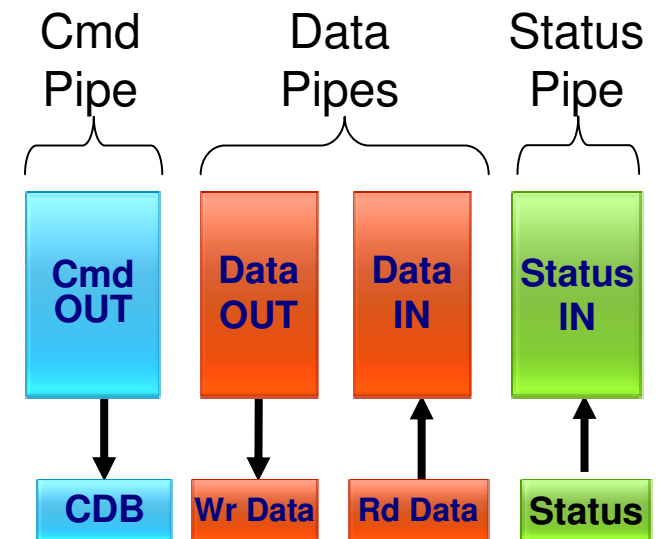
*Not available on Isoch, Interrupt, or Control endpoints*

# Example UASP Pipe Allocation



- Init time Pipe allocation
  - All pipes are Bulk
- Command OUT Pipe
  - Transfer MSC commands to the device
  - Each command is tagged with a Stream ID
- IN and OUT Data Pipes
  - IN Data
    - Receives Read data from device
  - OUT Data
    - Transmits Write data to device
  - Support Streams
    - Enables FPDMA
- Status IN Pipe
  - Return Command Completion status to host
  - Support Streams
    - Enables Core Targeting of Command Completions

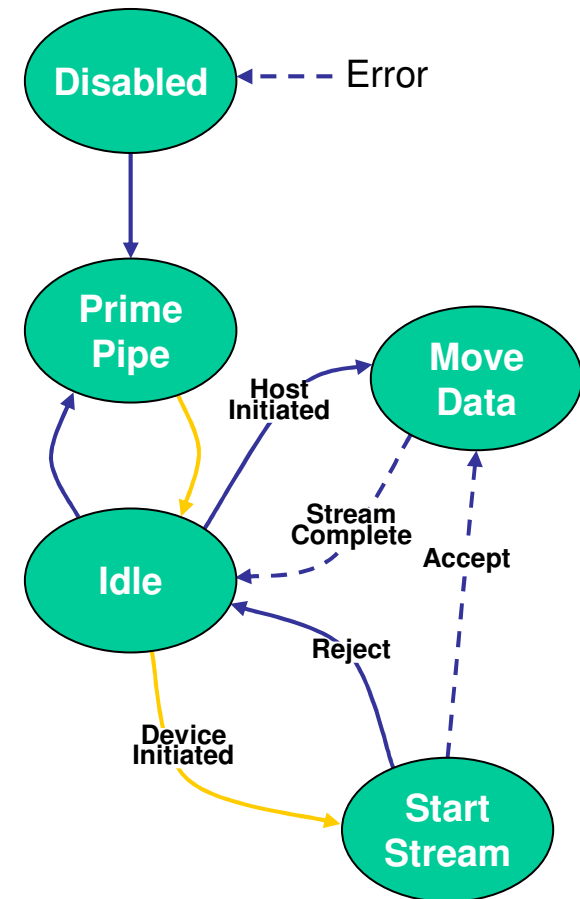
Endpoints presented by UASP device



# General Stream State Machine



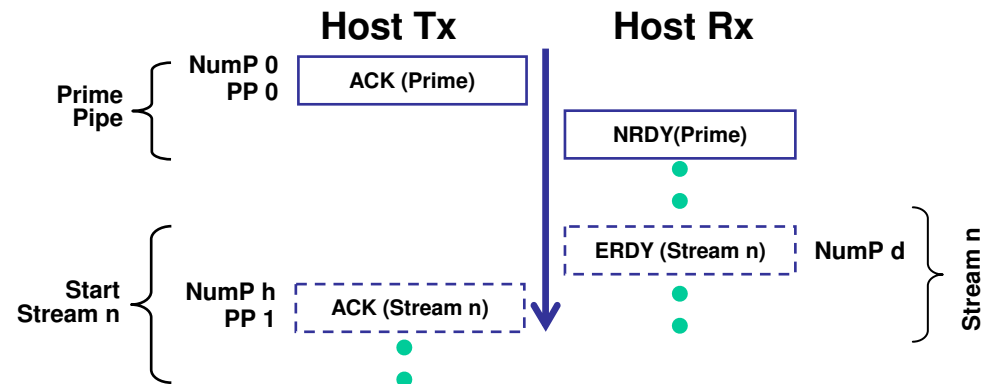
- Disabled
  - Initial pipe state or forced by error; No Stream activity
  - Host exits when initial stream data/buffers are posted by software
- Idle
  - Default stream state; No stream activity
  - Exited by *Prime Pipe* or *Host Initiated Move Data* from Host, or *Start Stream* from Device
- Prime Pipe
  - Initiated by Host
  - May be asserted if more data/buffers are made available for the EP
- Start Stream
  - Initiated by Device to move Stream data
  - If the Device selected stream is accepted by the host:
    - Establishes **Current Stream**
    - Enter *Move Data* state
  - If the Device selected stream is rejected by the host :
    - Return to *Idle* state
- Move Data
  - Transfers Stream data
  - Maybe entered from *Idle* state by *Host Initiated Move Data*
    - Device may reject
  - Releases **Current Stream** when complete



# IN Stream – Prime Pipe



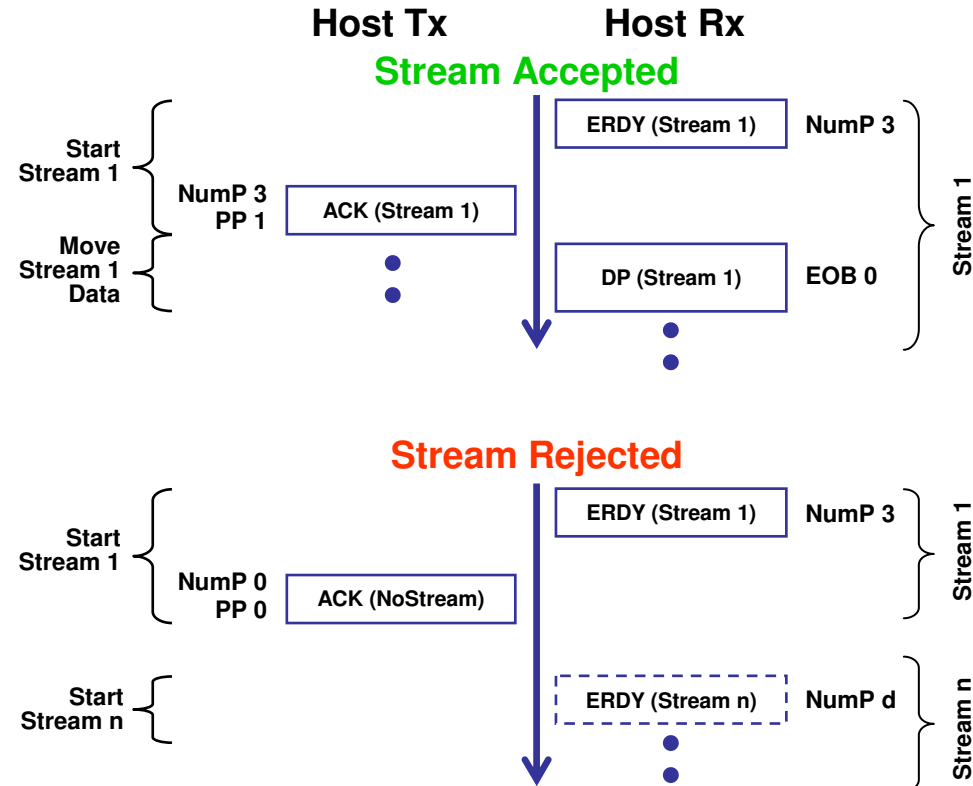
- May be initiated by Host when IN buffers are posted by software
  - Immediately, if currently in the *Disabled* or *Idle* state
  - During the next *Idle* state, if currently in the *Start Stream* or *Move Data* states
  - ACK(Prime) & NumP = PP = 0
- Device always responds with NRDY(Prime)
- Sets up the device to initiate *Start Stream*
  - *Start Stream* (ERDY) may immediately follow NRDY



# IN Stream – Start Stream



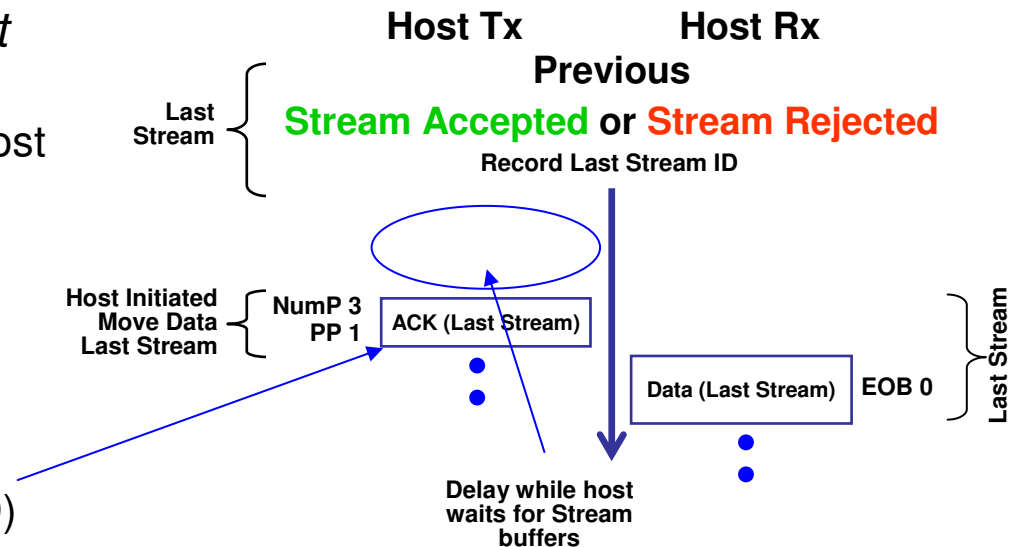
- Informs host that IN Stream transfer is required
- ERDY
  - SID = 1 – Stream 1 transfer is required
  - NumP = the minimum number of data buffers available in the Device for the Stream
- **Accepted** – ACK (Stream 1)
  - Host has buffers available for the Stream 1
  - Sets the **Current Stream** in the Host to Stream 1
  - NumP > 0, PP = 1
    - Identifies the Number of Packet buffers available in the Host for the Stream
  - Transition to *Move Data* state
- **Rejected** – ACK (NoStream)
  - Host currently has no buffers available for the requested Stream
    - The device may initiate a Start Stream for Stream 1 later; response Device Class defined
  - NumP = 0, PP = 0
  - Transition to *Idle* state



# IN Stream – Host Initiated Move Data



- Requirements
  - The pipe is *Idle*
  - A previous device initiated *Start Stream*
    - *Last Stream ID* recorded by host
  - Software posts buffers to the endpoint
- Host Initiated Move Data
  - If buffers were posted for the *Last Stream ID*
    - Issue an ACK (Last Stream ID) to transition to the *Move Data* state
  - else
    - Issue an ACK (Prime) to transition to *Prime Pipe* state
  - Device may reject with NRDY



# IN Stream – Move Data

Transfer  $\leq$  Max Burst Size



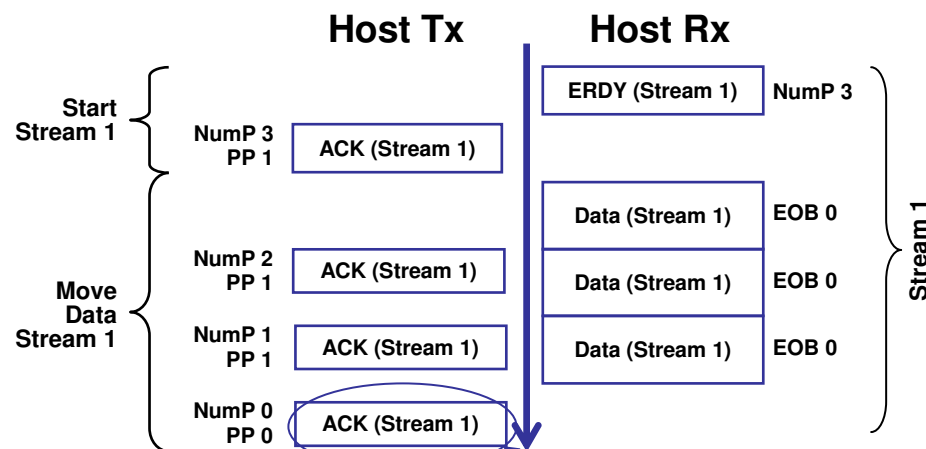
- Start Stream

- ERDY (Stream 1)

- Informs host that Stream 1 transfer is required
    - NumP = the number of data buffers available in the Device for the Stream (3)

- ACK (Stream 1)

- Sets the **Current Stream** in the Host to Stream 1
    - NumP = the Number of Packet buffers available in the Host for the **Current Stream**
      - Value set to ERDY NumP if Host buffer space is  $\geq$  ERDY NumP \* 1K
      - Value set to Host buffer space if Host buffer space is  $<$  ERDY NumP \* 1K
      - Else Value set to Max Burst Size or 15 if Max Burst Size  $>$  15



- Move Data

- Normal IN handshake
    - *Terminating ACK*
      - Completes Stream Transfer
      - NumP = 0, TP = 0
      - Sets Host **Current Stream** to NoStream
    - Transition to *Idle* state

# IN Stream Termination

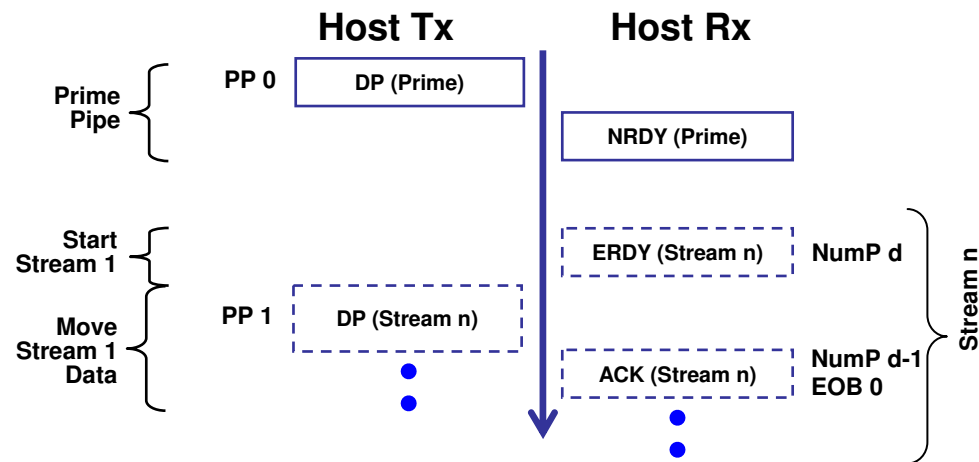


- Terminating ACK
  - NumP = 0 & PP = 0
- Terminating DP
  - EOB = 1
- NRDY
  - Flow Controls Stream
    - Temporarily Terminates Stream and pipe transitions to *Idle* state
    - Device must issue a subsequent *Stream Start* to complete a Stream transfer
- Error
  - Forces pipe to *Disabled* state
  - Stalls pipe, i.e. All Streams associated with the pipe
  - Requires system software recovery



# OUT Stream – Prime Pipe

- May be initiated by Host when OUT data is posted by software
  - Immediately, if currently in the *Disabled* or *Idle* state
  - During the next *Idle* state, if currently in the *Start Stream* or *Move Data* states
  - DP(Prime) & Length = PP = 0
- Device always responds with NRDY(Prime)
- Sets up the device to initiate *Start Stream*
  - *Start Stream* (ERDY) may immediately follow NRDY

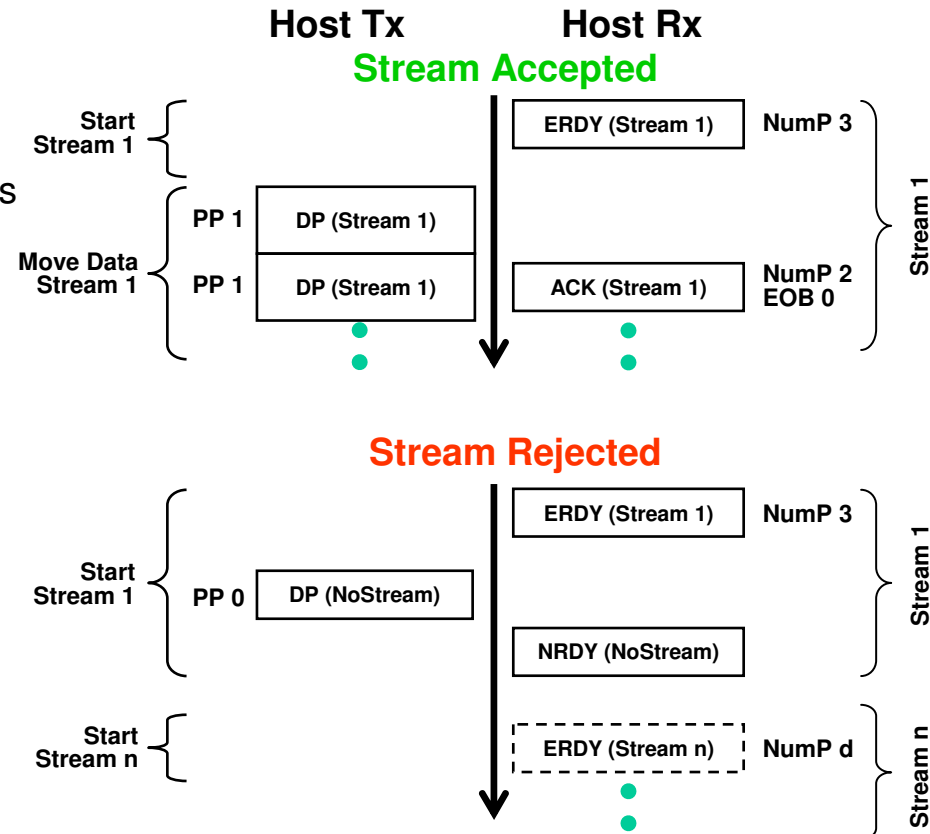


*Similar to IN Stream Prime Pipe, except that the Host issues zero-length DP, rather than Terminating ACK*

# OUT Stream – Start Stream



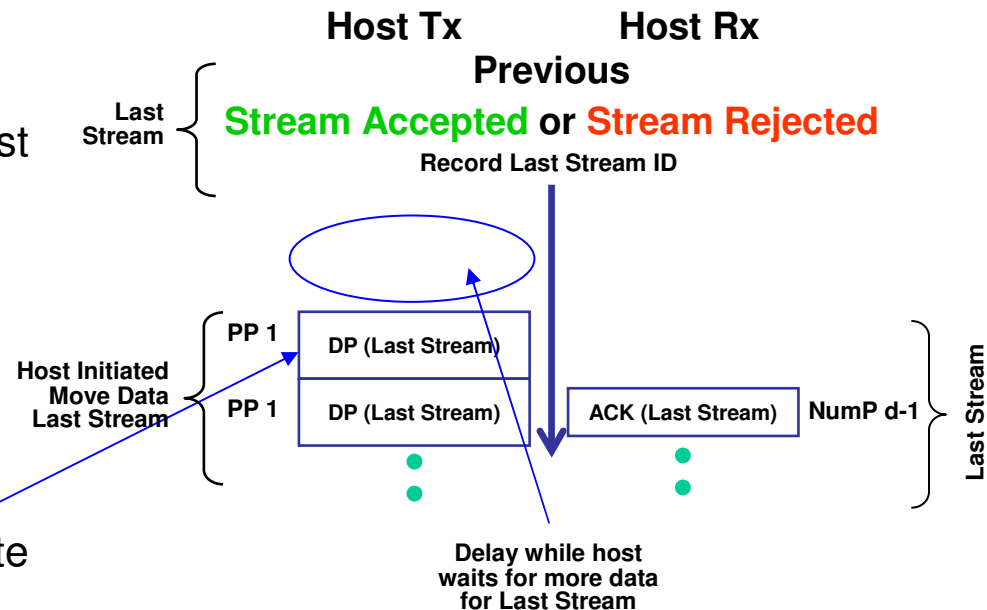
- Informs host that OUT Stream transfer is required
- ERDY
  - SID = 1 – Stream 1 transfer is required
  - NumP = the minimum number of data buffers available in the Device for the Stream
- **Accepted** – DP (Stream 1)
  - Host has buffers available for the Stream 1
  - Sets the **Current Stream** in the Host to Stream 1
  - if more than one packet to move PP = 1, else PP = 0
  - Transition to *Move Data* state
- **Rejected** – DP (NoStream)
  - Host currently has no buffers available for the requested Stream
    - The device may initiate a Start Stream for Stream 1 later; response Device Class defined
  - Length = 0 & PP = 0
  - Transition to *Idle* state



# OUT Stream – Host Initiated Move Data



- Requirements
  - The pipe is *Idle*
  - A previous device initiated *Start Stream*
    - *Last Stream ID* recorded by host
  - Software posts data to the endpoint
- Host Initiated Move Data
  - If data was posted for the *Last Stream ID*
    - Issue an DP (Last Stream) to transition to the *Move Data* state
  - else
    - Issue an ACK (Prime) to transition to *Prime Pipe* state
  - Device may reject with NRDY





# OUT Stream Termination

- Terminating DP
  - $PP = 0$
- Terminating ACK
  - $NumP = 0$ .
- NRDY
  - Flow Controls Stream
    - Temporarily Terminates Stream and pipe transitions to *Idle* state
    - Device shall issue a subsequent *Stream Start* to complete a Stream transfer
- Error
  - Forces pipe to *Disabled* state
  - Stalls pipe, i.e. All Streams associated with the pipe
  - Requires system software recovery



# Questions

- References

- Section 8.12.1.4 in core spec

- USB Attached SCSI (UAS)

- [http://www.t10.org/drafts.htm#SCSI3\\_UAS](http://www.t10.org/drafts.htm#SCSI3_UAS)

- USB Attached SCSI Protocol (UASP)

- <https://www.usb.org/apps/org/workgroup/uasp/>

- Access requires IP agreement