SpaceWire-RT Requirements

Steve Parkes

Space Technology Centre

University of Dundee

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Technology
Centre
University of Dundee

SpaceWire-RT

- RT
  - Real-Time
  - Reliable, Timely
- Is concerned primarily with Quality of Service

- Aim to support:
  - Control applications over SpaceWire
  - CCSDS SOIS Services

CCSDS SOIS

- Five sub-network services:
  - Memory access
  - Packet
  - Test
  - Time distribution
  - Device discovery
- Quality of service
  - Best Effort
  - Assured
  - Resource-reserved
  - Guaranteed

Best Effort

- Neither reliable nor timely

- Single attempt to deliver data
- Cannot ensure that it will be delivered successfully
- Data is provided
  - in-sequence,
  - without errors
  - without duplication
- Priority shared with assured QoS

Assured

- Reliable but not timely

- Ensures delivery of data to its destination
- Should it not be possible to provide the assured service this is indicated to the sending entity
- Data is provided
  - in sequence (within a priority value),
  - complete,
  - without errors
  - without duplication
- Priority shared with best effort QoS

Resource-reserved

- Timely but not reliable

- Single attempt to deliver data
- Cannot ensure that it will be delivered successfully
- Data is provided
  - in sequence
    - (within the channel and within a priority value),
  - without errors
  - without duplication.
- Channel defines resources used to transmit SDU
- Priority is within a channel

Guaranteed

- Reliable and timely

- Ensures delivery of data to its destination
- Should it not be possible to provide the guaranteed service this is indicated to the sending entity
- Data is provided
  - in-sequence
    - (within a channel and within a priority value),
  - complete,
  - without errors
  - without duplication
- Channel defines resources used to transmit SDU.
- Priority within a Channel

Key recommendation to SOIS

- Change best effort and resource-reserved services to not require in-sequence delivery and rejection of duplicates
- Example
  - Packets sent in order 1, 2, 3, 4, 5, 6
  - Arrive in order 1, 3, 2, 4, 5, 6
- If in sequence delivery is required then
  - Accept 1
  - Reject 3 (out of sequence)
  - Accept 2 (restart sequence counter)
  - Reject 4 (out of sequence)
  - Accept 5 (restart sequence counter)
  - Accept 6
- Lost two packets

Sending Information Requirements

- **R1-1   Packets**
  - SpW-RT shall send information in SpaceWire packets.

- **R1-2   Packet Length**
  - SpaceWire packets shall be of variable length up to a defined maximum.

- **R1-3   Packet Address**
  - The SpaceWire packets used to transfer SpW-RT information shall have a header containing the SpaceWire address of the destination which can be composed of SpaceWire path, logical or regional logical address characters.

Sending Information Requirements

- **R1-4   Primary Route**
  - If there are two or more routes available from a source to a destination one route shall be selected as the primary route which is normally used for sending packets.

- **R1-5   Alternative Routes**
  - Alternative routes from a source to a destination may be defined and used in the event of a fault occurring on the primary route.

Sending Information Requirements

- **R1-6   Channel Identifier**
- A channel shall identify a collection of network resources associated with a route from a source to a destination which is used to control the flow of information across the network and help to ensure timely delivery.

Sending Information Requirements

- **R1-7   Channel Time-Division**
  - A channel identifier may identify one or more time slots in a time-division multiplexed system where communication from a specific source to a specific destination is only allowed during a particular time slot.

- **R1-8   Channel Bandwidth Reserved**
  - A channel identifier may identify a bandwidth limit in a bandwidth reserved system where communication from a specific source to a specific destination is controlled by limiting the available bandwidth.

QoS Requirements

- **R2-1   Quality of Service**
  - SpW-RT shall support four classes of quality of service:
  - best effort,
  - assured,
  - resource-reserved
  - guaranteed.

Best Effort Requirements

- **R2.1-1   Best Effort Service**
  - SpW-RT shall provide a best effort service.

- **R2.1-2   Best Effort Single Attempt**
  - The best effort service shall make a single attempt to deliver data to its destination but cannot ensure that it will be delivered successfully.

- **R2.1-3   Best Effort Not In-Sequence**
  - The best effort service shall not necessarily deliver data in the order in which it was sent

SpaceWire-RT Requirements

- **R2.1-4   Best Effort Without Error**
  - The best effort service shall ensure that data delivered has a low probability of containing errors.

- **R2.1-5   Best Effort Discard Errors**
  - The best effort service shall discard any data found to contain errors.

- **R2.1-6   Best Effort No Duplication**
  - The best effort service shall not deliver duplicate data.
  - Can we remove this requirement?

SpaceWire-RT Requirements

- **R2.1-7   Best Effort Priority**
  - The best effort service shall send packets of high priority before sending packets of lower priority.

- **R2.1-8   Best Effort Assured Priority**
  - The best effort service shall share a priority domain with the assured service i.e. a high-priority best effort packet shall be sent prior to a lower-priority assured packet and vice versa.

Assured Requirements

- **R2.2-1   Assured Service**
  - SpW-RT shall provide an assured service.

- **R2.2-2   Assured Delivery**
  - The assured service shall ensure that data is delivered to its destination.

- **R2.2-3   Assured Non-Delivery Notification**
  - If for whatever reason it is not possible to deliver data to its destination the assured service shall notify the sending entity.

Assured Requirements

- **R2.2-4   Assured In-Sequence**
  - The assured service shall deliver data in-sequence (within a priority value).

- **R2.2-5   Assured Complete**
  - The assured service shall deliver all the data that it is requested to send.

- **R2.2-6   Assured Without Error**
  - The assured service shall ensure that data delivered has a low probability of containing errors.

Assured Requirements

- **R2.2-7   Assured Discard Errors**
  - The assured service shall discard any packet found to contain errors.

- **R2.2-8   Assured Retry**
  - If a packet goes missing or arrives in error at the destination the assured service shall send the packet again to make sure that all the data arrives at the destination.

Assured Requirements

- **R2.2-9   Assured No Duplication**
  - The assured service shall not deliver duplicate data.

- **R2.2-10   Assured Priority**
  - The assured service shall send packets of high priority before sending packets of lower priority.

Resource-Reserved Requirements

- **R2.3-1   Resource-Reserved Service**
  - SpW-RT shall provide a resource-reserved service.

- **R2.3-2   Resource-Reserved Single Attempt**
  - The resource-reserved service shall make a single attempt to deliver a data to its destination but cannot ensure that it will be delivered successfully.

- **R2.3-3   Resource-Reserved Not In-Sequence**
  - The resource-reserved service shall not necessarily deliver data in the order in which it was sent (within a channel and within a priority value).

Resource-Reserved Requirements

- **R2.3-4   Resource-Reserved Without Error**
  - The resource-reserved service shall ensure that data delivered has a low probability of containing errors.

- **R2.3-5   Resource-Reserved Discard Errors**
  - The resource-reserved service shall discard any data found to contain errors.

- **R2.3-6   Resource-Reserved No Duplication**
  - The resource-reserved service shall not deliver duplicate data.

Resource-Reserved Requirements

- **R2.3-7   Resource-Reserved Priority**
  - The resource-reserved service shall send packets of high priority before sending packets of lower priority.

- **R2.3-8   Resource-Reserved Guaranteed Priority**
  - The resource-reserved service shall share a priority domain with the guaranteed service.

- **R2.3-9   Resource-Reserved Timely**
  - The resource-reserved service shall provide timely delivery of packets to the destination.

Guaranteed Requirements

- **R2.4-1   Guaranteed Service**
  - SpW-RT shall provide a guaranteed service.

- **R2.4-2   Guaranteed Delivery**
  - The guaranteed service shall ensure that data is delivered to its destination.

- **R2.4-3   Guaranteed Non-Delivery Notification**
  - If for whatever reason it is not possible to deliver data to its destination the guaranteed service shall notify the sending entity.

Guaranteed Requirements

- **R2.4-4   Guaranteed In-Sequence**
  - The guaranteed service shall deliver data in-sequence (within a channel and within a priority value).

- **R2.4-5   Guaranteed Complete**
  - The guaranteed service shall deliver all the data that it is requested to send.

- **R2.4-6   Guaranteed Without Error**
  - The guaranteed service shall ensure that data delivered has a low probability of containing errors.

Guaranteed Requirements

- **R2.4-7   Guaranteed Discard Errors**
  - The guaranteed service shall discard any packet found to contain errors.

- **R2.4-8   Guaranteed Retry**
  - If a packet goes missing or arrives in error at the destination the guaranteed service shall send the packet again to make sure that all the data arrives at the destination.

- **R2.4-9   Guaranteed No Duplication**
  - The guaranteed service shall not deliver duplicate data.

Guaranteed Requirements

- **R2.4-10   Guaranteed Priority**
  - The guaranteed service shall send packets of high priority before sending packets of lower priority.

- **R2.4-11   Guaranteed Timely**
  - The guaranteed service shall provide timely delivery of packets to the destination.

Address Resolution Requirements

- **R3-1   Local Global Addresses**
  - A global address shall be used to represent user entities attached to the SpaceWire sub-network.

- **R3-2   Global Address Number**
  - There shall be a maximum of 65536 local addresses on a single SpaceWire sub-network.
  - DISCUSS are 223 addresses enough?

- **R3-3   Address Resolution**
  - SpW-RT shall convert from the global address to a SpaceWire address in order to route a packet to its intended destination.

Retry and Redundancy Requirements

- **R4-1   Retry and Redundancy Strategies**
  - SpW-RT shall support the following retry and redundancy strategies:
  - Simultaneous retry
  - Resend
  - Resend Redundant
  - Report and Reconfigure

- **R4-2   Simultaneous Retry**
  - When simultaneous retry is being used two identical packets shall be sent over different routes through the sub-network to the intended destination.

Retry and Redundancy Requirements

- **R4-3   Resend**
  - If a packet is not known to be delivered without error to its destination, an identical packet shall be resent over the same route for a specified maximum number of retry attempts.

- **R4-4   Resend Alternative**
  - If after the resending of a packet for the specified number of attempts through the primary route the packet still has not been delivered successfully, SpW-RT shall use an alternative route through the SpaceWire network a specified maximum number of retry attempts, assuming that an alternative route is available.

Retry and Redundancy Requirements

- **R4-5   Retry Multiple Alternatives**
  - If after the resending of a packet for the specified number of attempts through the alternative route the packet still has not been delivered successfully, SpW-RT shall use other alternative routes in turn a specified maximum number of retry attempts each, assuming that other alternative routes are available.

Retry and Redundancy Requirements

- **R4-6   Report Failure**
  - If after the resending of a packet through all the possible alternative routes to the destination it is still not delivered correctly, then the user entity requesting the packet to be sent shall be informed of the failure.

- **R4-7   Report and Reconfigure**
  - SpW-RT shall support the reconfiguration of a network that has failed consistently to deliver a packet to a destination.

Retry and Redundancy Requirements

- **R4-8   Retry Priority**
  - The guaranteed service shall treat retry packets as any other packet as far as priority is concerned i.e. a retry packet is not sent before another packet unless the retry packet has the higher or the same priority.

Non-Functional Requirements

- **N-1 Small footprint**
  - The SpW-RT protocols shall be efficient to implement.

- **N-2 Hardware or Software**
  - SpW-RT should be implementable in hardware or software or a combination of the two.

- **N-3 Timeliness**
  - For a moderate size SpaceWire network with three routers to be traversed the resource reserved and guaranteed service shall be able to deliver a packet within 1 millisecond

SpaceWire-RT Requirements

- Missing requirements?

- End to end flow control
- Others?

SpaceWire-RT Use Cases

- There are six principal use cases for SpW-RT:
  - Best effort service with priority
  - Assured service with primary/alternative retry
  - Resource-reserved service using time-division multiplexing
  - Resource-reserved service using bandwidth reservation
  - Guaranteed service using time-division multiplexing and retry
  - Guaranteed service using bandwidth reservation and retry
- Two others to cover different retry techniques
- Assured service with simultaneous retry
- Guaranteed service using bandwidth reservation and simultaneous retry.

Best Effort with Priority
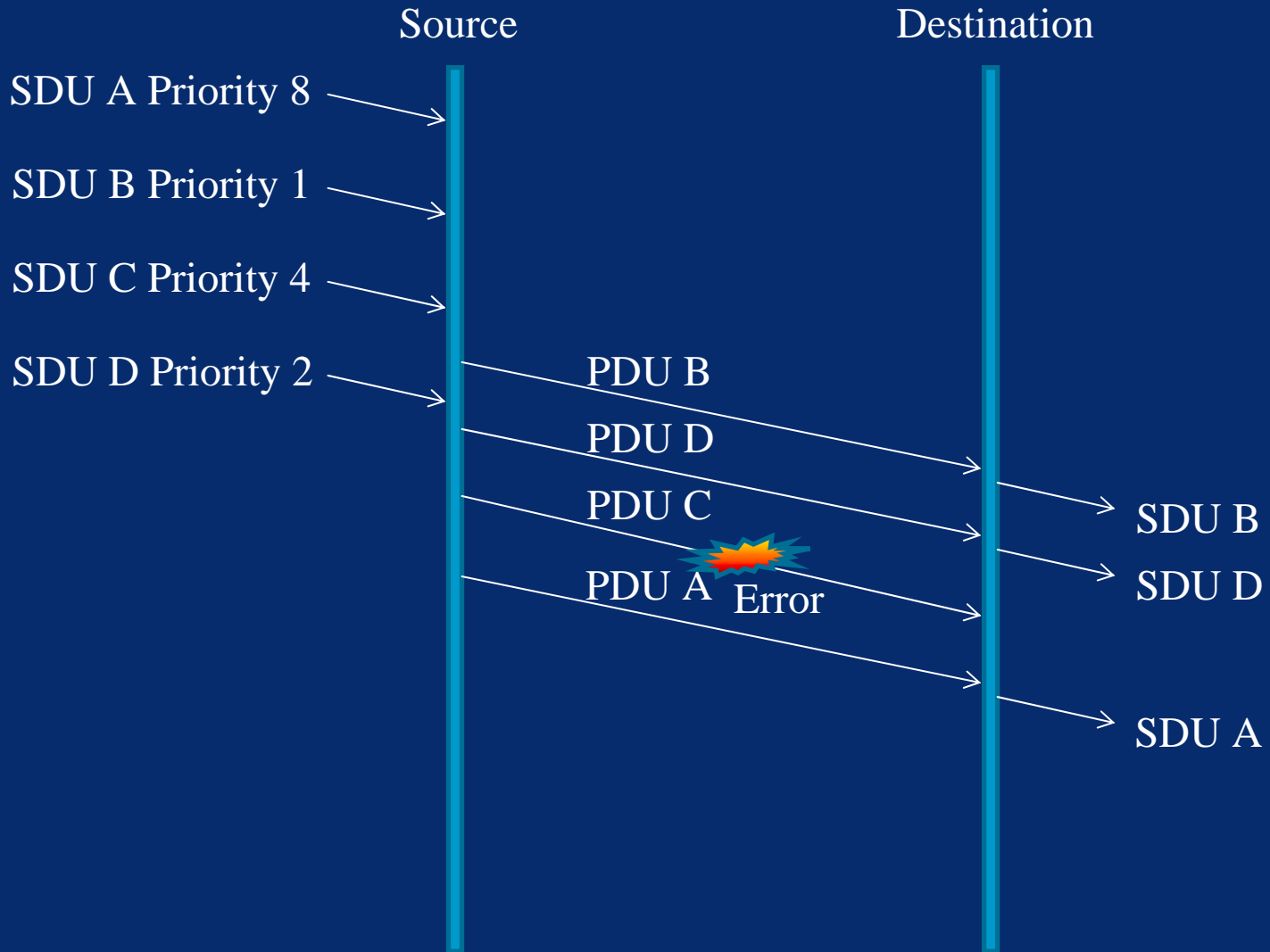
Assured with Primary/Alternative Retry
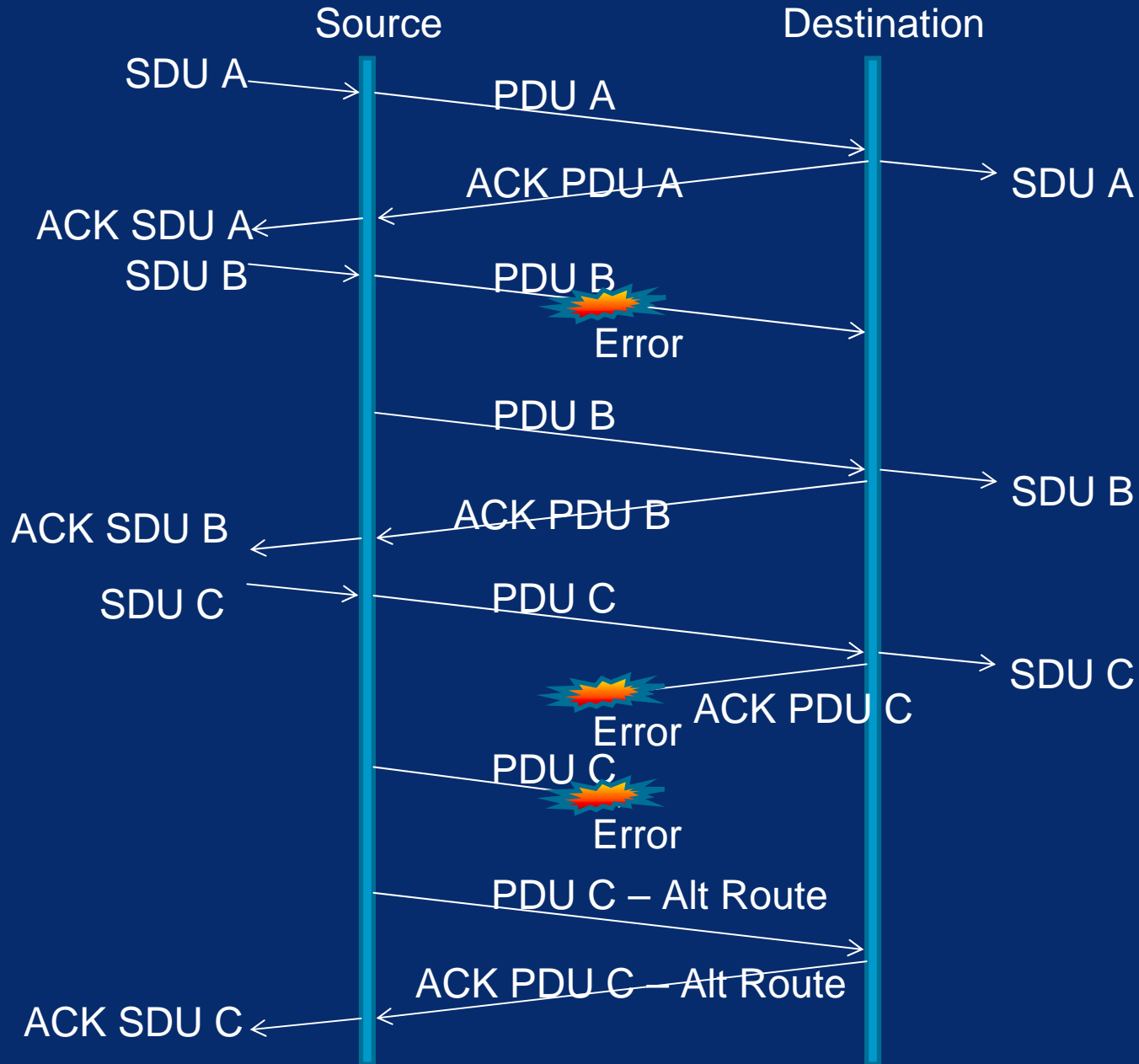
Resource-Reserved with Time Div Mux

Source   Destination

SDU A Ch 10

SDU B Ch 25   Slot 1

SDU C Ch 3   PDU B Ch 25   Slot 2

SDU D Ch 10
                                                           Slot 3   SDU B Ch 25

                                   PDU A Ch 10   Slot 4

Channel to slot mapping   PDU C Ch 3   Slot 5   SDU A Ch 10
Ch 3 -> Slot 5
Ch 10 -> Slot 4 and Slot 7   Error
Ch 25 -> Slot 2 and Slot 6   Slot 6

                                   PDU D Ch 10   Slot 7

                                                          Slot 8   SDU D Ch10

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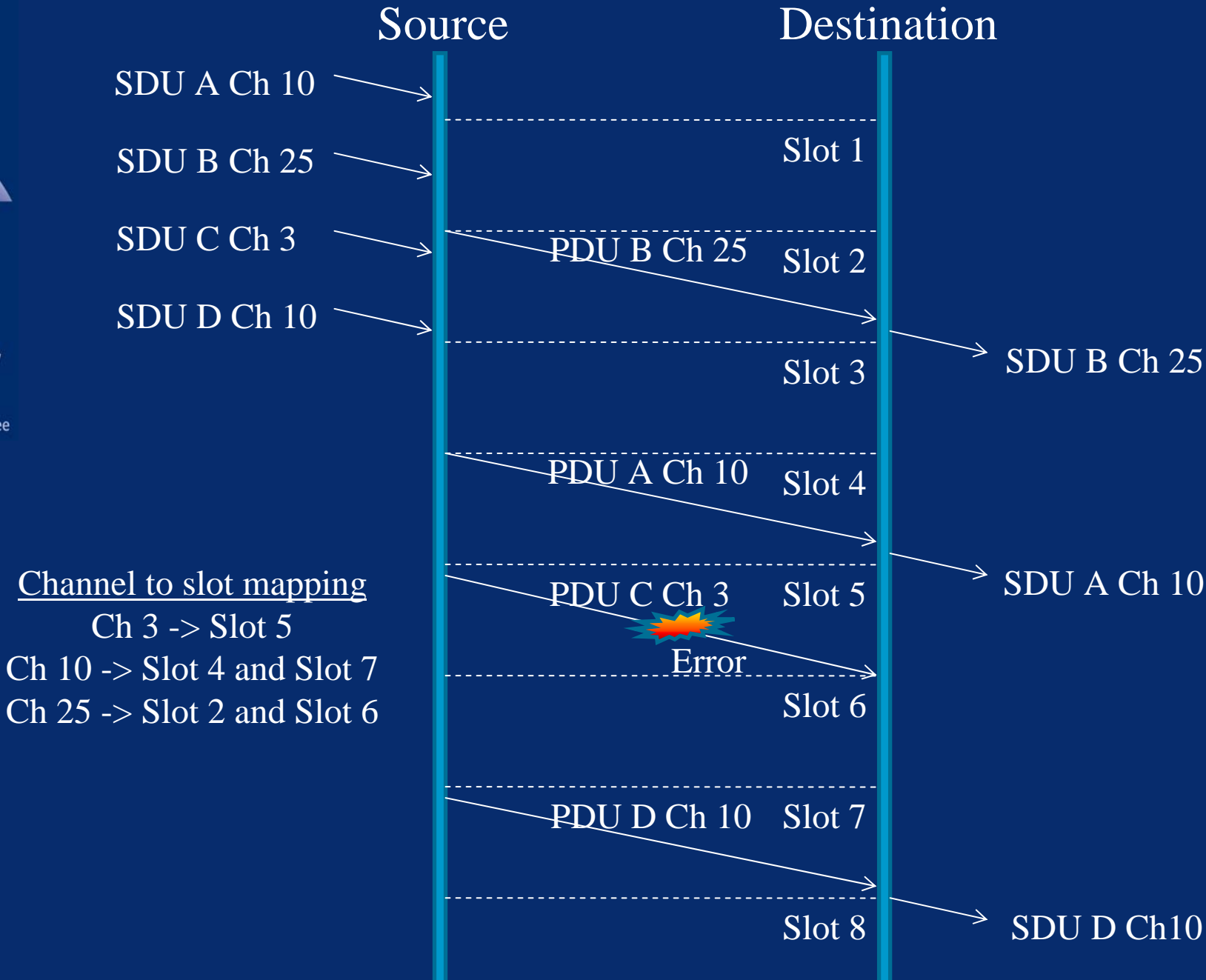
Resource-Reserved with BW Reservation

Source   Destination

SDU A Ch 10

PDU A Ch 10

SDU B Ch 25

SDU C Ch 3

SDU A Ch 10

PDU C Ch 3

SDU D Ch 10

PDU D Ch 10

SDU E Ch 10

SDU C Ch 3

SDU D Ch 10

PDU B Ch 25

Channel to Bandwidth Mapping
Ch 3 -> 25%%
Ch 10 -> 30%
Ch 25 -> 10%

PDU E Ch 10

SDU B Ch25

Error
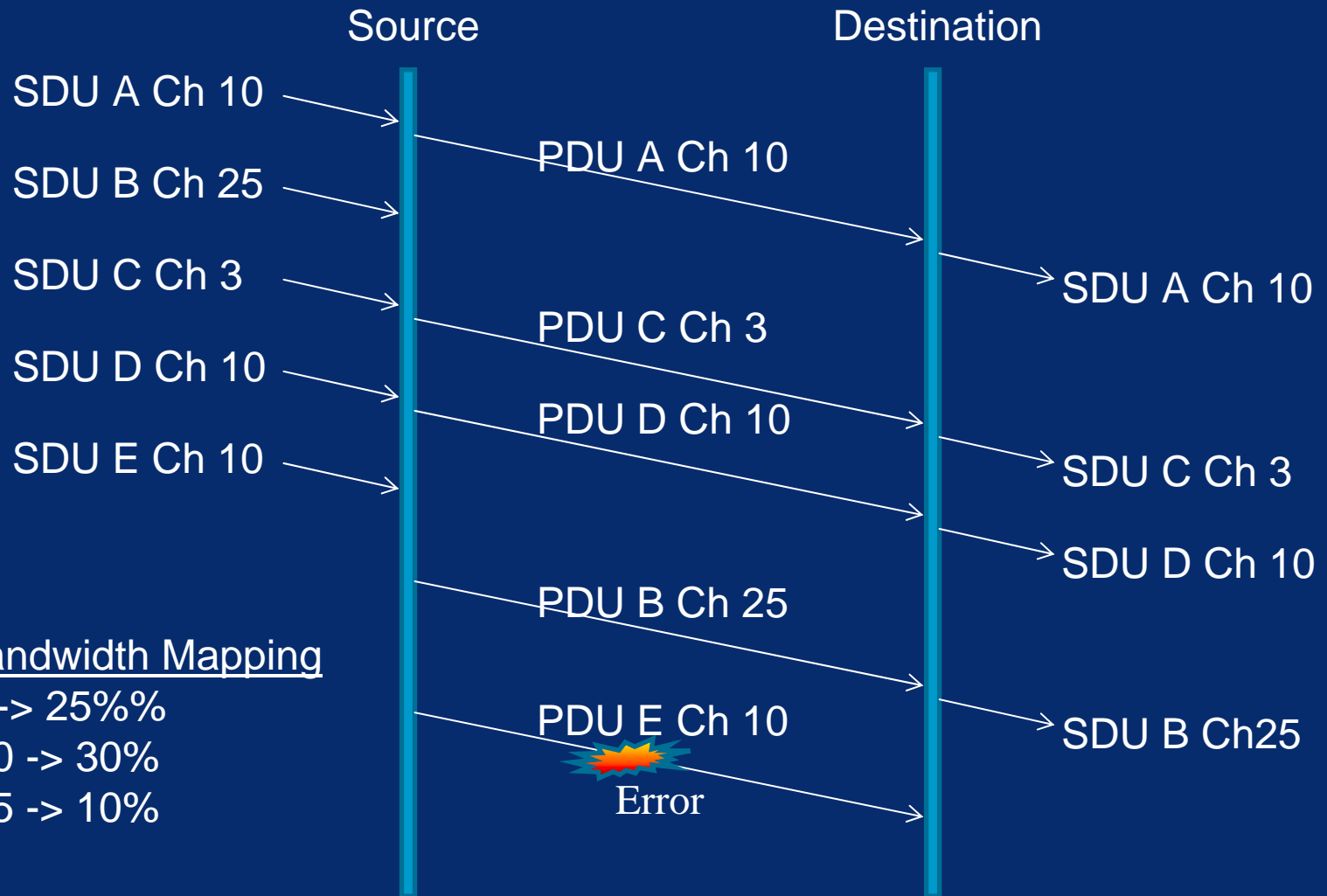
Guaranteed TDM and Retry

Source   Destination

SDU A Ch 10

SDU B Ch 25

PDU B Ch 25

SDU B Ch 25

ACK SDU B

ACK   Slot 2

SDU C Ch 3

SDU D Ch 25

Slot 3

PDU A Ch 10

ACK SDU A

SDU A Ch 10

ACK   Slot4
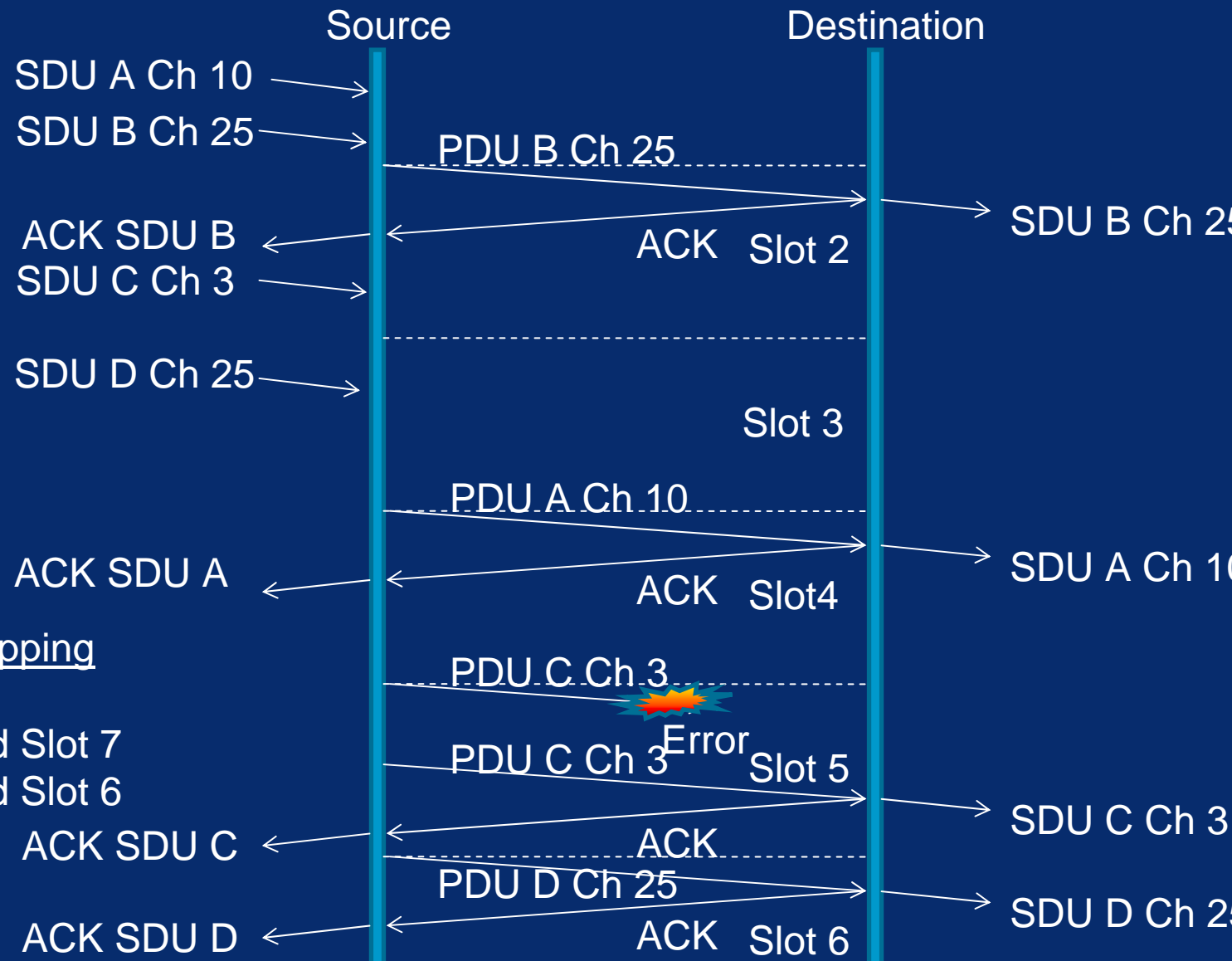
Channel to slot mapping
Ch 3 -> Slot 5
Ch 10 -> Slot 4 and Slot 7
Ch 25 -> Slot 2 and Slot 6

PDU C Ch 3

Error

PDU C Ch 3   Slot 5

SDU C Ch 3

ACK SDU C

ACK

PDU D Ch 25

SDU D Ch 25

ACK SDU D

ACK   Slot 6

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Guaranteed with BW Resv and Retry

Source   Destination

SDU A Ch 10 ——→   PDU A Ch 10
SDU B Ch 25 ——→   ——→ SDU A Ch 10
                              ACK
ACK SDU A ←——

SDU C Ch 3 ——→   PDU C Ch 3
SDU D Ch 10 ——→
                              ACK   ——→ SDU C Ch 3
ACK SDU C ←——

                              PDU D Ch 10

                              ACK   ——→ SDU D Ch 10

ACK SDU D ←——

Channel to Bandwidth Mapping   PDU B Ch 25
      Ch 3 -> 25%%   Error
      Ch 10 -> 30%   PDU B Ch 25
      Ch 25 -> 10%
                              ACK   ——→ SDU B Ch25

ACK SDU B ←——
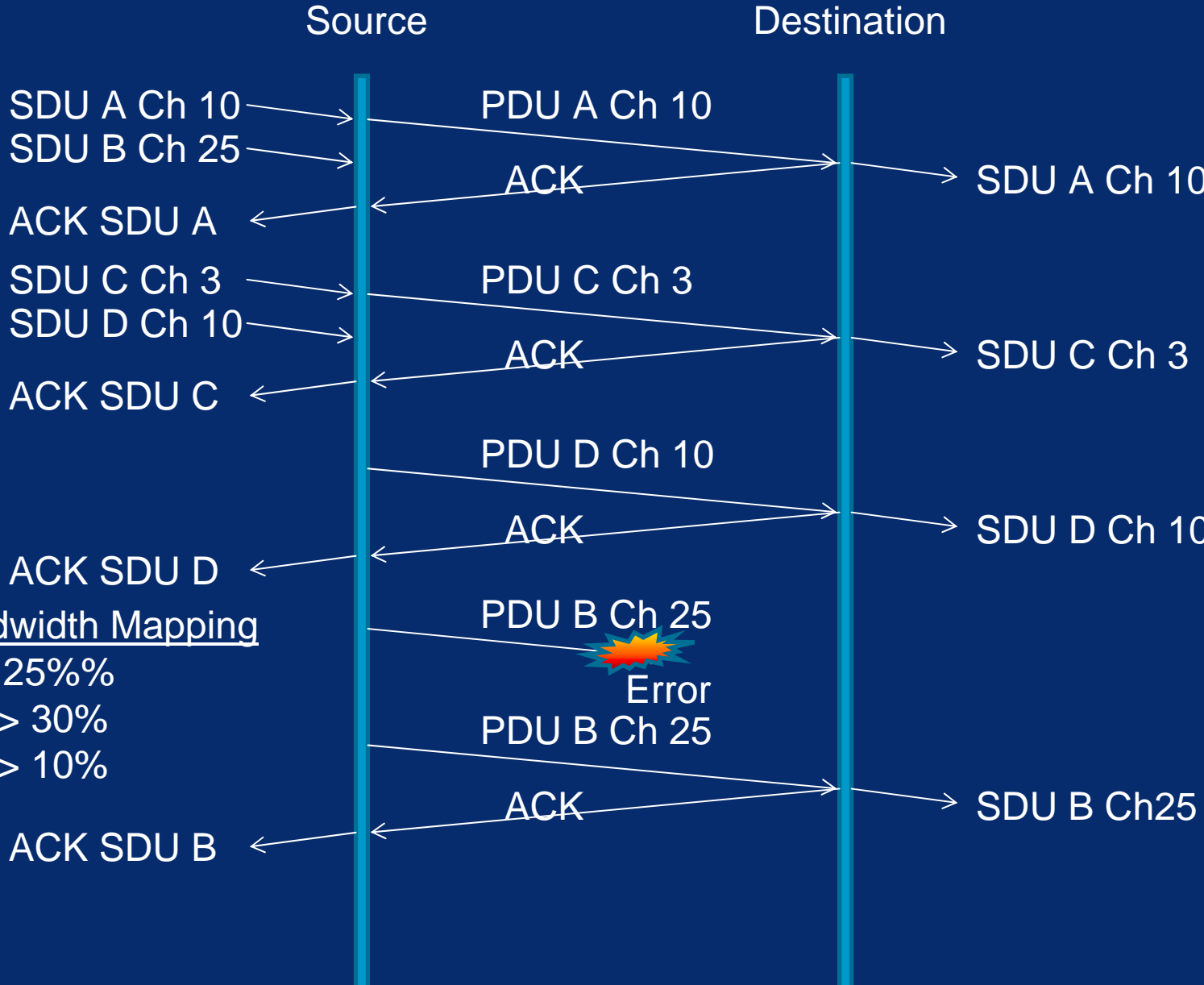
Assured with Simultaneous Retry

Source   Destination

SDU A →   PDU A - Primary

                         PDU A - Alternative →   → SDU A

                         ACK PDU A - Primary

ACK SDU A ←   ACK PDU A - Alternative

SDU B →   PDU B - Primary

                                          Error

                         PDU B-Alternative →   → SDU B

                         ACK PDU B - Alternative

ACK SDU B ←

SDU C →   PDU C - Primary

                         PDU C - Alternative →   → SDU C

                                          Error

                                          Error   ACK PDU C
                                                   - Primary

Fail SDU C ←
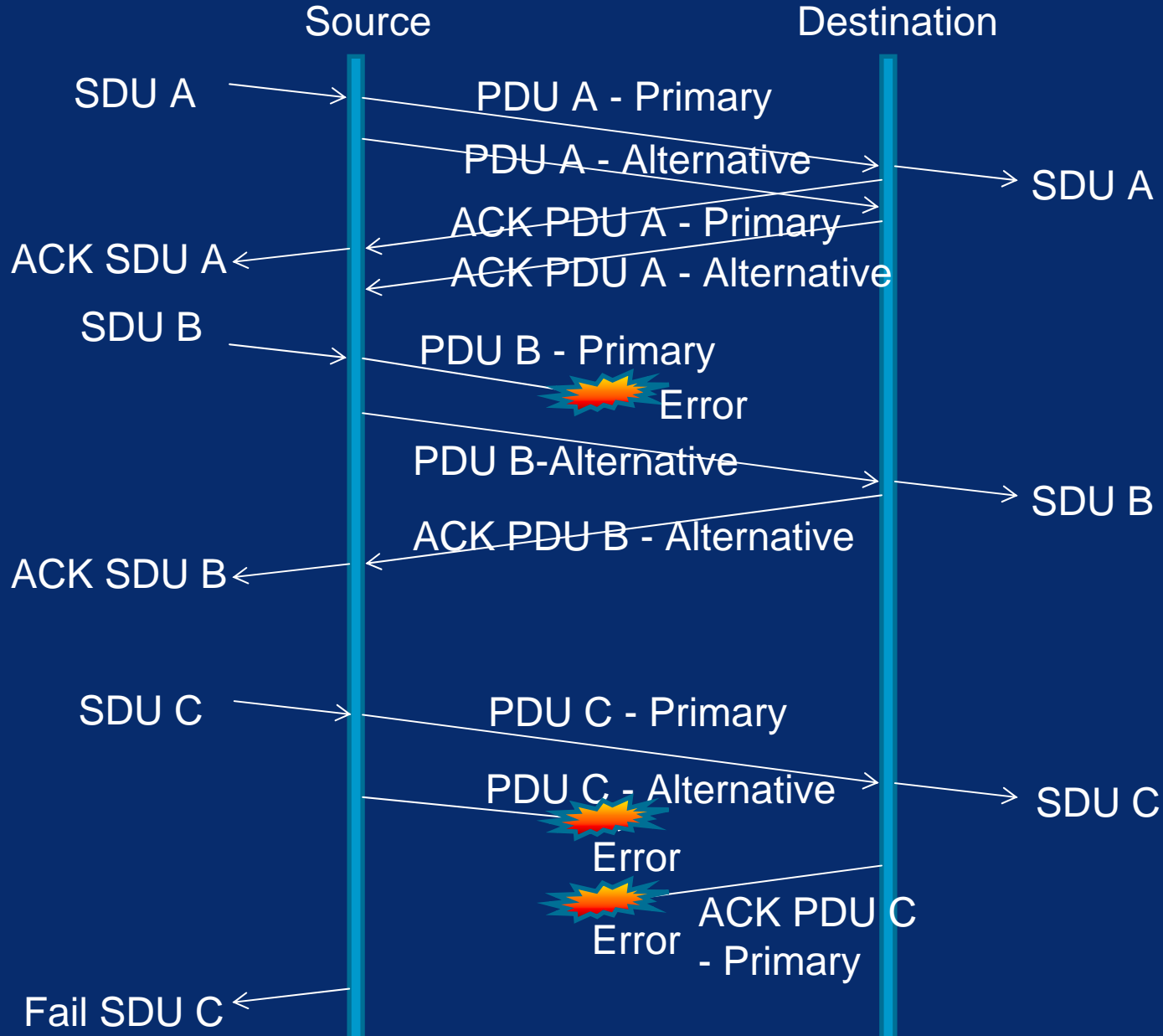
Guaranteed with BW Resv & Sim Retry
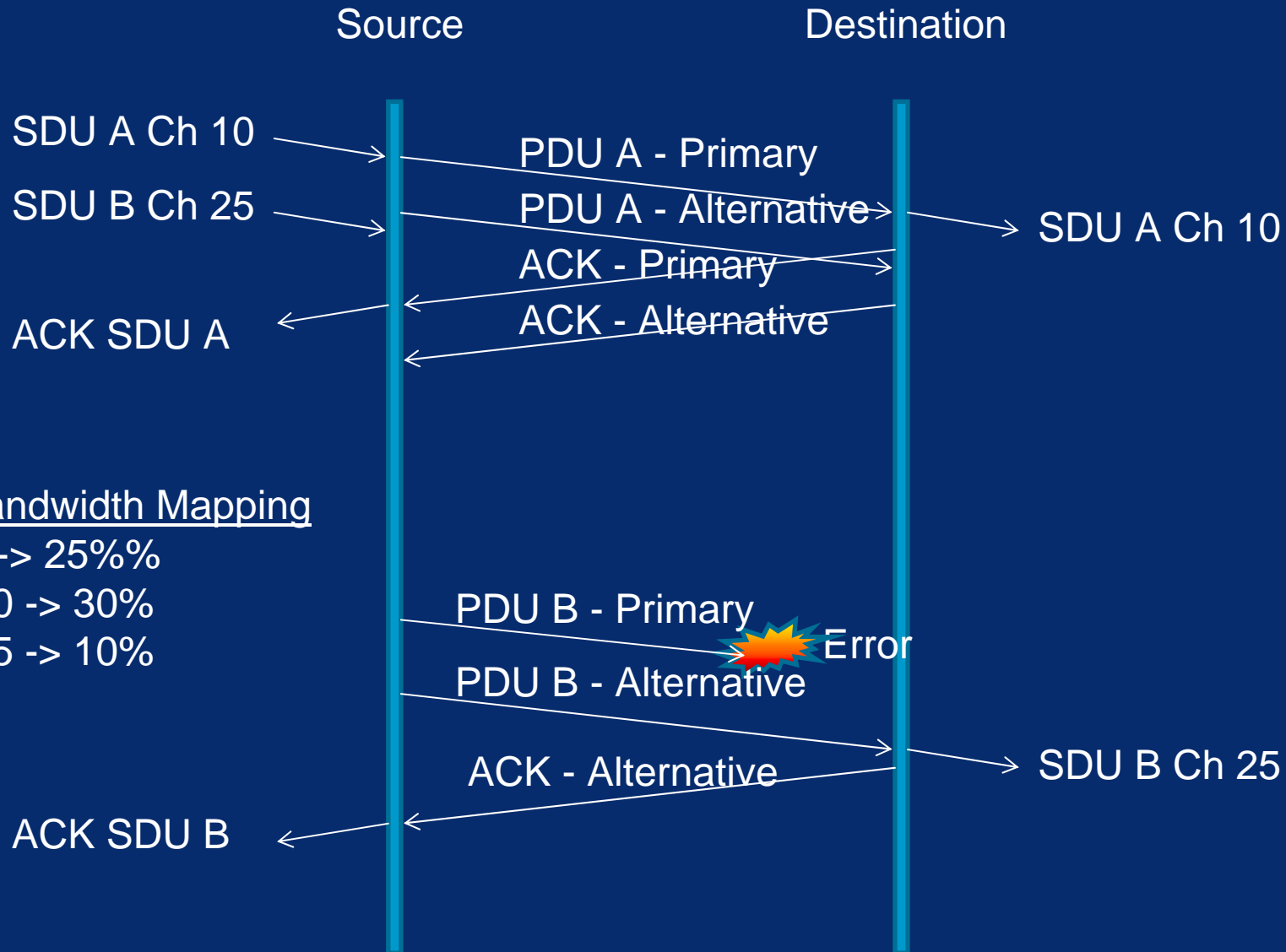
Source   Destination

SDU A Ch 10 → PDU A - Primary

SDU B Ch 25 → PDU A - Alternative → SDU A Ch 10

ACK - Primary

ACK SDU A ← ACK - Alternative

Channel to Bandwidth Mapping
Ch 3 -> 25%%
Ch 10 -> 30%
Ch 25 -> 10%

PDU B - Primary ✦ Error

PDU B - Alternative

ACK - Alternative → SDU B Ch 25

ACK SDU B

Conclusions

- Protocols discussed in April 2007
  - Developed by CCSDS TCONS
- Requirements formalised
- Next step
  - Initial protocol definition
  - Prototyping of various protocols to reduce risk
  - Revised protocol definition
  - Protocol implementation and testing