Virtual Channels, Broadcast Channels, and SpaceFibre

Steve Parkes[1], Albert Ferrer[1], Martin Suess[2]

[1]Space Technology Centre, University of Dundee

[2]ESA, ESTEC, The Netherlands

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Virtual Channels

- SpaceWire networks
  - Wormhole routing switches
    - Packet routed as soon as its leading character arrives
    - Provided the required output port is not busy
    - Otherwise the packet has to wait for port to become free
  - Advantages
    - Simple
    - Low latency unless port busy
    - Minimises amount of buffer memory required
    - Allows arbitrary sized packets
  - Disadvantages
    - If a packet gets blocked
    - Will block all links that the packet is occupying
      - i.e. from blocked router to source of packet
    - Causes further packet blocking

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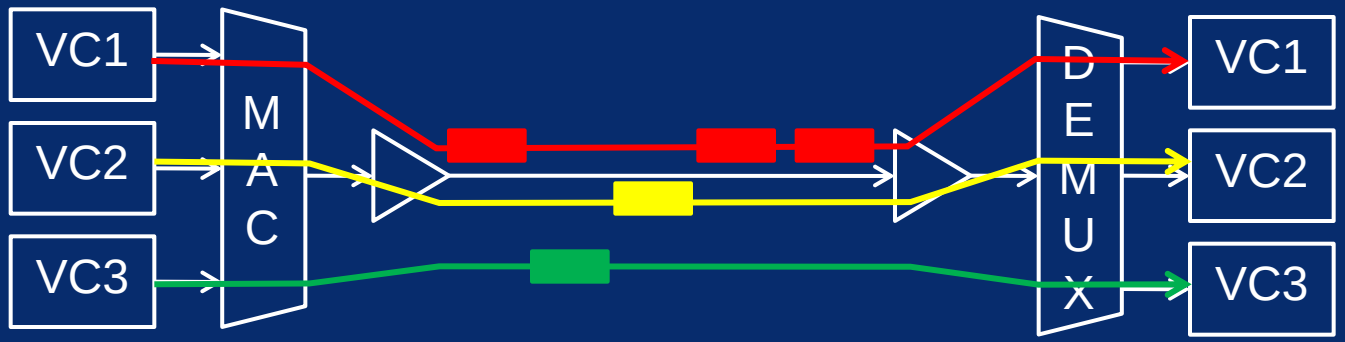
Possible Solutions to Packet Blocking

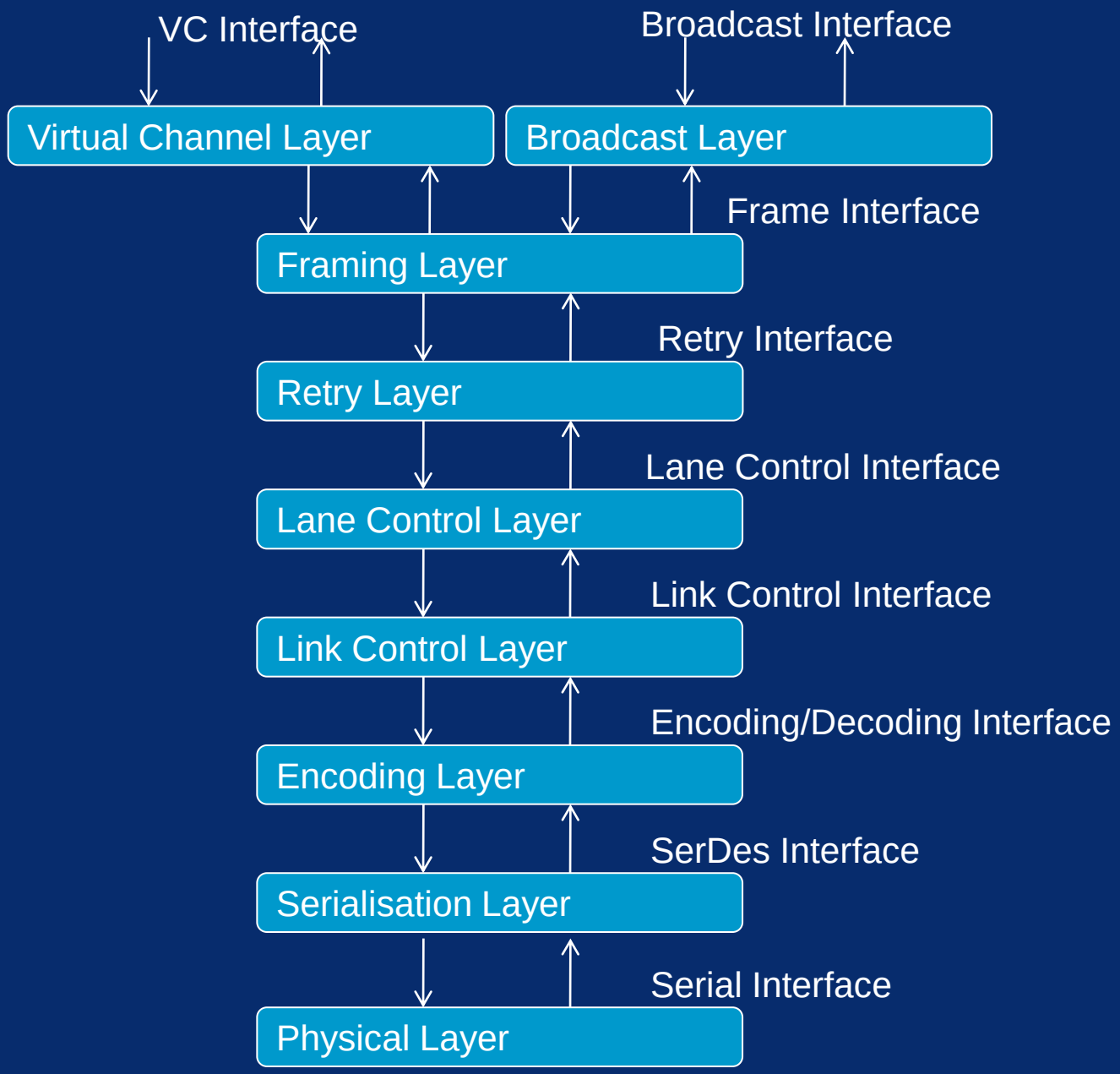
- For many SpaceWire applications
  - Actually not a problem
  - Need to be aware of possible packet blocking
- Manage traffic
  - Schedule traffic flowing over network
  - SpaceWire-D
- Packet buffering
  - Buffer each packet in the router
  - Requires large amount of memory
  - Arbitrary packet length not possible
- Virtual channels
  - Widely used concept to solve blocking problem

Virtual Channels



- VC sends when
  - Source VC buffer has data to send
  - Destination VC buffer has space in buffer
  - QoS for VC results in highest precedence
- A SpW packet flowing through one VC does not block another packet flowing through another VC

SpaceFibre Overview



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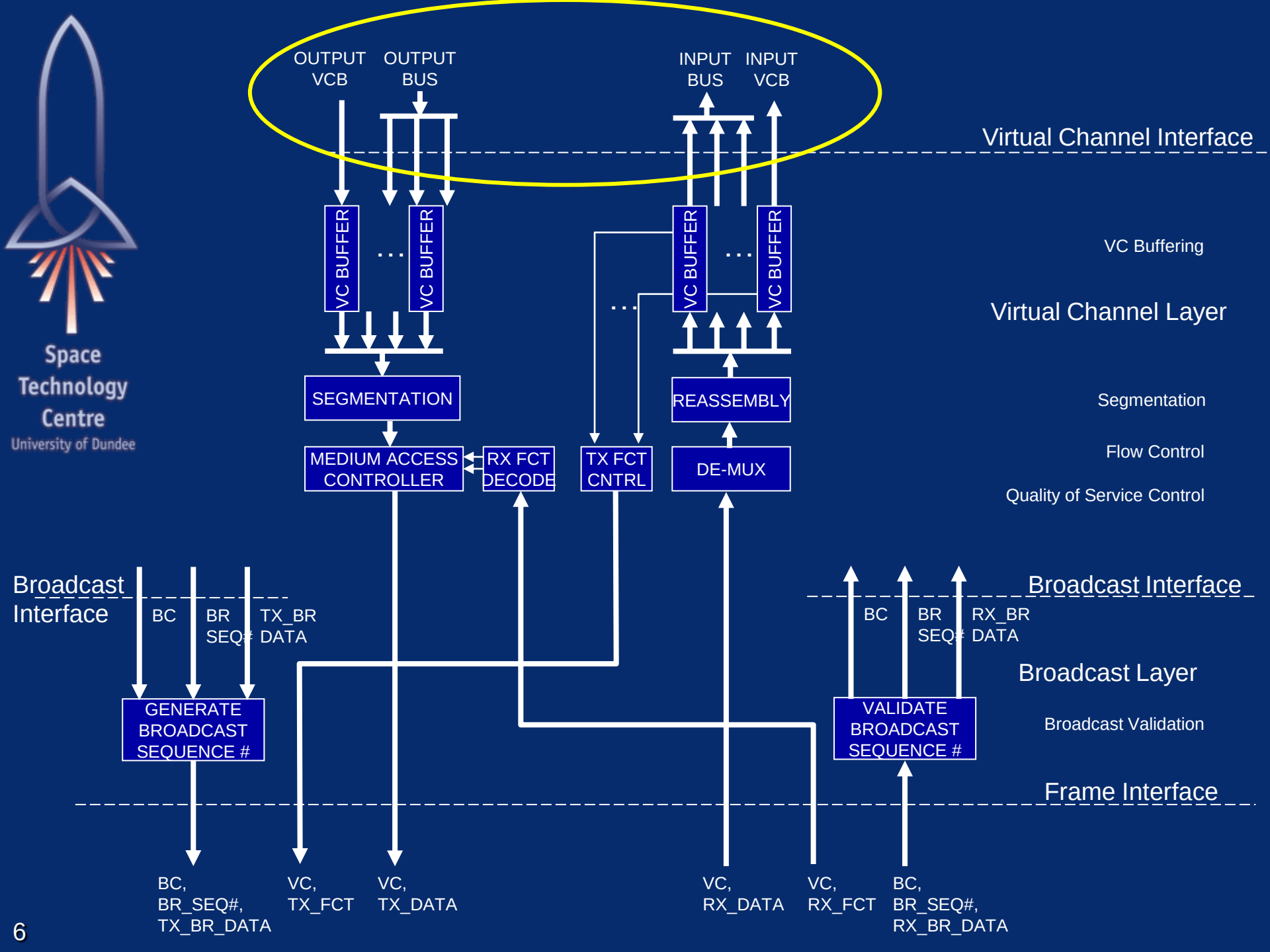
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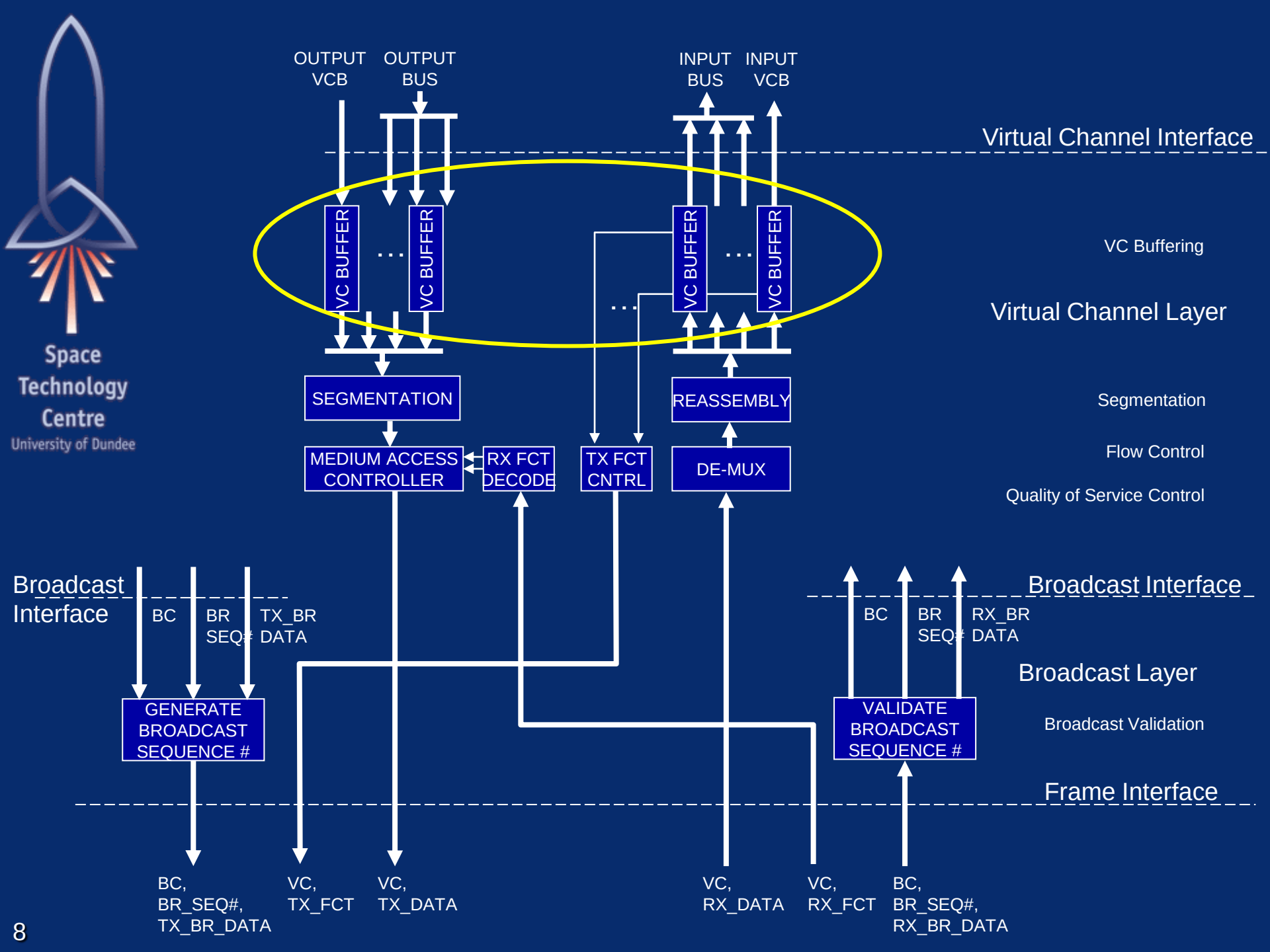
SpaceFibre Virtual Channels

- Virtual Channel Interface
  - Used to send and receive SpaceWire packets
  - Comprises a number of virtual channel buffers
    - Output VCBs for sending SpaceWire packets
    - Input VCBs for receiving SpaceWire packets
    - Conceptual FIFO type interface
    - Accepts SpaceWire N-Chars (data + EOP/EEP)
  - Application
    - Loads packet information sequentially into VCB
    - Addressing and routing is identical to SpaceWire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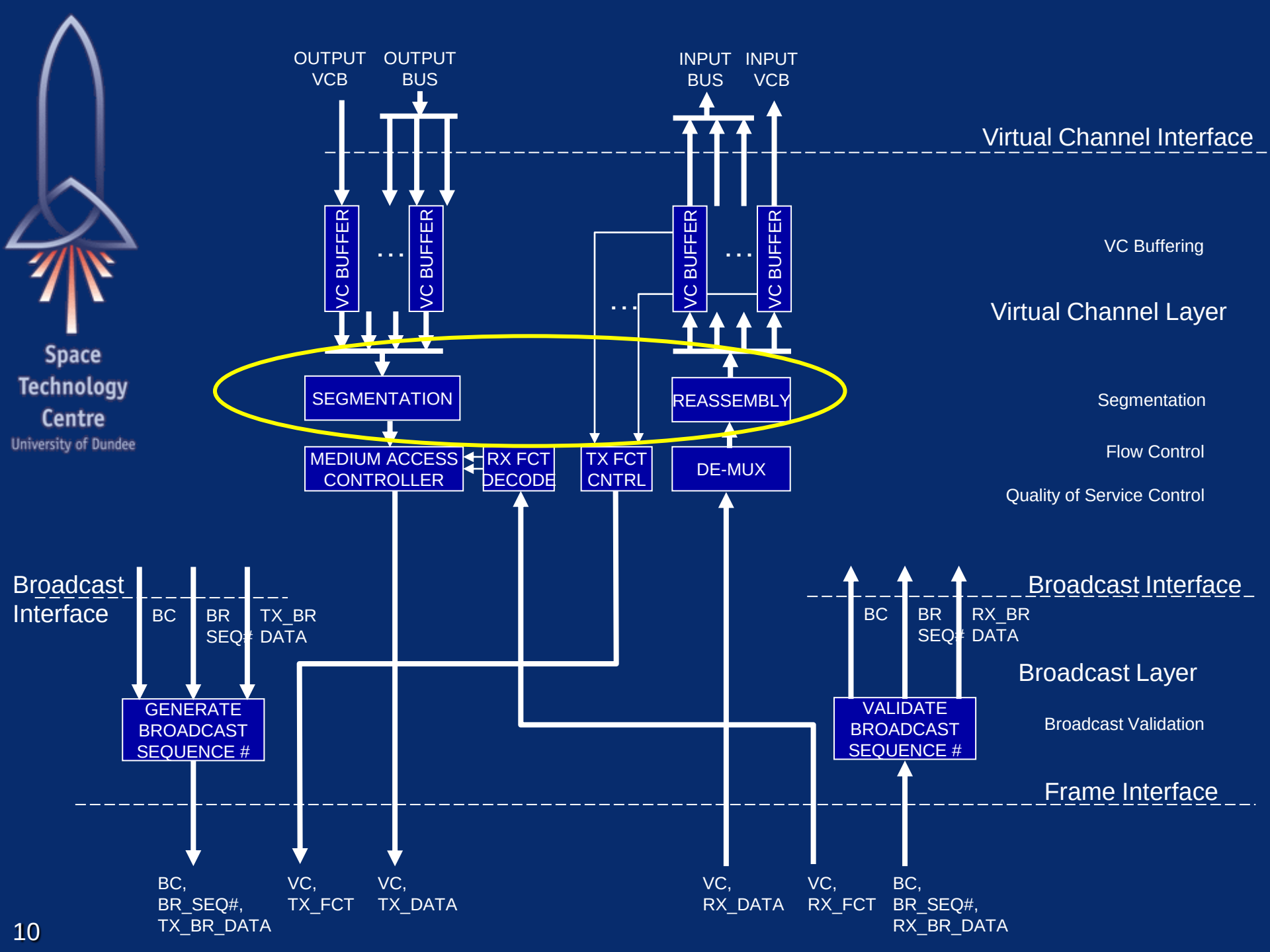
SpaceFibre Virtual Channels

- Virtual channel buffering
  - VCBs buffer SpaceWire packets
  - Output VCB
    - Buffers data before it is sent
  - Output VCB must contain
    - A full frame of data (256 N-Chars)
    - Or an EOP / EEP
    - Before it is put forward for arbitration and sending
  - Inputs VCBs
    - Holds at least one full data frame
    - Application can read data at its leisure
      - Without affecting the network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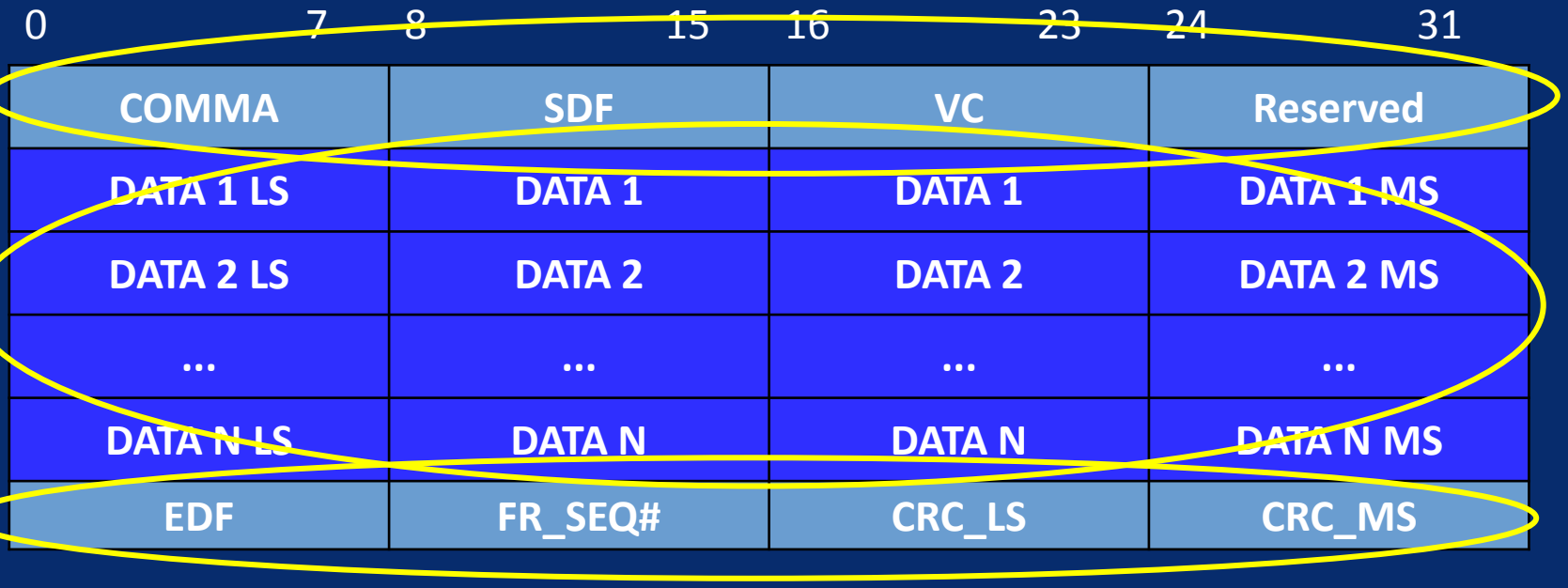
SpaceFibre Virtual Channels

- Segmentation
  - Splits SpaceWire packet stream into data frames
  - Each frame contains a chunk of data
    - Up to 256 N-Chars
  - Room for frame indicated by FCT
  - Framing permits
    - Additional FDIR information
      - CRC
      - Sequence number
    - Isolates any errors, containing them in frame
    - Supports retry for robust communication
  - Allows QoS to be implemented efficiently

SpaceFibre Data Frame



- 32-bit oriented, control words and data words
- Start Data Frame
  - Virtual Channel Number
- Data field contains N-Chars
  - From one or more SpaceWire packets
- End Data Frame
  - Frame sequence Number, CRC

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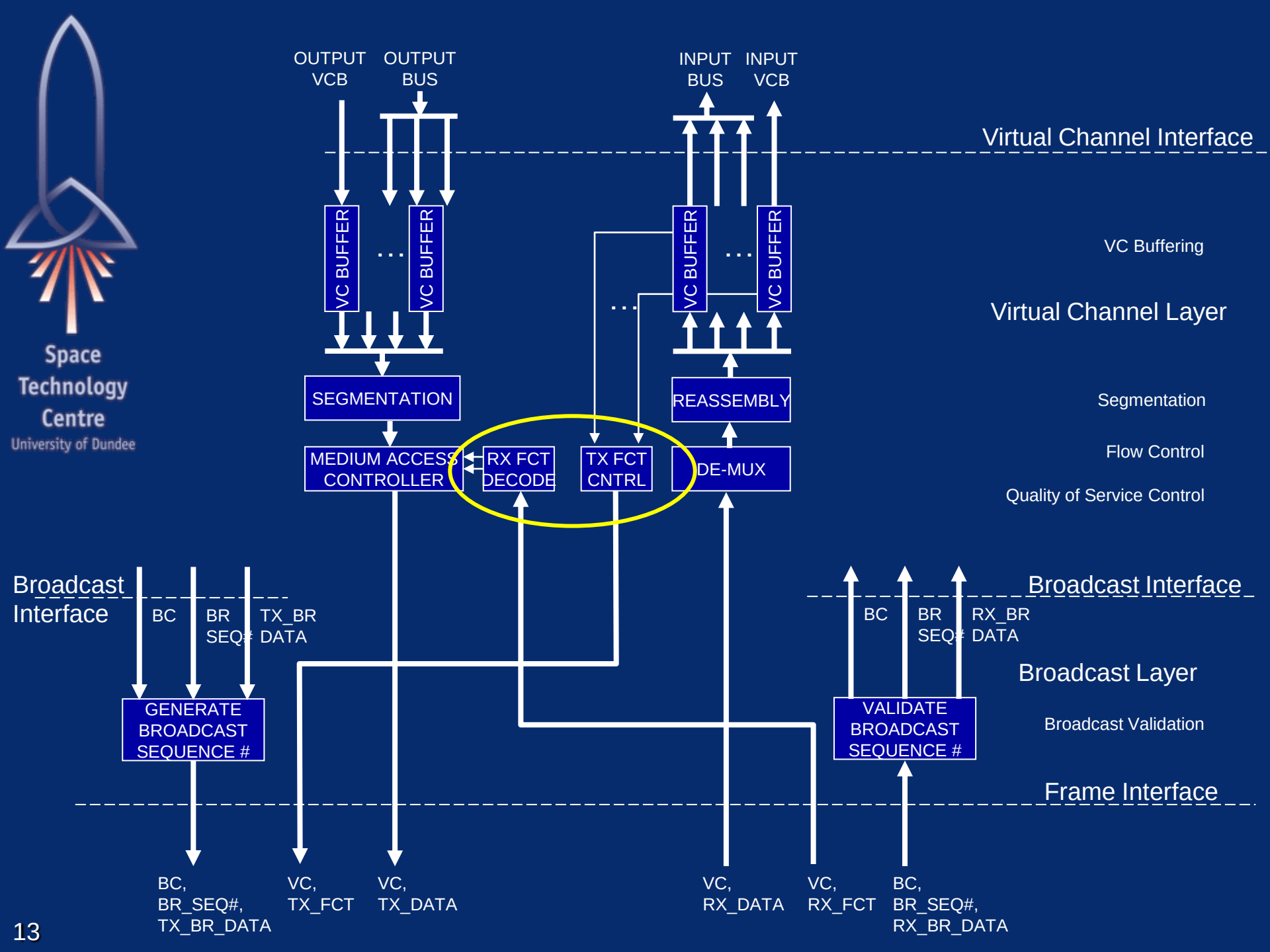
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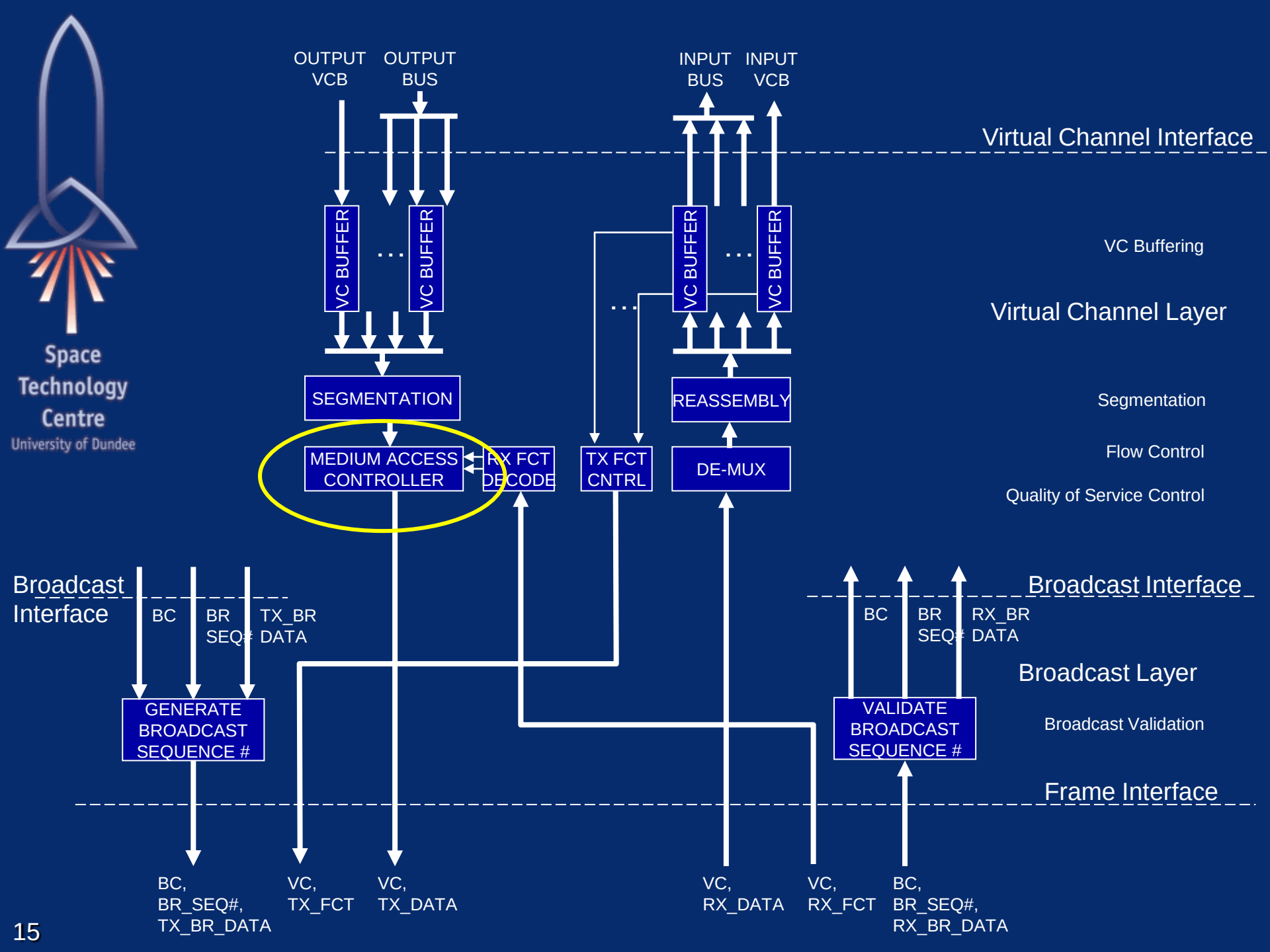
SpaceFibre Virtual Channels

- Flow Control
  - Makes sure there is room in input VCB at far end of the link
  - Before sending a data frame
  - Avoids blocking
  - FCT exchanged for 256 N-Chars (full frame)
  - FCT sent when input buffer has room for another full data frame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SpaceFibre Virtual Channels

- Medium Access Controller
  - Determines what output VCB to send next frame from
  - Depends on:
    - Which output VCBs have data to send
    - Which input VCBs at other end of link have room
    - Arbitration or QoS policy in force for each virtual channel

SpaceFibre Virtual Channels

- Quality of service
  - Fair arbitration
    - Each virtual channel has equal opportunity to use link
  - Priority
    - Virtual channel with highest priority goes first
  - Bandwidth reserved
    - Virtual channel with allocated bandwidth and recent low utilisation goes next
  - Scheduled
    - Time-slots defined by broadcast messages
    - Virtual channels allocated to specific time-slots
    - In allocated time-slot, virtual channel allowed to send

Simulation Results

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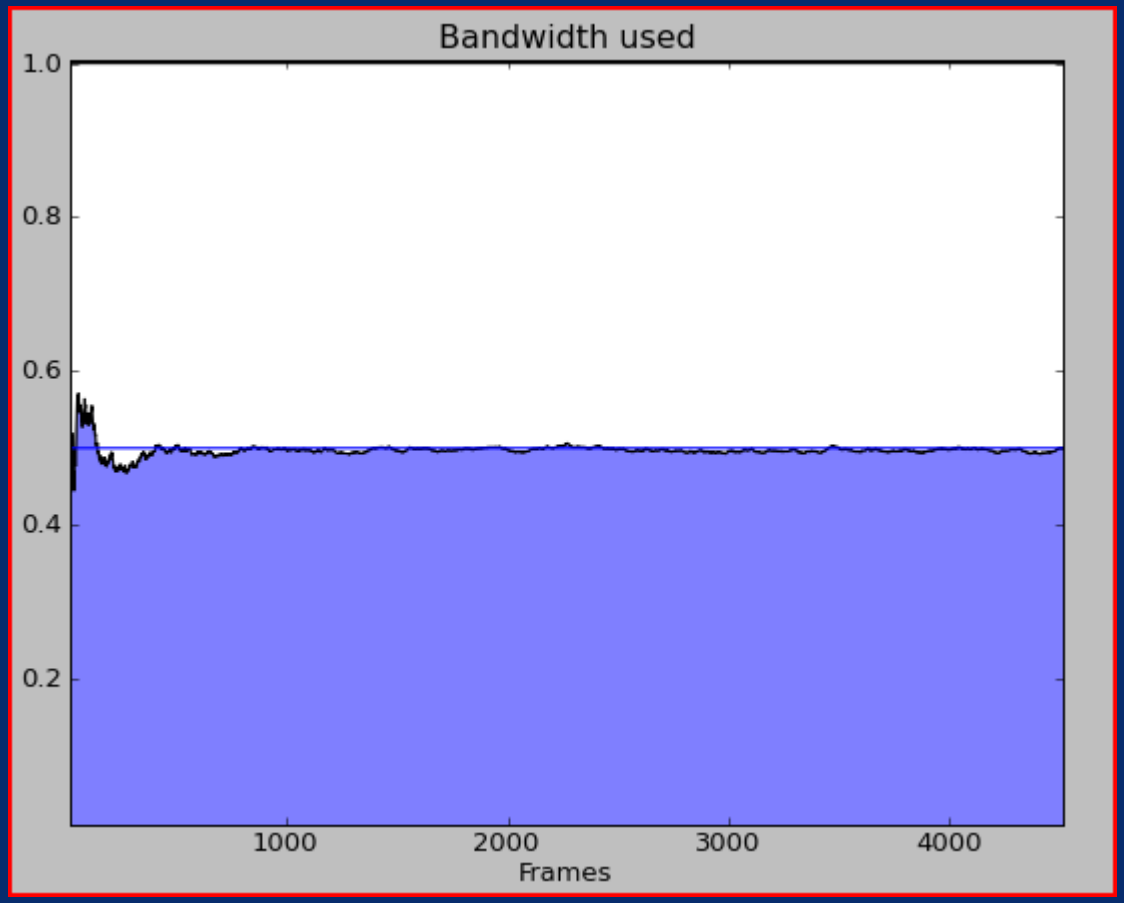
Simulation Results

- One virtual channel that uses half bandwidth



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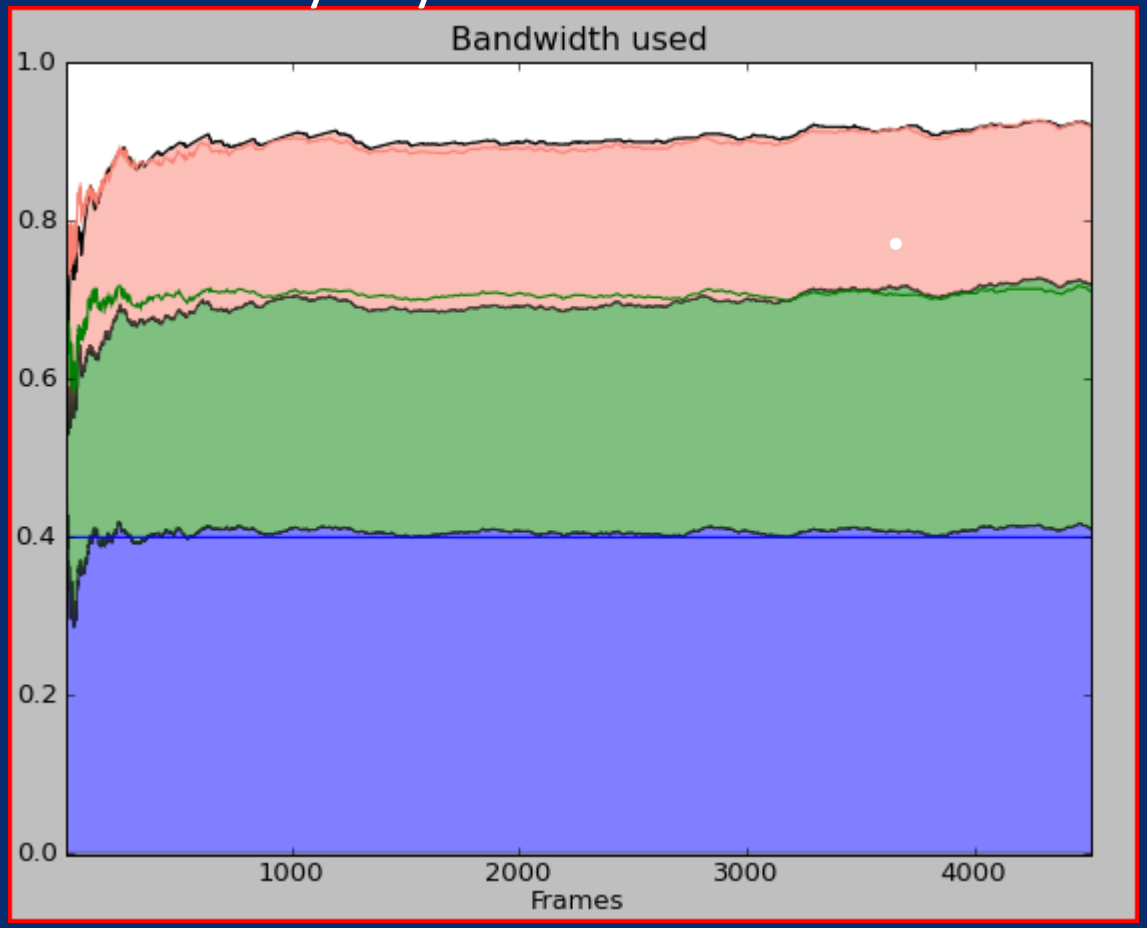
Simulation Results

- Three virtual channels
- Throughput equal to allocated bandwidth
- 10% of available bandwidth not allocated and is not used by any channel



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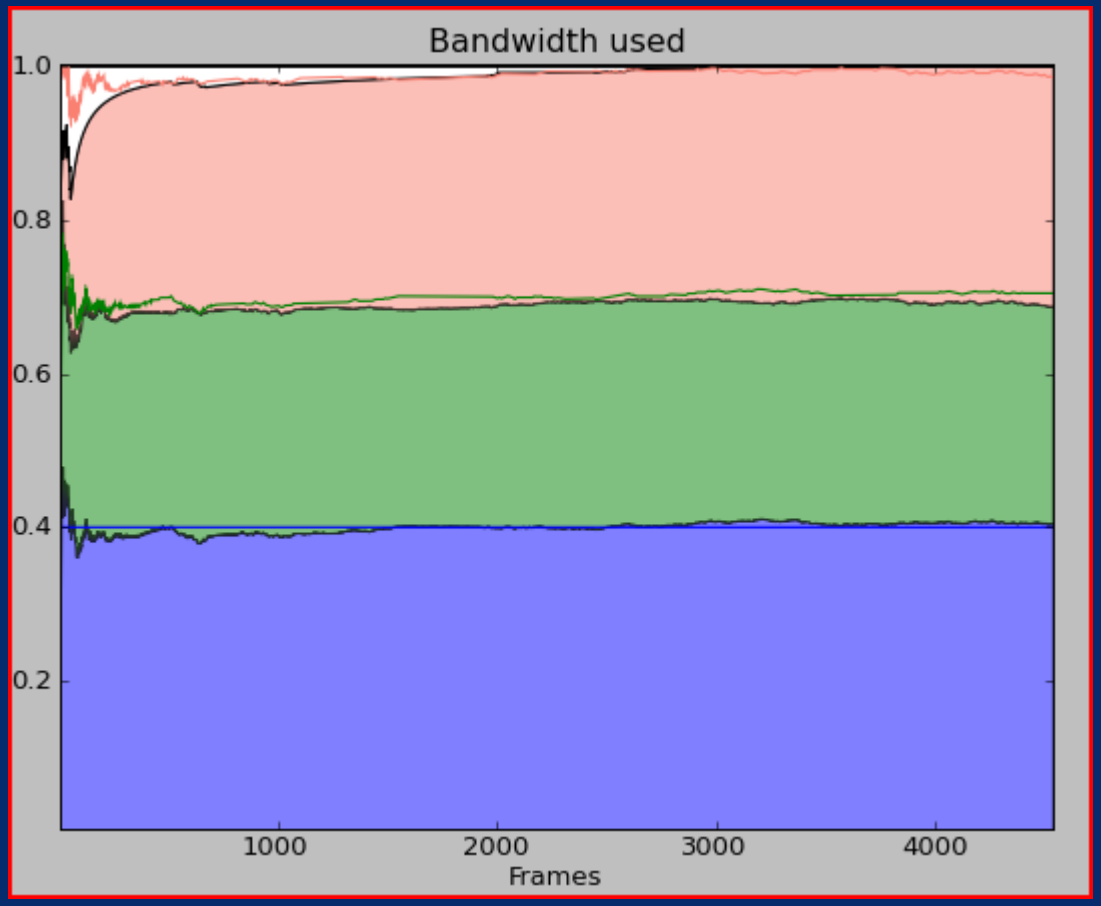
Simulation Results

- Three virtual channels
- Throughput equal to allocated bandwidth
- 100% of bandwidth allocated



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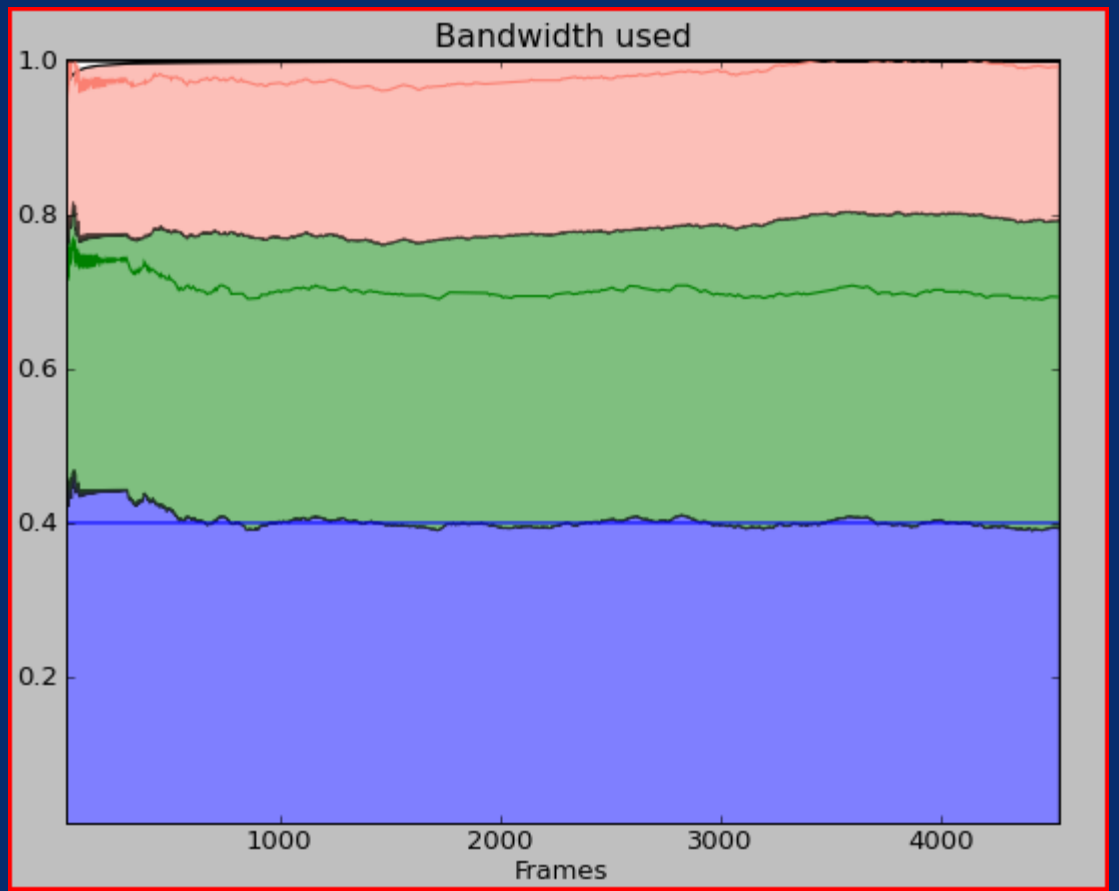
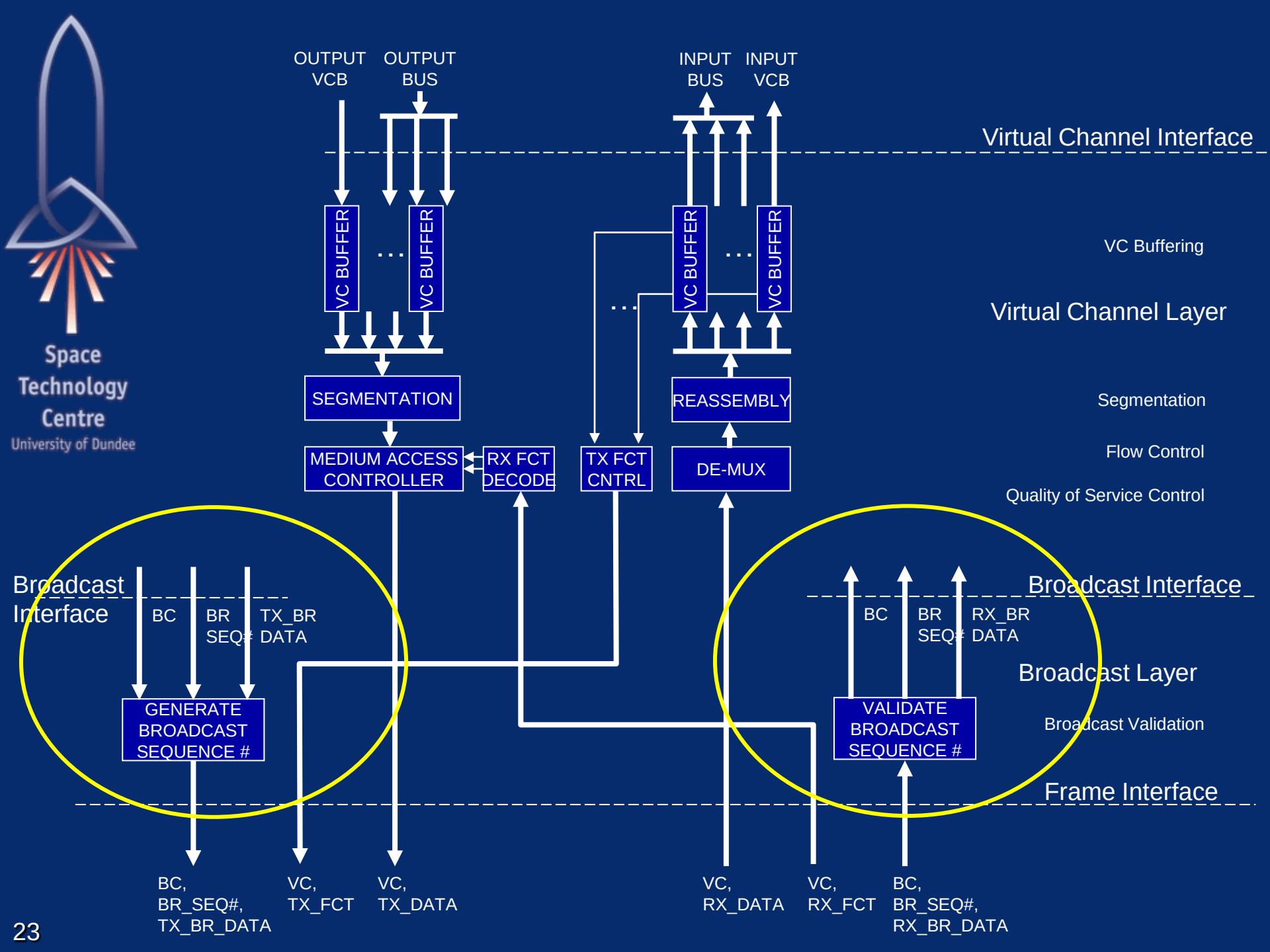
Simulation Results

- Three virtual channels
- Throughput equal to allocated bandwidth
  - Except for green channel
  - Green channel has more data to send than allocated
  - Uses the non-allocated bandwidth

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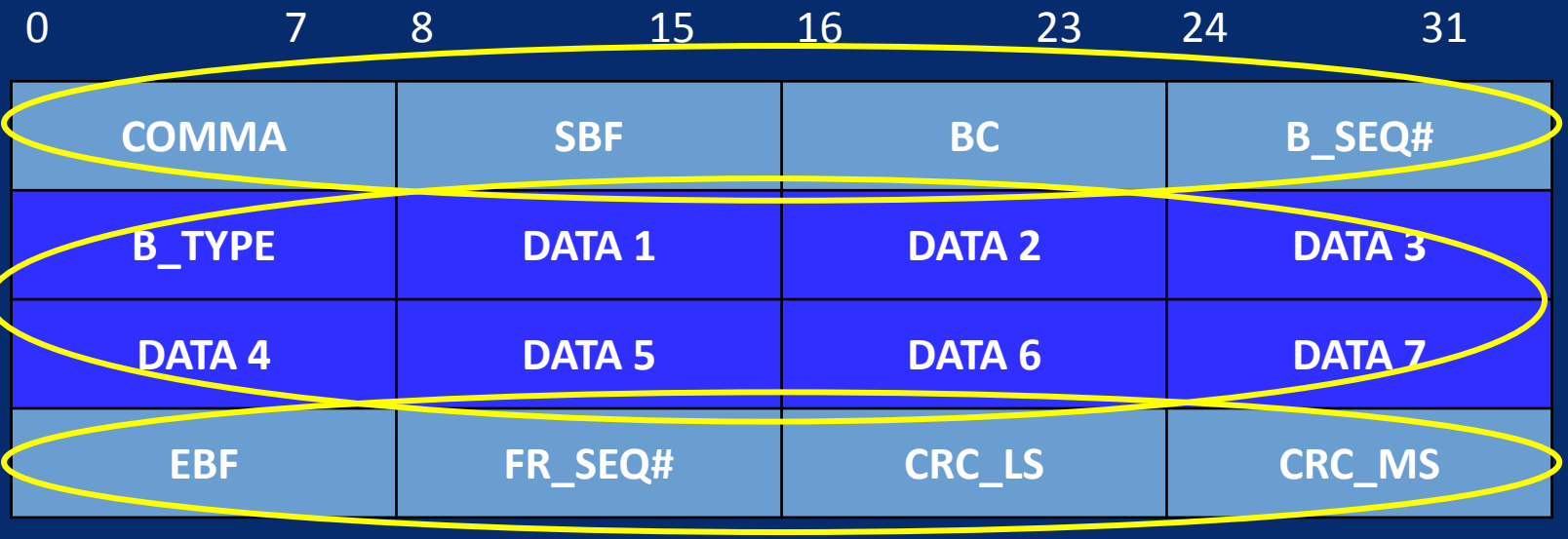
SpaceFibre Broadcast Channels

- Broadcast Channel Interface
  - Use to broadcast short messages across the network and to receive those messages
  - Can be used for many functions
    - Time distribution
    - Synchronisation
    - Network management
    - Event signalling
  - Broadcast interface is a set of registers
    - Broadcast channel
    - Broadcast sequence number
    - Message type
    - Message data

SpaceFibre Broadcast Frame



- Start Broadcast Frame
  - Broadcast Channel, Broadcast Sequence Number
- Message field contains
  - Broadcast message type
  - Broadcast message data
- End Data Frame
  - Frame sequence number, CRC

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SpaceFibre Broadcast Channels

- Broadcast mechanism
  - Operates like SpaceWire time-codes
- Broadcast sequence number
  - Used to support broadcast
  - Incremented for each broadcast message sent
  - Like SpaceWire time-code
- Broadcast channel
  - Each broadcast channel runs its own set of broadcast sequence numbers
  - Enables 256 independent broadcast channels

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SpaceFibre Broadcast Channels

- Broadcast channels split into three types:
  - Network management broadcast channels (0-31)
    - 0-7: Time synchronisation
      - 0-3 Time distribution
      - 4-7 Synchronisation
    - 8-31: Network control,
      - Configuration, control, and FDIR of a SpaceFibre network
  - Node broadcast channels (32-253)
    - Each broadcast channel associated with the node
    - With logical address of the same value as the broadcast channel number
  - Reserved broadcast channels (254, 255)

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SpaceFibre Broadcast Channels

- Broadcast type
  - Defines sematics of broadcast message
  - E.g. “Time” type
    - Data field contains seven bytes of system time
- Subscription
  - User application can subscribe to particular
    - Broadcast channels
    - Broadcast message types
  - Only receive notification of messages they subscribe to

SpaceFibre Benefits

- Sends and receives SpaceWire packets
- Virtual channels
  - Multiplexes SpaceWire packets over link
  - Overcomes SpaceWire router blocking problem
- Broadcast messages
  - Provides low latency messaging
  - Based on an extension of the SpaceWire time-code mechanism
- Coherent quality of service mechanisms
  - Bandwidth sharing for payload data-handling applications
  - Deterministic data delivery for command and control applications

Benefits

- FDIR support including
  - Galvanic isolation
  - Fault detection with disparity, CRC, sequence #
  - Fault isolation to prevent fault propagation
  - Fault recovery to provide rapid recovery from transient faults
- Lanes
  - For higher throughput with graceful degradation
  - Hot and cold redundancy support
- QoS in the CODEC
  - Providing inherent robustness against a range of system errors, like babbling idiots

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Schedule

- Currently simulating in software and OPNET
- Full details in December 2011
  - SpaceWire Working Group meeting
- Draft ECSS standard in January 2012
  - Available for Working Group members
- Initial review feedback by March 2012
- Update to draft standard by May 2012
- ECSS standardisation process starts


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Link Error Recovery

The handling of link errors by the link state machine is described in the section "Link Error Handling". This section considers what happens to a packet that is travelling across a link when an error occurs.

If an error is detected by a link interface, the following sequence of events takes place to recover from the error:

1. Detect Error

A Disconnect, Parity, Escape, or Credit error is detected.

Figure 46 shows the two directions of the link transferring packets, from an end user buffer passing data to the SpaceWire transmitter, via the SpaceWire interface transmit FIFO, across the link, into the SpaceWire interface receive FIFO at the other end of the link, and on into the end user buffer taking data from the receiver. In the left to right direction of the link the head of a packet is in the receive user buffer and the tail of the packet with the EOP is in the transmit end user buffer. An error has just occurred in this direction of the link.