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SpaceWire-RT

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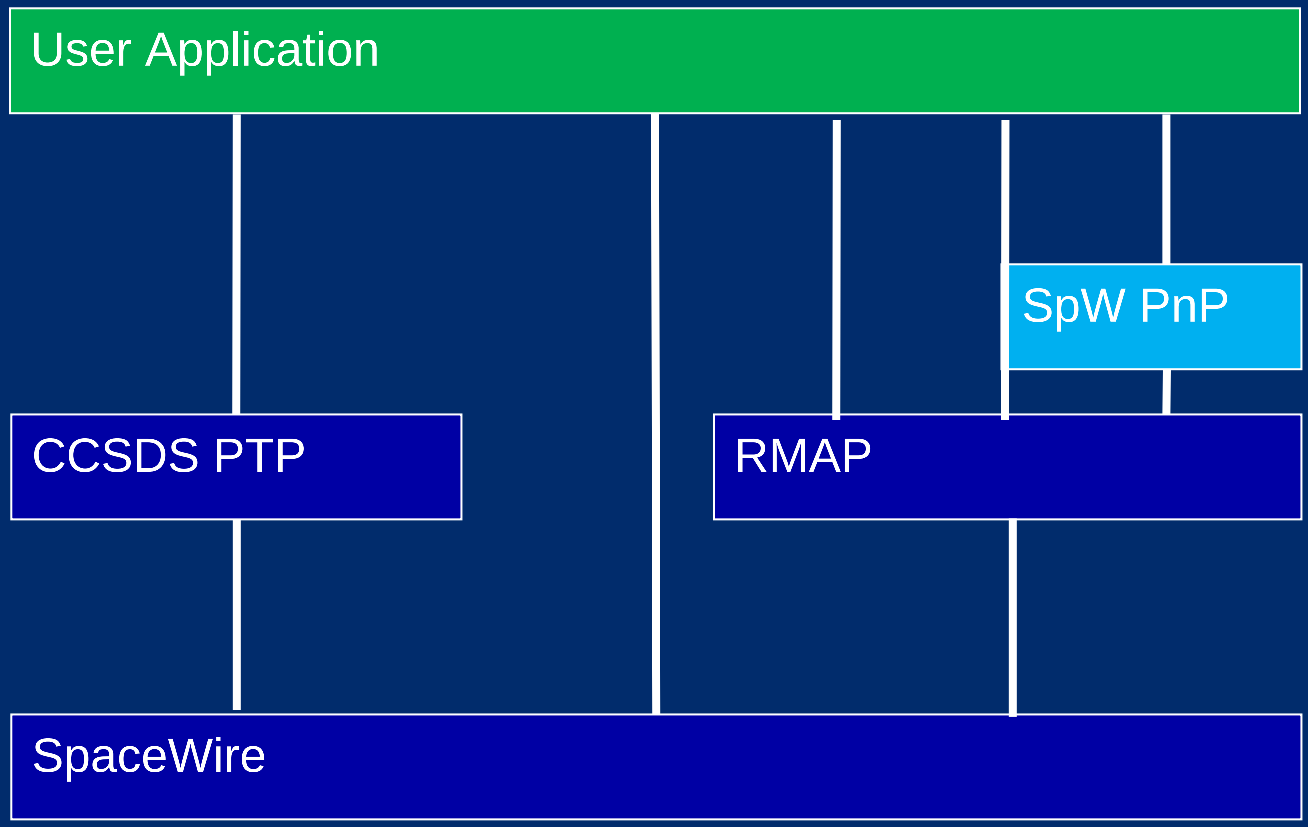
Contents: Concepts

- SpaceWire protocol stack
- SOIS and the motivation for RT
- Key features of RT
- SpaceWire-RT functions
- Asynchronous SpaceWire-RT
- Scheduled SpaceWire-RT
- SpaceWire-T

SpaceWire Protocol Stack



SpaceWire RMAP

- Remote Memory Access Protocol
- RMAP service runs over SpaceWire
- Means of reading and writing to memory
  - Of a remote node
  - Over SpaceWire network
- Supports
  - Device configuration, control & monitoring
  - Transfer of data from instrument to memory etc

SpW CCSDS Packet Transfer Protocol

- Transfers CCSDS Space Packets across a SpaceWire network
- Defines a common format for putting a CCSDS Space Packet into a SpaceWire packet

SpaceWire-PnP

- SpaceWire Plug and Play
- Mechanisms for:
  - Consistent configuration of nodes and routers
  - Discovering presence of nodes on a network
- Designed to use RMAP protocol
  - To reduce additional hardware needed

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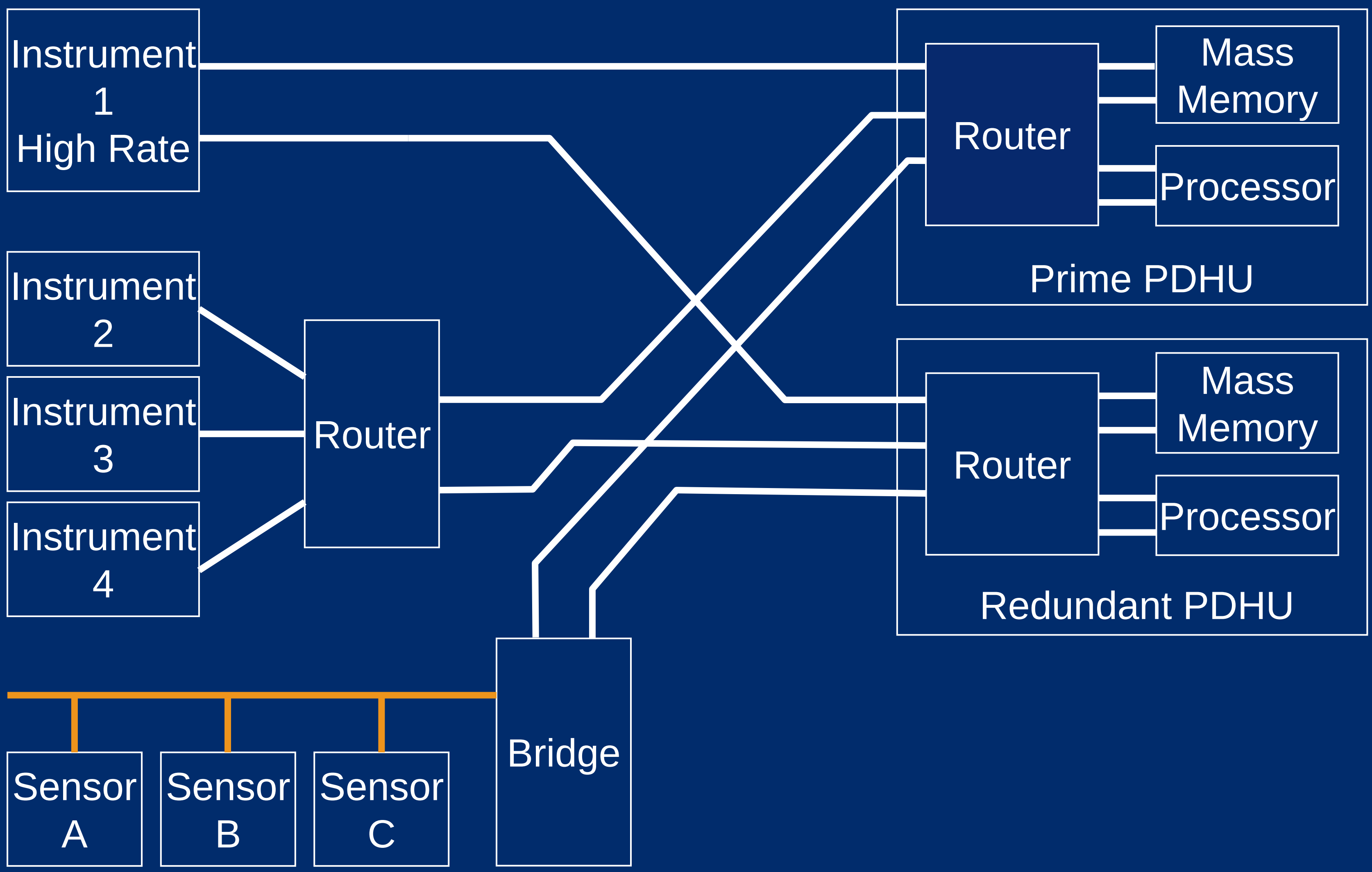
Why is SpaceWire successful?

- Driving need
  - For high-speed data links/networks on board spacecraft
- Simple, flexible solution
  - Easy to build a network architecture that suits a specific application
- Standard
  - Replacing proprietary solutions
- Radiation tolerant components available
  - Driven by ESA initially
- Test and development equipment available
- It works

Why is SpaceWire successful?



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Centralised payload data-handling unit

- Most payload data-handling architectures have a centralised data handling unit
- Makes managing network resources easy
- Managing data transfers does not require any support from the network
- Can all be done under control of central payload data-handling unit

CCSDS SOIS
and
Motivation for SpaceWire-RT

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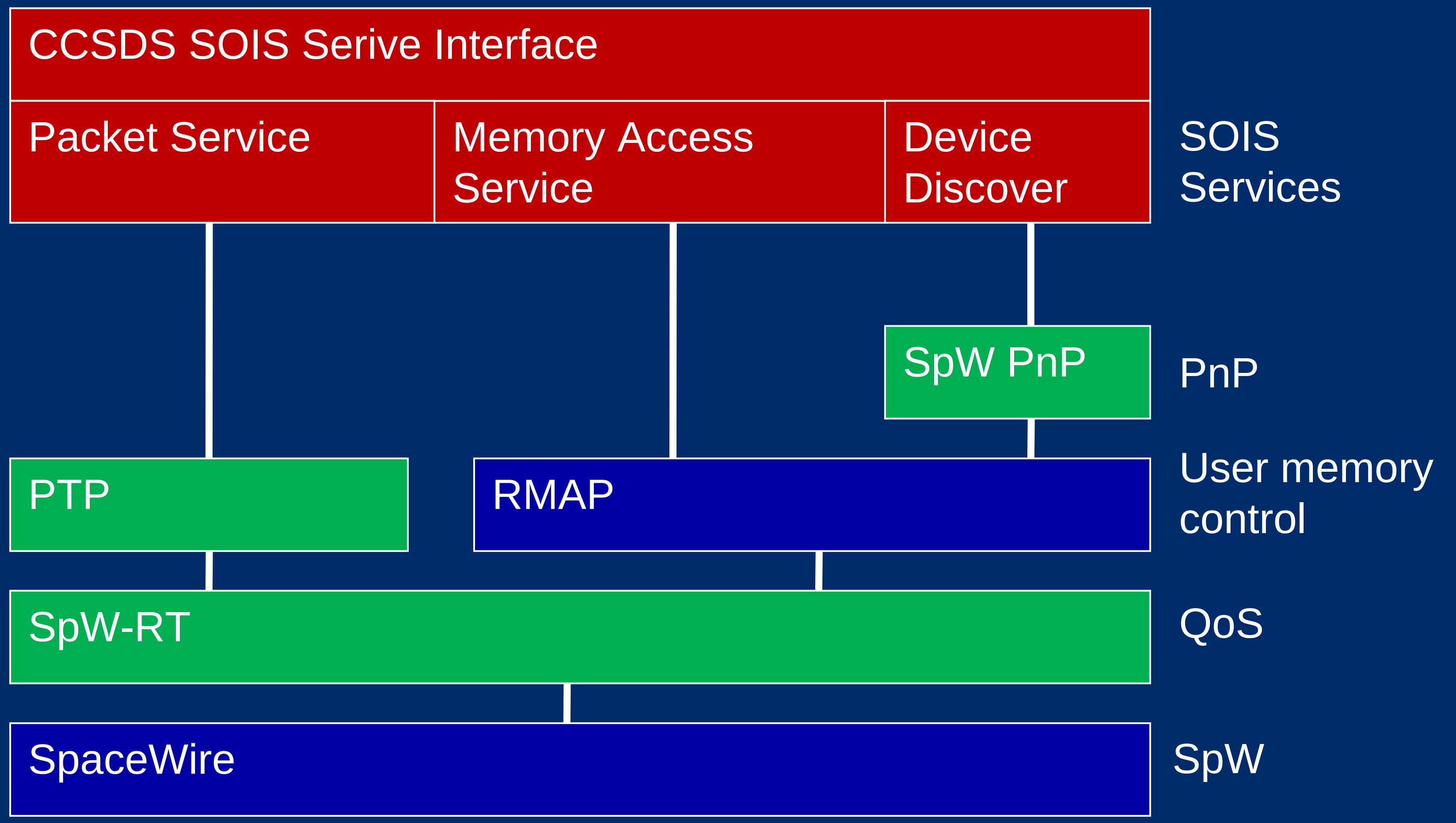
CCSDS SOIS and motivation for SpW-RT

- CCSDS SOIS
  - Separates software applications from network
    - Application can then run over different networks
  - Aims to
    - Simplify software development
    - Enable reuse of software components
    - Integrate into broader set of CCSDS protocols
  - SOIS outlines set of services that network has to provide

CCSDS SOIS and motivation for SpW-RT



SOIS Services

- Memory Access Service
  - – Reads and writes to “user” memory
  - – Requires management of “user” memory
  - – Various QoS requirements
  - – “User” memory considered part of sub-network
- Packet Delivery Service
  - – Delivers packets from source to destination
  - – Requires management of packet buffers
  - – Various QoS requirements
- Device Discovery Service
  - – Discovers (new) devices on the network
- Synchronisation Service
- Test Service

QoS Requirements from CCSDS SOIS

- Best Effort
  - Single attempt to deliver
  - In order delivery
- Assured
  - Retry in event of failure to deliver
- Resource Reserved
  - Single attempt
  - Over reserved network resource
- Guaranteed
  - Retry in event of failure to deliver
  - Reserved network resource

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Key Benefits of SpaceWire-RT

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Key Benefits of SpW-RT

- Provides range of quality of service
  - Supporting different user requirements
- Helps to prevent network congestion
- Confirms delivery of data
- Ensures data delivery
- Delivers data within specific time bounds
- Works with existing SpaceWire devices and standards

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Channels

- Channel is:
  - Set of network resources
  - Connects SpW-RT user in source
  - To SpW-RT user in destination
  - Uni-directional
- Channel specified by
  - Source / destination / channel number
  - E.g. 231 / 82 / 3

Asynchronous and Scheduled Systems

- Two types of system supported:
- Asynchronous
  - Sending information is asynchronous
  - Best Effort and Assured QoS only
- Scheduled
  - Network bandwidth split up using time-slots
  - Each source channel assigned one or more time-slots
    - When it is allowed to send data
  - Provides deterministic delivery
  - Support all SOIS QoS classes

SpaceWire-RT
Architecture and Functions

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Architecture

- User interface
  – Interface to users of SpaceWire-RT
- Segmentation
  – Chops SDUs into chunks to send in Data PDUs (DPs)
  – Ensures that a large SDU does not hog the SpW network
- Address translation
  – SpW logical addresses used to identify nodes
  – Translates from logical address to path or logical address
  – Includes prime/redundant path addresses

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Architecture

- Retry
  - Resends DPs that are lost or arrive with errors
  - Uses acknowledgement to confirm receipt
- Redundancy
  - Alternative paths through SpaceWire network
- End to end flow control
  - Check destination buffer ready before sending packet
  - Ensures that DPs accepted immediately by destination to prevent blocking

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Architecture

- Resource reservation
  - Asynchronous network:
    - No reservation of resources
  - Scheduled network:
    - Time-codes sent periodically
    - Divide time into time-slots
    - One source can send in any one time-slot
      - Avoids conflicting use of network resources
    - Or several sources can send if they do not use the same network resources – i.e. links

Address Translation

- Nodes identified using SpaceWire logical addresses.
- Up to 223 logical addresses
  - Sufficient for most spacecraft applications
- Routing can be done with path and/or logical addressing
- Node identification done with logical addresses

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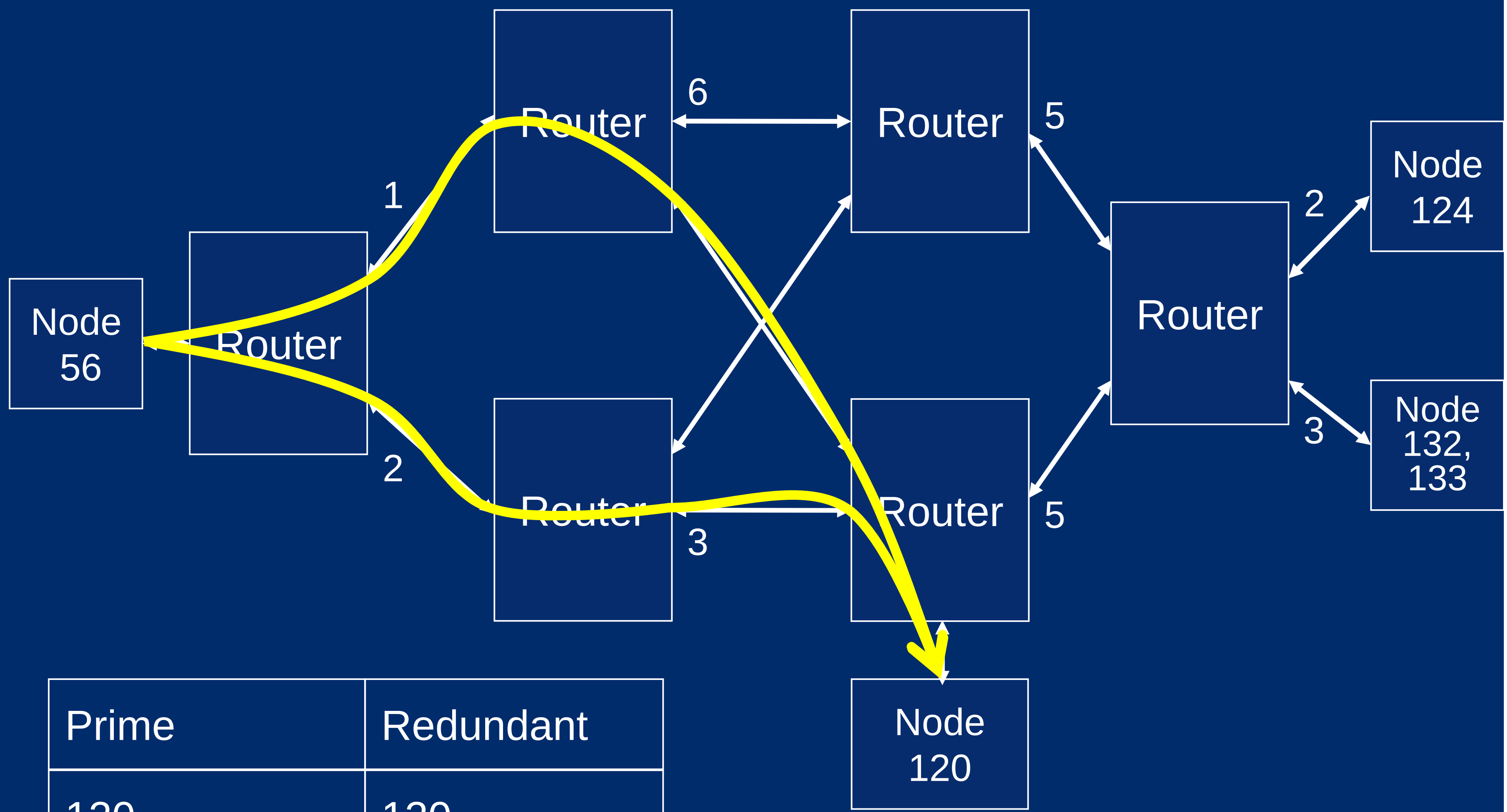
Address Translation

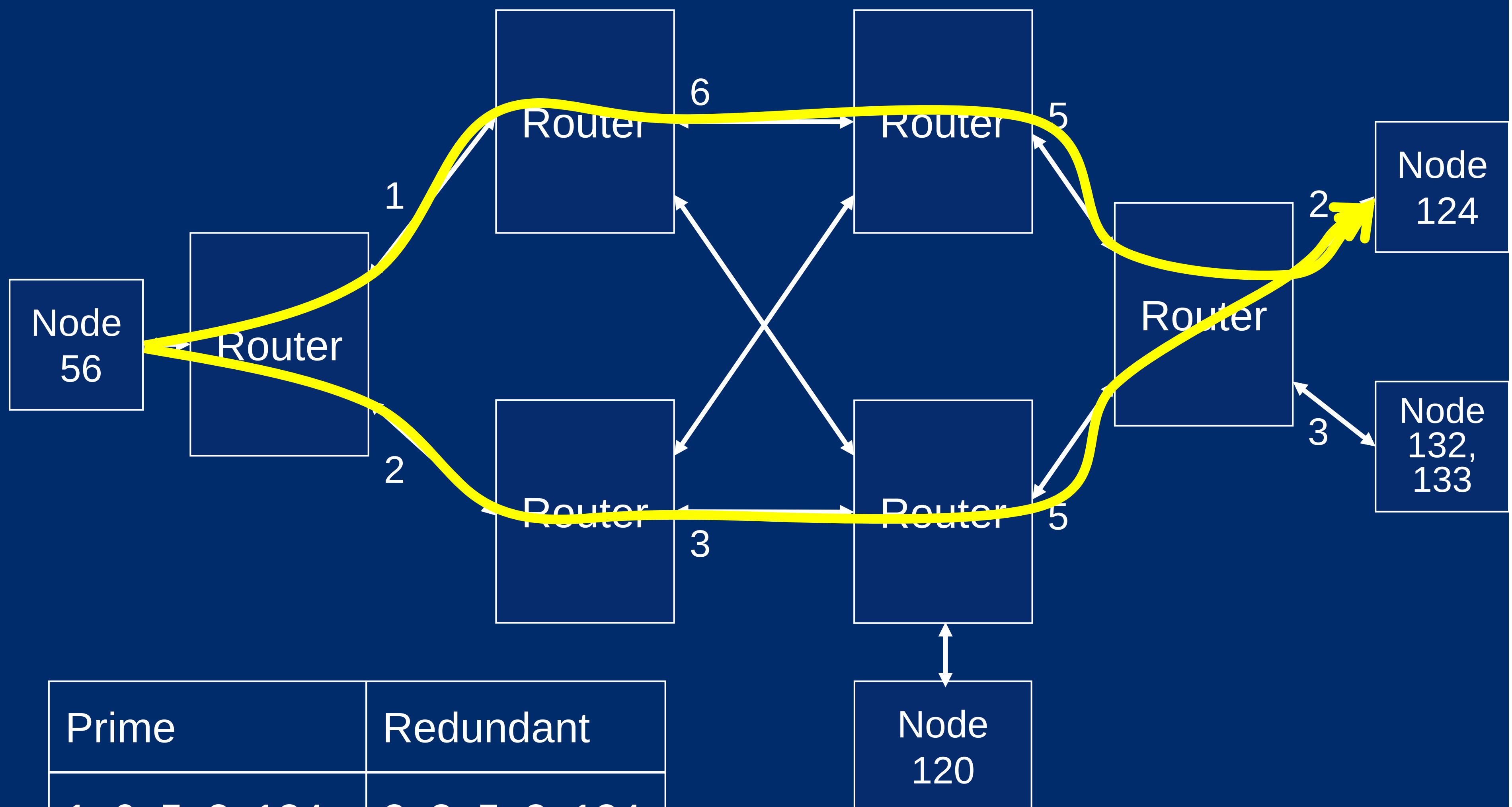
SpaceWire Logical Address	Prime SpaceWire Address	Redundant SpaceWire Address
120	120	120



Prime	Redundant
120	120

Address Translation

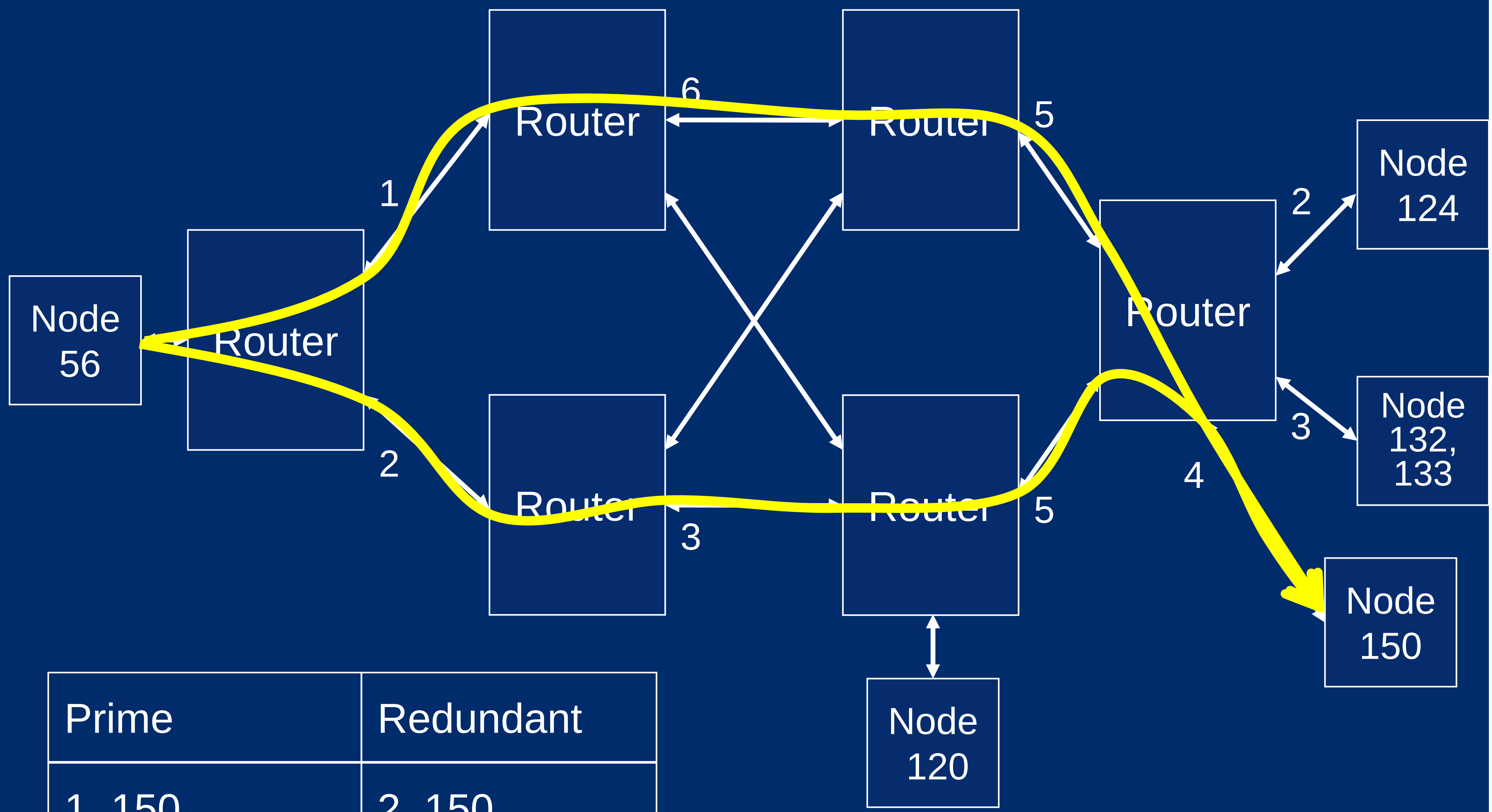
SpaceWire Logical Address	Prime SpaceWire Address	Redundant SpaceWire Address
120	120	120
124	1, 6, 5, 2, 124	2, 3, 5, 2, 124



Prime	Redundant
1, 6, 5, 2, 124	2, 3, 5, 2, 124

Address Translation

SpaceWire Logical Address	Prime SpaceWire Address	Redundant SpaceWire Address
120	120	120
124	1, 6, 5, 2, 124	2, 3, 5, 2, 124
150	1, 150	2, 150



Prime	Redundant
1, 150	2, 150

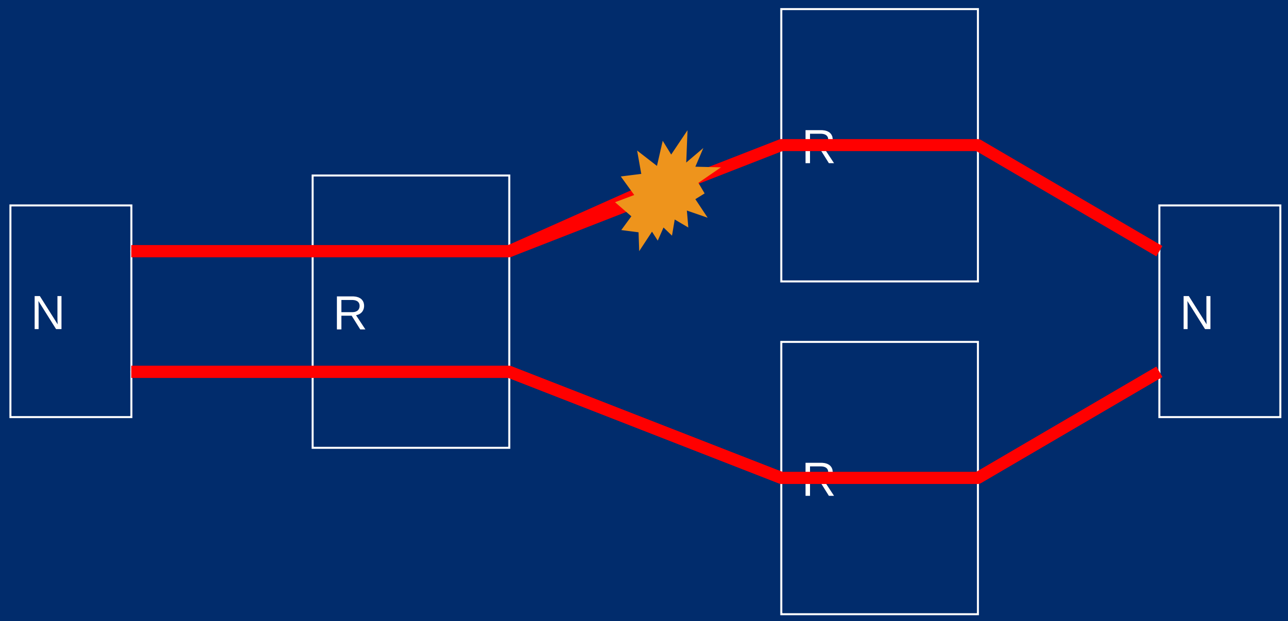
Address translation

- Address tables for reply etc
  - Accessed via SLA, DLA, Ch#
  - Held in each node
  - May require updating if network changes
- Multiple network configuration regimes may be incorporated in the table
  - To allow rapid re-organisation of channel paths
  - Depending on network state

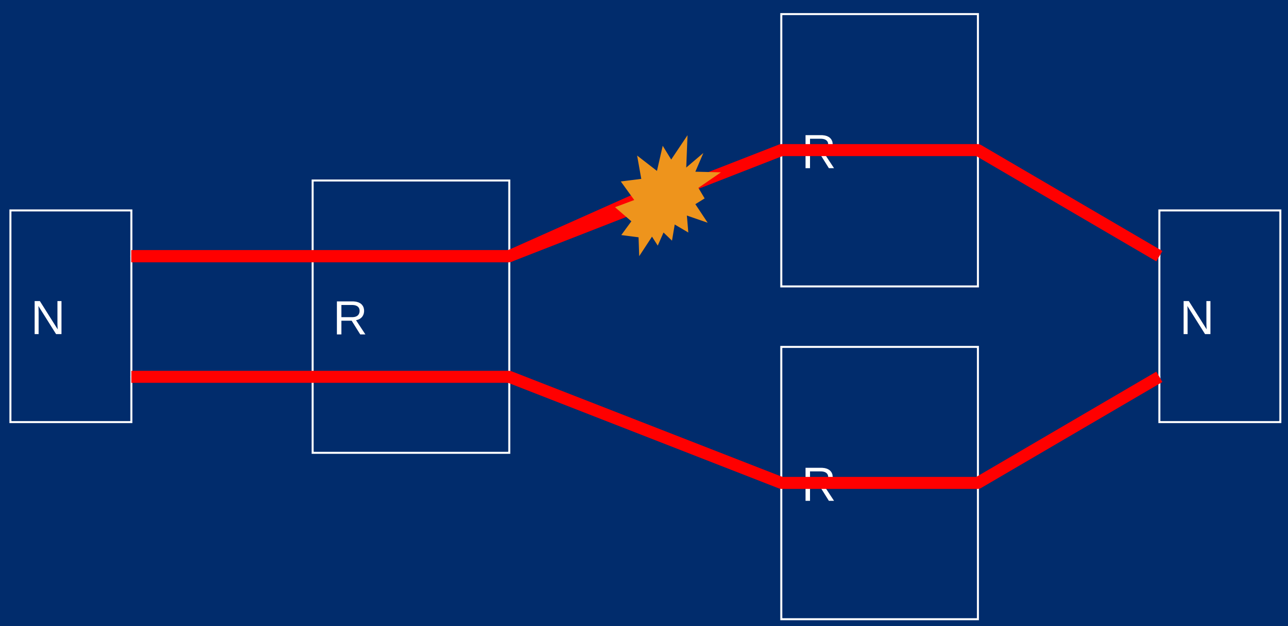
Redundancy

- Redundancy model:
  - Alternative paths from source node to destination node
- Managed and autonomous redundancy switching
- Redundancy supported in several ways:
  - Hot redundant
    - Send over both paths simultaneously
  - Warm redundant
    - Send over prime path
    - If failure send over redundant path
  - Cold redundant
    - Send over prime path
    - If failure power up redundant path and send over it

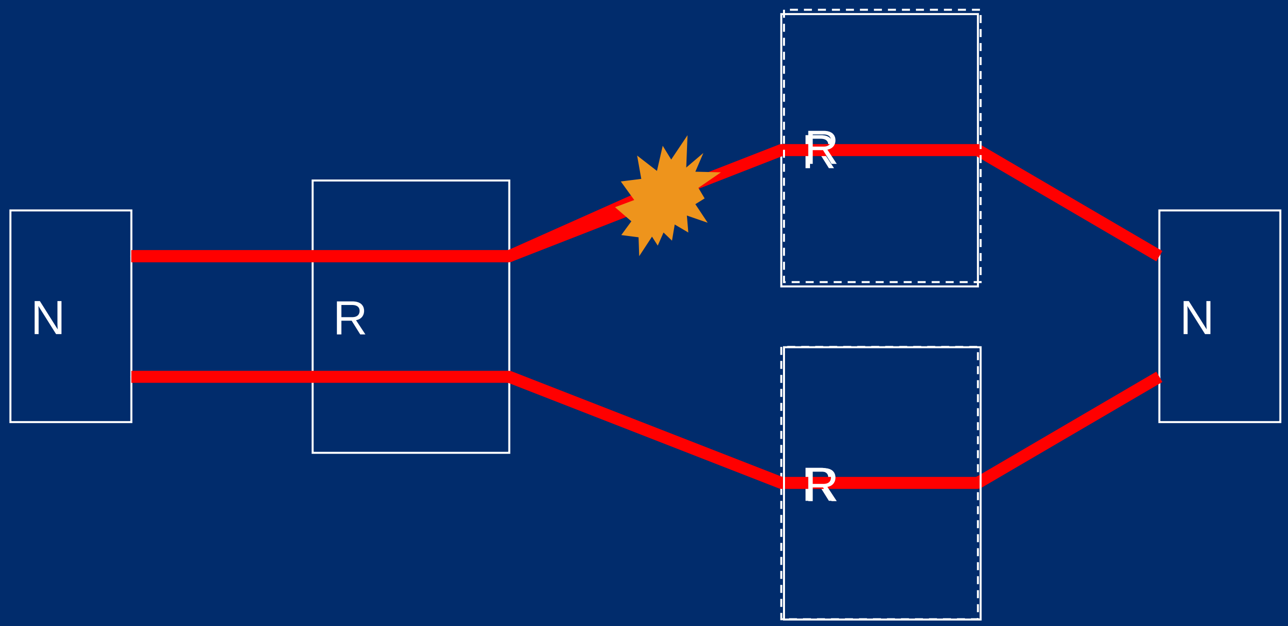
Hot Redundant



Warm Redundant



Cold Redundant



Redundancy Parameters

- Simultaneous retry on/off
- Number of attempts on prime path
- Autonomous reconfiguration enabled/disabled
- Number of attempts on redundant path
- Number of attempts on other alternative paths when appropriate

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Example

- Try once on prime path & report failure
  - Simultaneous retry = off
  - Number attempts on prime path = 1
  - Autonomous reconfiguration = disabled
  - Number attempts on redundant path = 0

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Example

- Try three times on prime path & report failure
  - Simultaneous retry = off
  - Number attempts on prime path = 3
  - Autonomous reconfiguration = disabled
  - Number attempts on redundant path = 0

Example

- Try twice on prime path, twice on redundant path & report failure
  - Simultaneous retry = off
  - Number attempts on prime path = 2
  - Autonomous reconfiguration = enabled
  - Number attempts on redundant path = 2

Example

- Try twice simultaneously on prime and on redundant paths & report failure
  – Simultaneous retry = on
  – Number attempts on prime path = 2
  – Autonomous reconfiguration = disabled
  – Number attempts on redundant path = 2

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Asynchronous SpaceWire-RT

Retry

Flow-Control

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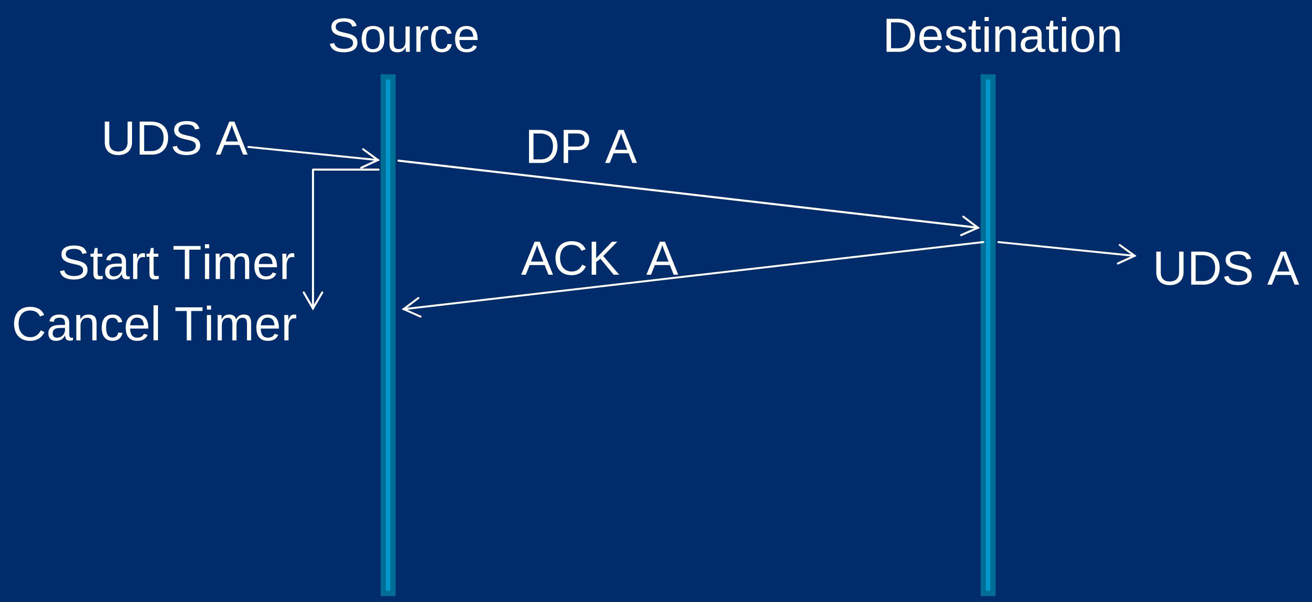
Retry

- Retry function necessary for reliability
  - In conjunction with redundancy
- Resends any segment
  - that goes missing
  - or that arrives in error
- Means that applications do not have to worry about providing a retry mechansim
- Delivery is ensured
- Simplifies application development
- Efficient implementation
- Flexible

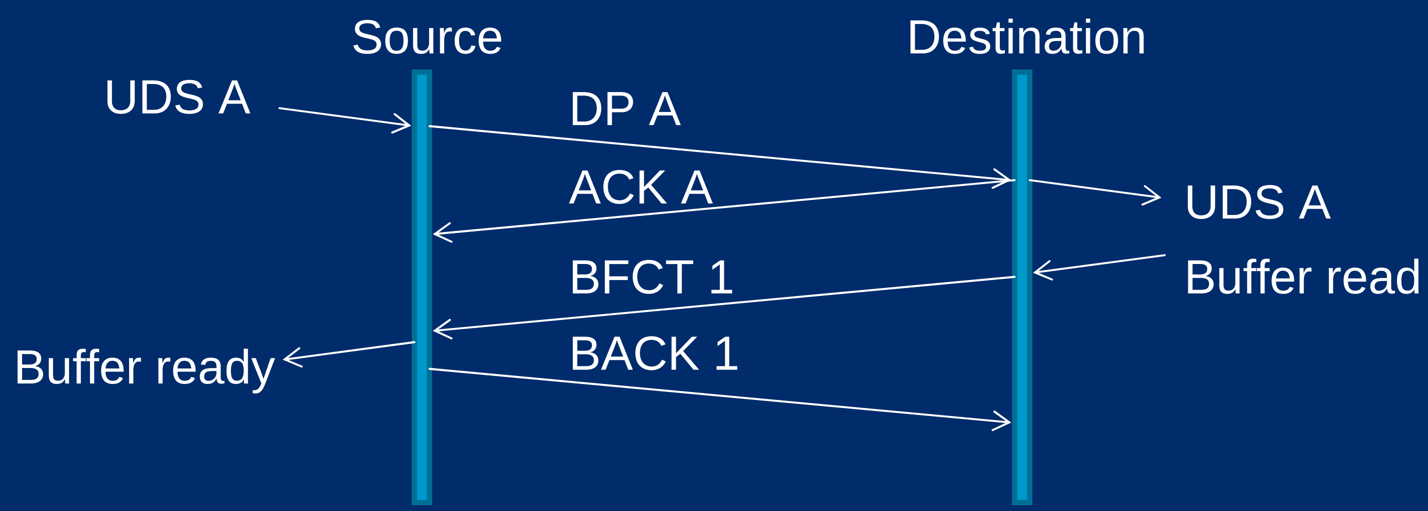
Retry: Normal Operation



End to End Flow Control

- Why do we need flow control?
  - SpaceWire uses worm hole routing
  - A blockage at a destination
  - Can cause disruption through network
- Two options
  - Throw away packets if no room in destination buffer
    - Wastes system bandwidth
    - Hinders timeliness
  - Use flow control

Flow-Control: Normal Operation



Scheduled SpaceWire-RT

Scheduled Network,

Retry,

Flow-Control

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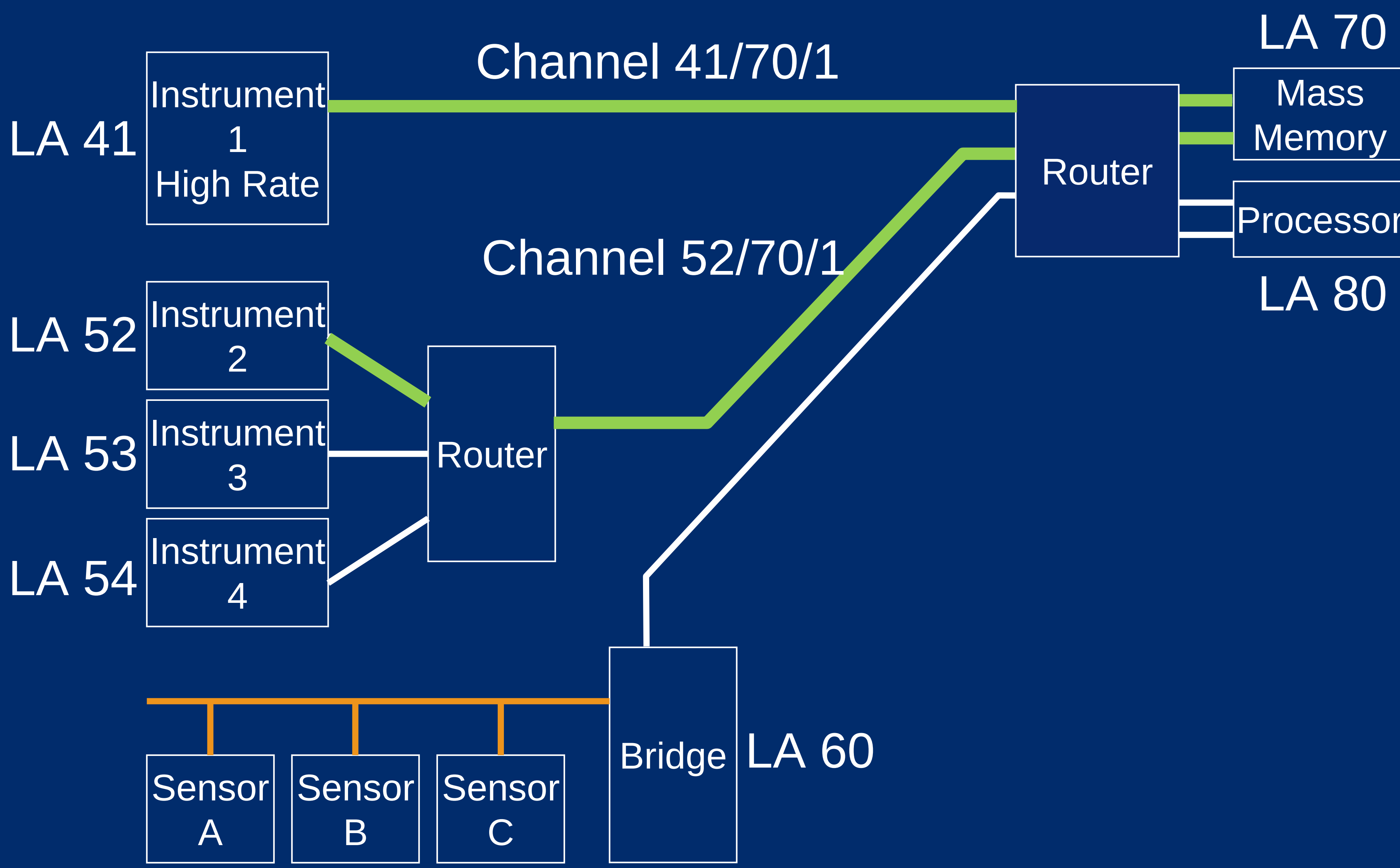
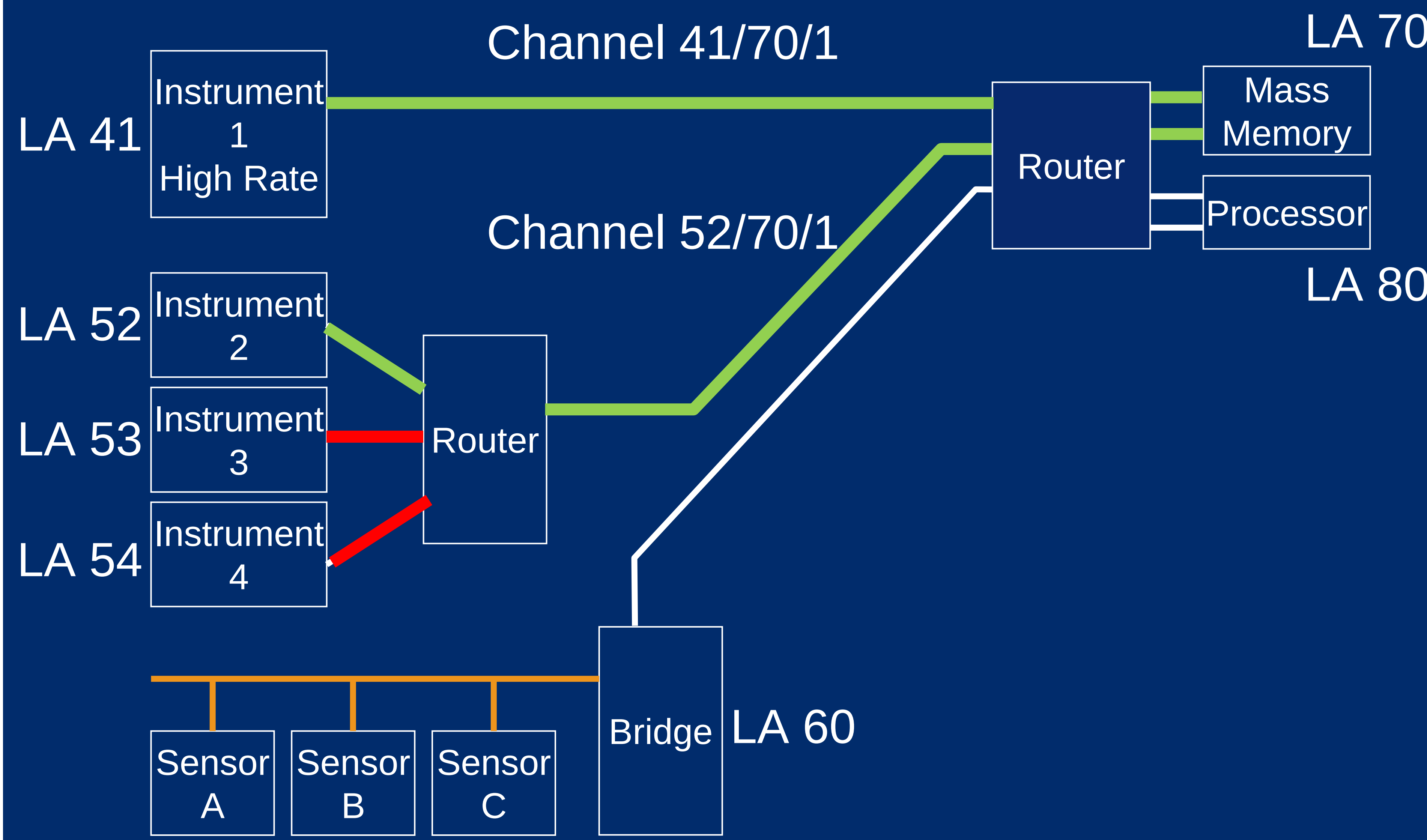
Scheduled Network

- Network bandwidth divided using time-slots
- Schedule table assigns communication to time-slots
- Avoids conflict
- Ensures deterministic delivery

Example Channels



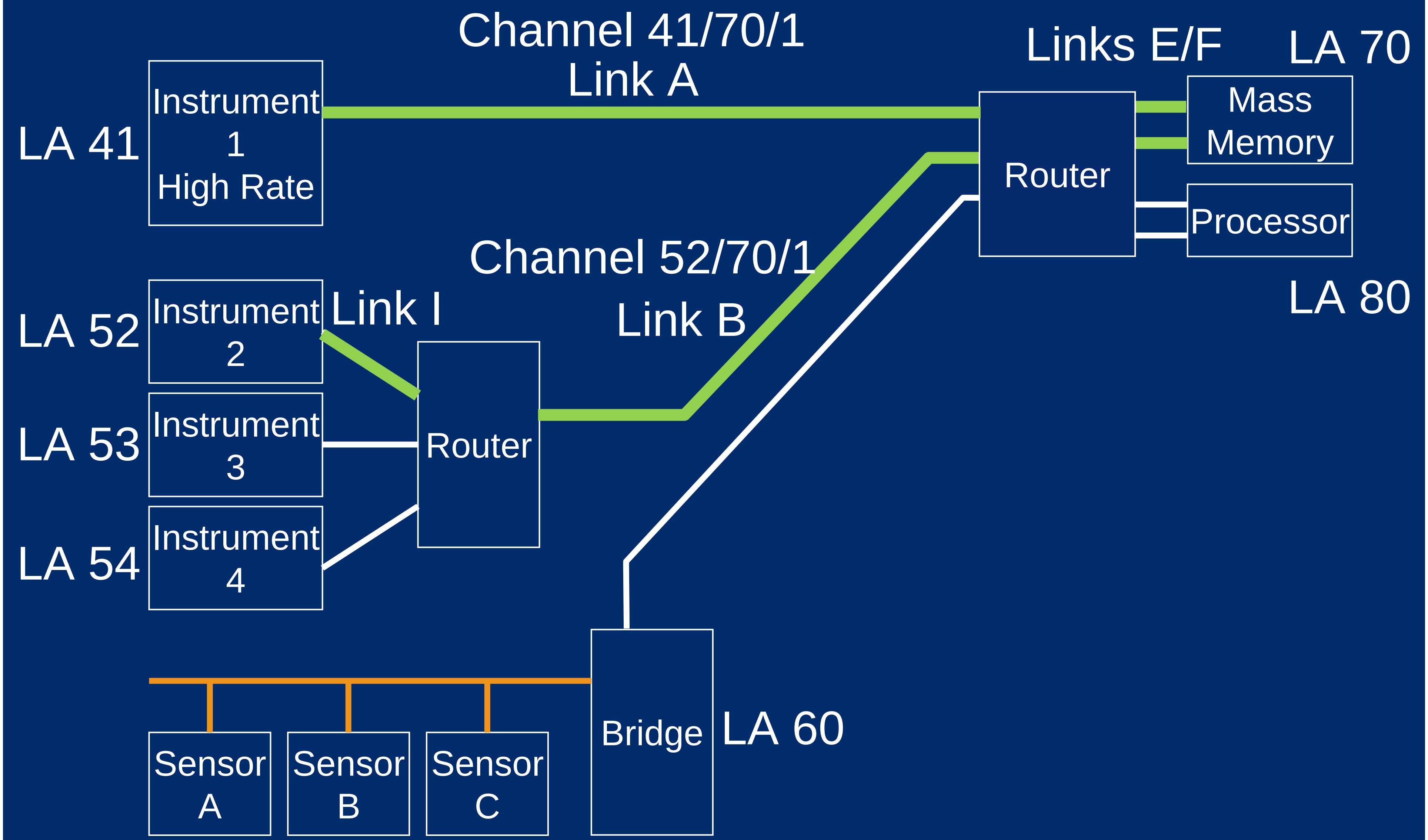
Example Scheduling



Allocating Channels to Time-Slots

	Slot 0
41/70/1	A, E/F
52/70/1	I, B, E/F
53/70/1	
54/70/1	
60/60/1	
80/70/1	
80/xx/1	

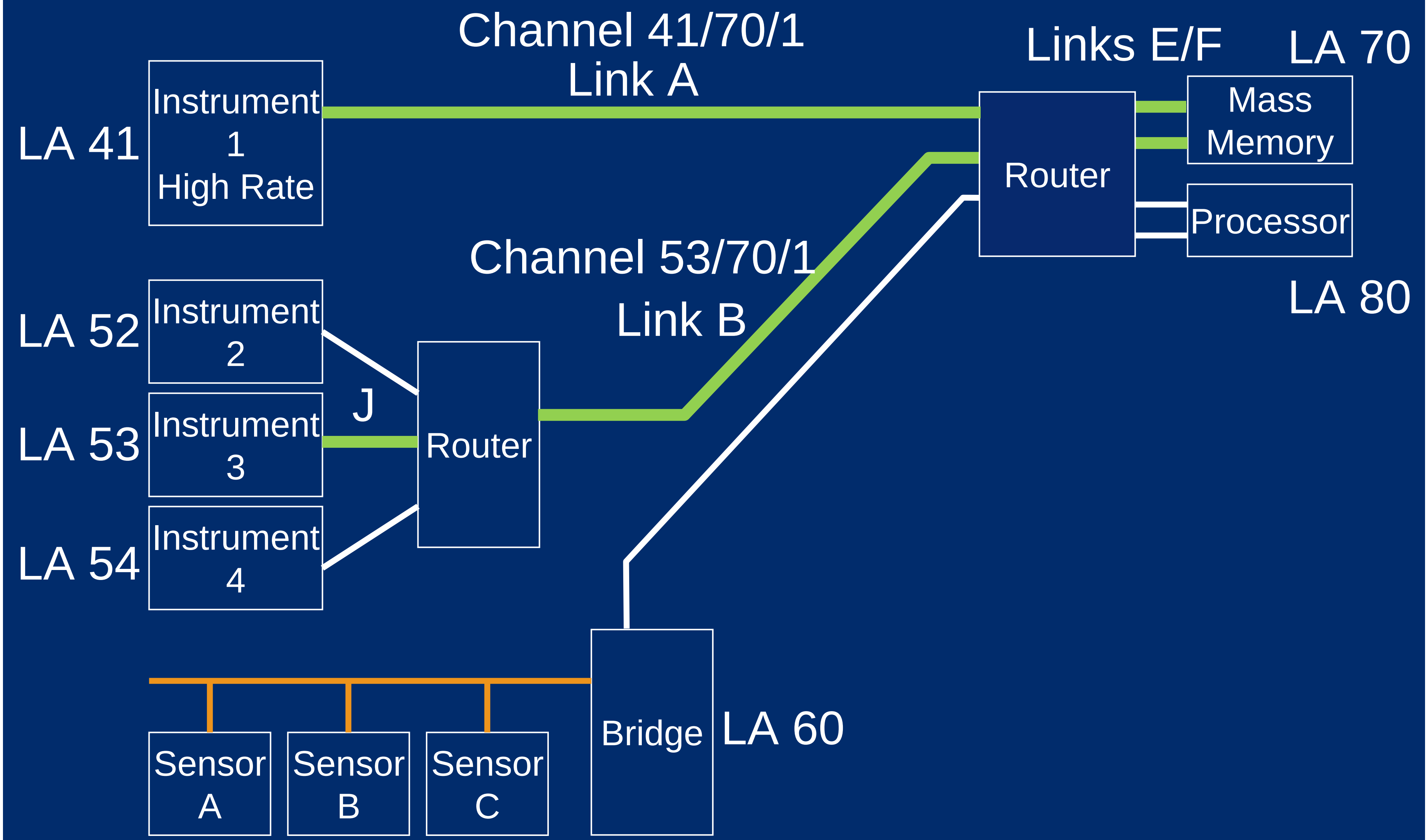
Example Allocating Time-Slots



Allocating Channels to Time-Slots

	Slot 0	Slot 1
41/70/1	A, E/F	A, E/F
52/70/1	I, B, E/F	
53/70/1		J, B, E/F
54/70/1		
60/60/1		
80/70/1		
80/xx/1		

Example Allocating Time-Slots



Allocating Channels to Time-Slots

	Slot 0	Slot 1	Slot 2	Slot 3	Slot 4	Slot 5	Slot 6	Slot 7	Slot 8	…	Slot 63
41/70/1	A, E/F	A, E/F	A, E/F	A, E/F	A, E/F	A, E/F	A, E/F	A, E/F			A, E/F
52/70/1	I, B, E/F				I, B, E/F						
53/70/1		J, B, E/F									
54/70/1			K, B, G/H								
60/60/1				C, E/F							
80/70/1						g/h, E/F					
80/xx/1							E/F, g/h, a,b,c, I,j,k				

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Resources for Flow-Control and ACKs

- Flow control & ACKs
  - Travel in opposite direction to data
  - May conflict with other data PDUs
- Resources have to be allocated for
  - Flow control information
  - Data
  - Acknowledgements

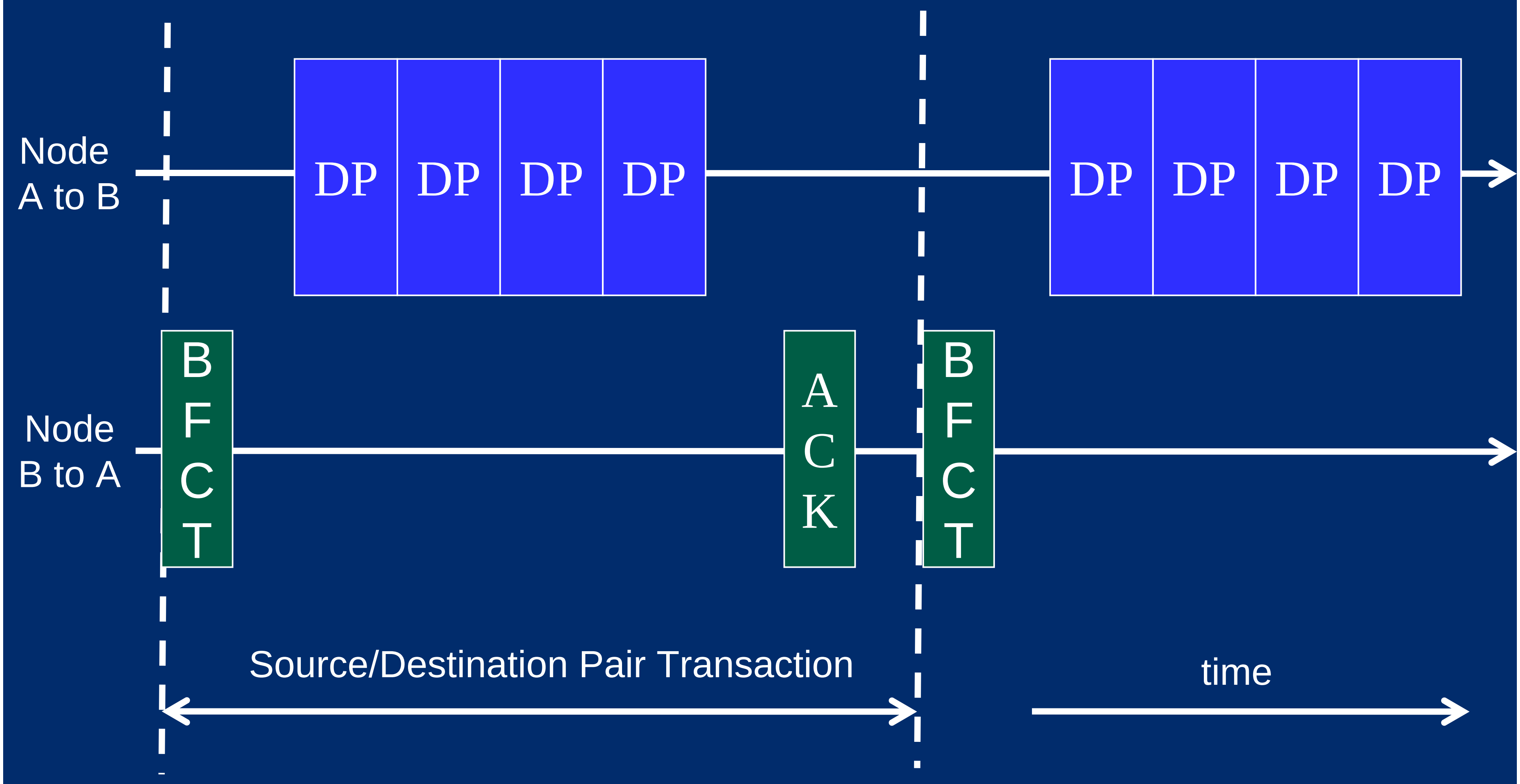
Sending and Receiving Data

- 1. Buffer flow control
  - Is there room in the destination buffer?
  - If there is no room in the destination
    - avoid sending data PDU or it will block the network
- 2. Send the data
  - Send one or more data PDUs
- 3. Confirm that data arrived
  - Did the data PDUs arrive ok?

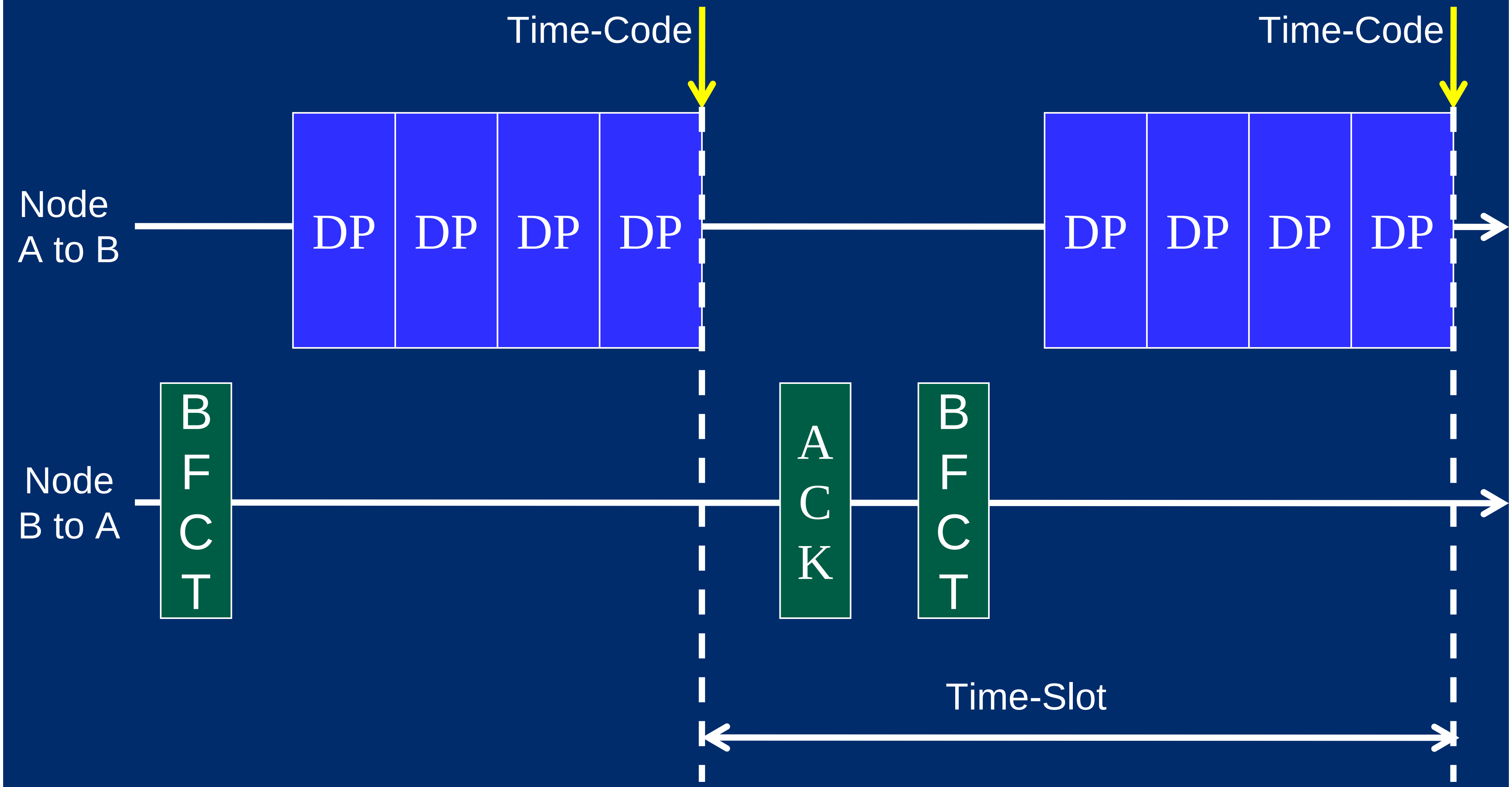
Resources for Flow-Control and ACKs

- Time-slots split into three parts:
  - Flow control phase
    - Which channels for this time-slot have room in destination channel buffer?
  - Data PDU transfer phase
    - Send data PDUs
    - For channels with room in destination channel buffer
  - Acknowledgment phase
    - Send acknowledgement of receipt of data PDUs
- This is the logical ordering

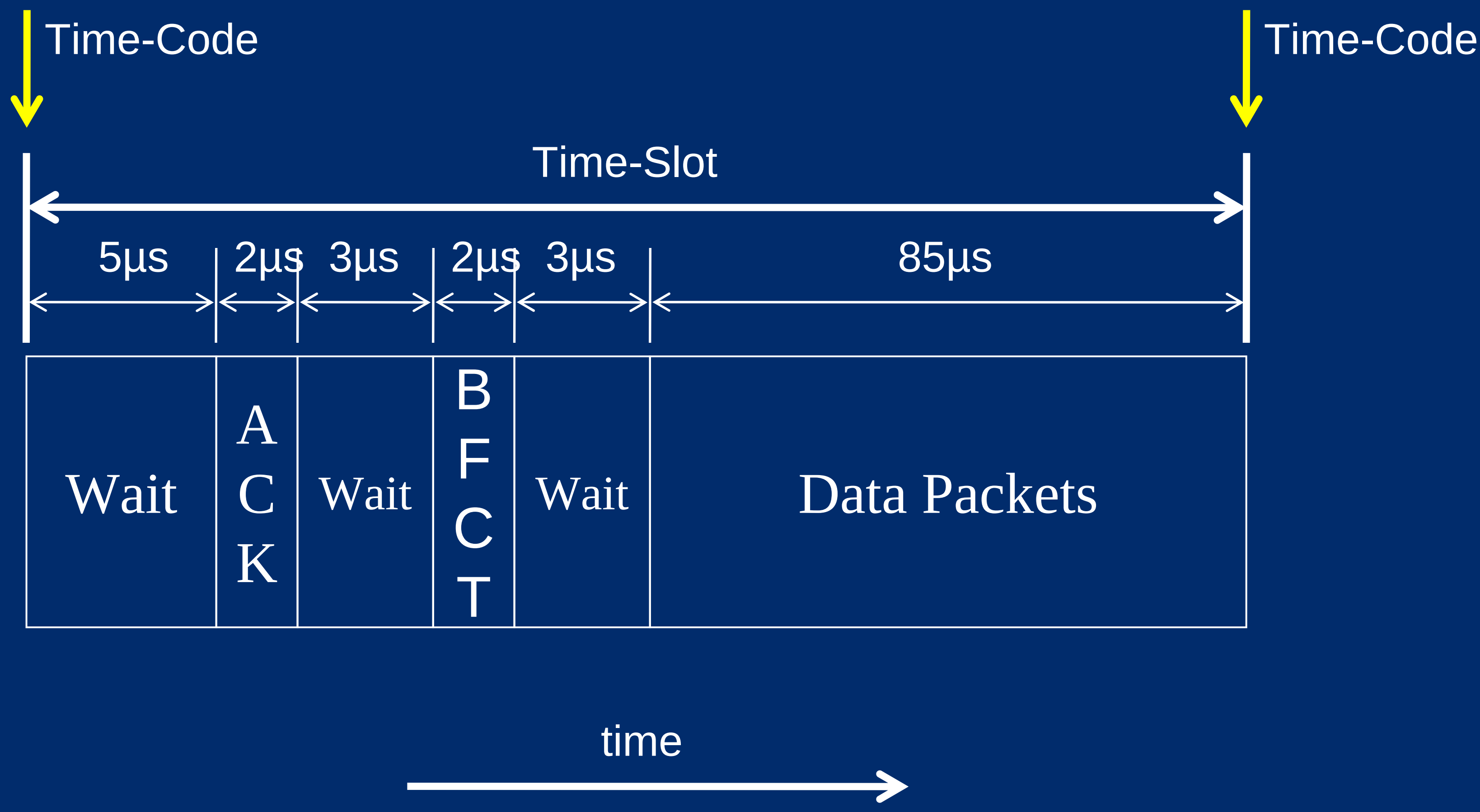
Transferring data from node A to node B



Time-Slot and Transaction



Resources for Flow-Control and ACKs



Timings are examples for hardware implementation.
Demonstration software implementation takes about two to three times as long

Resources for Flow-Control and ACKs

- This it the actual ordering
  - Receive time-code
  - Everyone stops sending
  - Wait long enough for network to become silent
  - Send acknowledgments for previous time-slot
  - Wait for ACKs to propagate across network
  - Send Buffer Flow Control Tokens (BFCTs)
  - To indicate room in destination buffers
  - Wait for BFCTs to propagate across network
  - Send Data PDUs

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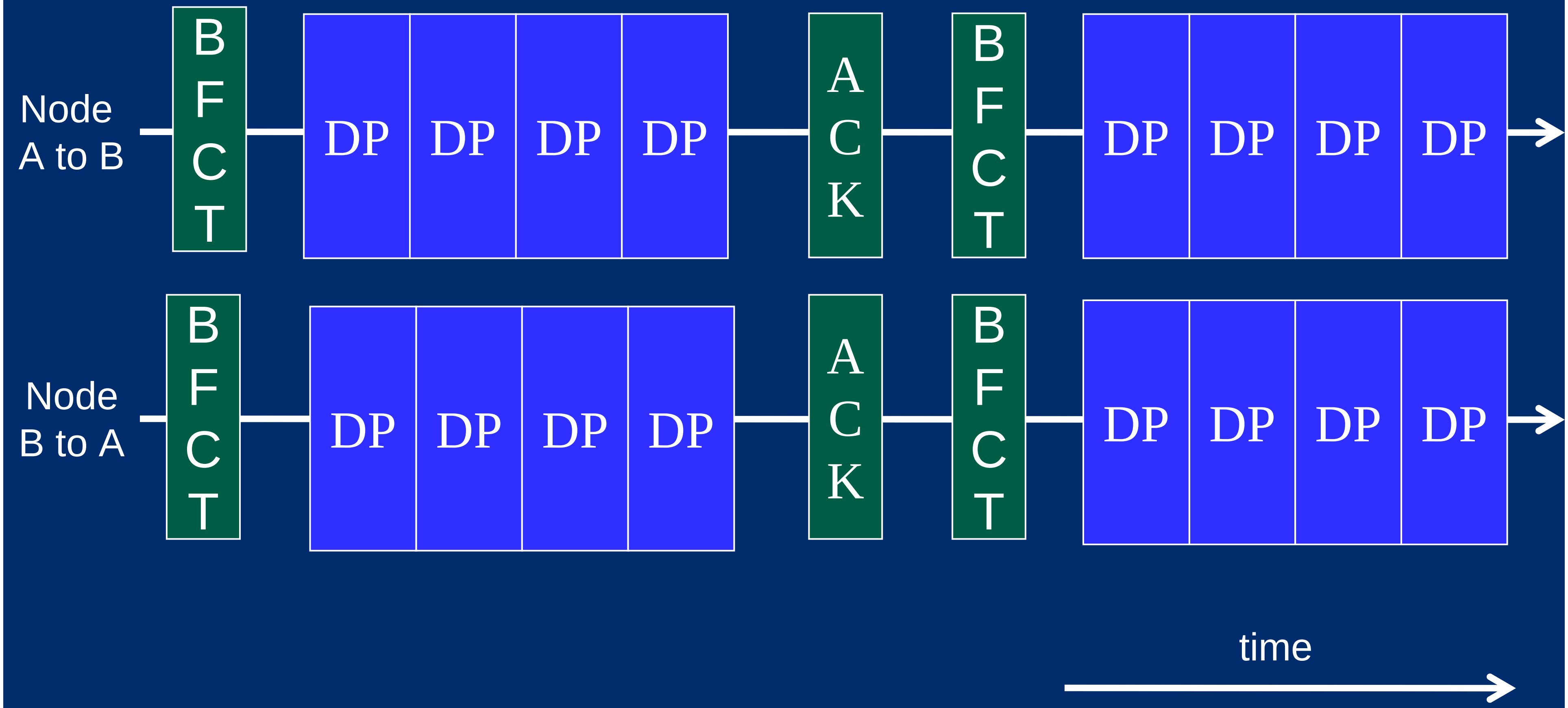
Scheduled Implementation

- When time-code received
  - Stop sending any more DPs
  - Wait
    - For network to become silent
  - Send ACKs for any DPs just received
  - Wait
    - For ACKs to propagate across network
  - Send Buffer Flow Control Tokens (BFCTs)
    - To indicate room in destination buffers
  - Wait
    - For BFCTs to propagate across network
  - Send any Data PDUs

node A to node B and node B to node A



Fault detection

- Can use bi-directional transfer capability to check for failures
- I.e. At start of transaction
  - Expect to receive BFCT from other end of source/destination pair
- At end of transaction
  - Expect to receive ACK from other end of source/destination pair
- One node is checking operation of other node
- Extend to all node checking that they are only receiving from devices they are permitted to receive from

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SpaceWire-T

- SpaceWire-RT without the R
- i.e. No reliability support
  – No retries
  – No redundancy
- Acknowledgement of data delivery is provided
- Mechanisms used are same as SpaceWire-RT

SpaceWire-T

- Over Asynchronous network provides:
  - Best Effort QoS
  - ACK for Best Effort QoS
    - So that the end user application is informed when something fails to be delivered
- Over Scheduled network provides:
  - Determinism
  - Resource Reserved QoS
  - With ACK

SpaceWire-T Architecture