The Operation and Uses of the SpaceWire Time-Code International SpaceWire Seminar 2003

Steve Parkes

Space Systems Research Group

University of Dundee

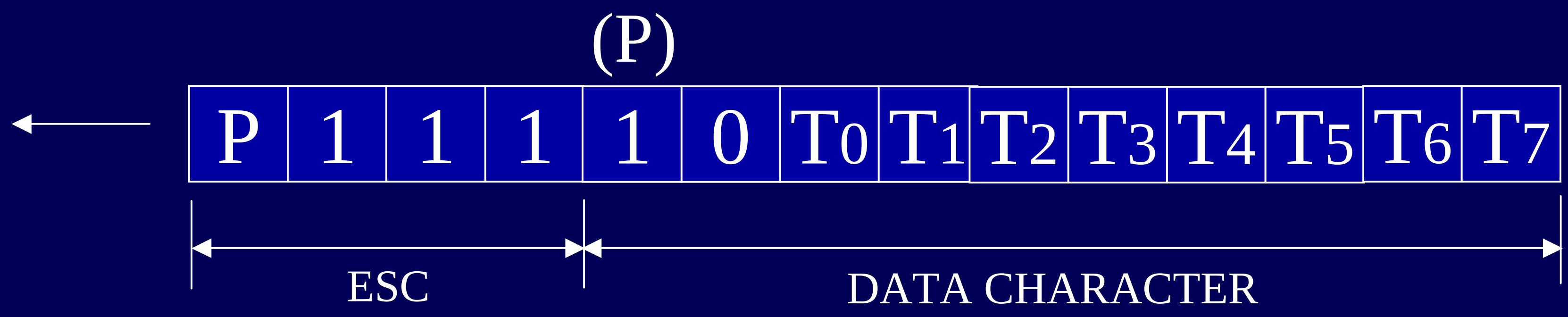
Need for Time-Codes

- Needed for control applications
  - Time accuracy better than 1msec (10 µs) across a fairly large network
  - Sub µs across links and small networks
  - Avoids having a separate network carrying time

Time-Codes

- Time-code comprises ESC, Data-Character
  - Data character holds an 8-bit time code
    - 6 bits of system time
    - 2 control flags
  - Time bits
    - used to distributed time
    - and to facilitate time-code broadcast
  - Control flags
    - General purpose
    - Broadcast to all nodes and routers

Time-Codes



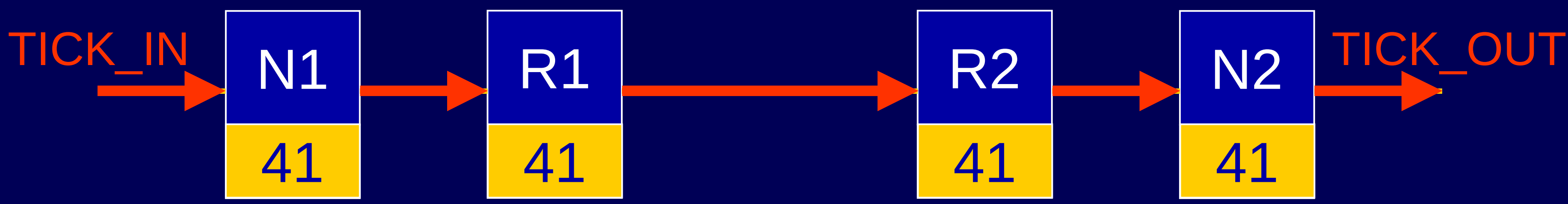
Nodes and Routers

- Each node or router has a 6-bit time counter
- Link interfaces have TICK_IN and TICK_OUT signals
- Asserting TICK_IN causes
  - time counter to be incremented
  - new time code to be transmitted
  - holding value of time counter
- TICK_IN used by only one, time-master node
- When valid time-code received
  - time counter is incremented
  - TICK_OUT is asserted

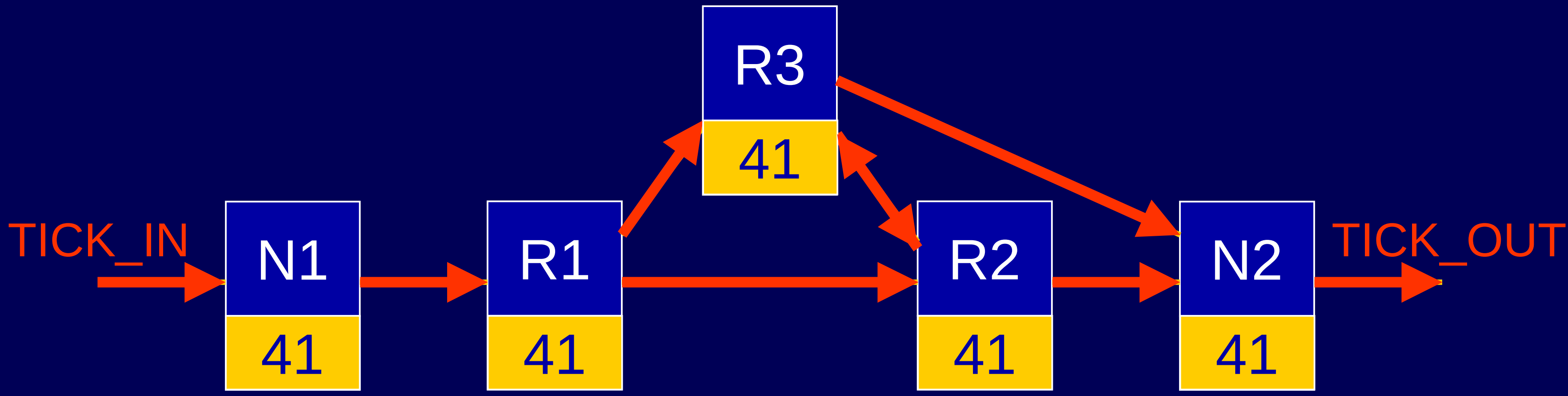
Nodes and Routers

- Valid time-codes have
  - Value of one more than the time-counter
  - At the receiver
- If valid
  - Set time-counter to new time-code value
  - Propagate time-code
- If NOT valid
  - Set time-counter to new time-code value
  - Do NOT propagate time-code

Time Distribution



Time Distribution



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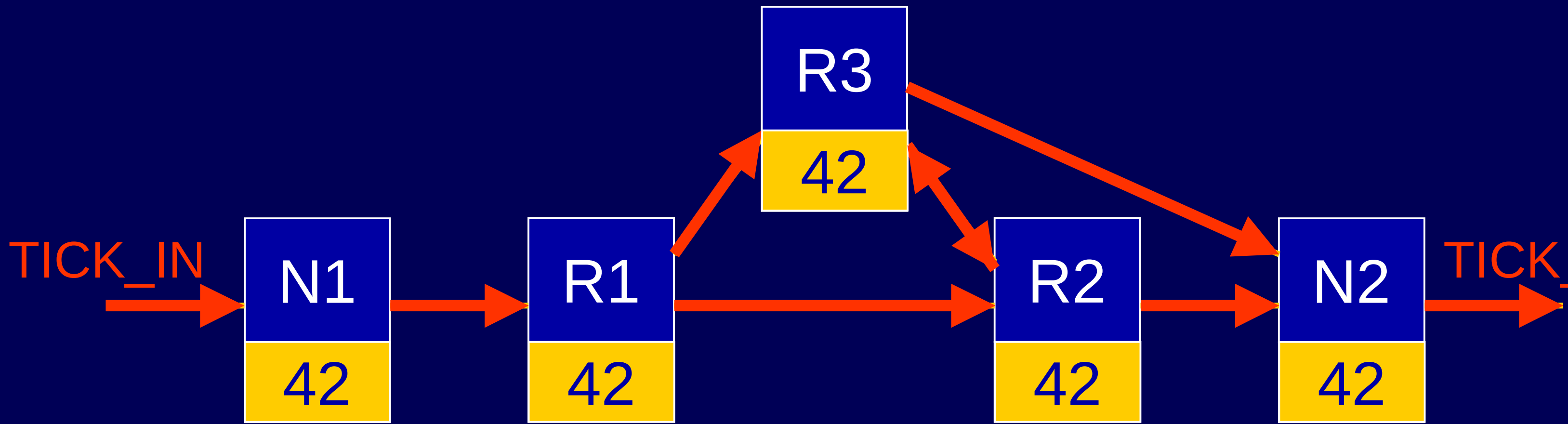
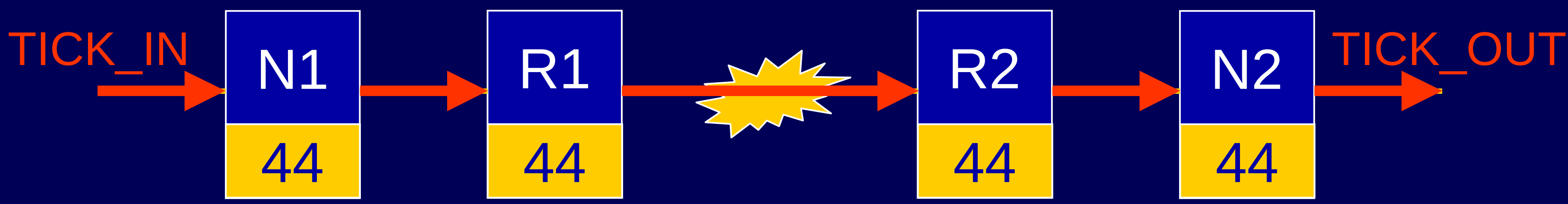


Time Distribution Error



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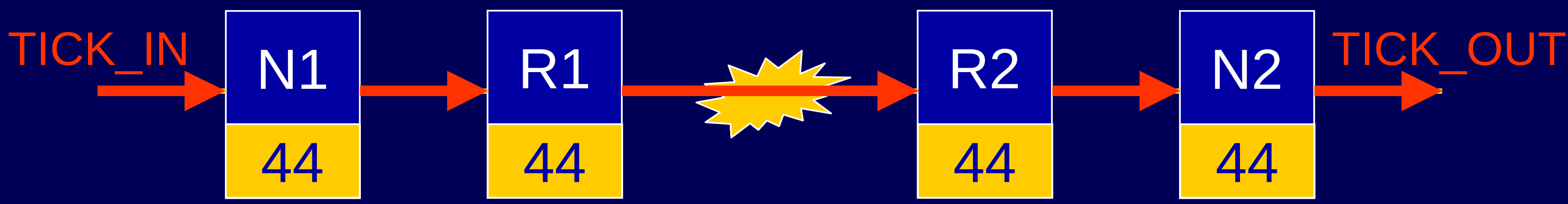

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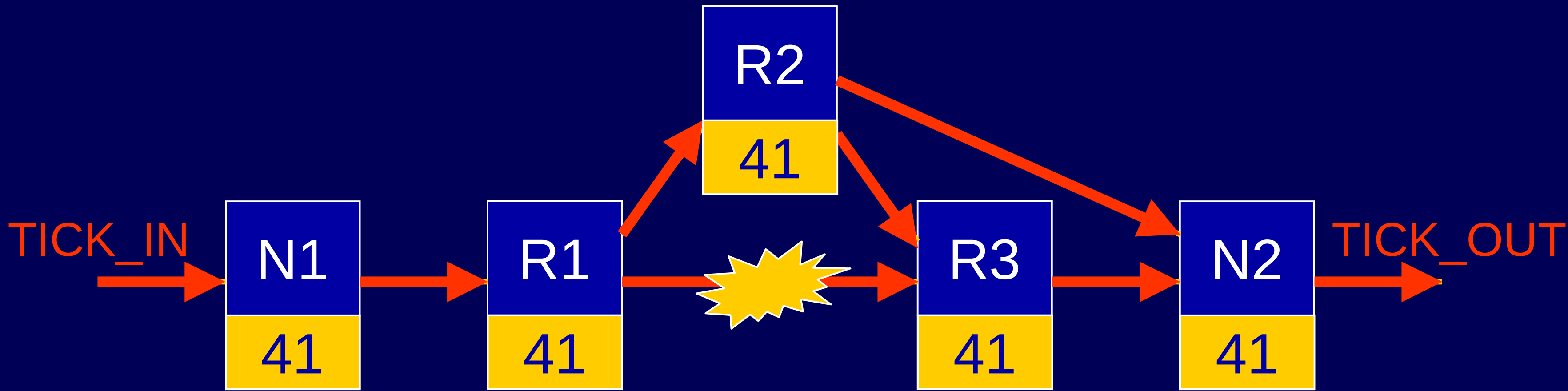

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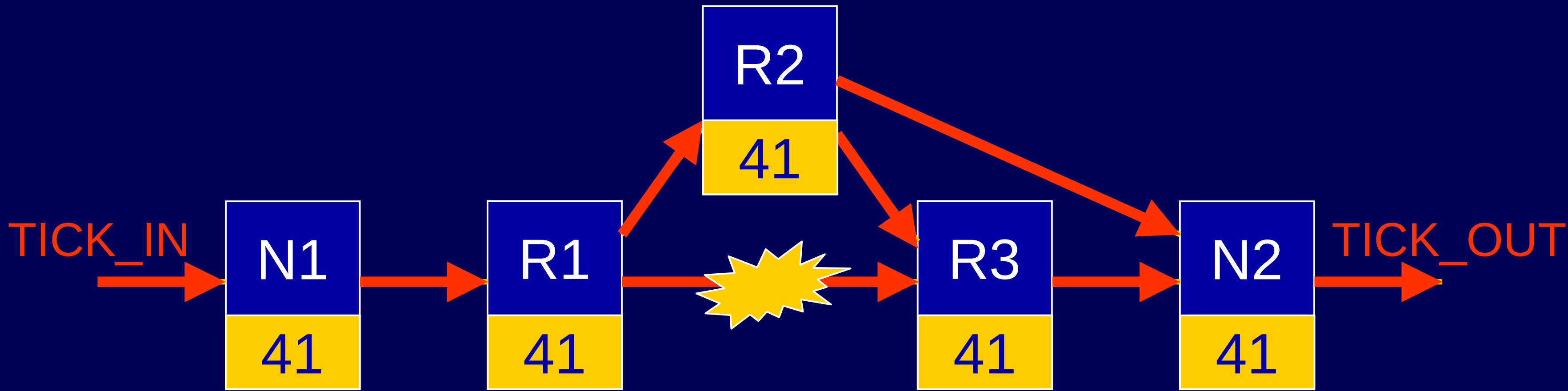


Time-Code Latency

- Latency dependent upon
  - Number of links over which time-code travels
  - Operating rate of the links
  - Delay at time-code source
  - Delay at each router
  - Delay at receiving nodes

Time-Code Latency

- Assuming all links operating at same rate, A Mbits/s
- Minimum delay at each router/node is
  - 14 bit periods (ESC + data character)
- This gives rise to minimum time skew of
  - 14.S/A
  - where S is the number of routers traversed
- Also get jitter at each router/node
  - Variation in time waiting for link to finish sending current character
  - Delay of 0 to 10-bits at each router/node
- Total jitter is then
  - 10.S/A
- Example A=100 Mbits/s, S = 10
  - Tjitter = 1.0 µs
  - Tskew > 1.4 µs
- Time-code distribution accuracy < 10 µs
- Probably much better than software response time

Time-Code Applications

- Time distribution
- Event signalling
- Isochronous communications

Time-distribution

- Time-codes can be used to distribute time information directly
  - E.g. six bits of system time sent in time code
  - Or time-code ticks uses to synchronise local time clocks
- Date/time can be sent in packets to all nodes and then synchronised with time-code
- Time dependent commands possible

Event Signalling

- Network
  - Two control-bits in time-code can be used to signal events
  - Broadcast to all nodes in a network
- Point-to-point link
  - Entire time-code could be used for event signalling
  - Do not do this if later a router will be attached

Isochronous communications

- Nodes assigned two addresses
  - Low priority – for sending asynchronous packets
  - High priority – for sending isochronous packets
- Isochronous packets can only be sent a certain times

Isochronous communications

- Every time a time-code is received
  - one node gets the chance to send out an isochronous packet
  - i.e. a packet with a high priority address
- 64 time-codes gives 64 time slots
- Nodes assigned zero, one or more of these slots
- For sending isochronous packets

Isochronous communications

- When node receives time-code
- If value matches one of the isochronous slots assigned to it
- Then it can send out an isochronous packet

Packet Delay

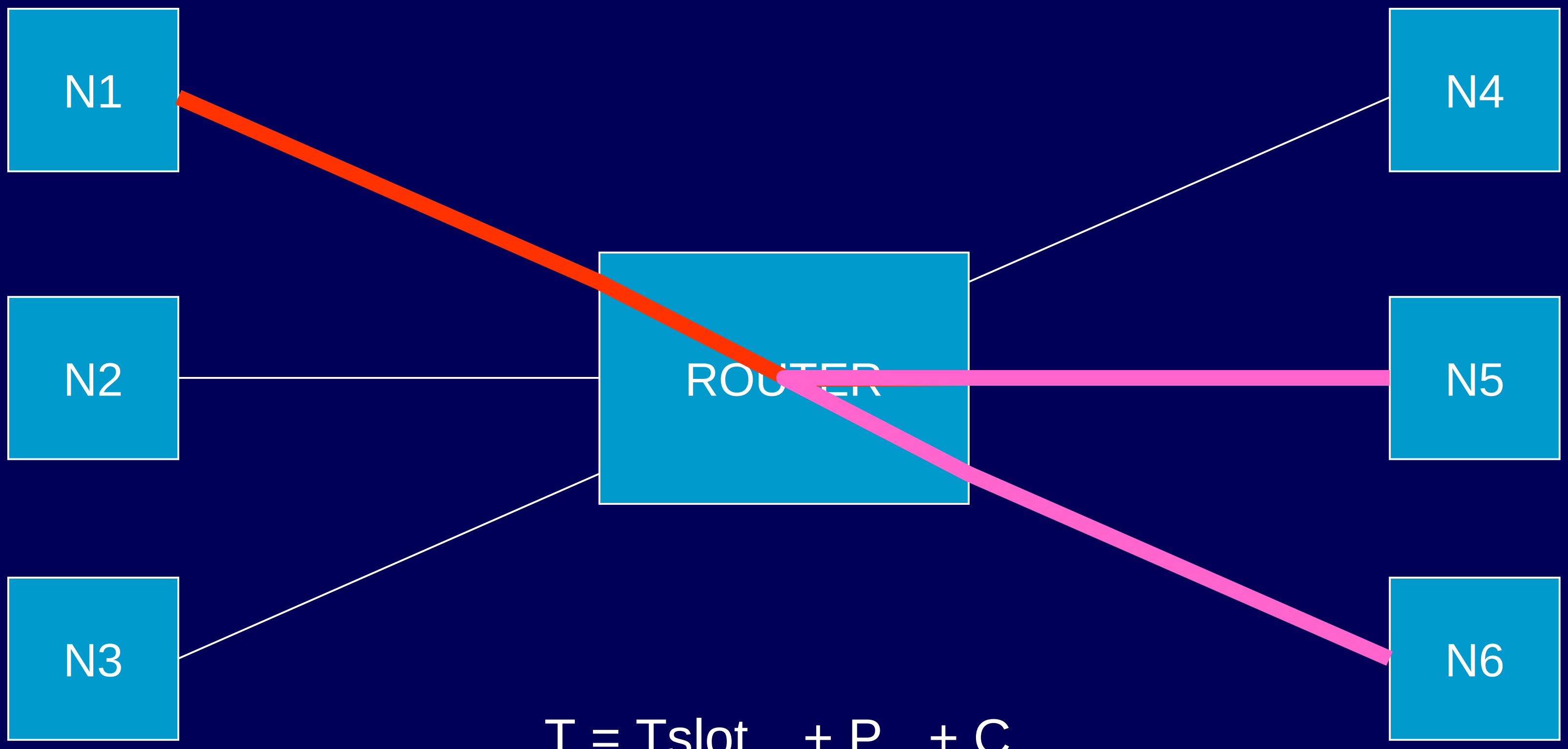
- Packet moves across network
- May have to wait at each router
  - While current packet completes
- Worst case delay depends upon maximum packet size
- Maximum packet length = L
- Effective data rate = D
- Max. time to wait at each router is P = L/D

Single Router Network

- Single router or redundant pair
- Connected to a number of nodes
- Total delay is
  - Time waiting for a slot, Tslot
  - Time waiting for current packet to complete, P
  - Time to send isochronous packet, C
- $T = Tslot + P + C = Tslot + 2L/D$

Single Router

Isochronous N1 to N5



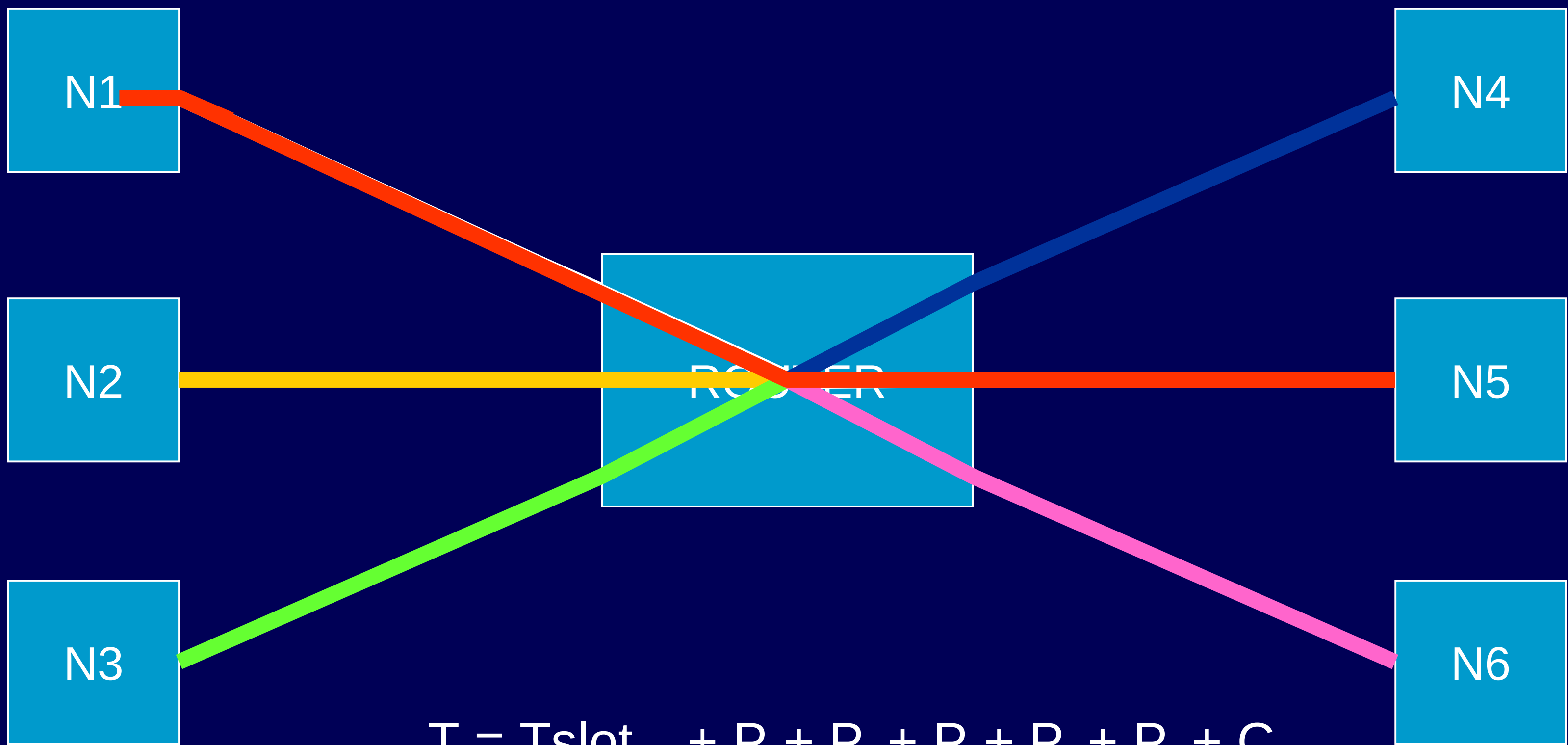
T = Tslot   + P   + C

Single Router Network

- Worst case situation is actually a bit worse
- Node that wants to send isochronous packet
  - could have just started to send a packet
  - to same destination as isochronous packet
  - Async packet has to wait for current packet to be completed
- $T = Tslot + (R-1)P + C$
- $T = Tslot + R.L/D$
- R = number of ports on router.

Single Router Worst Case

Isochronous N1 to N5



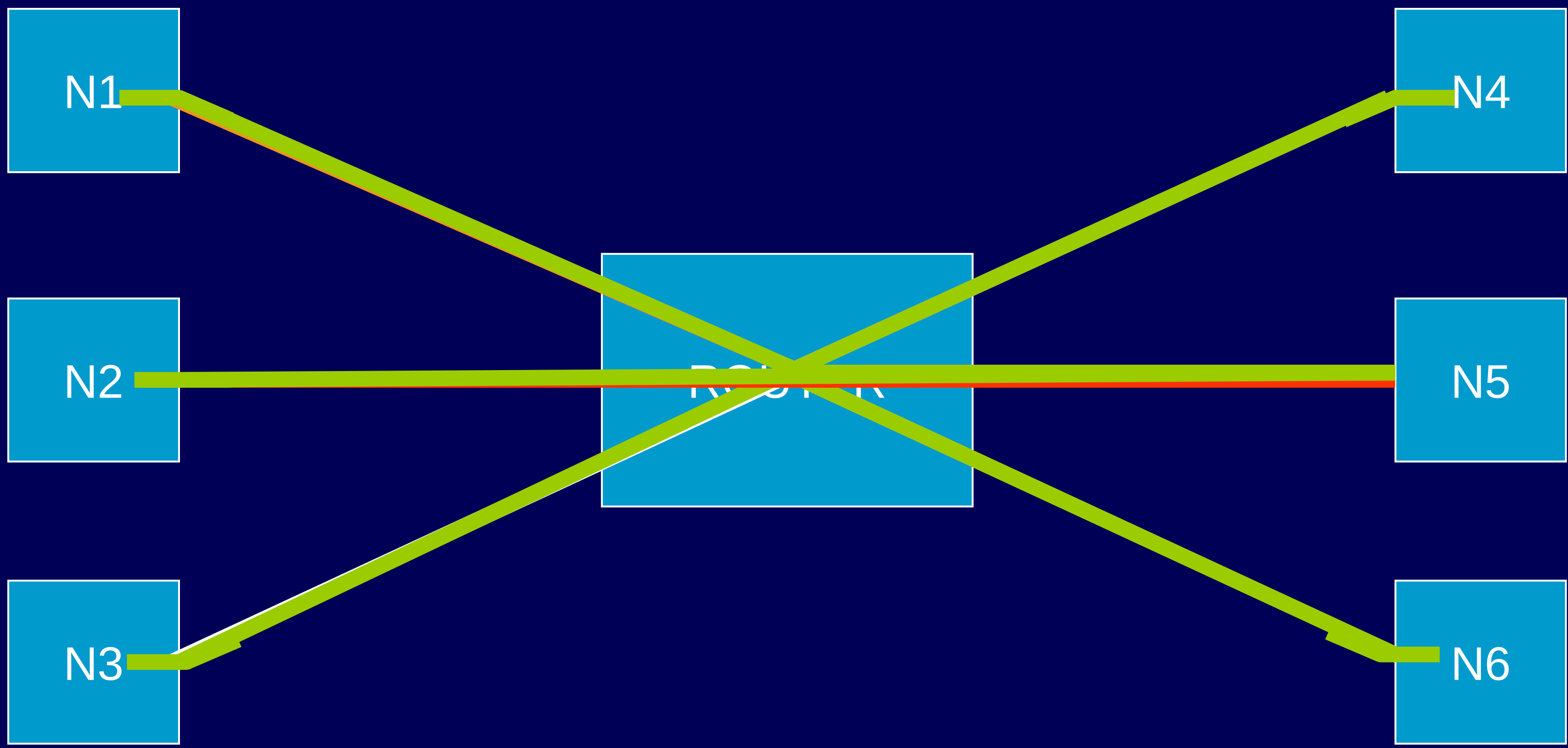
$$T = T_{slot} + P + P + P + P + P + C$$

$$T = T_{slot} + (R-1)P + C$$

Two Router Network

- Worst case is a bit better than above!
- If all nodes want to send isochronous packet
- They can all send one packet every Tslot
- Since the high priority packets will be routed once they have access to network.

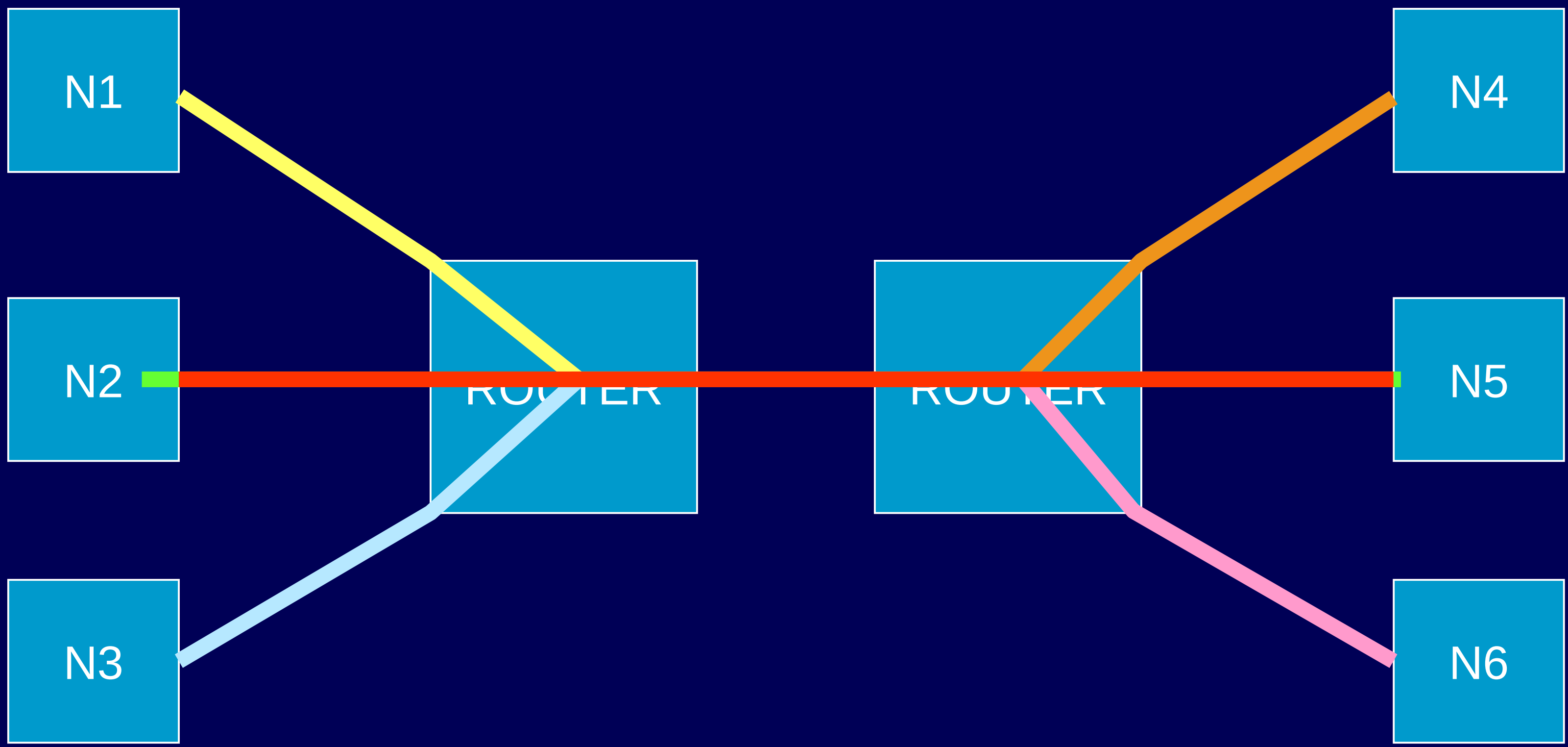
Single Router Multiple Isochronous Packets



T = Tslot + P+C + P+C + P+C + P+C + P+C

T = Tslot + (R-1)P + (R-1)C

Two Router Network



Two Router Network

- Delay is

  $T = Tslot + (N + (R-1)(R-1)) L/D$

- Multi-Router Delay is

  $T = Tslot + (N + (R-1)^{Q}) L/D$

- E.g. L = 2000, D = 200 Mbps, L/D = 100 us, R = 8, Q = 2, N = 8, Tslot = 10 ms

  T = 10 +(14 + 7x7)x 0.1 = 16.3 ms

Two Router Network

- E.g. L = 2000, D = 200 Mbps, L/D = 100 us, R = 8, Q = 2, N = 14, Tslot = 10 ms

  T = 10 +(14 + 7x7)x 0.1 = 16.3 ms

- E.g. L = 500, D = 200 Mbps, L/D = 25 us, R = 8, Q = 2, N = 14, Tslot = 2 ms

  T = 2 +(14 + 7x7)x 0.025 = 3.6 ms

- E.g. L = 500, D = 200 Mbps, L/D = 25 us, R = 8, Q = 1, N = 7, Tslot = 0.5 ms

  T = 0.5 +(7 + 7)x 0.025 = 0.85 ms

Destination Stalling

- Isochronous analysis assumes that no destination node stalls
- i.e. receiver never delays reception of packet

Conclusion

- SpaceWire time-codes
  - Unique form of time distribution
  - Time sent over data network
  - No need for separate time bus
- Able to broadcast
  - 6-bits time
  - 2-bits control information

Future Research

- Work at Goddard on
  - Improving accuracy of time-codes distribution
    - Delay time-code transmission
    - By holding tx clock
    - Routers send all time-codes at same time
  - Support for multiple time-codes
    - Four time-counters
    - Uses 2 control bits to determine which time-counter to use
- Work at Dundee on
  - Isochronous communication mechanisms