Low-Latency Packet Delivery in SpaceWire Networks

Quantifying worst-case latency for Virtual SpaceWire Networks

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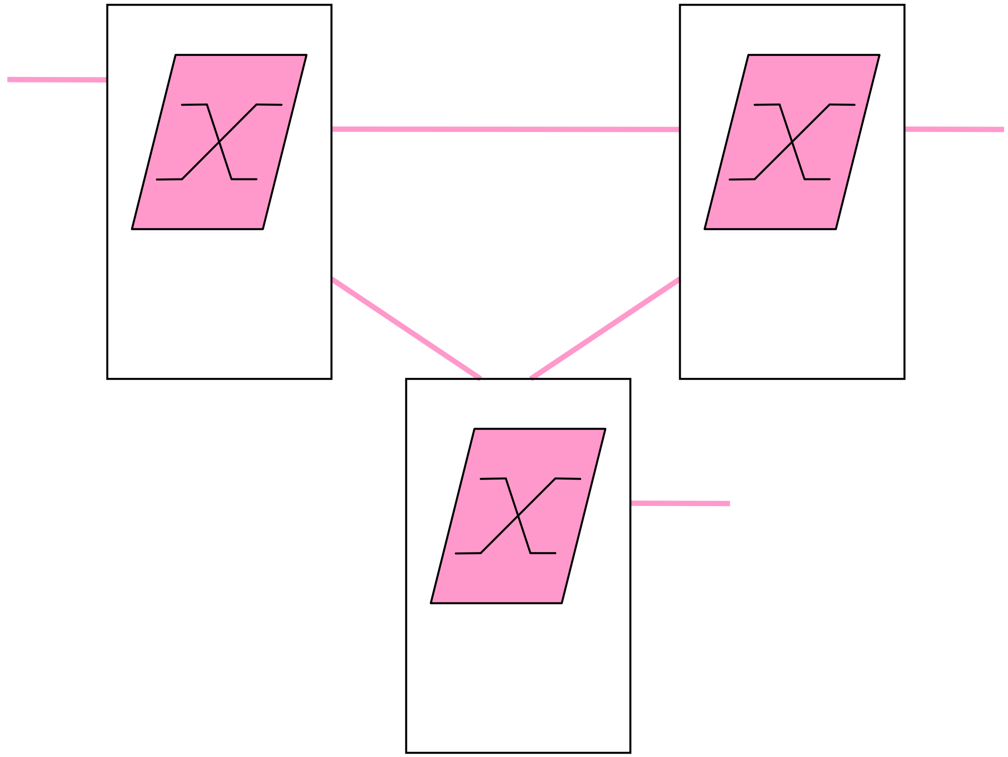
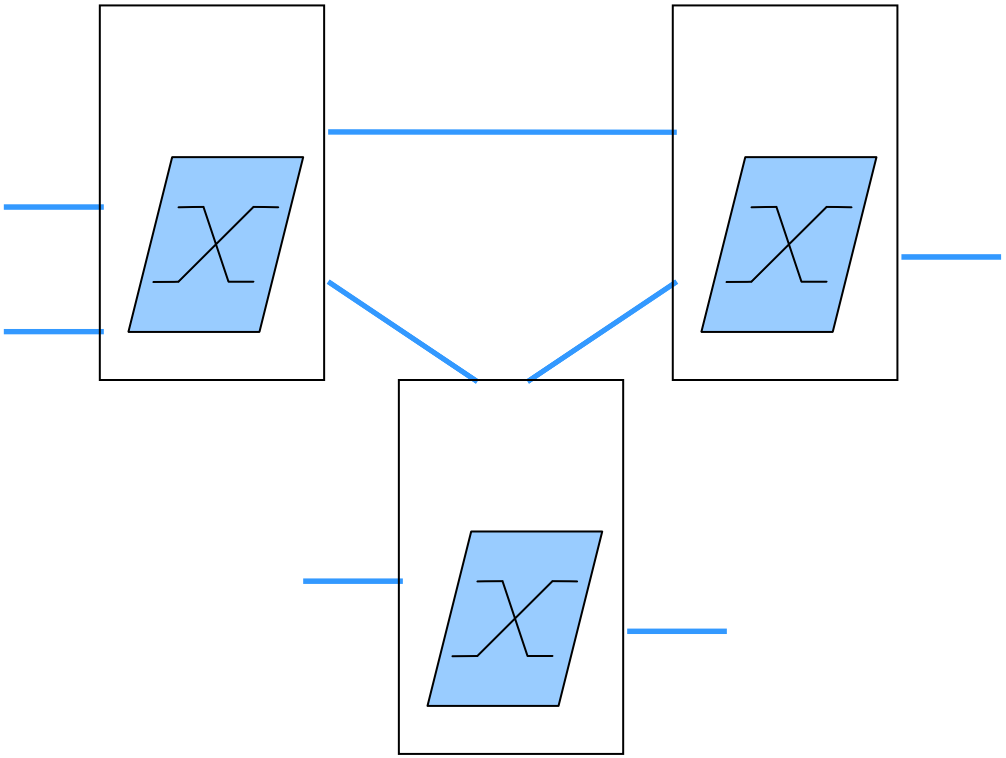
Command/control Network

- All small packets, bounded latency requirements

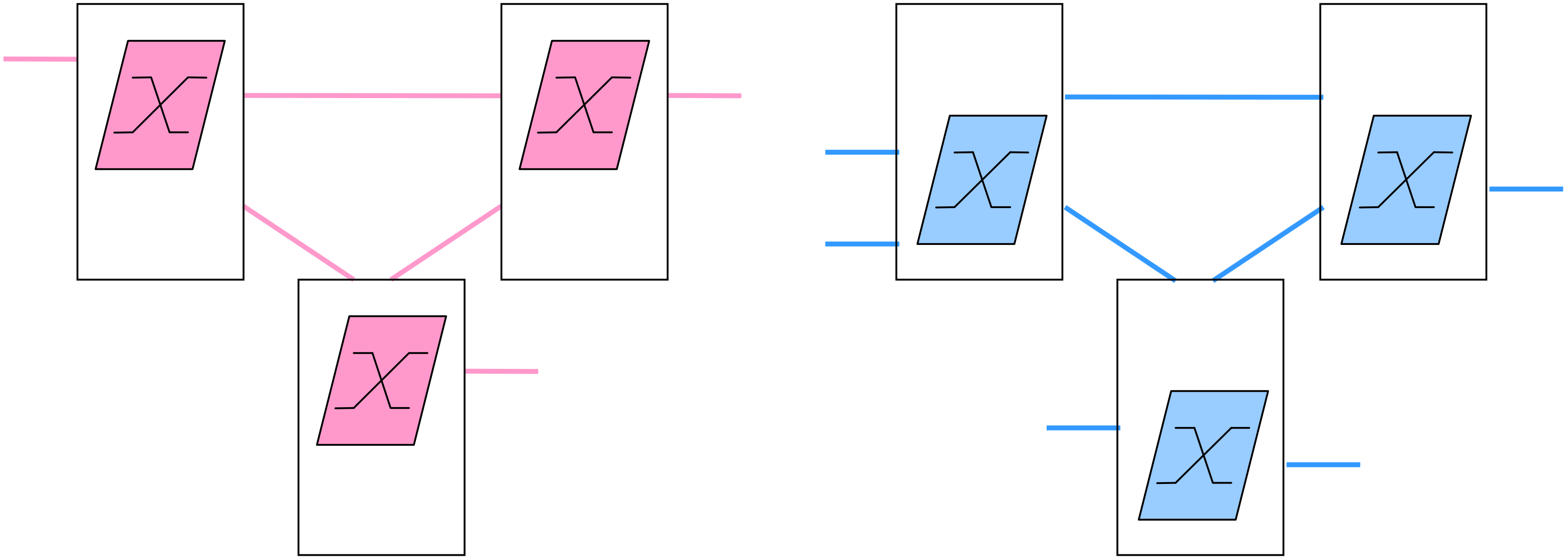


Telemetry Network



- **Large / very large packets, may be considerable latency**

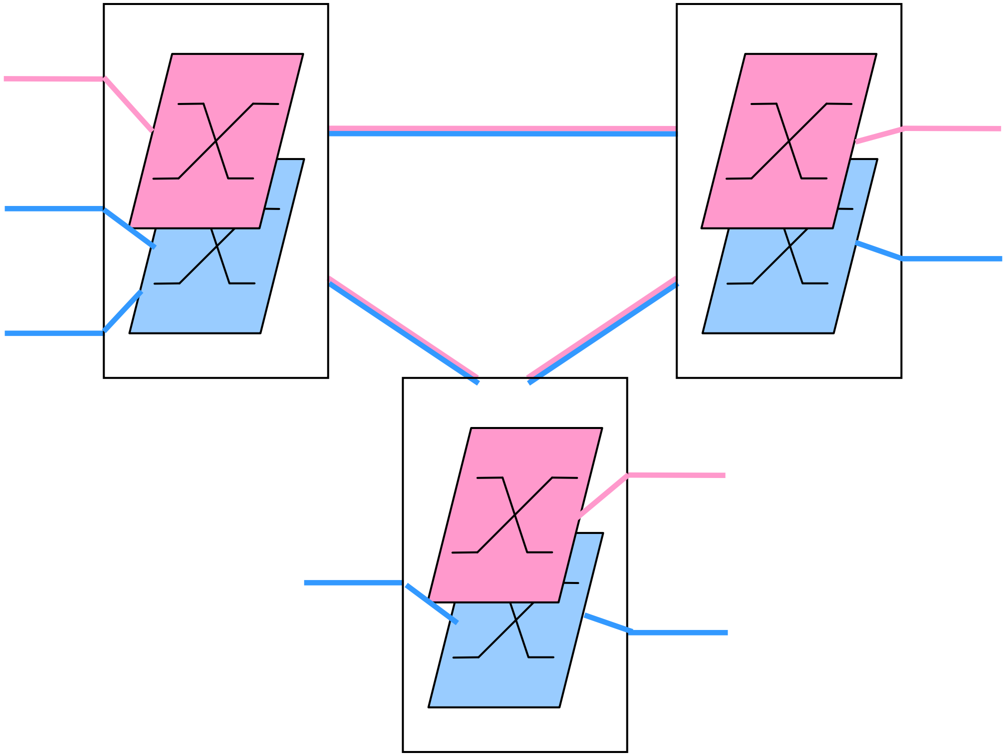
Two Networks



- **But having two networks costs mass, power, money**

Virtual SpaceWire Networks

- Logically two (or more) networks - but in one set of hardware

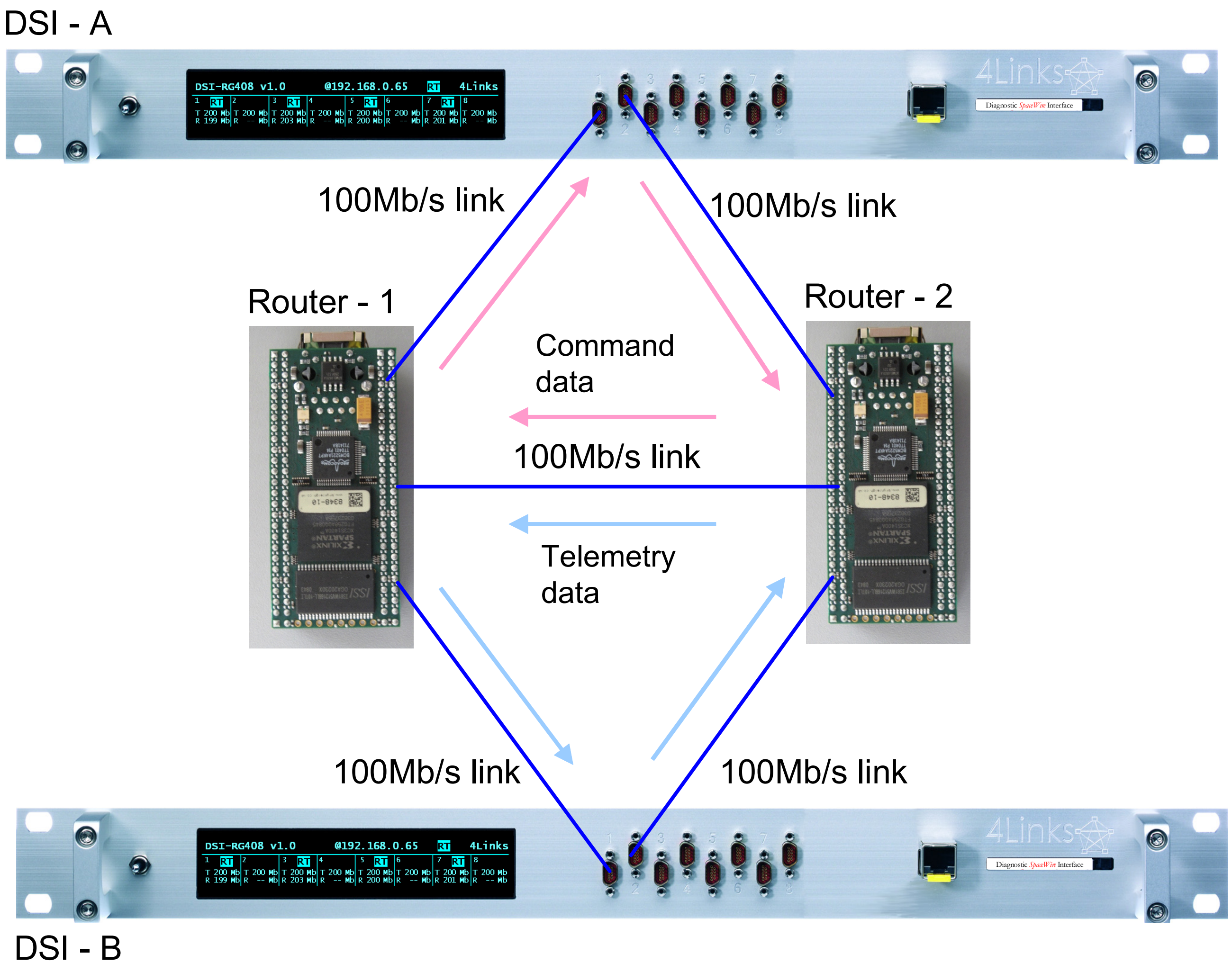


- Command/control data on one Virtual Network (red) and Telemetry data on the other Virtual Network (blue)

Benefits

- Improved cost etc.
  - Saving in mass, power and complexity, from having mixed buses
  - But no need to change anything in existing nodes
- Improved FDIR
  - The platform command and control is firewall protected from the payload data
  - All VSNs are isolated from faults at a lower priority level
  - Faults can be recovered by accessing via higher or lower priority VSNs
  - Timeouts can be chosen appropriately for the traffic type
- Improved performance
  - Maximized data throughput
  - Minimized worst-case latency
  - No need for accurate Time Codes for scheduling

Virtual Networks demo, 2009



Performance comparison

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	Command/ control latency	Command/ control jitter	CCSDS throughput
Empty non-Virtual Network	1.14 µs	0.2 µs	0%
Busy non-Virtual Network	173 µs	381 µs	~100%
Busy 2-priority Virtual Network	1.4µs	0.3 µs	~100%

- Two orders of magnitude improvement in latency and jitter compared with busy non-VSN network
- Negligible reduction in throughput for CCSDS traffic compared with busy non-VSN network

Worst-case latencies

- User response to Virtual Networks was extremely positive
- Users asked for a way to assess the worst case latencies
- The paper in the proceedings gives such a suggestion
- Here is a brief summary

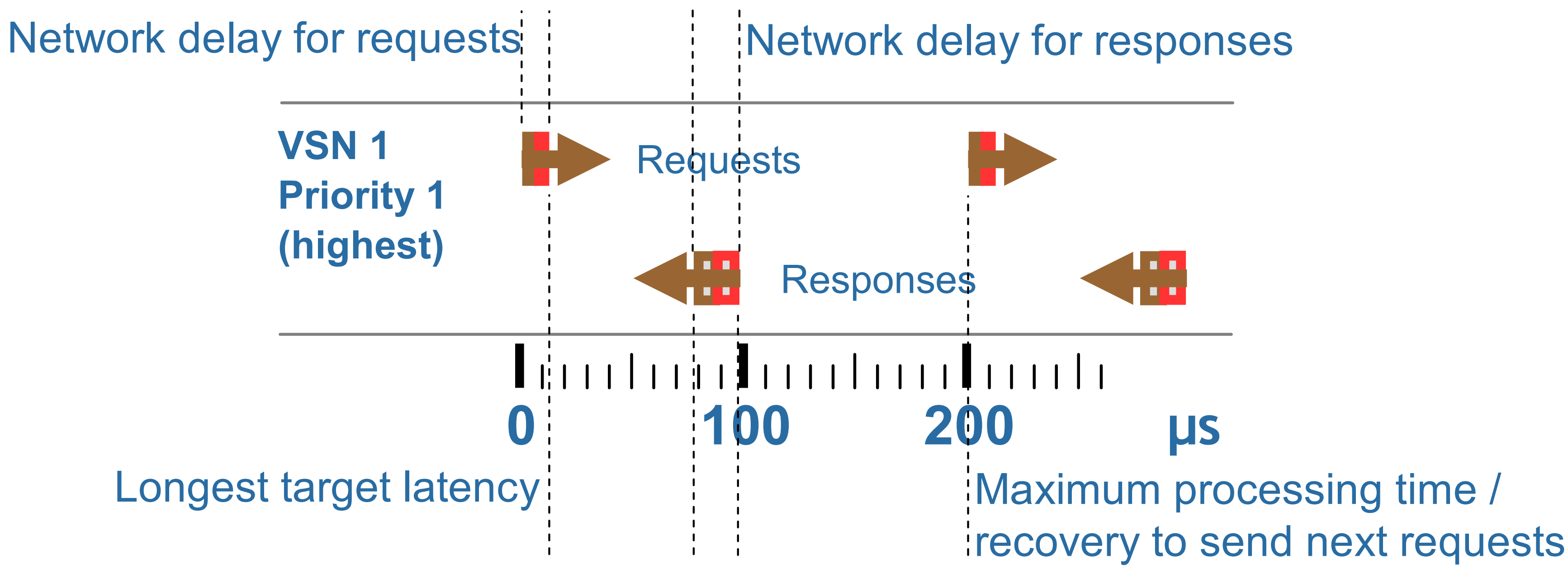
Assumptions for worst-case

- All the network traffic is shared on a single Virtual SpaceWire Network link
- All the accesses are RMAP Read requests and responses
- All RMAP initiators, whatever their priority level, start their accesses at the same time and so will be queued
- The node transmitting the RMAP request has buffer space to receive the response
- All nodes are to the current ECSS standard, without supporting Virtual SpaceWire Networks in the node
- And we use a link speed of 50Mbits/s

Example traffic mix

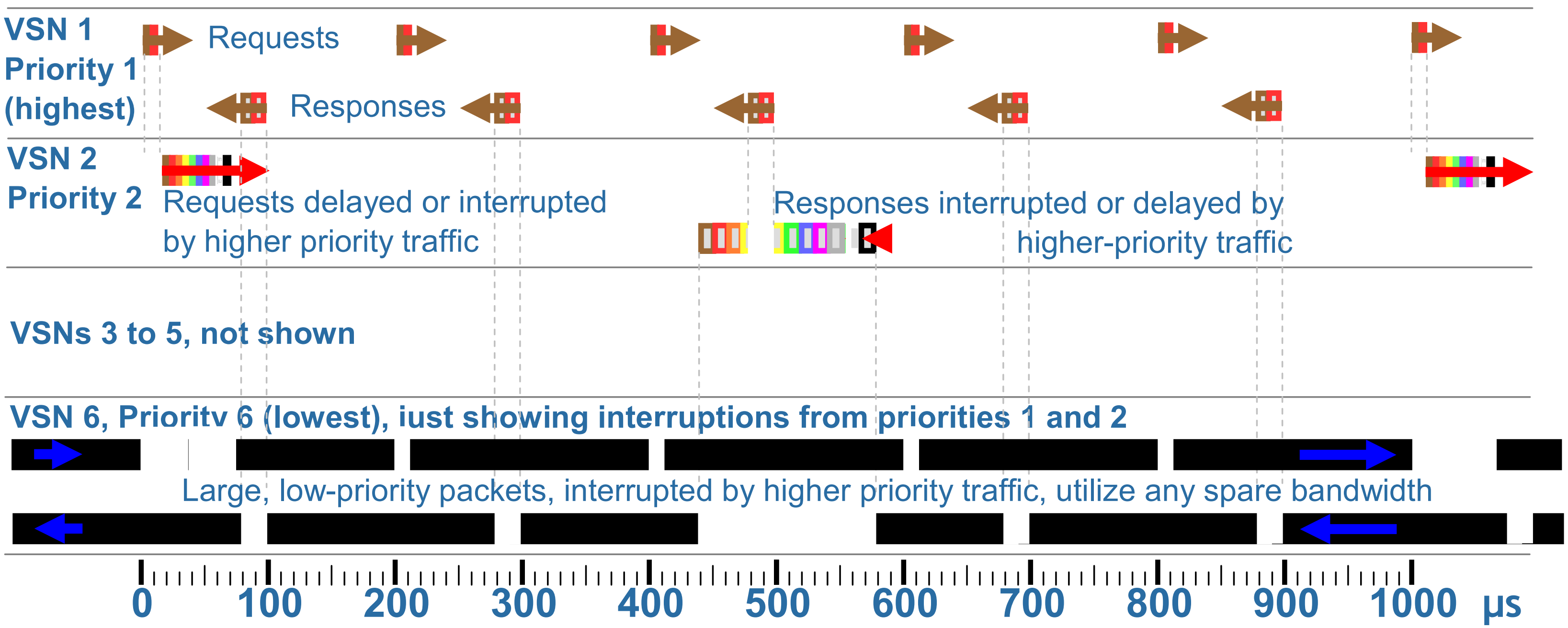
Frequency of control loop	Number of requests in period	Response Payload, Bytes
5kHz	2	20
1kHz	10	50
100Hz	25	200
10Hz	50	200
1Hz	100	200
Volume data at lowest priority		

For highest priority network



1. **Sum for each VSN in each of that VSN's period:**
   - **Total network delay for requests**
   - **Longest target latency**
   - **Network delay for responses**
   - **Longest initiator processing time before it can send next request**

Activity with several VSNs



Algorithm for all VSNs

2. Sum for each VSN in each of that VSN's period:
   - Total network delays for requests on all (higher or equal)-priority VSNs
   - Total network delay for requests on this VSN
   - Longest target latency
   - Network delay for responses on all (higher or equal)-priority VSNs
   - Longest initiator processing time before it can send next request
3. If this sum is less than the period, then the set of accesses can be guaranteed to take place within the period

Summary for the example traffic mix

Virtual Space-Wire Network (VSN)	Prio-rity	Period, µs	Freq-uency	Number of requests in period (n)	Response Payload, Bytes	Worst case network delay for requests on this VSN in this period, µs (% of period)	Worst case network delay for responses on this VSN in this period, µs (% of period)	Shared link Request direction utilization	Shared link Response direction utilization
1	1	200	5kHz	2	20	13.8 (6.9%)	19.8 (9.9%)	5.4%	8.9%
2	2	1000	1kHz	10	50	57 (5.7%)	157 (15.7%)	5.4%	15.5%
3	3	10000	100Hz	25	200	138 (1.4%)	1214 (12.1%)	1.3%	12.1%
4	4	100000	10Hz	50	200	273 (0.3%)	2428 (2.4%)	0.3%	2.4%
5	5	1000000	1Hz	100	200	542 (0.1%)	4853 (0.5%)	0.1%	0.5%
					Real-Time utilization			12.5%	39.5%
6	6	**Available bandwidth for (lowest priority) bulk data**						>80%	>50%
		Total network utilization possible						>90%	>90%

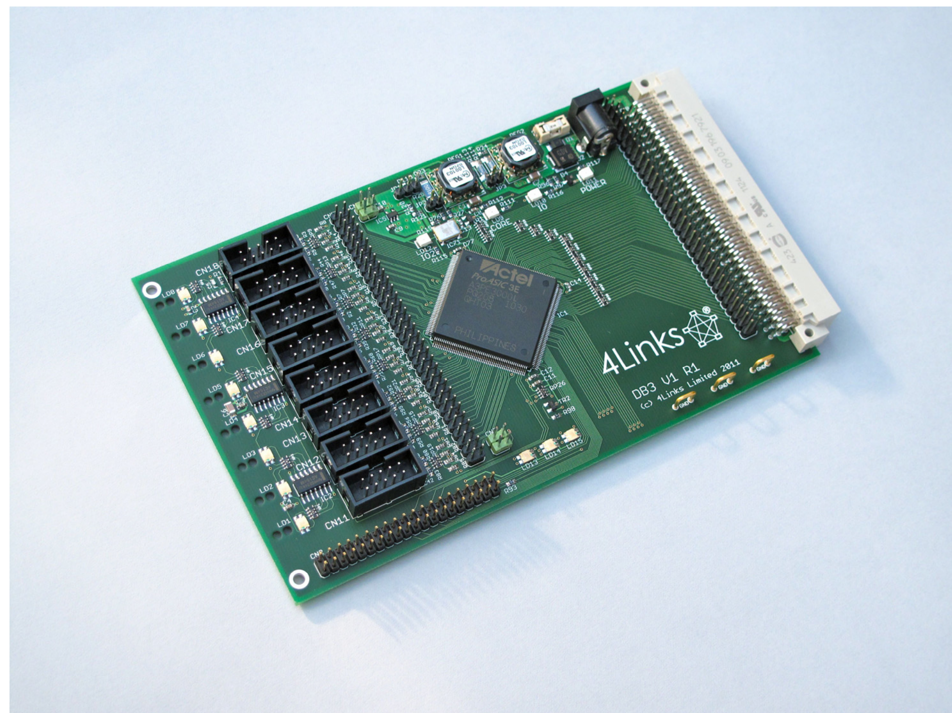
- **5kHz control loops can allow 50µs for target latency and 100 µs for initiator processing time and still have spare time**

Conclusions 1

- By replacing only the routing switches in a SpaceWire network, Virtual SpaceWire Networks provide the following benefits for missions:
  - the simplicity in both concept and use of Virtual SpaceWire Networks, reducing mission complexity;
  - use of a single physical network both for command/control and, separated by a firewall, for volume data;
  - reduced power consumption, cable/harness mass, and cost
  - complete compatibility with existing SpaceWire nodes;
  - complete compatibility with higher-level protocols (including CCSDS, SOIS and PnP) running over SpaceWire;
  - consistency with the layering of the SpaceWire standard so that no change is required to the ECSS SpaceWire standard;
  - greatly improved fault-isolation and recovery.

Conclusions 2

- Virtual SpaceWire Networks are also a simple solution for real-time SpaceWire, amply adequate for 5kHz control loops, even with a low SpaceWire link speed of 50Mbits/s
- All bandwidth not used for high-priority traffic is available for bulk data
- One of the Virtual SpaceWire Networks could be time triggered



- Chips and development boards will be available
- Visit 4Links exhibition booth for a demo