IAC-06-B5.7.1
Ethernet over SpaceWire – Hardware Issues

Barry M Cook, Paul Walker

4Links Limited

Bletchley Park

MK3 6ZP

UK

Introduction

4Links™

Amongst other things …

Ethernet

- Is a long established technology with extremely wide take-up in computer networks;
- Has enabled a huge variety of applications through a rich set of supported protocols.

SpaceWire

- Is a newcomer which has, nonetheless, generated wide interest and significant take-up, worldwide, in the space industry;
- Is capable of being built into highly fault-tolerant networks and systems;
- Comes with a very limited, but growing, set of protocols targeted to the space industry.

Introduction (2)

4Links™

What if SpaceWire networks could offer Ethernet services as well as supporting the new Space-related SpaceWire, and other, protocols?

This would automatically support that rich set of protocols we are familiar with and its very wide variety of applications (and allow re-use of existing code).

This paper is based on a successful Linux proof-of-concept implementation.

Context for Comparison

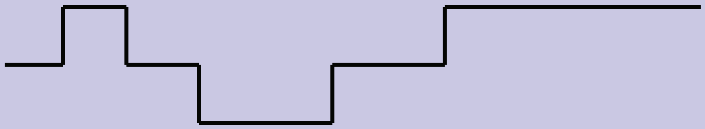
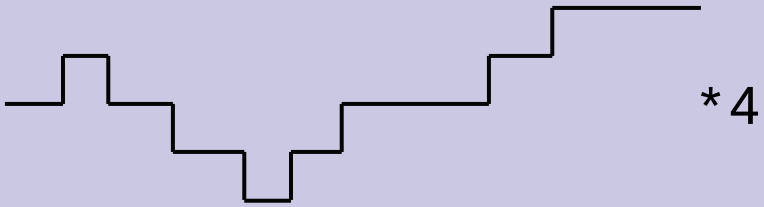
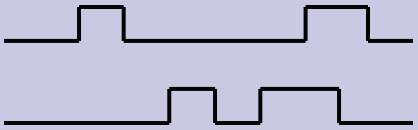
4Links™

The ISO OSI 7-layer model

Layer 7 – Application
Layer 6 – Presentation
Layer 5 – Session
Layer 4 – Transport
Layer 3 – Network
Layer 2 – Data link
Layer 1 – Physical

Physical Layer

4Links™

Ethernet	SpaceWire
3-level analogue (100Mb/s)  5-level analogue (1Gb/s)  *4	Digital (LVDS) D S 
Limited set of speeds (speed negotiation adds logic)	Any speed (‘autobaud’ <2Mb/s to >600Mb/s)

Data Link Layer

4Links™

Ethernet	SpaceWire
Sequence of octets encodes data	Sequence of tokens allows data to be interrupted by high-priority time codes
Crude flow control (optional)	Precise flow control (mandatory)
Minimum and maximum packet size	No limits on packet size

Network Layer (1)

4Links™

Ethernet	SpaceWire
Must be tree	Any topology – permits multiple paths
Allows multicast and broadcast	Multicast not permitted (due to possibly multiply connected network)
Bandwidth increase with aggregation	Bandwidth increase with group-adaptive Routing
Passive redundancy (disable parts of network to maintain tree structure)	Active redundancy through group-adaptive routing (use everything available)

Network Layer (2)

4Links™

Ethernet	SpaceWire
Store and forward routing	Wormhole (cut-through) routing – low latency
Best effort delivery	“Guaranteed delivery” due to FCT – but failures can occur
Routing by address at front of packet (48-bit address)	Routing by address at front of packet (8-bit)

Transport Layer

4Links™

Ethernet	SpaceWire
Rich set of protocols – with existing software	A very small number of protocols – more being developed

Ethernet packet structure

4Links™

Destination address	Source address	Type / length	Data	CRC

- Device address is (unique) 48-bits
- One of the destination address bits indicates multicast
  - Multicast packet is received by ALL nodes
  - Unicast packet is received by the one node with the corresponding address
    - Until location is known – send to all nodes
    - Each router in the network learns the port corresponding to an address by inspecting the source address of packets received
    - Each router must maintain a table of addresses
      - Of unknown size
      - Which must be updated – adding is easy, removal is not

SpaceWire packet structure

4Links™

There is no defined structure.

The receiver determines how to interpret the data.

- Extensions are being proposed to add some structure
  - Protocol Identification – like Ethernet's Type/Length field

SpaceWire Routing

4Links™

One, or more, bytes at the front of the packet are interpreted by routing switches in the network.

- The first data byte is interpreted by the first routing switch
  - 0 is communication with the switch
  - 1-31 sends the data to that physical port
    - Deleting the address byte
  - 32-255 indexes a table in the switch to determine disposition
    - The address byte may be retained or deleted
    - A set of acceptable output ports may be specified – group-adaptive routing
- The address table in the switch must be explicitly written
  - The switch has no learning capability

SpaceWire Routing

4Links™

A packet my be routed through the network by

- Using a logical address configured at each switch (similar to Ethernet but 8-bit, not 48-bit)
- Using a set of physical address, one per hop
- A mix of the above

Ethernet over SpaceWire (1)

4Links™

An Ethernet 48-bit address must be converted to one or more bytes of SpaceWire routing and, if necessary, the routing table entries in the routing switches must also be set

IF the network topology is static, with known devices at known ports on known routers then the tables and translations can be fixed

- Group-adaptive routing can provide fault tolerance – for limited topologies

Otherwise use (plug-and-play) techniques to dynamically configure translations and tables

Note: Ethernet is plug-and-play

Ethernet over SpaceWire (2)

4Links™

Fault-tolerant SpaceWire networks will contain multiple paths – broadcast would result in deadlock

Broadcast is not supported by the hardware

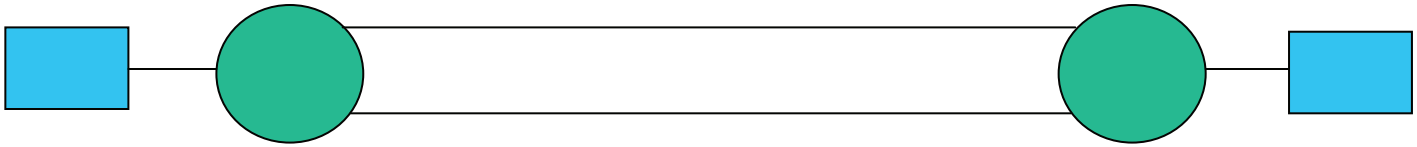
Broadcast may be simulated by software as multiple unicast

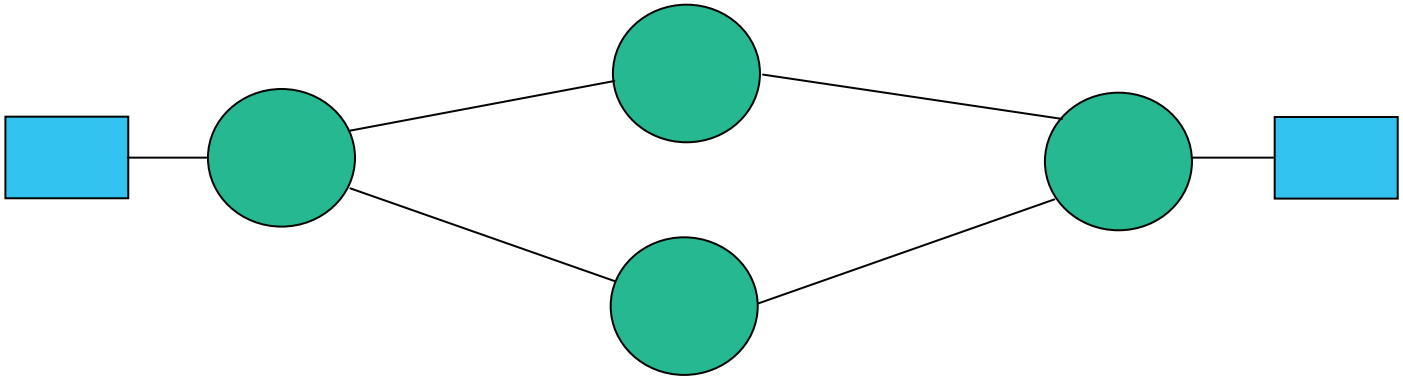
- At some cost in network traffic
  - OK if broadcast is not too frequent

One exception – SpaceWire does allow broadcast of a time-code

Static configuration limitations

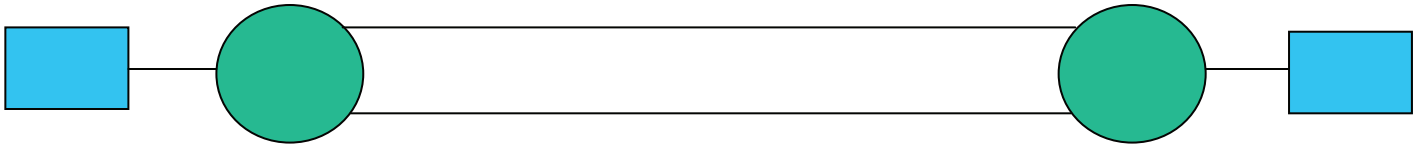
4Links™

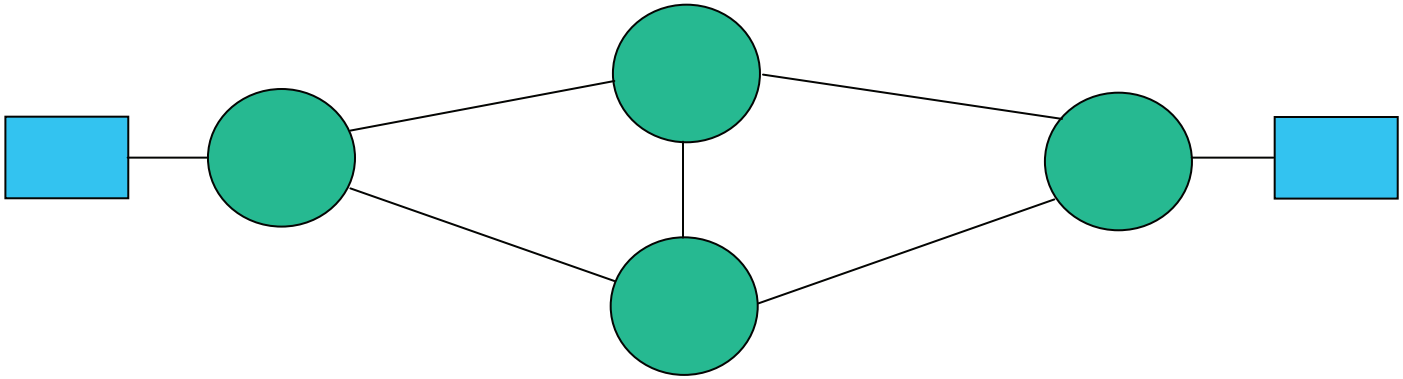




Static configuration limitations

4Links™





Static configuration limitations

4Links™

Dynamic configuration can provide a working network with a wider range of faults than static configuration

- Even with a static topology, dynamic configuration offers advantages
- Static becomes partially-dynamic when faults occur
- Enabling cold-redundant units produces a dynamic, not static, network

Conclusions

4Links™

- SpaceWire is easy to implement and very well suited to the construction of highly fault-tolerant networks and systems
- Ethernet offers a rich set of tried-and-tested protocols – and software
- Ethernet and SpaceWire deliver largely similar low-level services – except multicast and broadcast
- Ethernet addressing has to be converted to (similar) SpaceWire addressing

Ethernet over SpaceWire can be delivered – but some software support is required ...