Internetworking Over SpaceWire: A Link-Layer Broadcast Service for Network Stack Support

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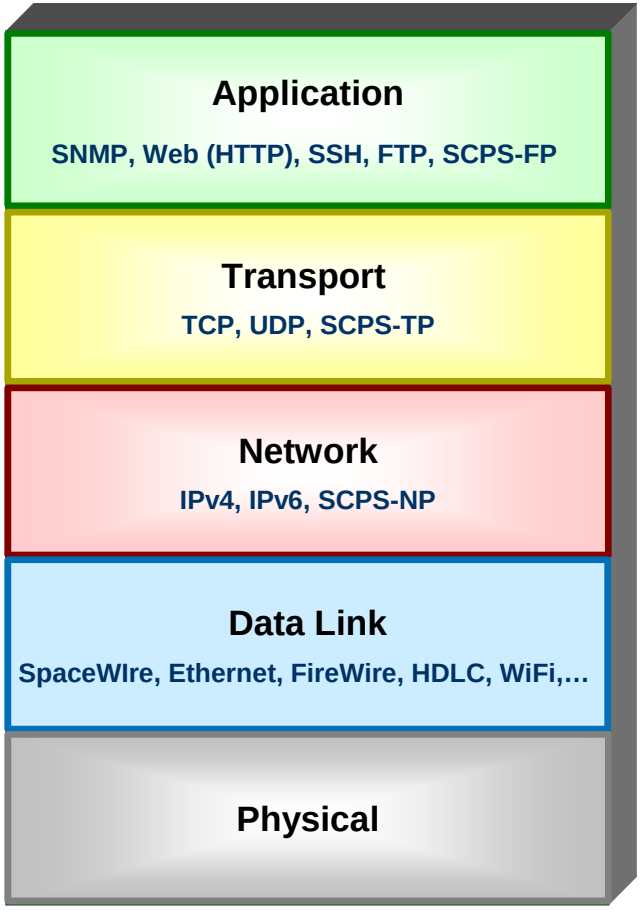
Standard Network Stack On-Board?

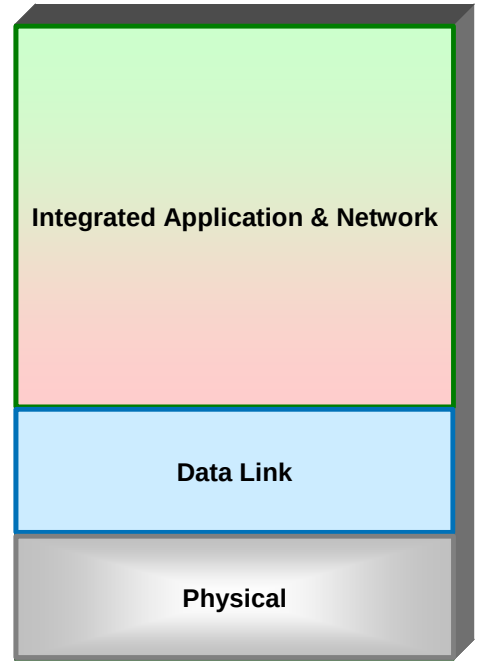
Standard Network Stack



Advantages

- **Software reuse; mature APIs and implementations.**
- **Simpler application code.**
- **Rapid development.**
- **Lower cost.**
- **Interoperability.**

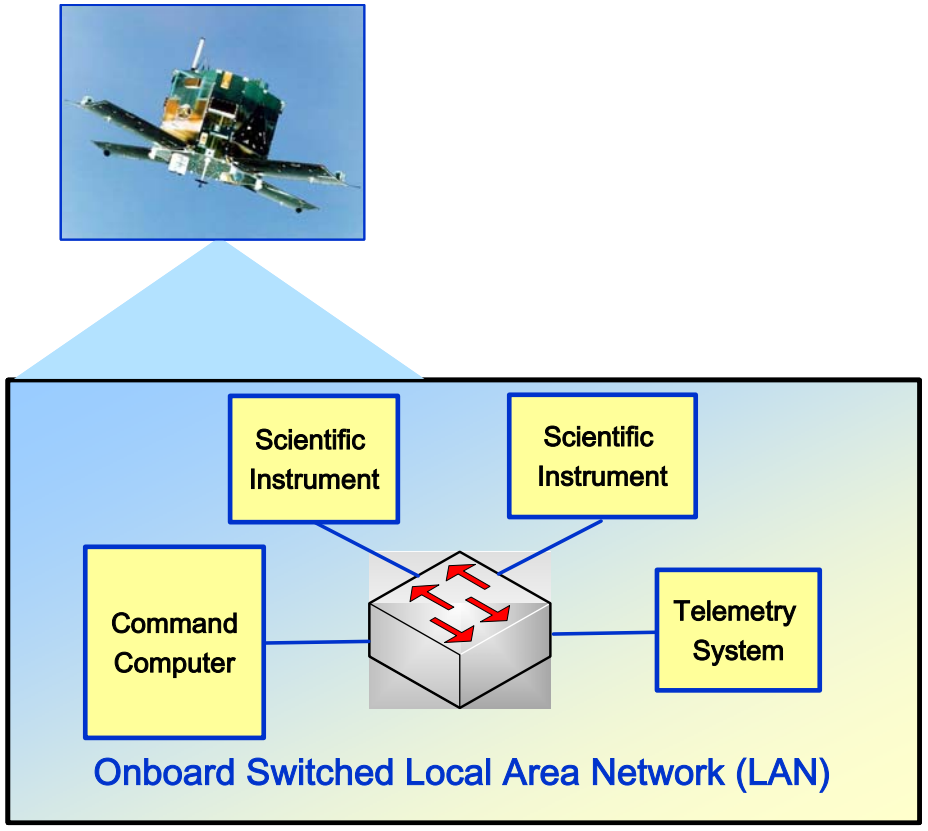
Platform-Specific



Disadvantages

- **Protocol assumptions may not hold**
  (e.g., TCP assumes delay is related to congestion, IP assumes end-to-end connectivity, …).
- **Performance may not be optimal**

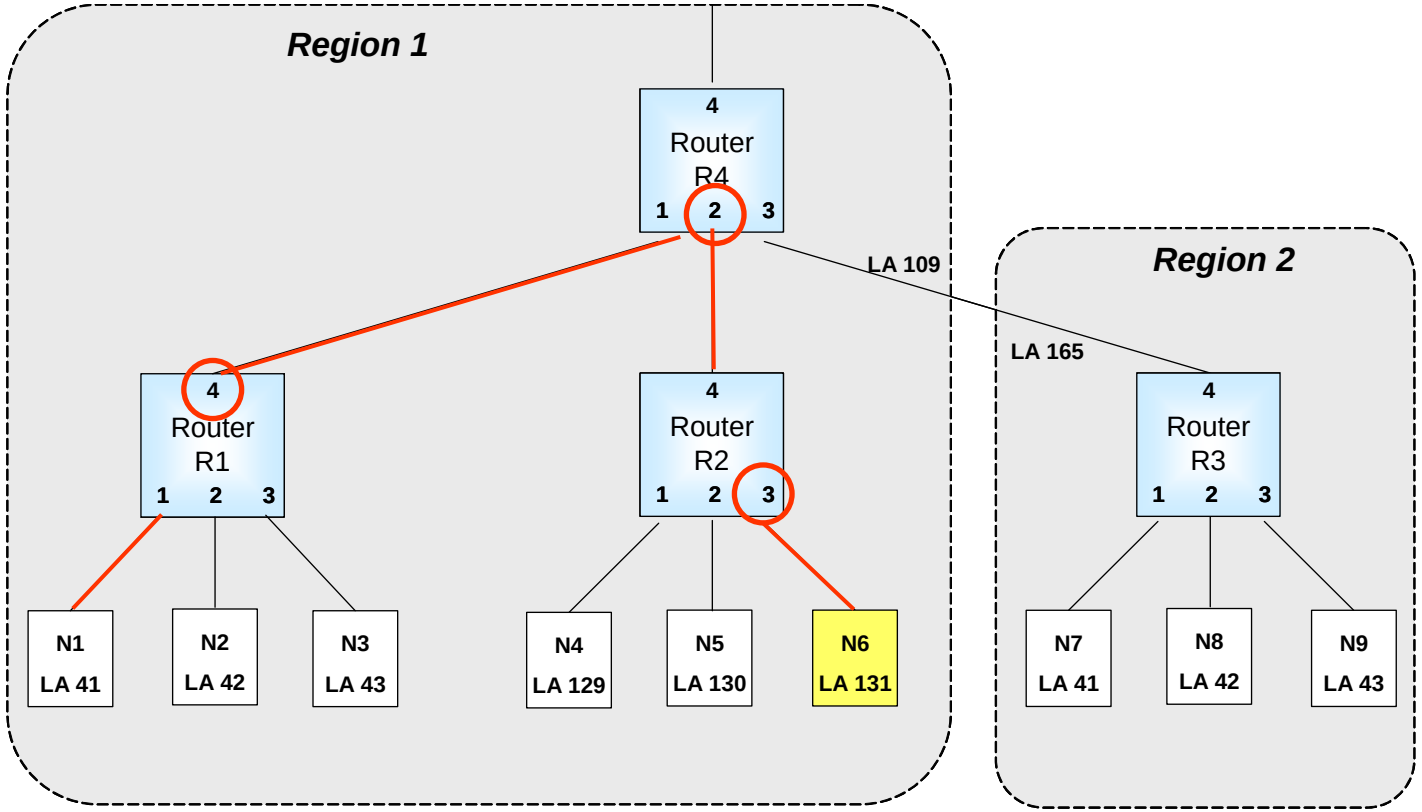
SpaceWire Overview



- Switched LAN designed for high speed on-board data handling.
- Low power, low cost.
- Scalable
- 2 to 400 Mbps, low latency.
- Backplane or Cables.
- Based on IEEE 1355 and LVDS.
- Wormhole routing
- ESA Specification ECSS-E-50-12A

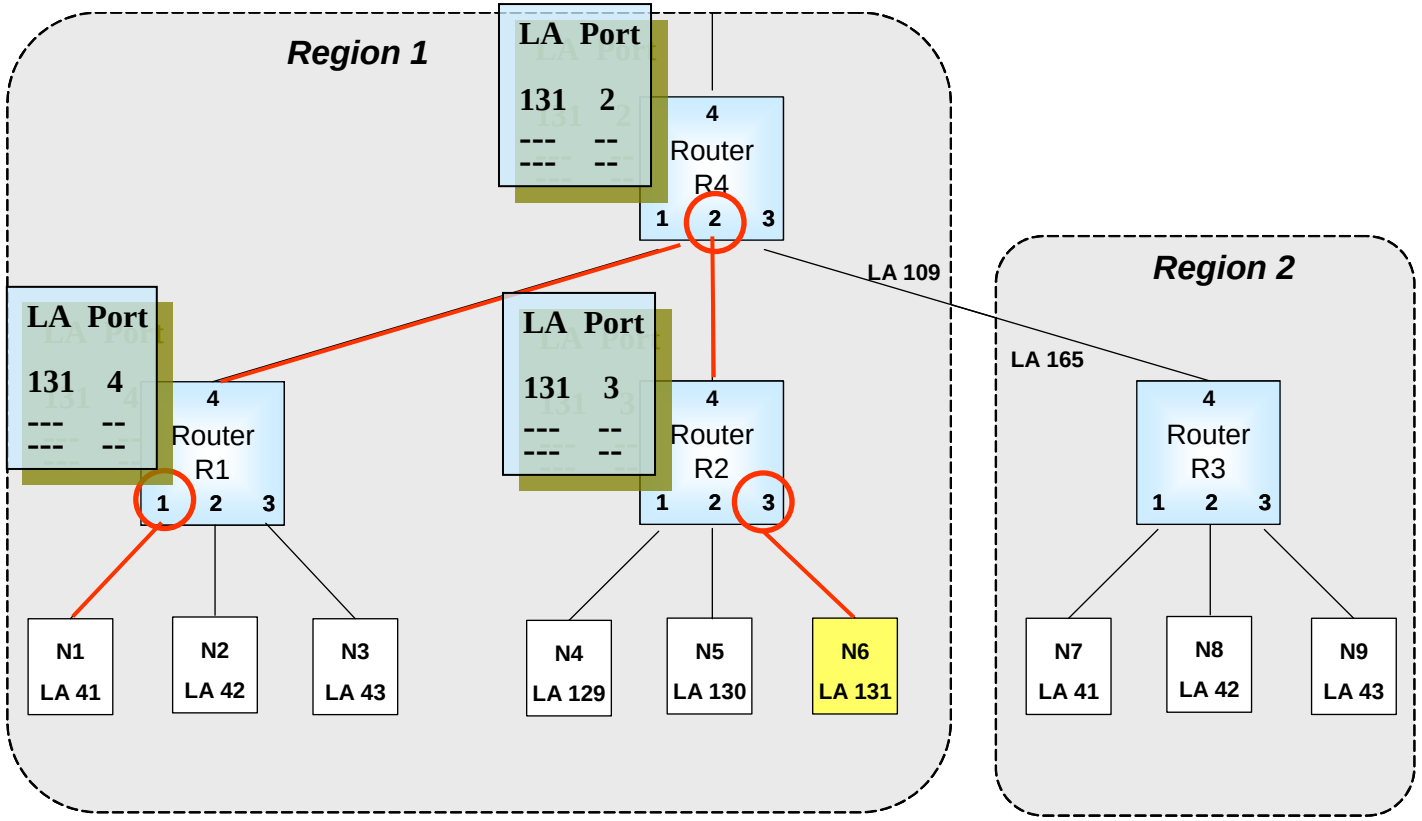
SpaceWire Path Addressing

- Header contains output port of each hop (0 .. 32)
- SpaceWire Routers apply header deletion
- Example: N1 sends to N6 `<4><2><3><cargo><EOP>`



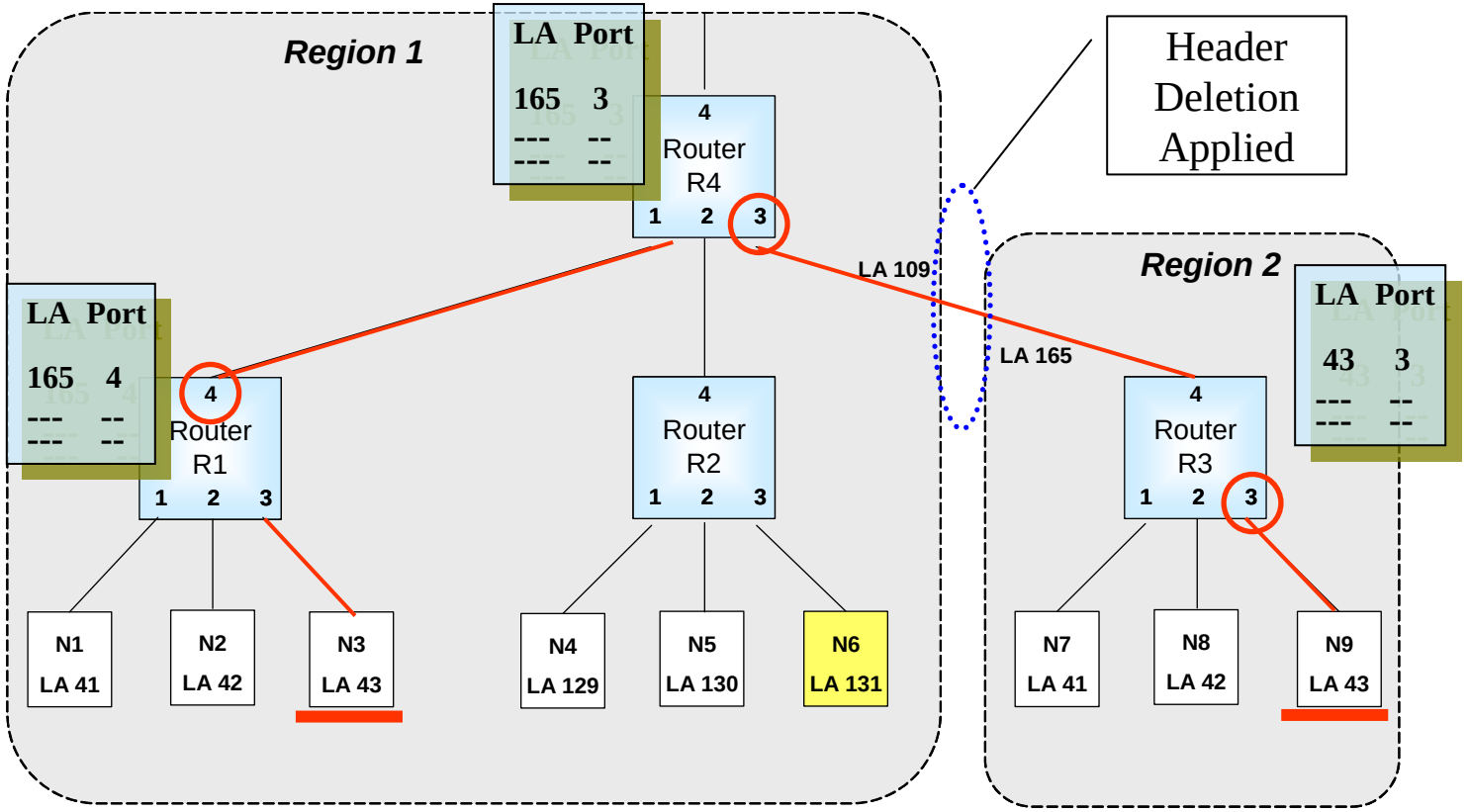
SpaceWire Logical Addressing

- Header contains logical address of destination (32 .. 254)
- Path determined by router forwarding tables.
- Example: N1 sends to N6 `<131><cargo><EOP>`

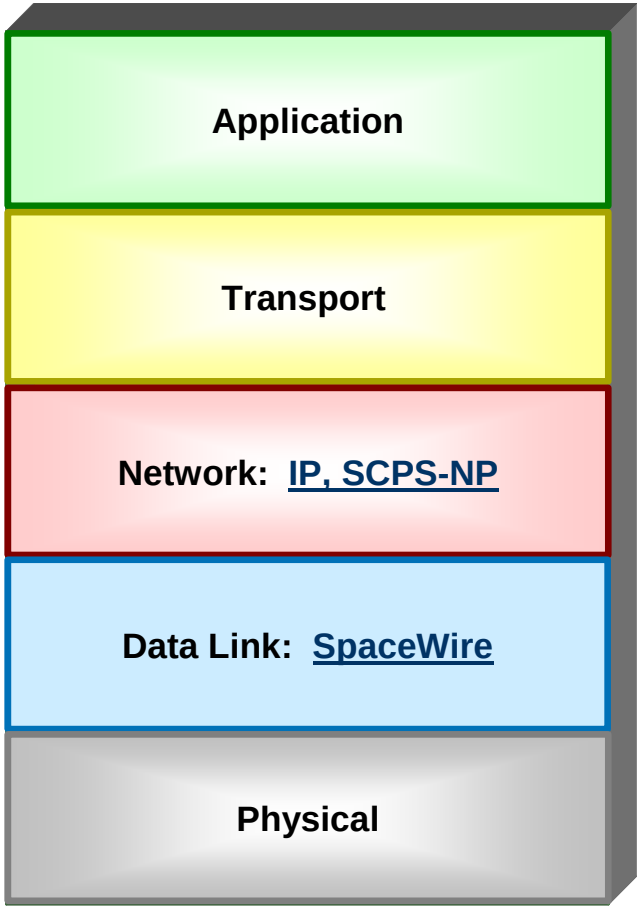


SpaceWire Regional Logical Addressing

- Regional addressing used for larger networks.
- Logical addresses may be reused in different regions.
- Routers configured as gateways between regions.
- Example: N1 sends to N9 **<165><43><cargo><EOP>**

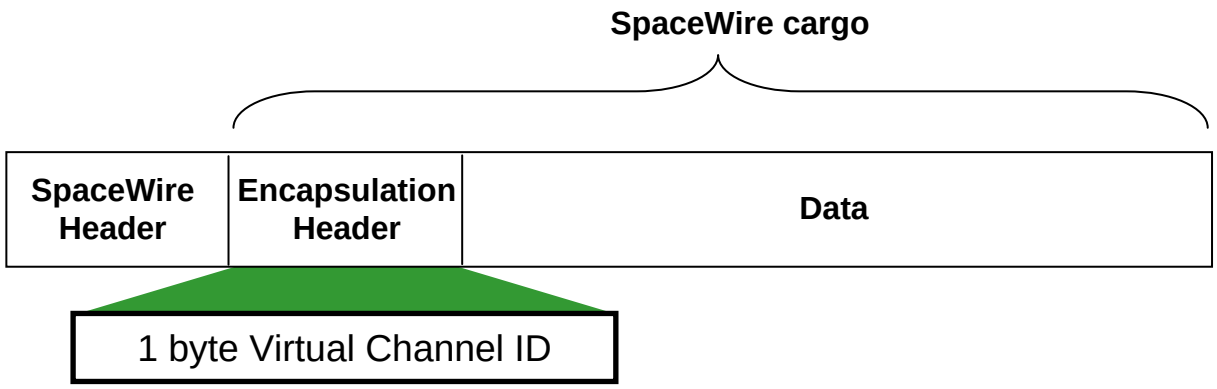


IP, etc. Over SpaceWire



- Interest in on-board IP / SCPS-NP, esp. for rapid development programs.
- Need to level the playing field with Ethernet by providing full support for network protocols and standard network management.
- SpaceWire is missing 2 key elements:
  - *Encapsulation service*
  - *Address Resolution Protocol (ARP)*

Encapsulation Service



Type	*Virtual Channel ID*
ARP	1
IPv4	2
IPv6	3
CCSDS SCPS-NP	4
CCSDS Source Packet	5
Broadcast	254

- **1 byte Encapsulation header (Virtual Channel ID).**
- **Identifies network protocol or software module on destination.**
- **Enables SpaceWire to support multiple network types.**
- **Lightweight but sufficient.**
  - SpaceWire Virtual Channel ID: 8 bits
  - Ethernet Type field: 16 bits

SpaceWire Address Resolution

IP Address	SpaceWire Address
192.168.0.1	41
192.168.0.2	129
192.168.0.3	54

- **No ARP defined for SpaceWire**
  - **Manual configuration of address resolution tables:**
    - **Assign SpaceWire and IP addresses.**
    - **Install table on each node.**
  - **Tables are static. Changing network topology requires new tables.**
- **SpaceWire cannot use standard ARP (RFC 826)**
  - **Logical addresses not unique.**
  - **No link-layer broadcast for full network.**
- **Solution: Develop these and use standard ARP**
- **Unique SpaceWire Address = Region + Node Logical Address**

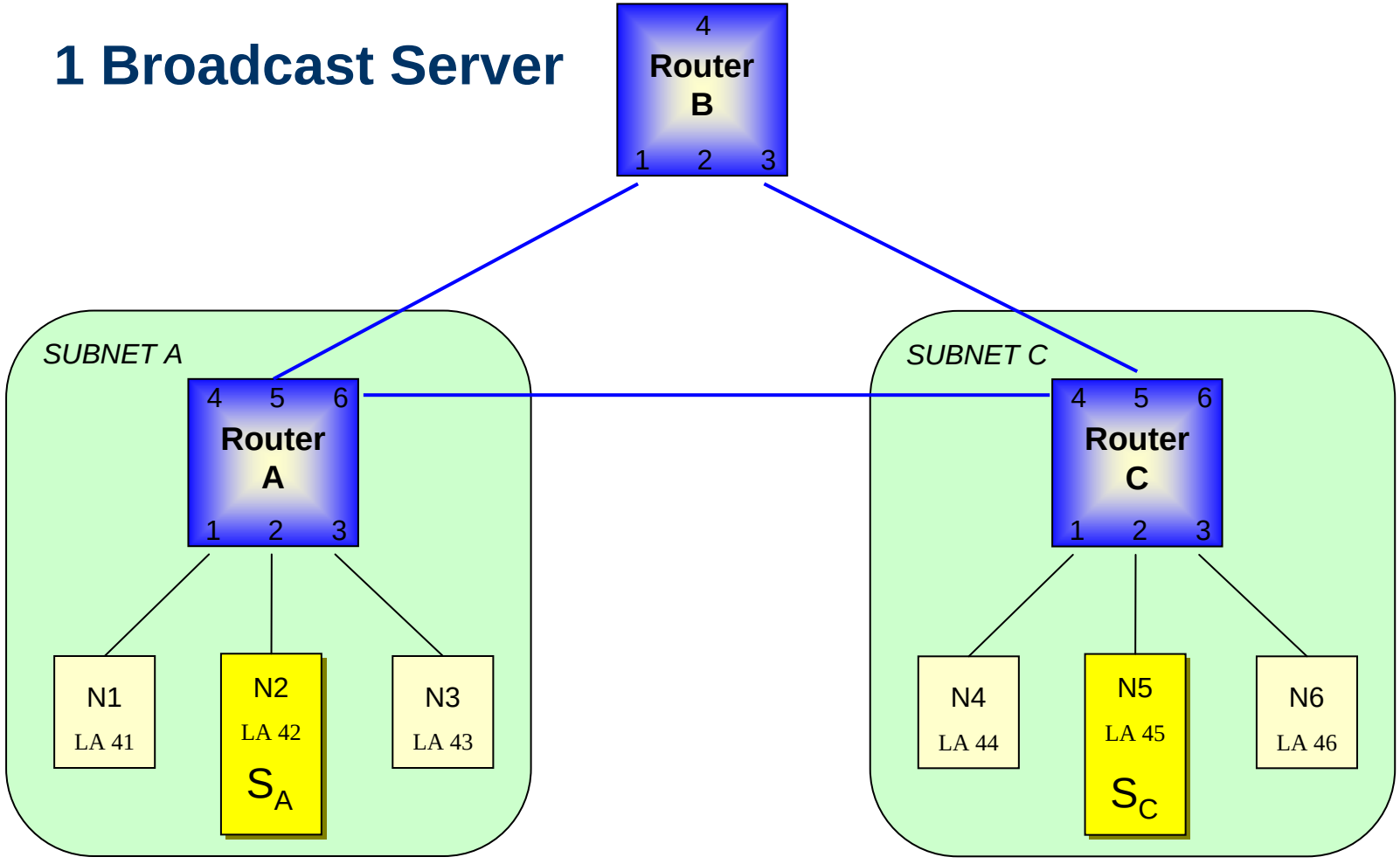
Broadcast Service

Features

- Guarantees loop-free broadcast
- Link-layer implementation, no modification to the network layer (e.g. IP, SCPS-NP)
- Host implementation; no modification to Spacewire routers.
- Driver software implementation, no modification to Spacewire interface hardware.
- Adheres to SpaceWire standard.

Broadcast Service

- Introducing Concept of a SpaceWire Subnet
  - Set of nodes attached to one routing switch
  - 1 Broadcast Server



Broadcast Service

- **Protocol Messages**
  - **Type 0: Subnet Broadcast**

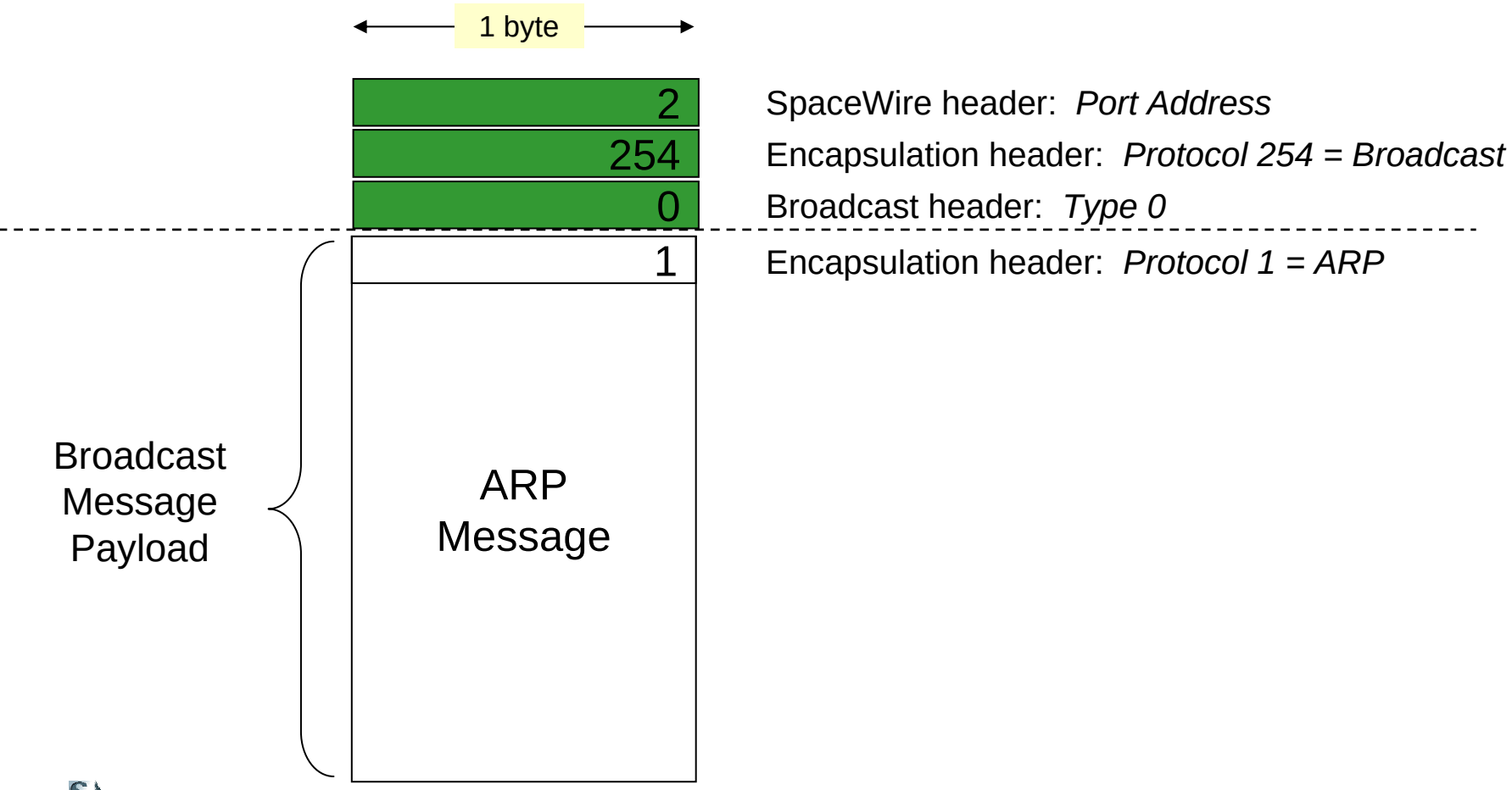
SpaceWire header: *Port Address*

Encapsulation header: *Protocol 254 = Broadcast*

Broadcast header: *Type 0*

Broadcast Service

- **Protocol Messages**
  - **Type 0: Subnet Broadcast**



Broadcast Service

- **Protocol Messages**
  - **Type 1: Server Broadcast**

SpaceWire header: *Logical Address*

Encapsulation header: *Protocol 254 = Broadcast*

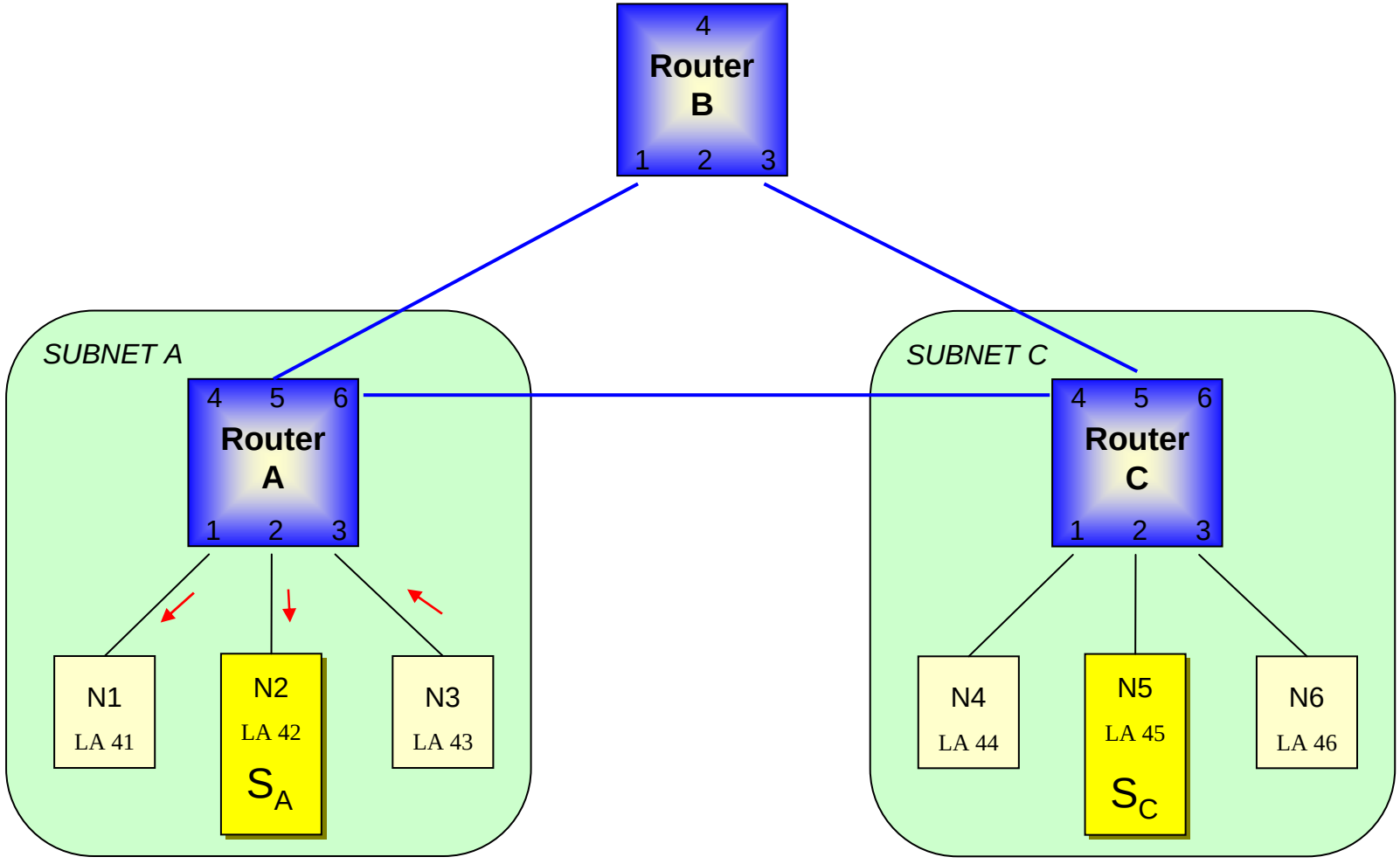
Broadcast header: *Type 1*

Broadcast Service

- **Protocol Operation**
  - **Node sends Subnet Broadcast**
    - **Sends Type 0 message to all other ports on local router using path addressing.**
    - **Neighbor Routers configured to discard LA 254**
  - **Broadcast Server sends Server Broadcast**
    - **On receipt of Type 0 message, extracts the broadcast payload, encapsulates in Type 1 message and sends to all other Broadcast Servers.**
  - **Remote Server sends Subnet Broadcast**
    - **On receipt of Type 1 message, extracts the broadcast payload, encapsulates in Type 0 message and sends to all other ports on local router.**

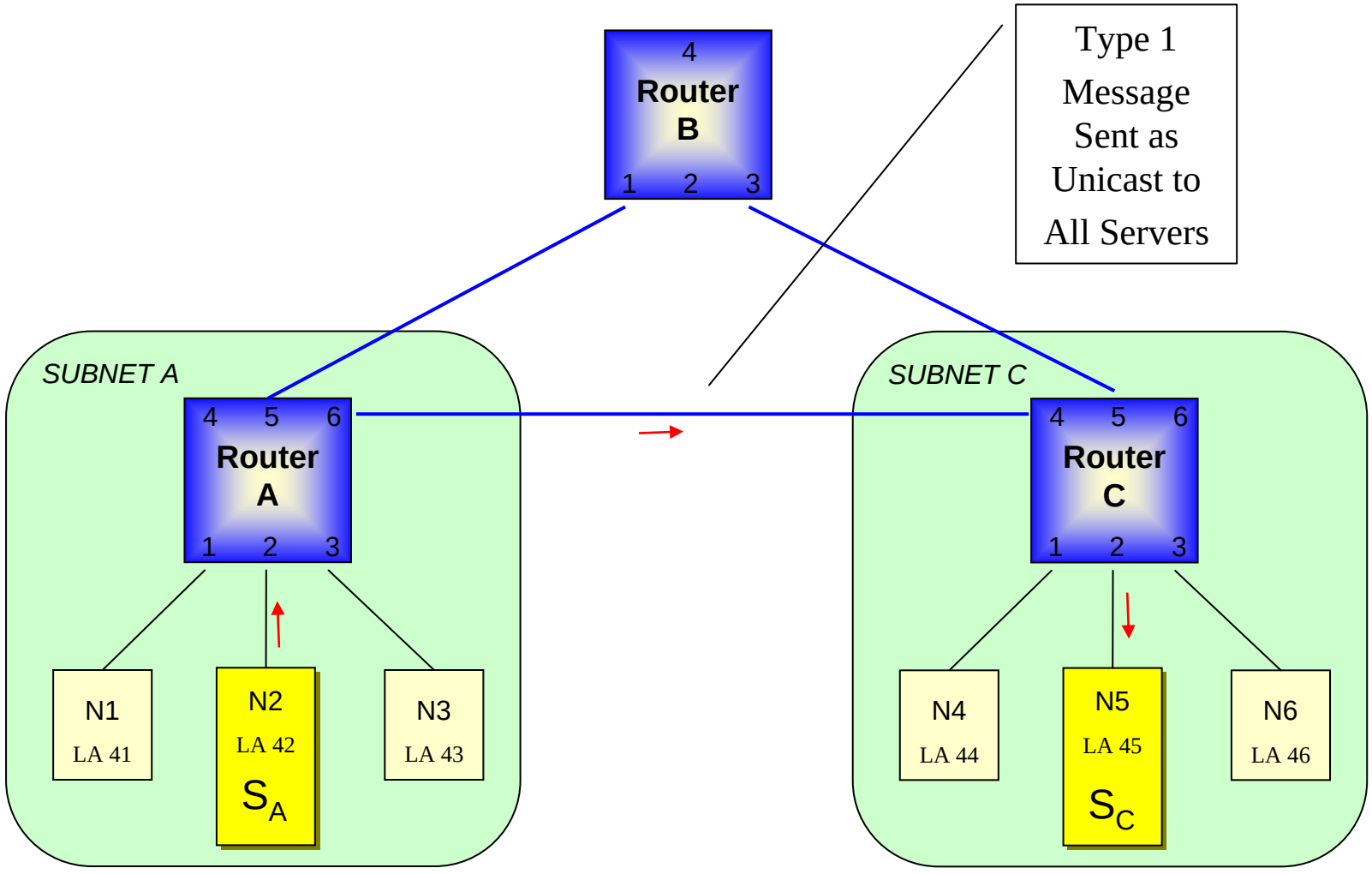
Broadcast Service

- **Node N3 sends Subnet Broadcast (Type 0)**



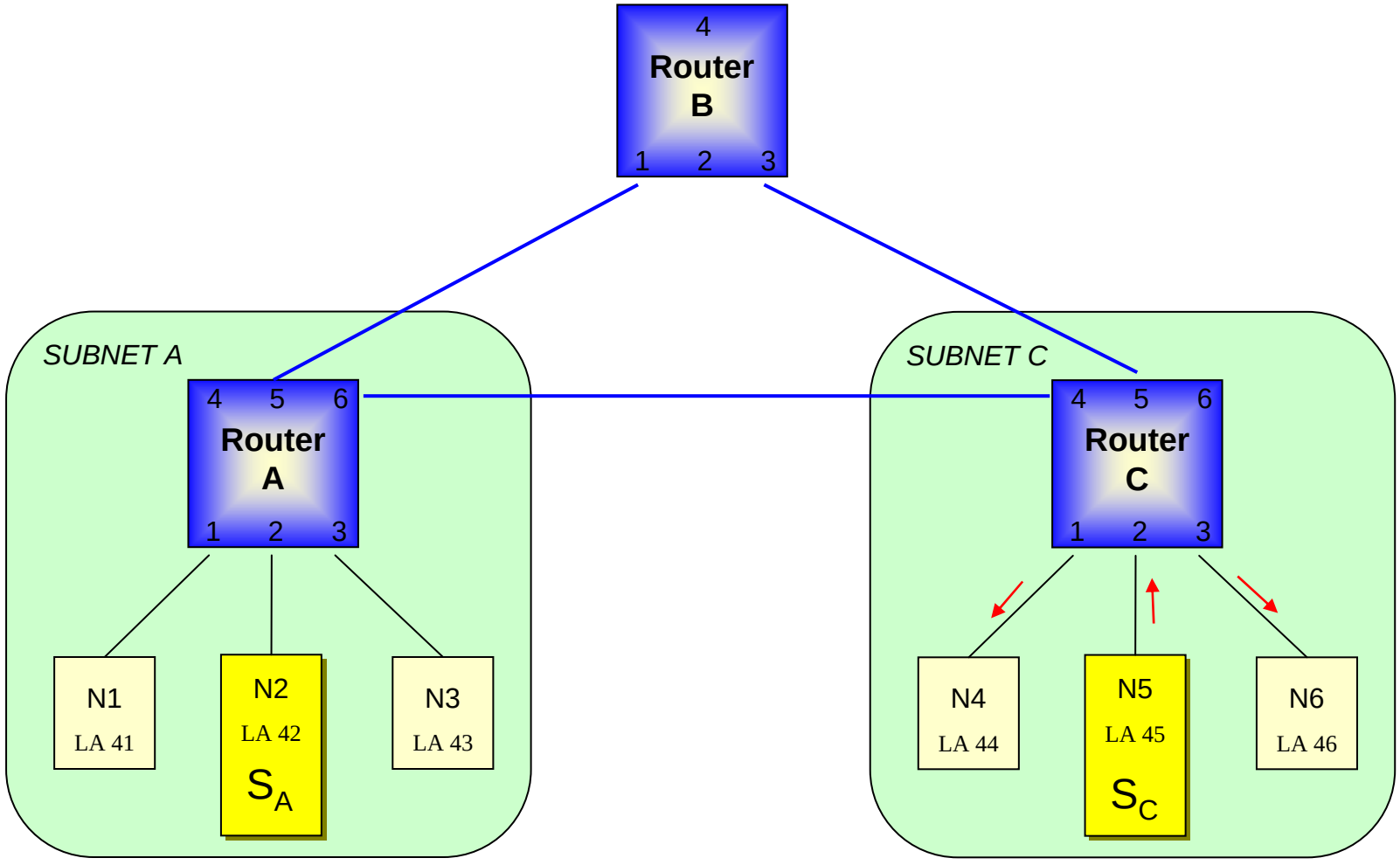
Broadcast Service

- **Broadcast Server sends Server Broadcast (Type 1)**



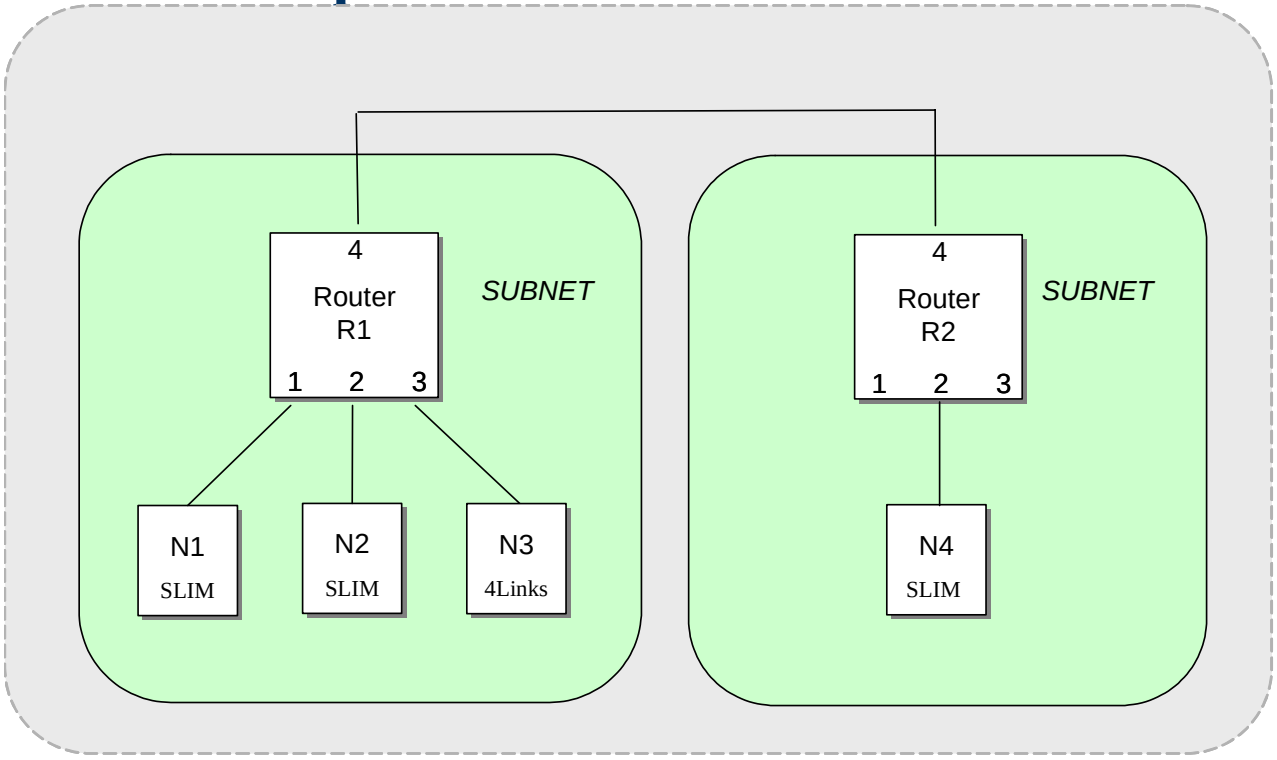
Broadcast Service

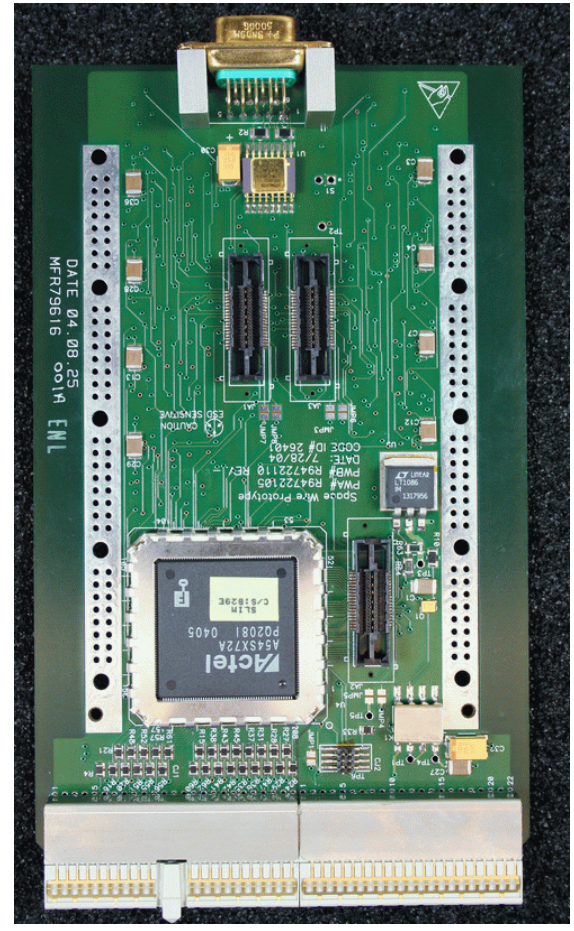
- **Remote Server sends Subnet Broadcast (Type 0)**



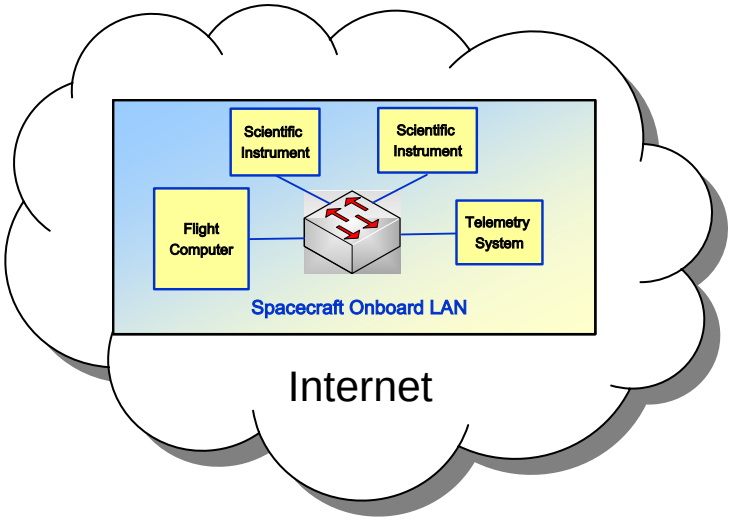
Test Network

- **SwRI SpaceWire Link Interface Module (SLIM)**
  - Single Channel, full-duplex SpaceWire Link Interface
  - Fully Compliant CompactPCI target interface
  - 3U cPCI form-factor
- **Star Dundee Routers (8 port)**
- **4Links SpaceWire-PCI**





Summary



- By adding missing elements, standard network stacks can be supported with SpaceWire
  - Encapsulation Service
  - Address Resolution Protocol (ARP)
- Standard ARP is possible if Broadcast Service supported
- Supports multiple network layer protocols (IPv4, IPv6, SCPS-NP).

Next step: Implement Broadcast and Encapsulation Service in device drivers for SwRI SLIM and COTS interface boards, and test IP and SCPS-NP applications on multi-router SpaceWire test network (SCPS-FP, DHCP, SNMP, HTTP, FTP, etc.).