Integration of Internet Protocols with SpaceWire using an Efficient Network Broadcast

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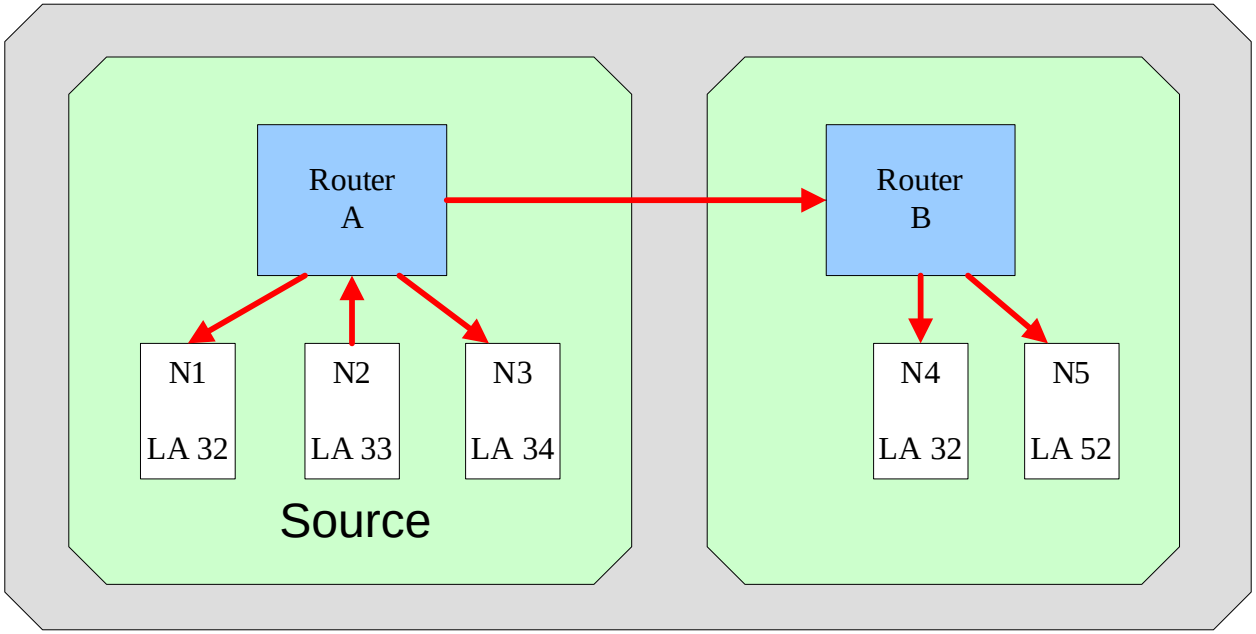
SpaceWire Overview

- High speed, low power, designed for space.
- European Space Agency Standard.
  - ESA Specification ECSS-E-50-12A.
- Based on IEEE 1355 serial standard.
- Used in current & future missions.
  - Geostationary Operational Environmental Satellite (GOES-R).
  - James Webb Space Telescope (JWST).
  - Multiscale Magnetospheric Mission (MMS).

Need for SpaceWire Broadcast

- Space development moving towards off-the-shelf.
- SpaceWire has:
  - Very simple data packet requirements.
  - No standard ARP, broadcast, or higher-level methods.
- SpaceWire would benefit from:
  - Defined integration with higher-level features (enables use of IP, etc...).
  - Automatic configuration, including DHCP.
- Defined broadcast protocol can reduce and balance router load across network (vs. sequential unicast).

Broadcast by Sequential Unicast



- Messages distributed by *sequential unicast* to each individual end node.

Goals for SpaceWire Broadcast

- Broadcast without knowing path to each destination.
- Support existing upper layer protocols (IPv4, IPv6, SCPS) or direct use by application.
- Work with existing ESA Standard.
- Work with existing COTS SpaceWire hardware.
- Solution could be added to hardware.
- Prevent Loops.

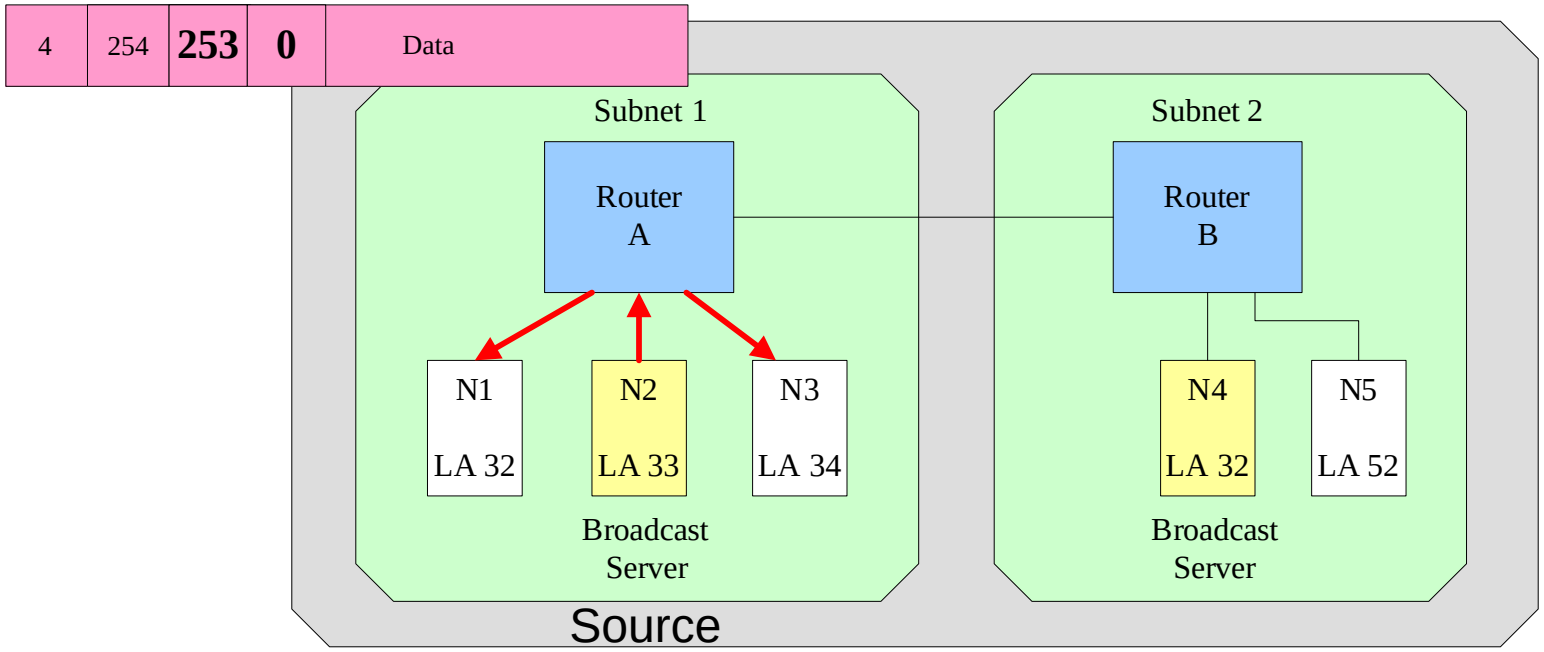
Definitions

- Subnet
  - Group of devices attached to one router.
- Protocol ID
  - Specific byte in the SpaceWire packet defining protocol type.
- Path Address
  - One-byte SpaceWire address indicating the router output port (1..31) to send the message.
- Logical Address
  - One-byte SpaceWire address (32..254) which identifies the final destination of the message.

Broadcast Protocol Basics

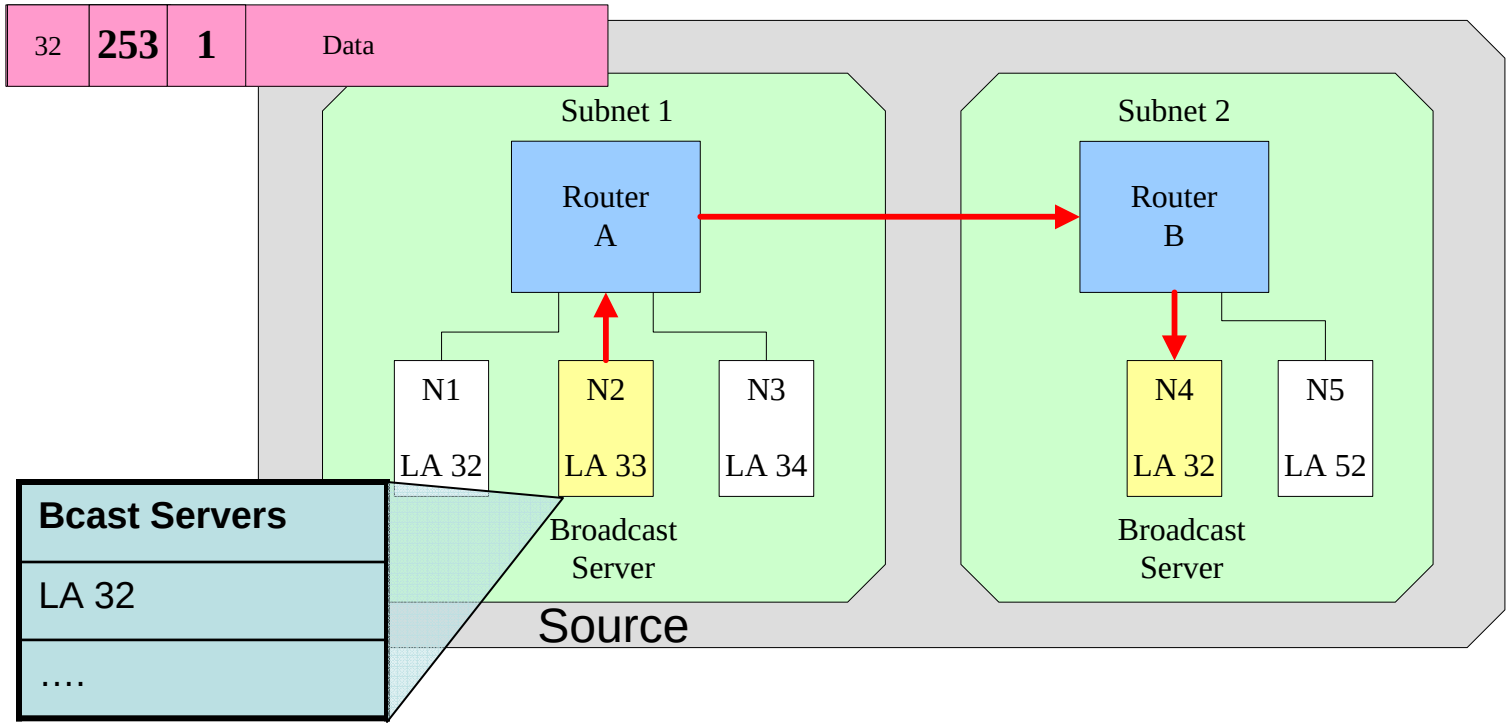
- Define a *“Subnet Server”* or *“Broadcast Server”* on each subnet.
- Distribute work of broadcast to local subnets.
- Define special message types to indicate local or subnet-to-subnet broadcast.
- Routers discard one message type to prevent loops (done by configuration).
- Simple.
- Efficient.

1. Local Subnet Broadcast



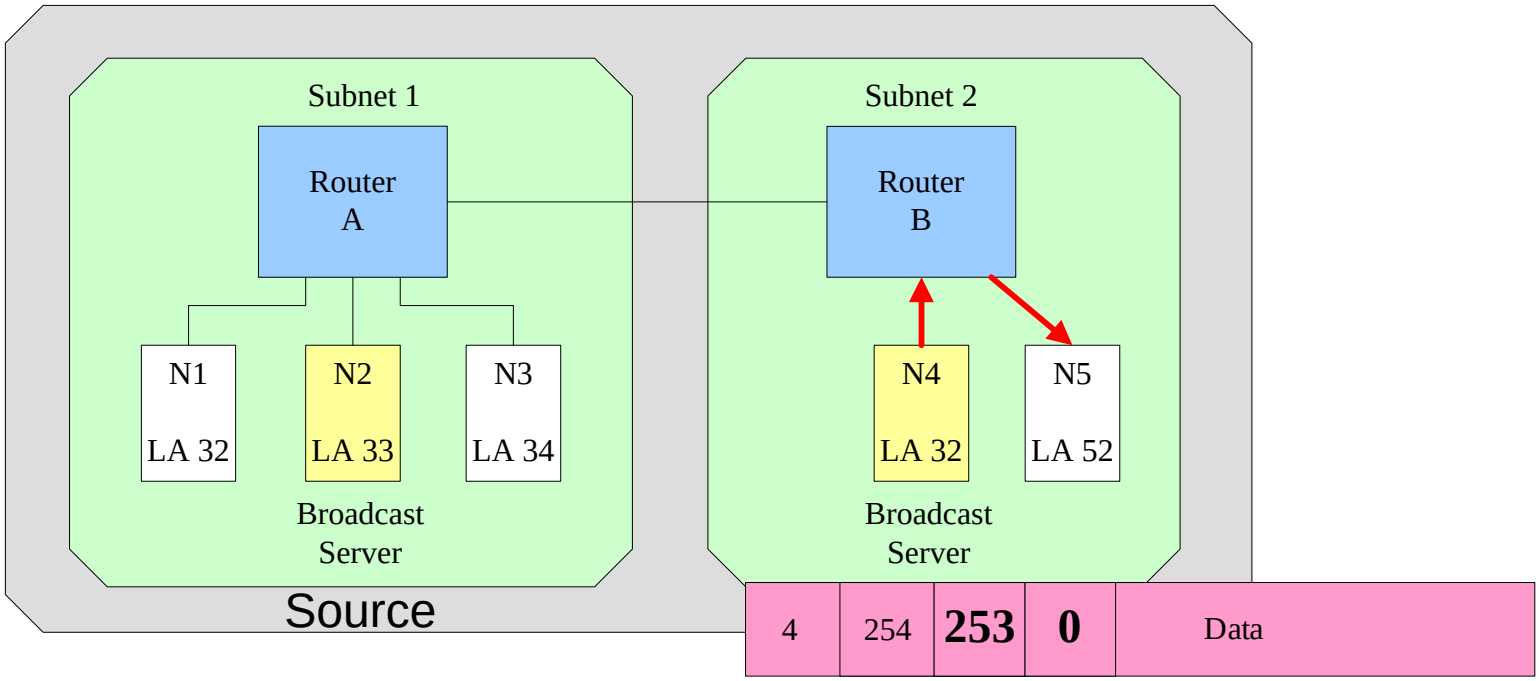
- Use Protocol ID (e.g., 253) for Broadcast messages.
- Node sends a Type 0 message to all ports on the local router.

2. Broadcast to other Subnets



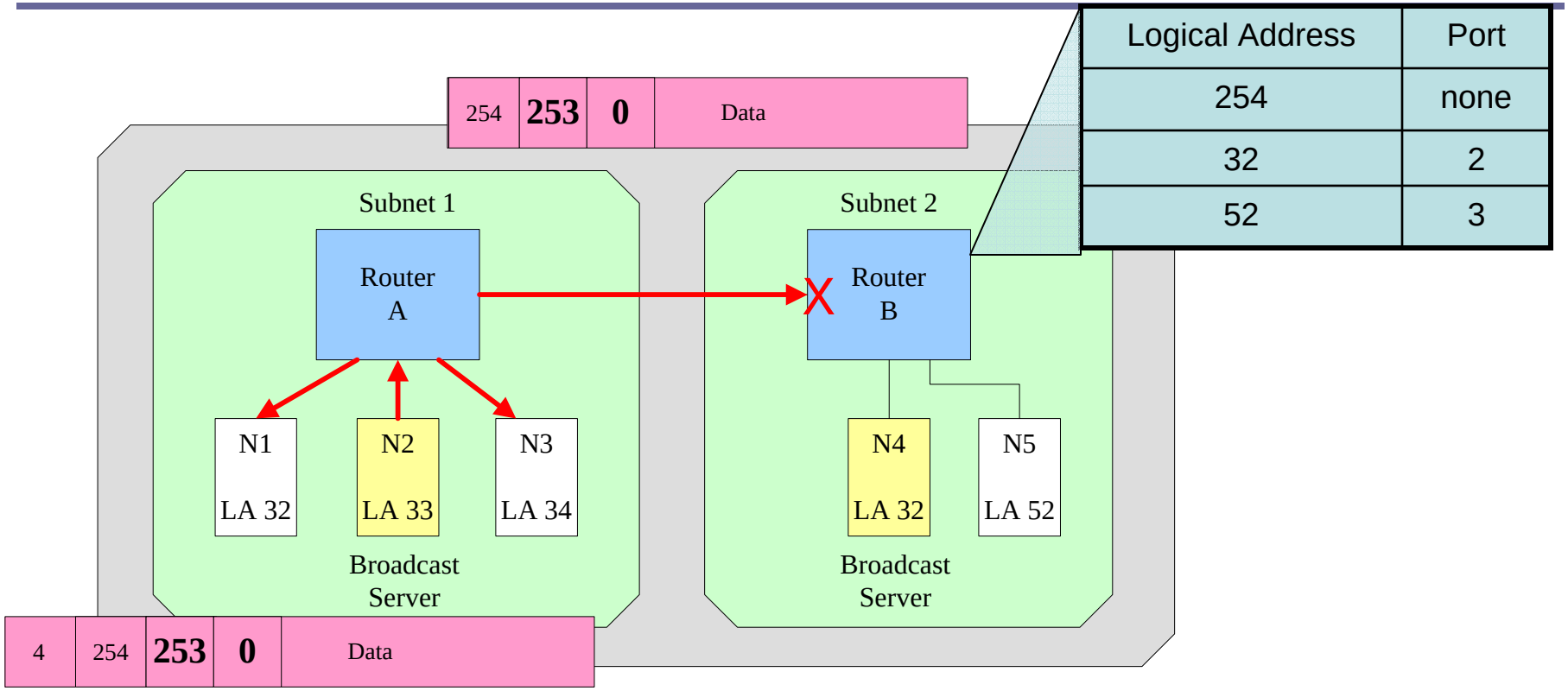
- Broadcast server sends a Type 1 message to all other Broadcast Servers.

3. Remote Subnet Broadcast



- Broadcast servers which receive a Type I message send a Type 0 message to all the ports on the local router (except self).

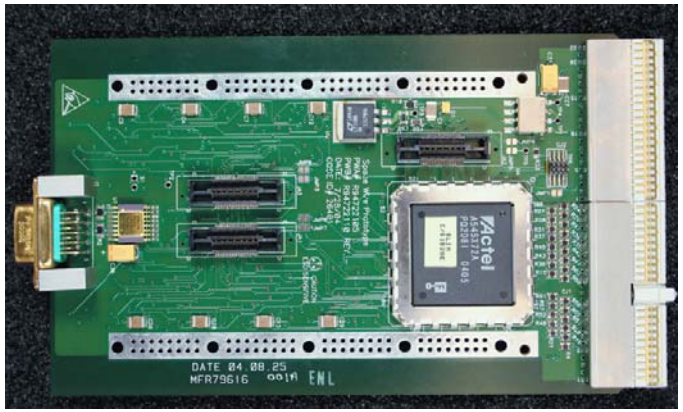
Method of Loop Prevention

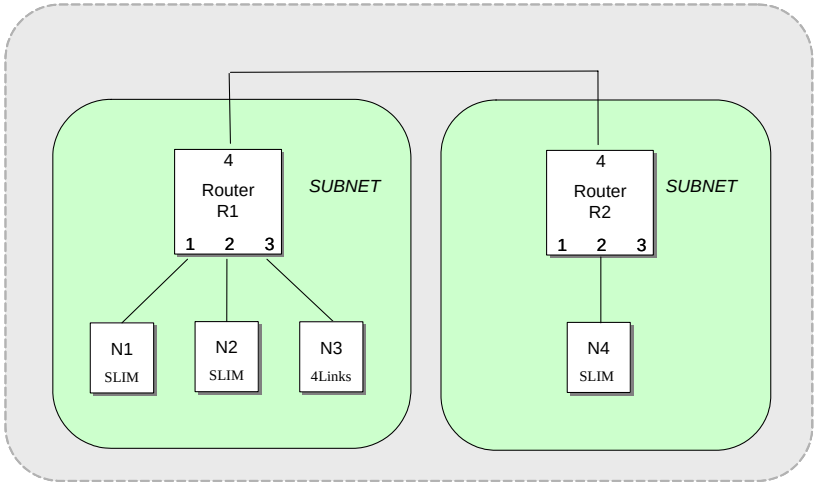


- Routers delete port addresses (0..31).
- Routers discard messages with logical address 254.

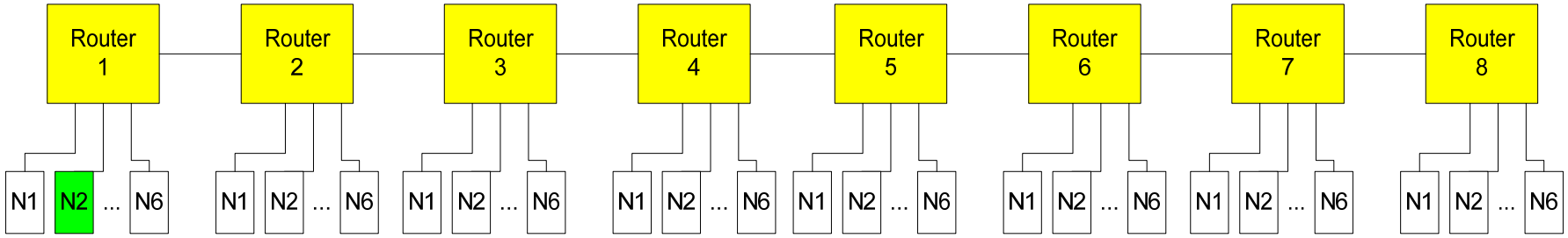
Protocol Evaluation

- Use existing unmodified Internet applications
  - e.g. DHCP server, Web Browser, etc.
- Driver Development
  - SwRI SpaceWire Link Interface Module (SLIM) driver.
  - Test network including:
    - 3 SwRI SLIM boards.
    - STAR-Dundee Routers.
    - 4-Links SpaceWire Board.
- Simulation and Analytic Results
  - Several topologies evaluated.

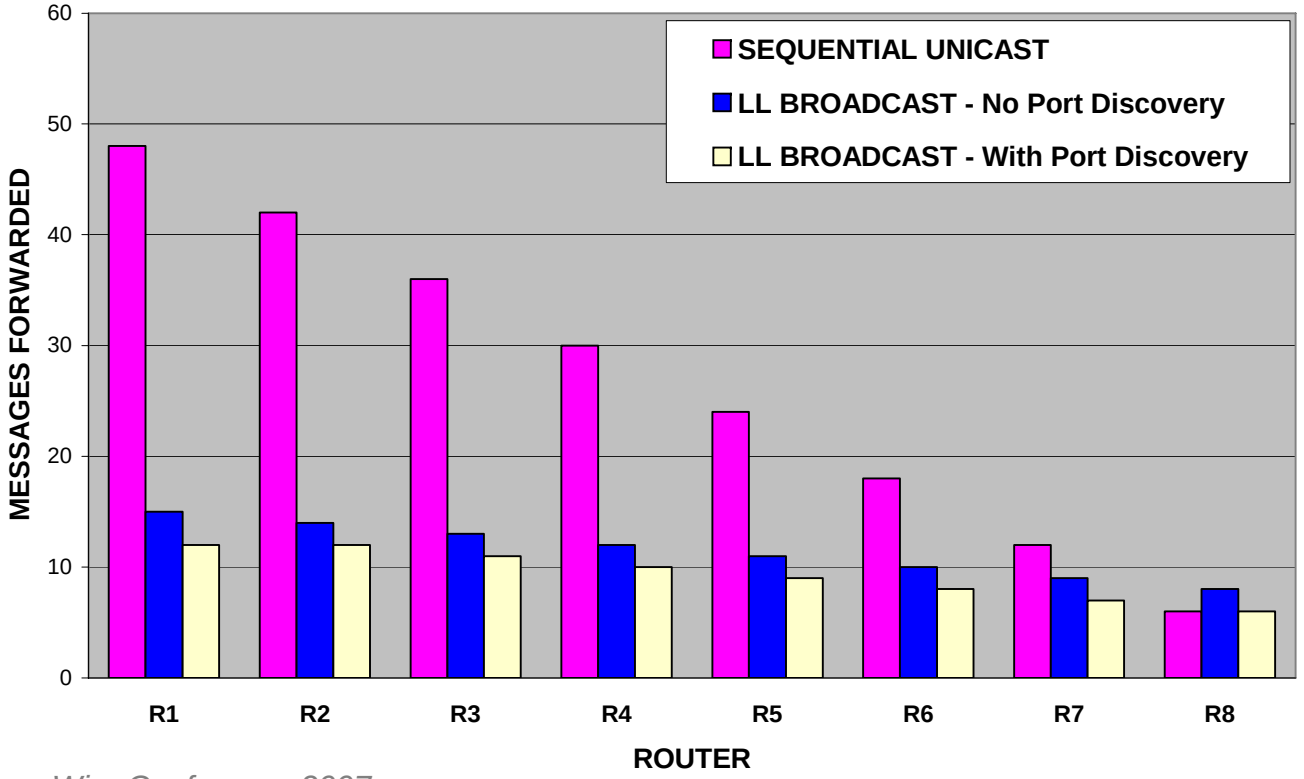




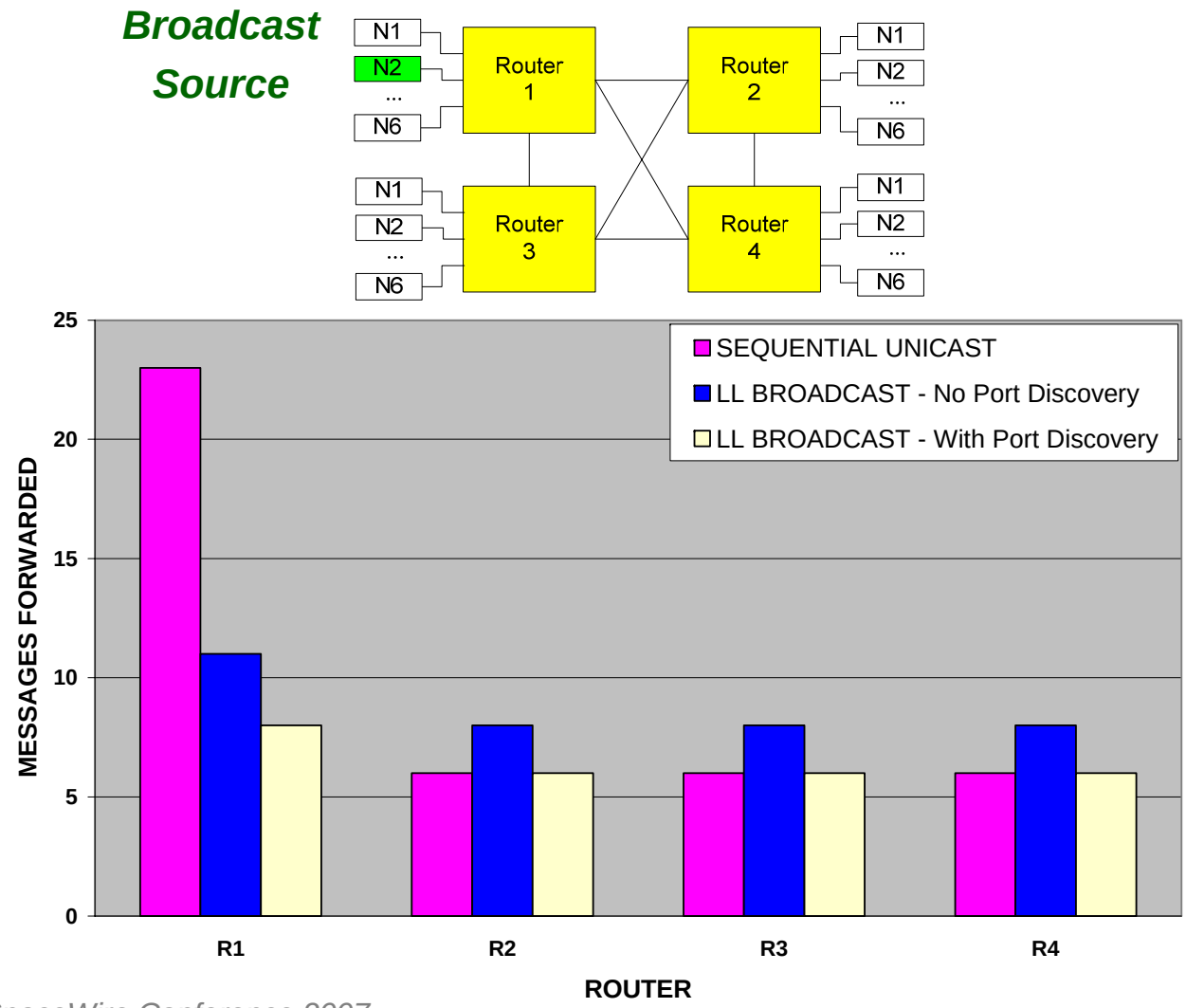
Traffic Load: Linear



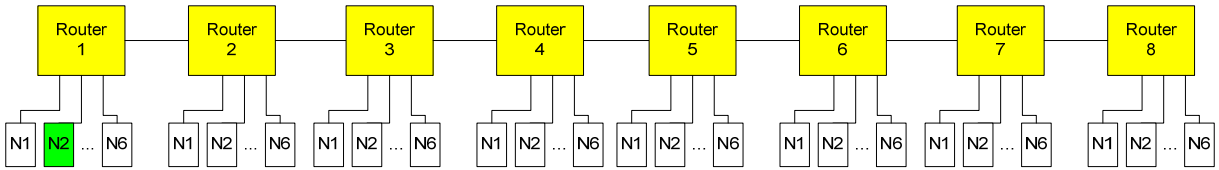
Broadcast Source

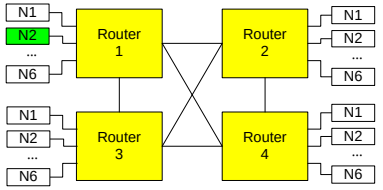


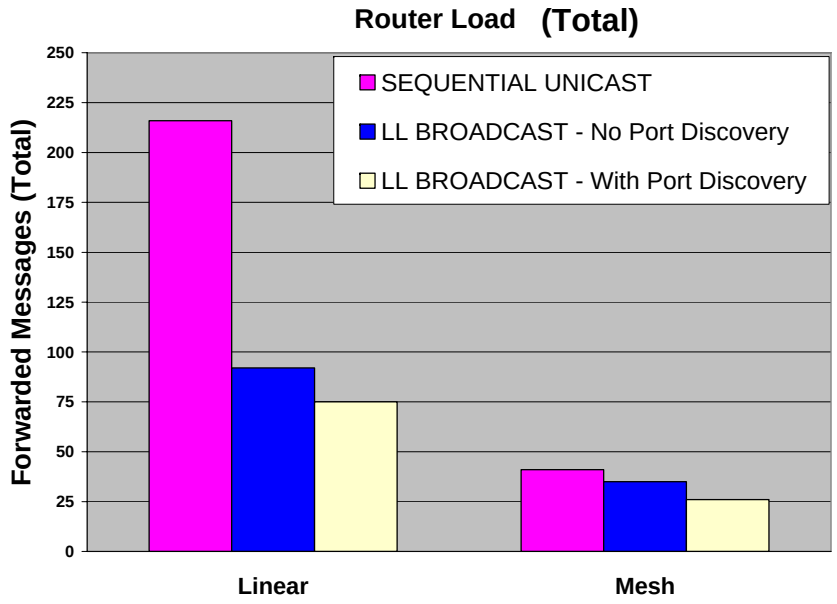
Traffic Load: Redundant Mesh

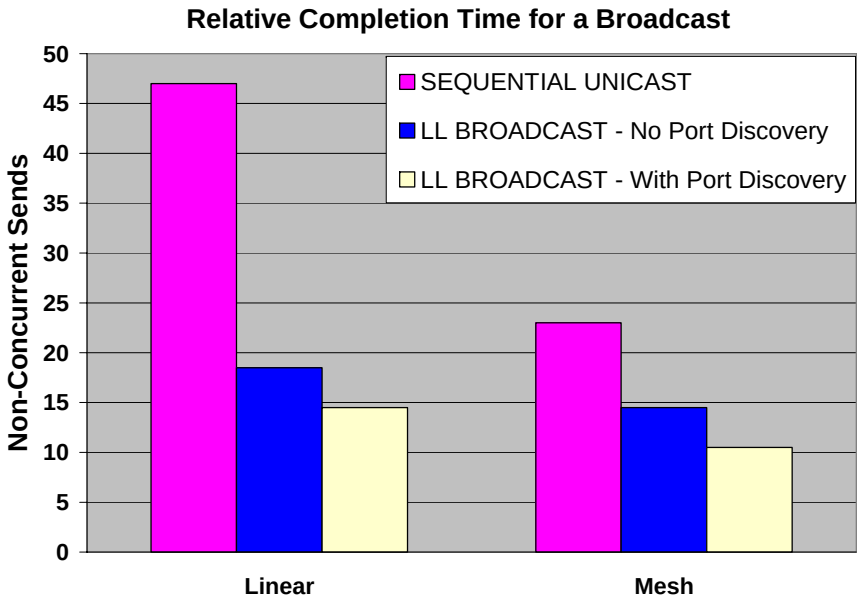


Router Load & Broadcast Latency









Summary

- SpaceWire Broadcast
  - Simple, software-based message distribution.
  - Compatibility with existing standards, devices.
  - Support for higher-level network functions.
- Protocol Evaluation
  - Reduction of load on routers.
  - Even distribution of router workload.