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# SpaceWire Network Simulation of System Time Precision


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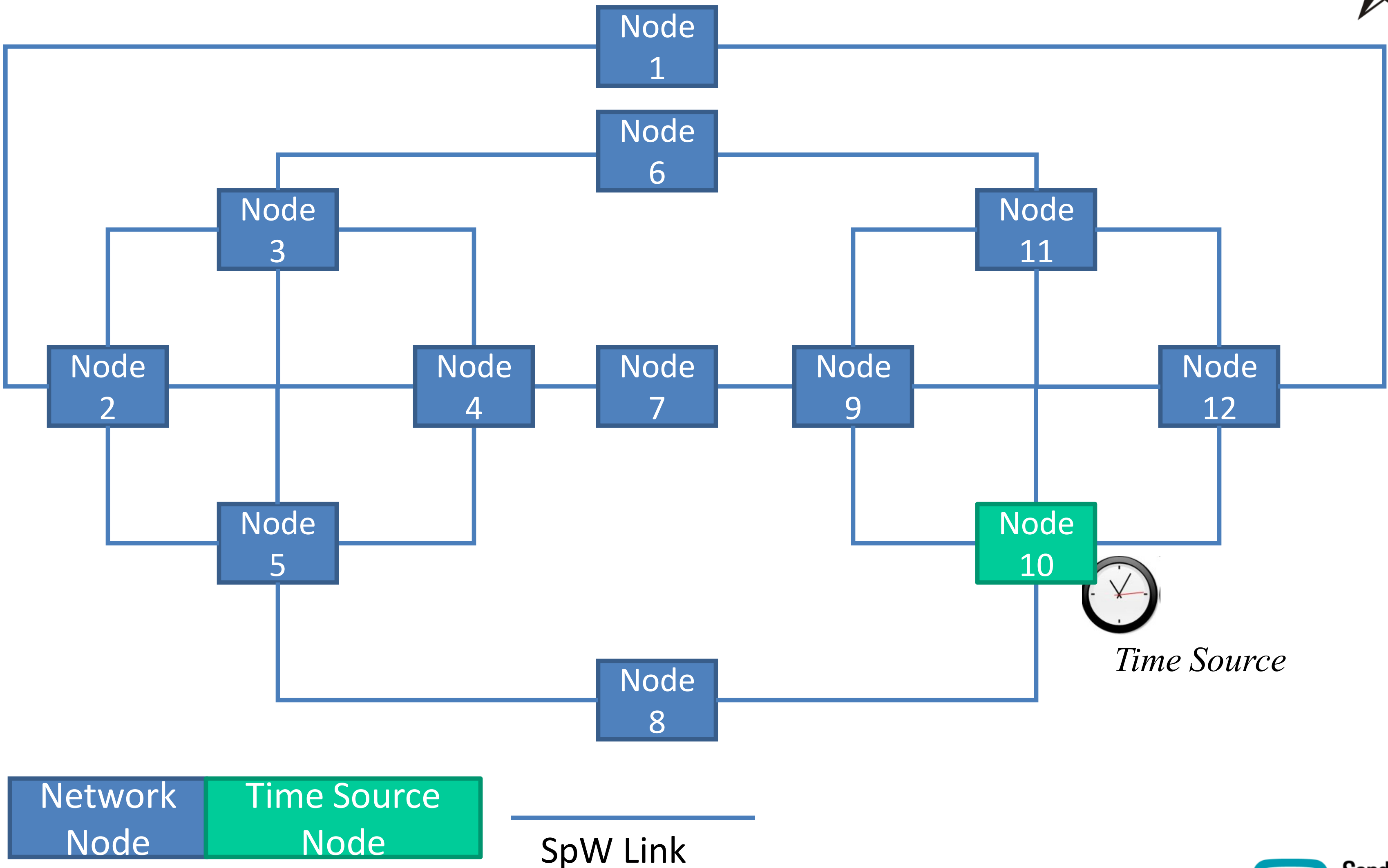
# Presentation Outline

- Introduction
- Time Distribution
- Broadcast Service
- Model Development
- Results and Discussion
- Future Work and Conclusions

# Presentation Context

- **Model based design**
  - Use network simulation to asses system design characteristics early in the design stage.
  - Developed model is reusable.
  - Apply model to a specific design requirement – broadcast of system time across a SpaceWire network.
- **General goals**
  - Prove out and validate the models.
  - Distribution of “time-of-day” throughout network.
  - Explore broadcast characteristics and timing performance.

# Simulated Network Topology



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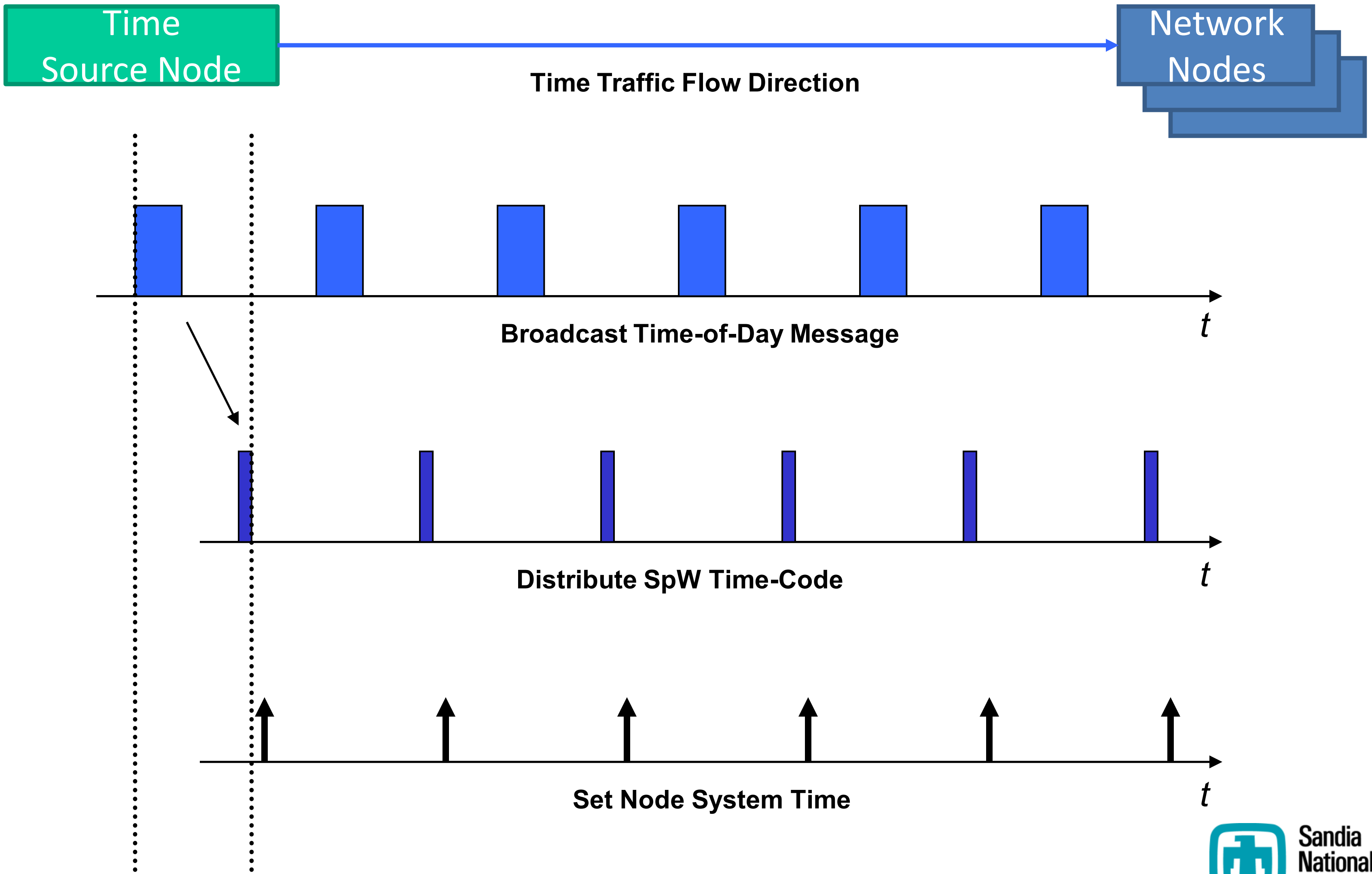
# Time Distribution Mechanism

- Builds upon standard SpaceWire network function.
- Uses a SpaceWire broadcast capability (SpWBS) to distribute "time-of-day" message.
  - General broadcast extension is layered upon the existing SpaceWire standard
  - Compatible with the existing SpW protocol and does not necessitate the modification of existing intellectual property or the revision of the existing SpaceWire standard.
- Uses SpaceWire Time-Code to synchronize "time-of-day" across the network.
- Together, the Time-Code function and broadcast capability enable a means to distribute time.

# Time Message Flows



# Time Logic

- Compares new time broadcast packet with last received packet.
- Endpoint is considered “Locked” if:
  - NewPacket.Time = LastPacket.Time + 1;
- When a tick is received:
  - Displays time from packet when “locked,”
  - Increments currently displayed time if not locked.
- If multiple time packets between ticks, only considers most recent one.

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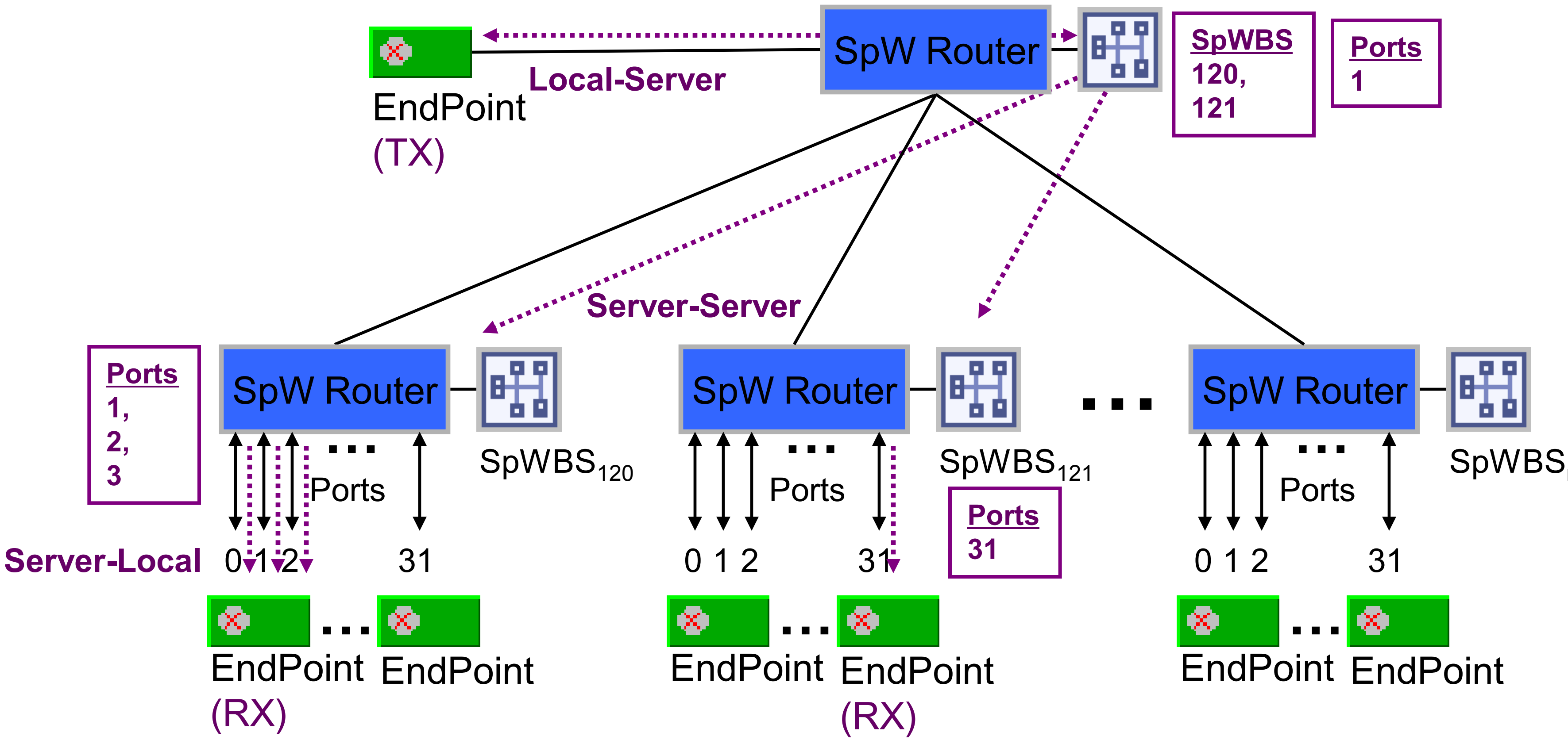
# SpWBS Broadcast Overview

- **SpWBS is a hybrid broadcast approach**
  - Broadcast initiator transmits once.
  - SpWBS performs two levels of rebroadcasts.
- **More like a multicast than a true broadcast**
  - Selective SpW router ports registered with local broadcast server
  - Selective message distribution between participating broadcast servers
- **Starting Reference: Roberts, A., Dykes, S. G., Klar, R., & Mangels, C. C. (2007, March). A Link-Layer Broadcast Service for SpaceWire Networks. Aerospace Conference, 2007 IEEE , 1-10.**

# SpWBS Implementation

- **Local-to-SpWBS Stage:**
  - A SpWBS receives a local-to-server type packet containing the broadcast message.
- **Server-to-Server Stage**
  - The initiating SpWBS sends a server-to-server type packet containing the broadcast message to SpWBS in the network.
  - Recipient SpWBS's are defined by configuration table.
- **Server-to-Local Stage**
  - Once the initiating SpWBS finishes the Server-to-Server stage, it sends Local-to-Server type packets with the broadcast message to local ports on the router.
  - When a recipient SpWBS receives a Server-to-Server type message, it sends Local-to-Server type packets with the broadcast message to every local port of the router its connected to.

# Example Broadcast Distribution



# Generated and Received Packet Formats

- **Type 0:** local-to-server -- Received Packet Format
  - Sent to server to start system-wide broadcast
  - Type assigned to local broadcasted messaged
- **Type 1** : Server-to-Server -- Generated server to server packet
  - Server to Server broadcast
  - Repeated as local Type 2 broadcast
  - Not sent to Server
- **Type 2**: Server to local – Generated packet type
  - Sent to local ports from Server
  - Ignored by Server to prevent broadcast storms

| Type 0: | | | |
|---|---|---|---|
| LA | SA | PID-0 | Broadcast Data |
| **Type 1:** | | | |
| LA | SA | PID-1 | Broadcast Data |
| **Type 2:** | | | |
| PA | LA | PID-2 | Broadcast Data |

LA = Logical Address
SA = Service Address of broadcast server
PA = Physical Address of a local router port
PID-x = Protocol Identifier

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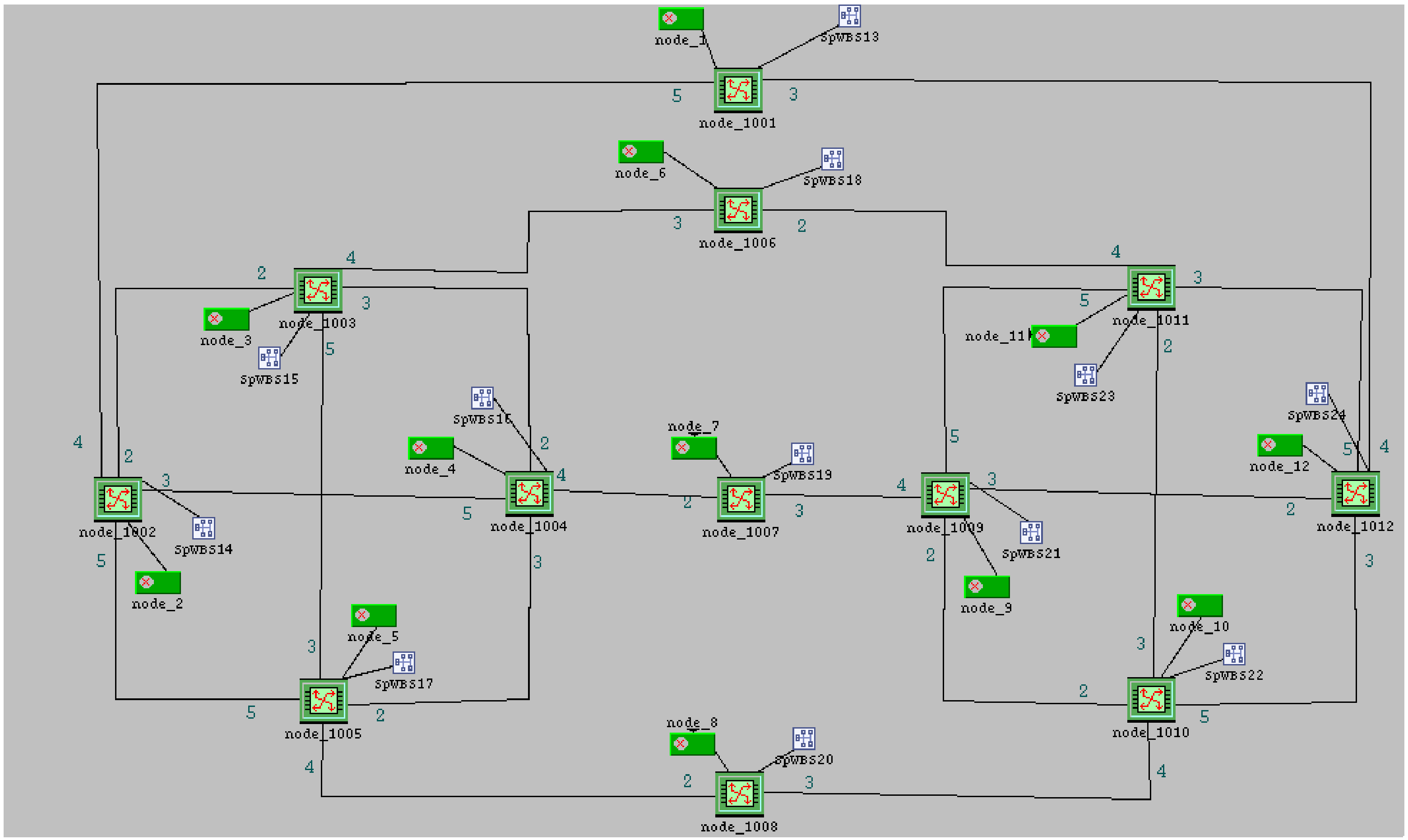
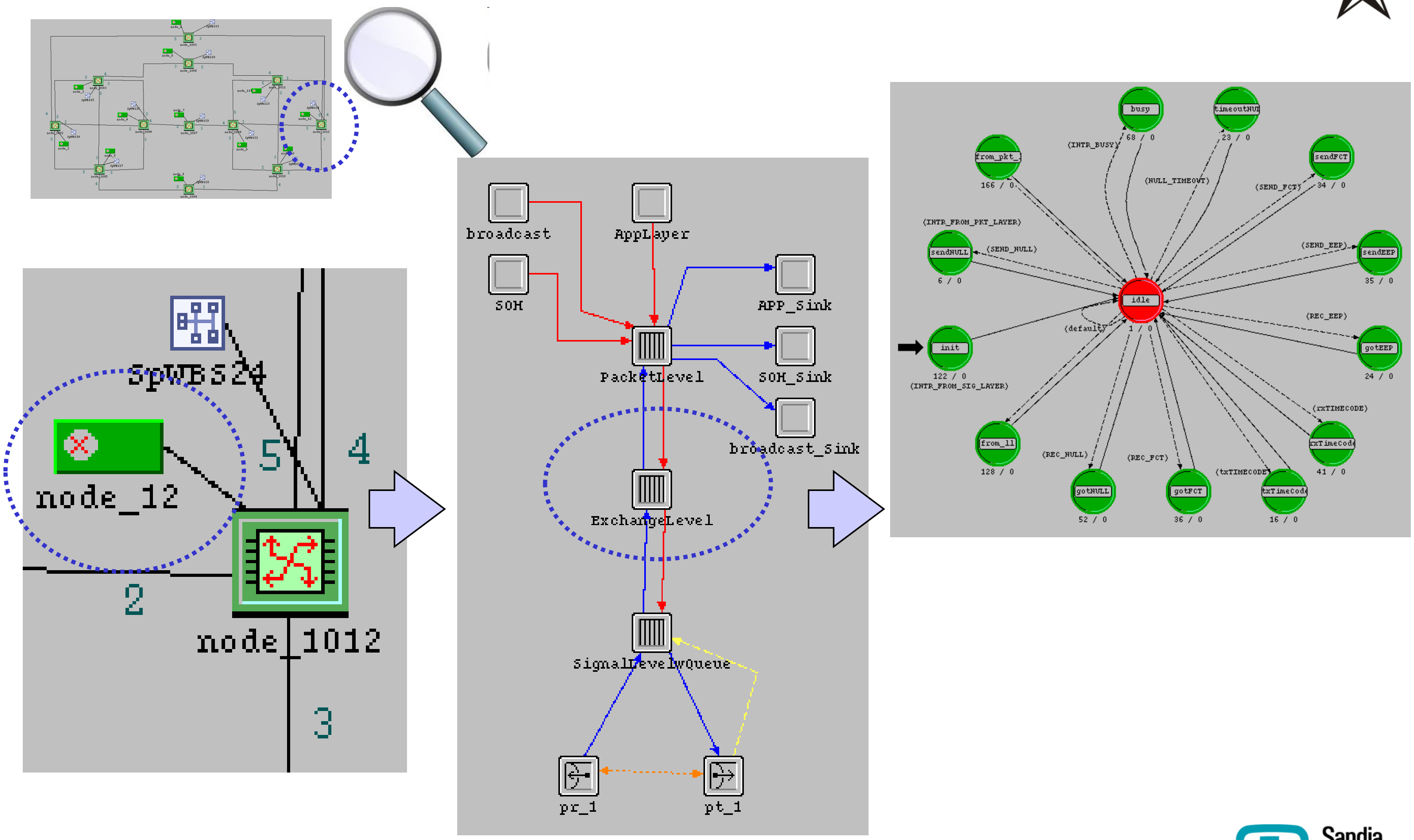
# OPNET Model of Simulated Network



# Model Detail Hierarchy

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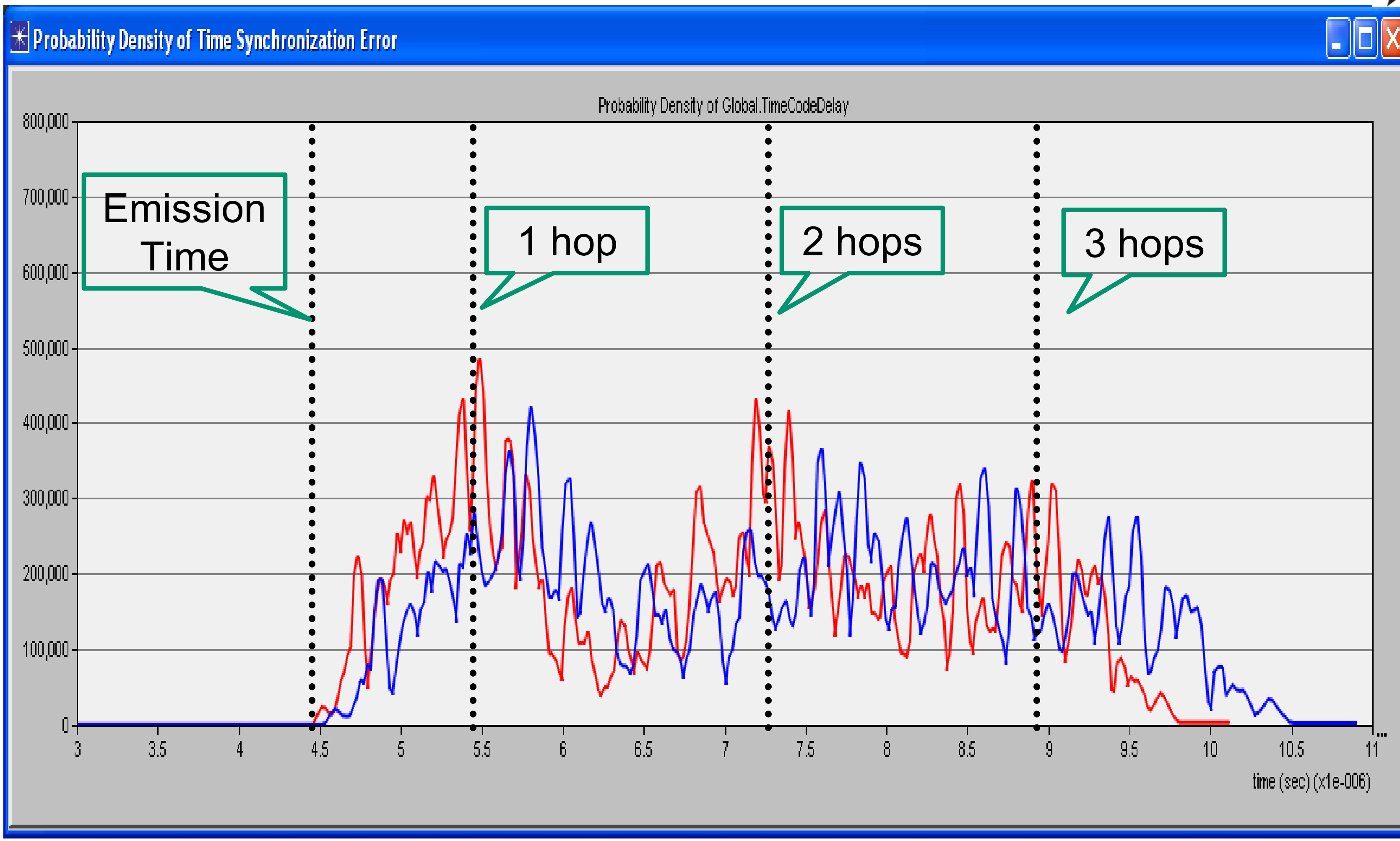
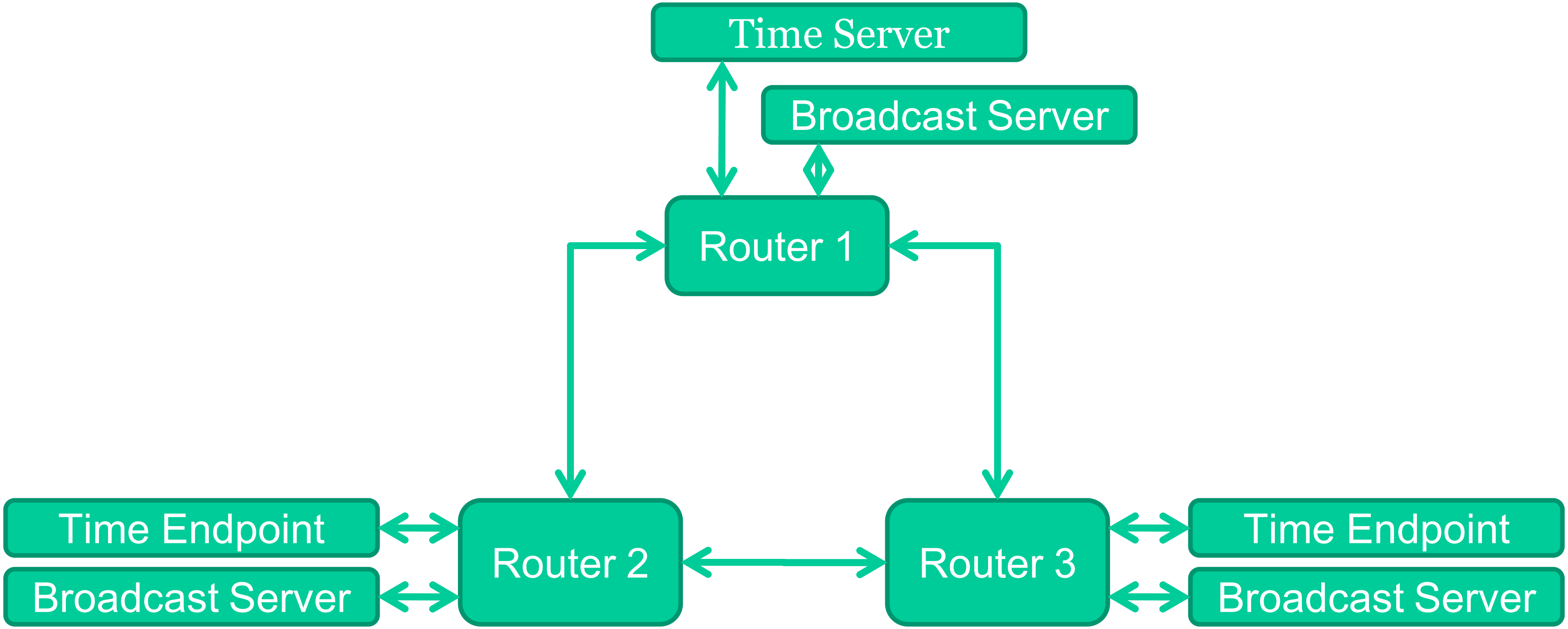
# Model Results: Time-Code Delay PDF




— Light traffic loading — Heavy traffic loading

# Hardware Time Demo




- **Tick periods of 4.7ms and below will not maintain lock**
- **Tick period of 4.8ms consistently stable.**
  - Will lose lock for 1 cycle on rare occasions
  - Regains lock consistently

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# Conclusions and Future Work

- **Time synchronization resolution is limited by the frequency of Time-Code transmissions.**
  - Limited by the requirement of sufficient time for the broadcast system time message to propagate throughout the network.
- **Upper limit of system time synchronization precision is limited by inherent latency and jitter of Time-Code and the broadcast functions.**
- **Time distribution approach has been modeled in a high-fidelity simulator.**
- **Time distribution approach has been fully developed in VHDL and tested in actual custom hardware.**

**Future Directions:**

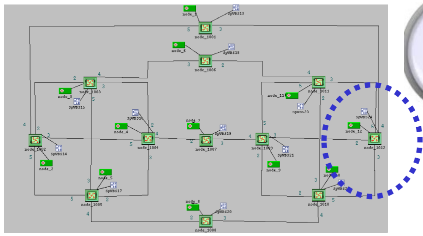
- **Validation of models against hardware implementations.**
- **Incorporate additional OPNET features to expand SpW model representation.**
  - RMAP, RDDP, JRDDP
  - Include link errors and processing delays.

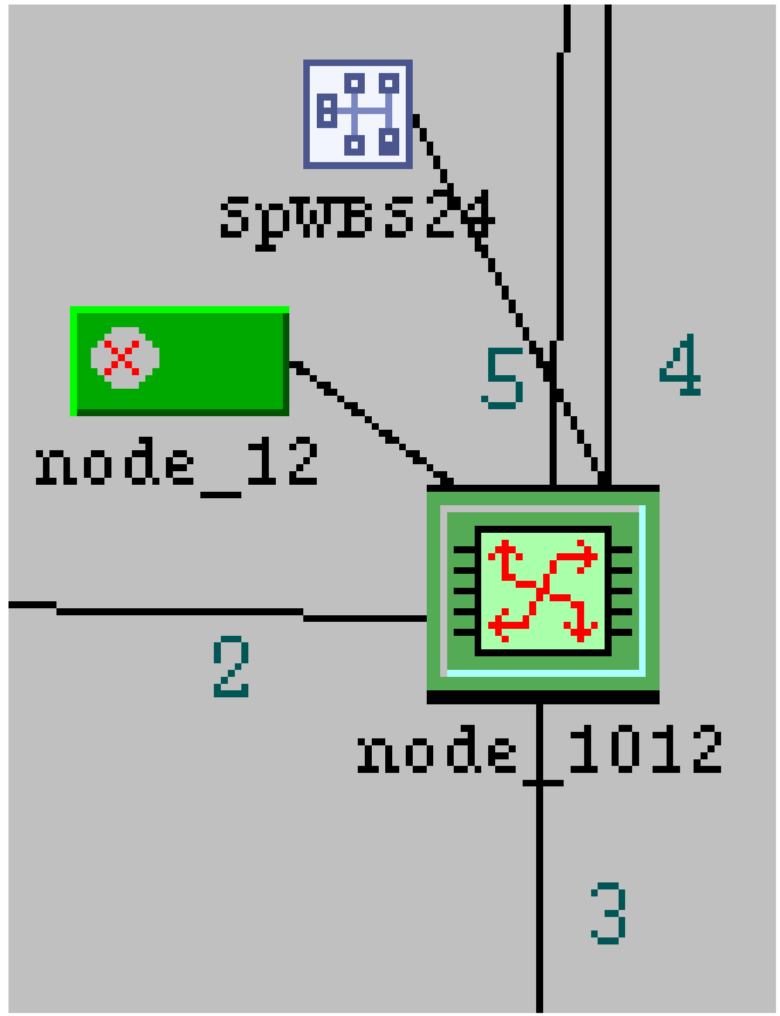
# Other Stuff

# Sending and Receiving Broadcasts

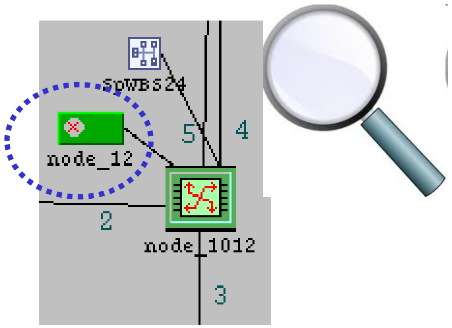
- **To send a system wide broadcast,**
  - Append the broadcast service SA and Local-to-Server PID to the front of the broadcast message,
  - Send the packet to the initiating SpWBS's SpaceWire address.
  - Any SpWBS in the network can initiate a system-wide broadcast.
- **Every node, including the originating node, will receive the broadcast message with 2 changes:**
  - the SA has been removed and the PID has been removed.
  - The packet is actually addressed to the router's local ports via physical addressing to optimize latency.
  - The PA will be stripped from the packet by the router prior to delivery.
  - The LA seen by the receiving node will be the first byte of the broadcast message and the SA seen by the receiving node will be the second byte of the broadcast message.

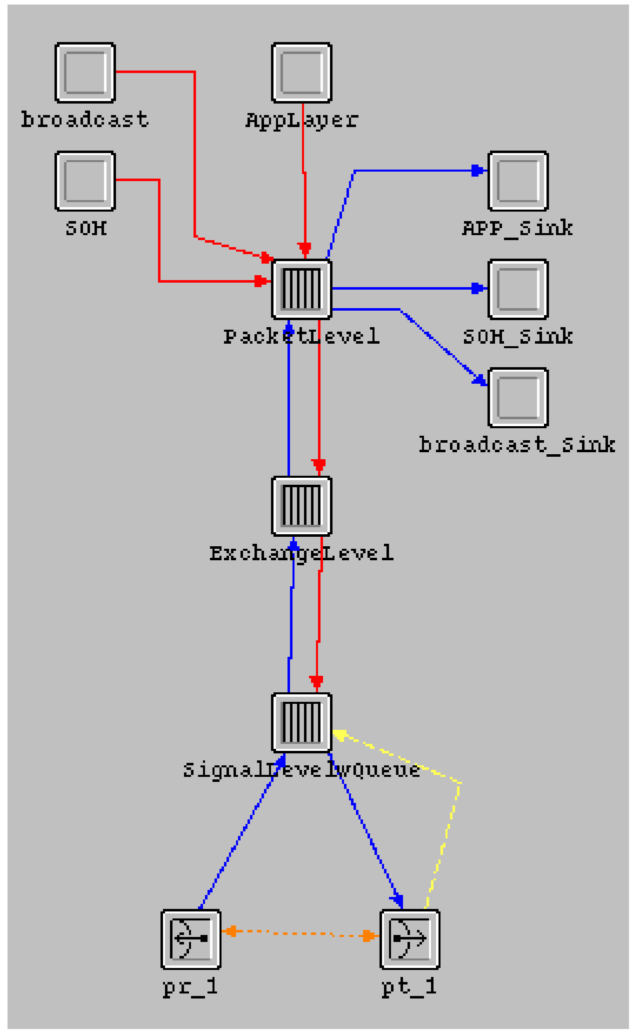
# Node Model Details



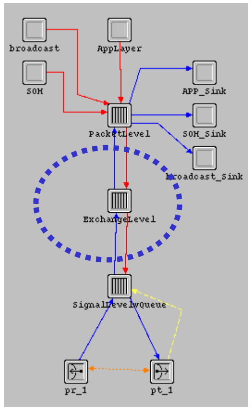


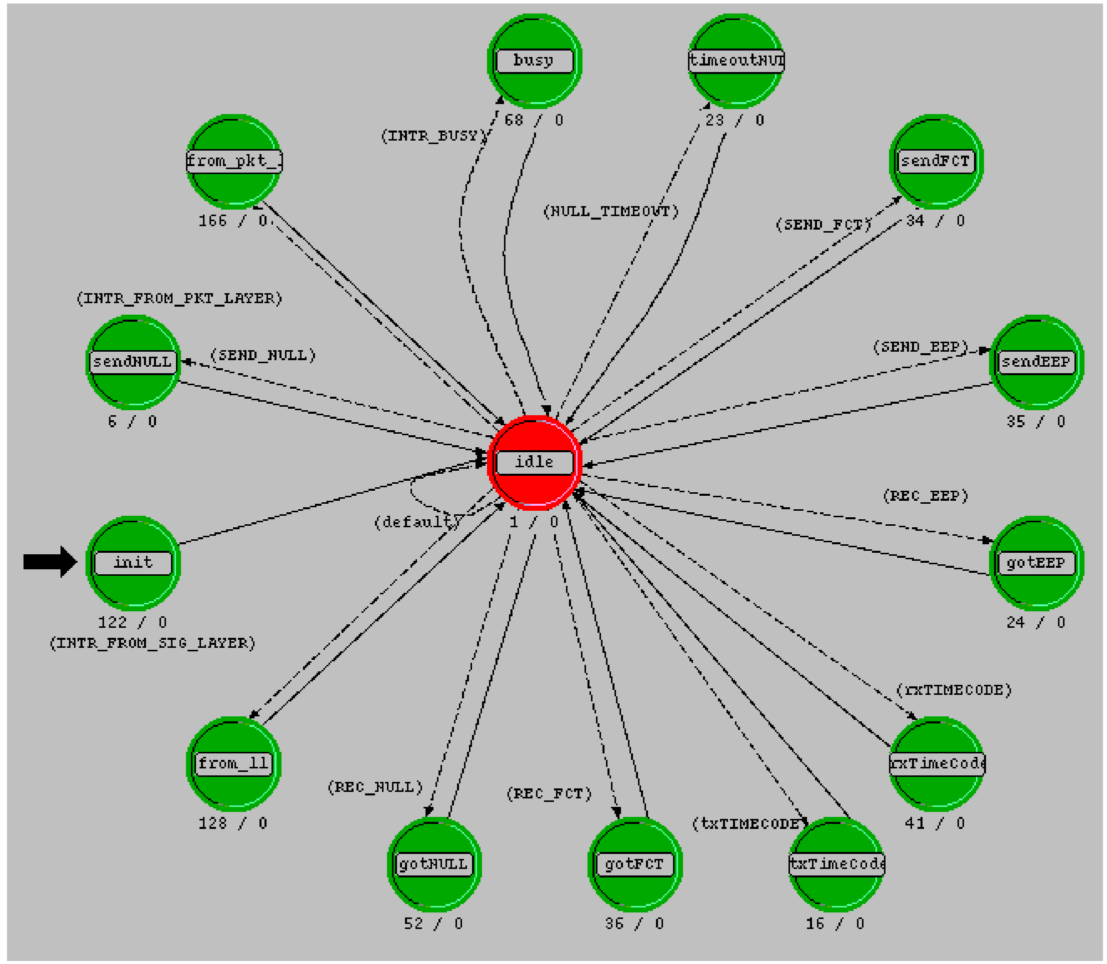
# Node Endpoint Model Details



# Exchange Queue Process Model Details



# Simulation Parameters

- **Time master source distributes both system time messages and SpW time-codes.**
  - Time-codes follow ESA SpaceWire Standard
- **Model Parameters**
  - Link speed: 10 Mbps
  - Time code period: 0.006
  - Broadcast packet interarrival time: constant(0.006)
  - Broadcast 1st time value: 10.003
  - Broadcast packet size: constant(40)