The SpaceWire Transport Protocol

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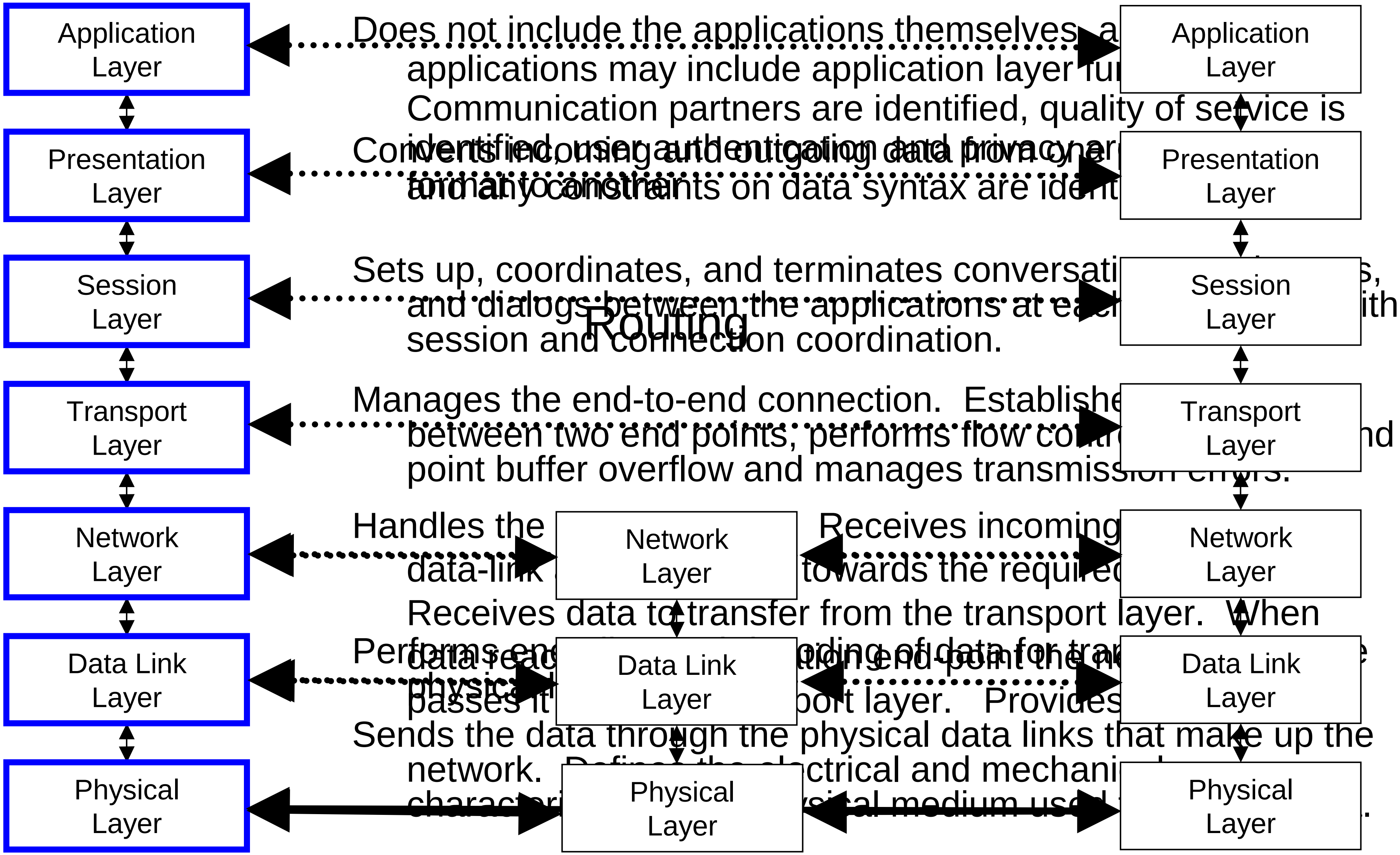
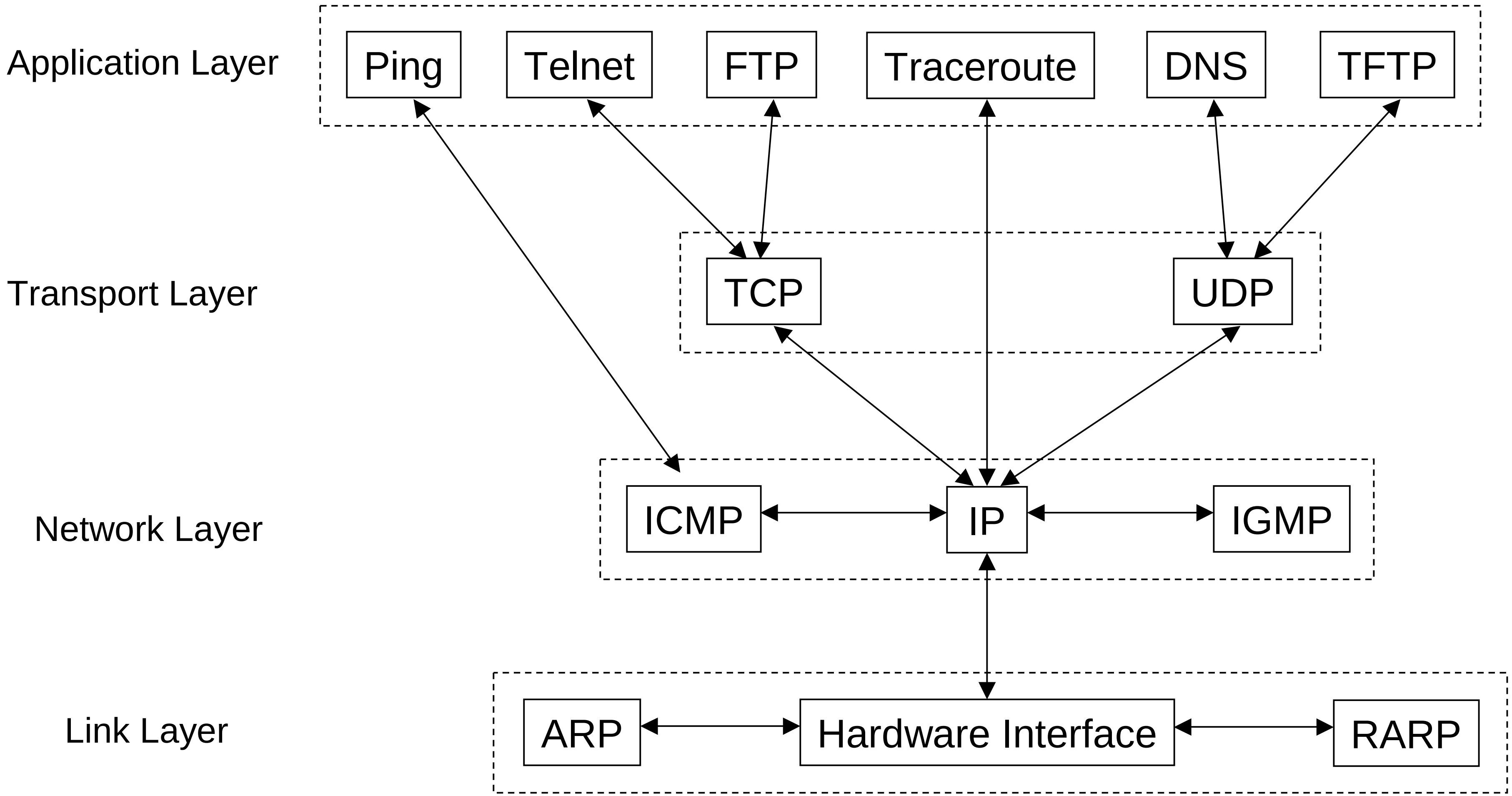
Introduction

- Background
  - The Protocol Stack, TCP/IP, SCPS
  - CCSDS and SOIF
  - SpaceWire
- SpaceWire-TP
  - Features
  - Packet Format
  - Packet Exchange
- Summary

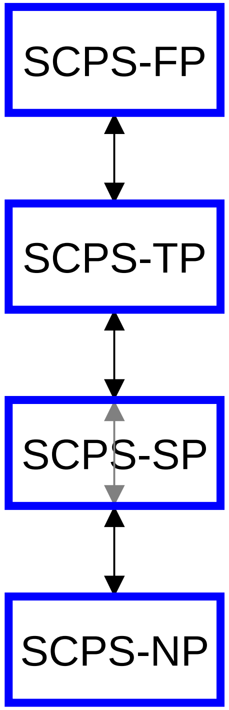
The Protocol Stack



TCP/IP


Application Layer
Ping
Telnet
FTP
Traceroute
DNS
TFTP
Transport Layer
TCP
UDP
Network Layer
ICMP
IP
IGMP
Link Layer
ARP
Hardware Interface
RARP

SCPS

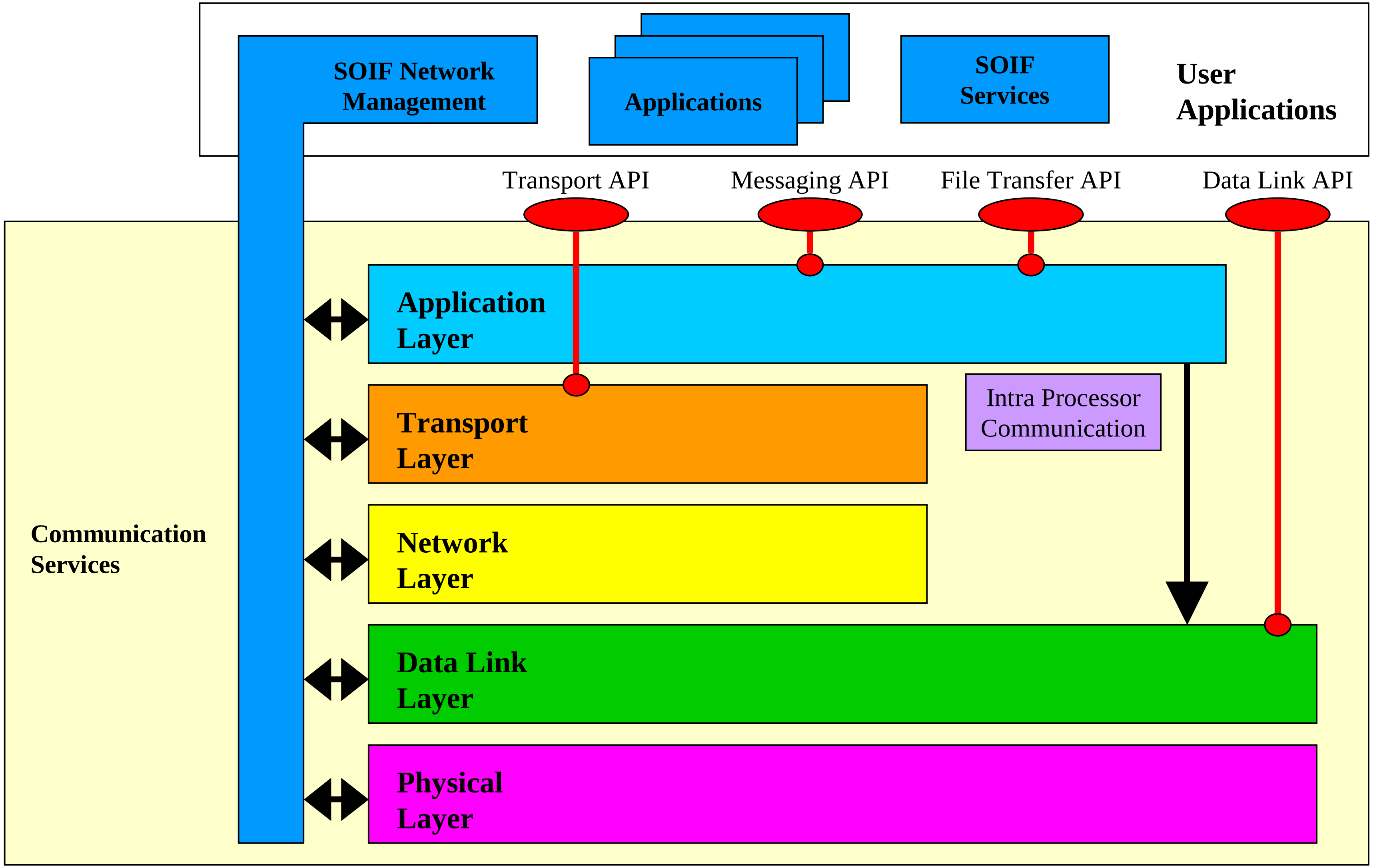


- Designed for communications involving long delays, high levels of corruption, and unbalanced bi-directional links
- SCPS Network Protocol
  - New protocol
  - Provides basic quality of service
- SCPS Security Protocol
- SCPS Transport Protocol
  - Based on TCP, UDP and extensions
  - Provides explicit corruption response
- SCPS File Protocol
  - Based on FTP

CCSDS

- Consultative Committee for Space Data Systems
- Spacecraft Onboard Interface Services (SOIS)
  - Recently renamed from Spacecraft Onboard InterFaces (SOIF)
  - Intend to produce recommendations for use of communication protocols onboard spacecraft
  - Considering use of current protocols such as TCP/IP and SCPS
  - But must also consider requirements specific to onboard spacecraft

SOIS Reference Model



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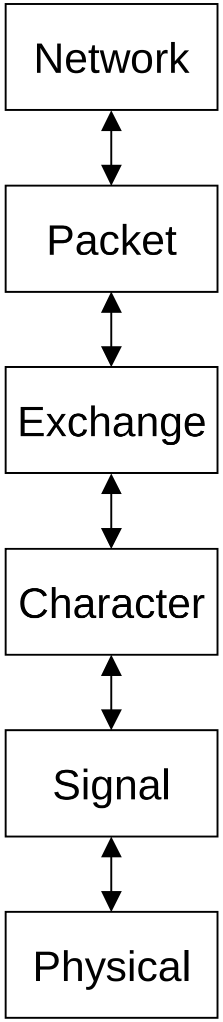
SpaceWire



- Full duplex, bi-directional, serial, point-to-point link
- Transmission rates of 400 Mbits/s possible, low bit error rates
- Provides Data Link Layer flow control and simple error detection using a parity bit
- Standard defined in the form of six levels
- But does not provide a Transport Level

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TCP/IP Over SpaceWire

- Developed by the University of Dundee
- Carries TCP/IP packets (and many other network protocols)
- Any application written to use TCP/IP will work over SpaceWire
- Provides SOIS's low overhead interface
- Implemented for SpaceWire-PCI and SpaceWire RouterUSB
- Using SpaceWire-PCI board can make use of all three links to send three packets at the same time
- Performance marginally better than 100 Mbits/s Ethernet using SpaceWire operating at 100 Mbits/s

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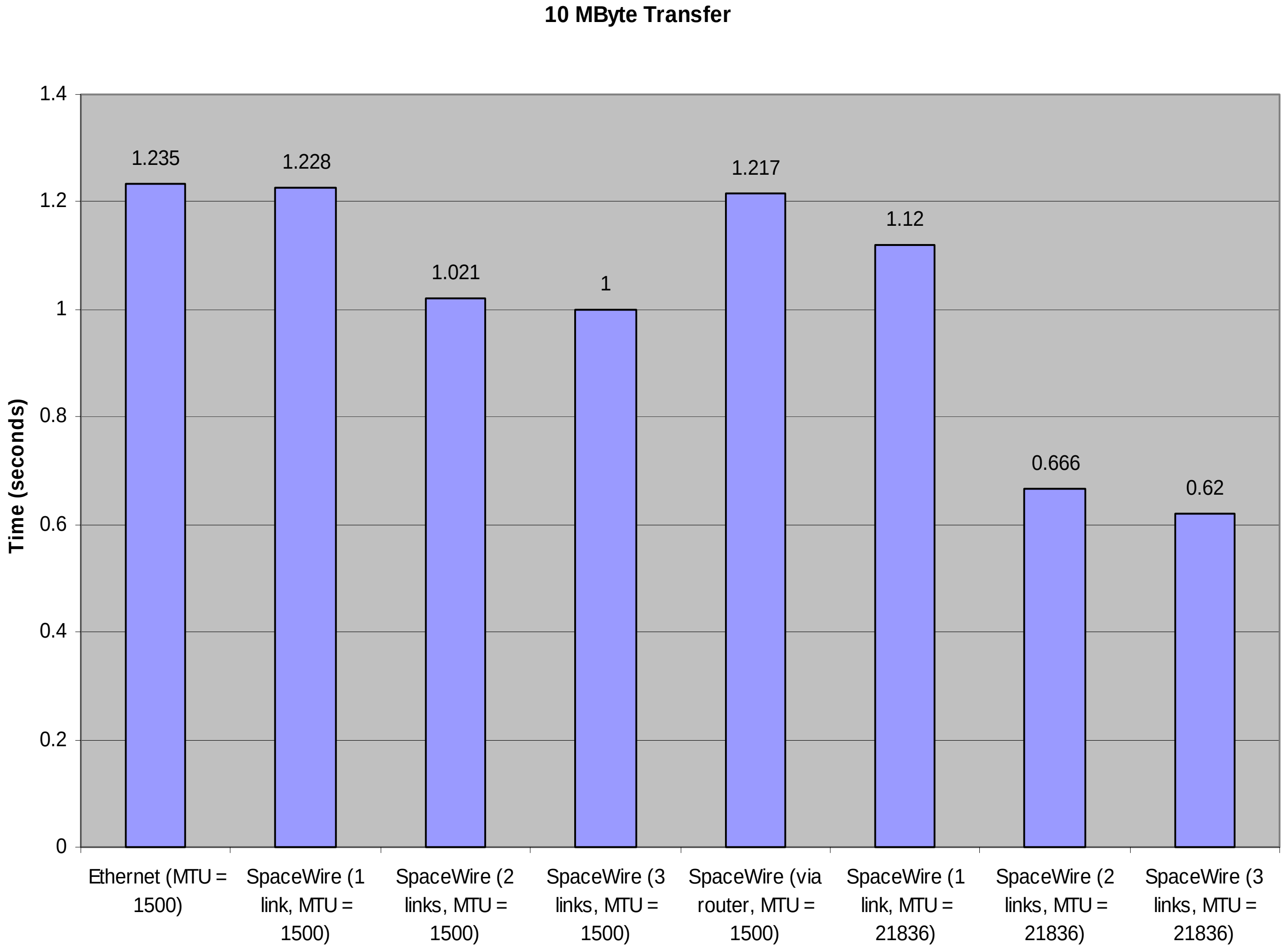
Performance of Driver

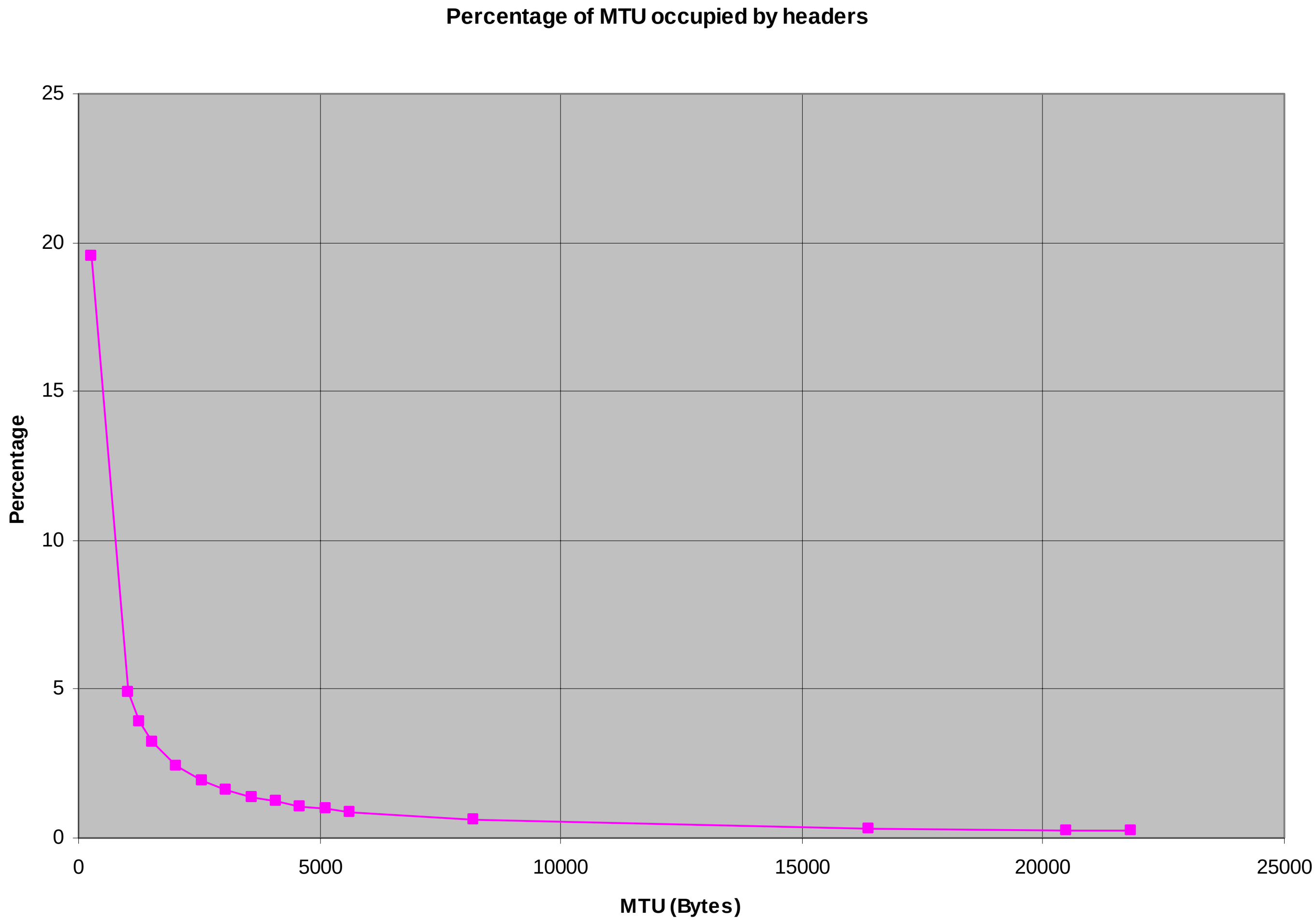
Comparison of SpaceWire-PCI Driver and Ethernet Driver, both operating at 100 Mbits/s



Limitations of TCP/IP

- Although effective for many purposes, TCP/IP is not ideal for onboard communication
- Minimum of 40 byte overhead
- IP concerned with routing **BETWEEN** networks, though there may only be one network onboard a spacecraft
- TCP expects all errors to be the result of packet loss
- Does not provide deterministic capabilities

Overhead of TCP/IP



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SpaceWire-TP

- The SpaceWire Transport Protocol
- Provides end-to-end reliability and flow control at the Data Link Layer
- No need for TCP/IP if communication is between nodes on the same network
- Carries TCP/IP compressed, so overhead is minimised when it is used
- Written specifically for SpaceWire so can exploit features of SpaceWire

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SpaceWire-TP Specifics

- Header size: may be as low as 5 bytes
- Maximum packet size: 32761 bytes
- Maximum message size: unlimited

- All communication is over uni-directional channels
- Channels may be configured, e.g. to guarantee delivery or carry a checksum
- High priority channels formed by opening channels between high priority addresses
- Support for old “dumb” devices provided

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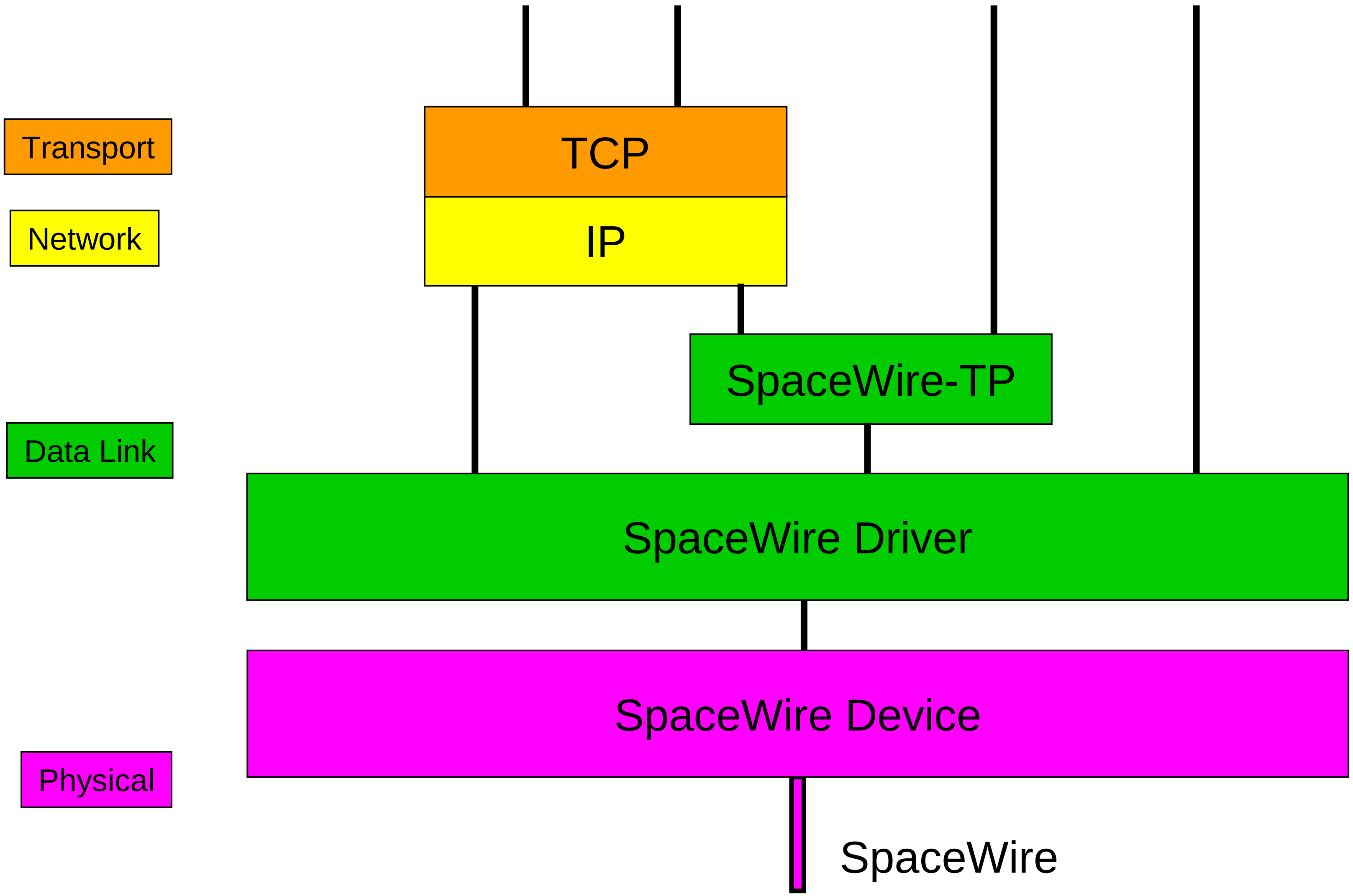
The SpaceWire Stack



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Packet Structure

Destination	Source	Channel	Length	Message Sequence	Packet Sequence	EOM Flag	ACK Flag	Data	Checksum
1 byte	1 byte	1 byte	1 or 2 bytes	3 bits	3 bits			0 - 32761 bytes	1 byte (optional)

- Structured as any other SpaceWire packet (first byte is 1 byte logical address)
- Most significant bit of Length field indicates if there are 1 or 2 bytes used for the length
- Messages are a concept provided to send data greater in length than the MTU of the channel
- End of Message (EOM) Flag indicates the end of a message
- Acknowledgement Flag indicates if packet contains data or is an acknowledgement of a previous data packet
- Checksum may be enabled or disabled per channel

Example Data Packet

Destination	Source	Channel	Length	Message Sequence	Packet Sequence	EOM Flag	ACK Flag	Data
74	70	1	12	0	0	1	0	11 22 33 44 55 66 77

- Node 70 sending a packet to node 74 over channel 1
- End of Message Flag set to indicate this is the end of a message
- ACK Flag indicates that the packet is data and not an acknowledgement
- Checksum disabled on this channel

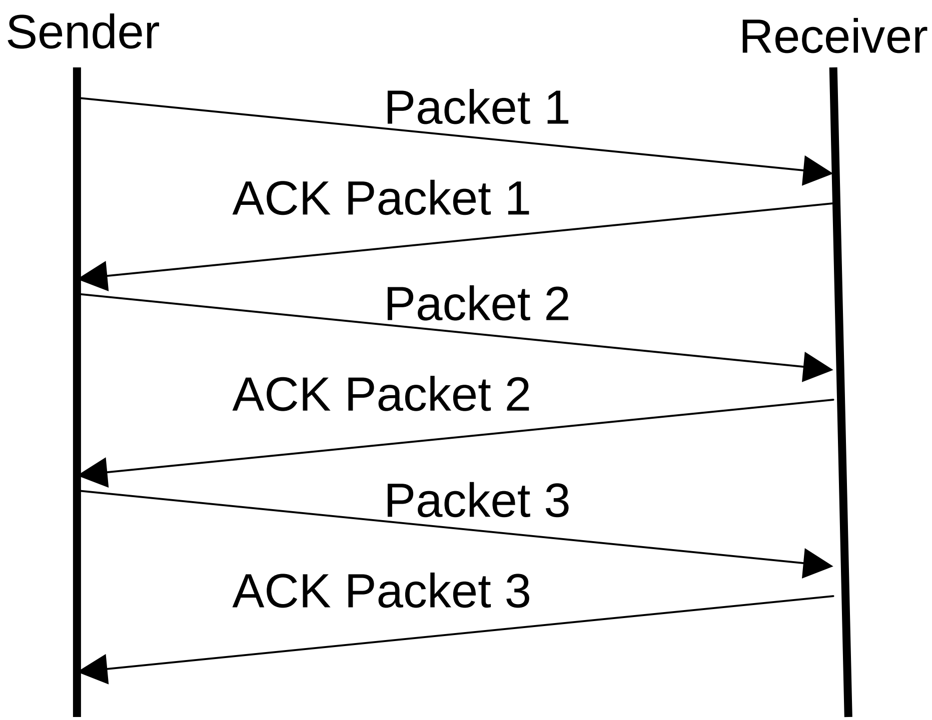
Example ACK Packet

Destination	Source	Channel	Length	Message Sequence	Packet Sequence	EOM Flag	ACK Flag	Data: Available Buffers	Data: Reserved
70	74	1	6	0	0	1	1	7	0
								4 bits	4 bits

- Acknowledgement of previous data packet
- ACK flag set to indicate acknowledgement
- Data field replaced by Available Buffers field
- Provides flow control by indicating the number of buffers available to write into
- Acknowledgements periodically sent so flow control provided even when packets lost

Reliability

- A guaranteed method of communication is provided where all packets are acknowledged when successfully received



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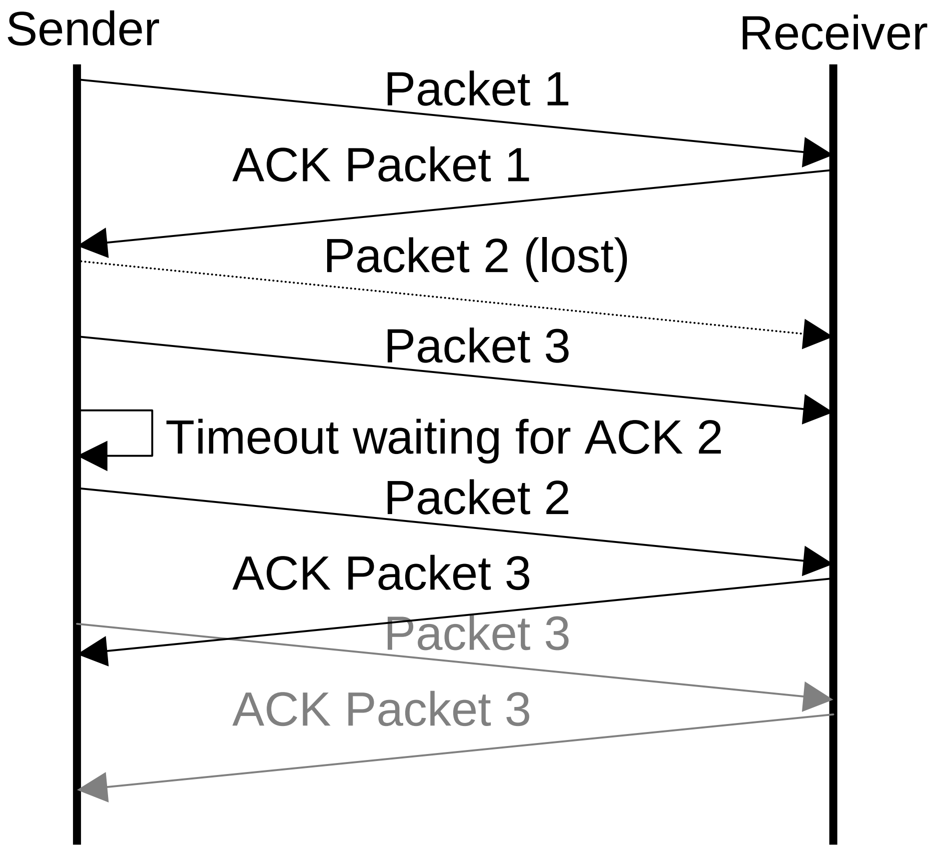
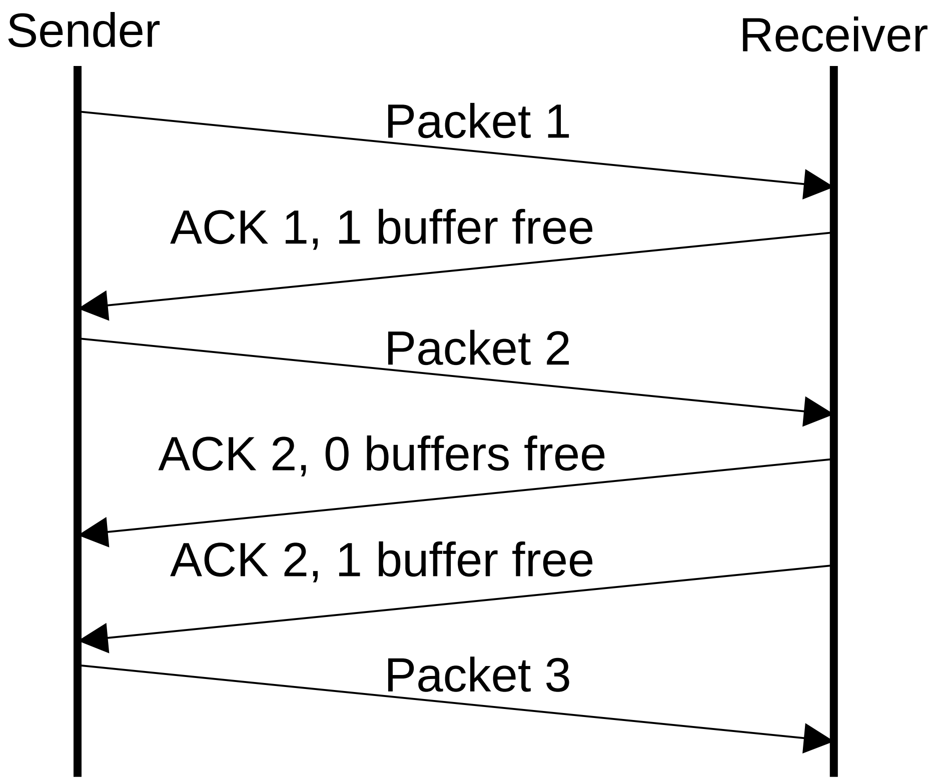
Retry Mechanism

- Using the guaranteed communication method, lost packets will be resent



Flow Control

- The guaranteed method of communication also provides end-to-end flow control



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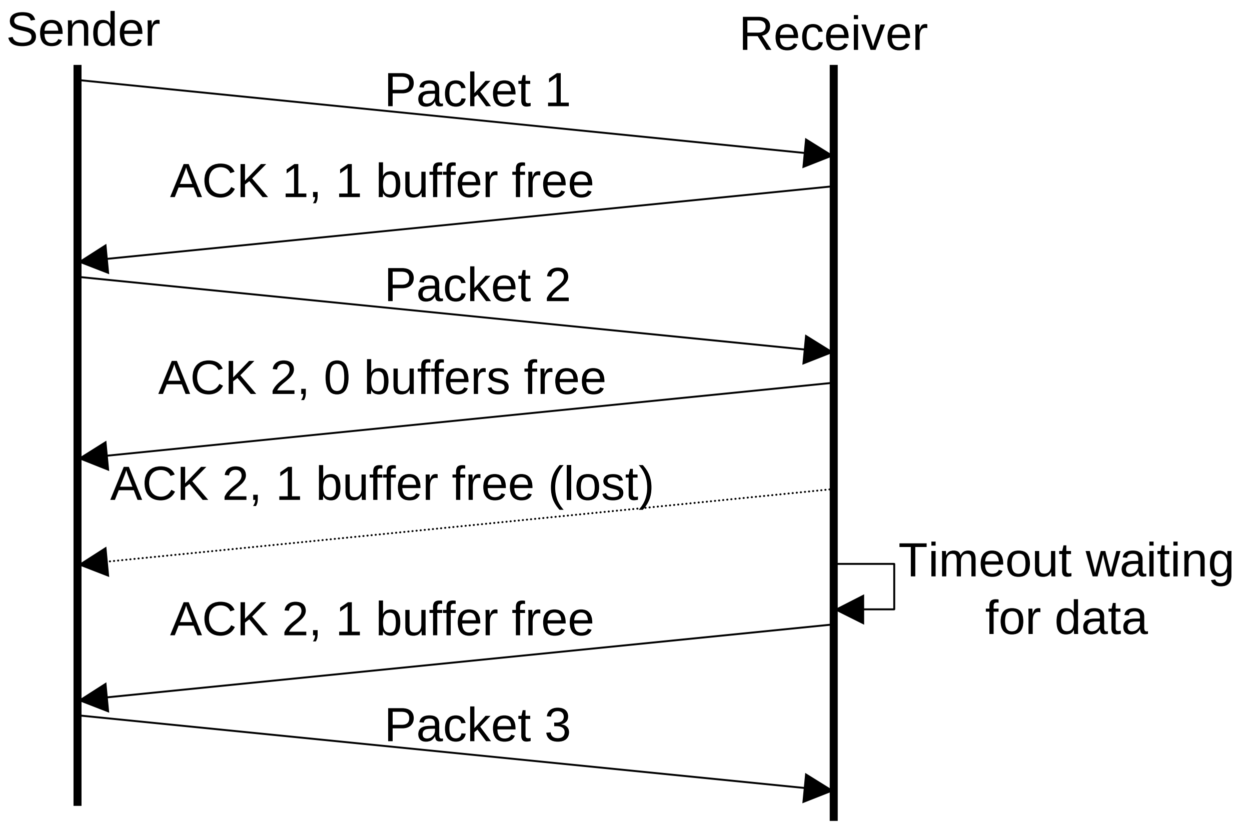
Flow Control Retry

- To cope with acknowledgements being lost, acknowledgements are periodically sent if no data is received



Channel 0

- The channel used to establish, terminate and configure other channels
- Always present, does not need to be established between nodes
- Channel properties that may be configured include:
  - The channel MTU
  - Whether checksums are to be transmitted with packets on the channel
  - Whether the guaranteed or non-guaranteed method of communication is to be used

"Dumb" Devices

- Communication with devices which do not support SpaceWire-TP is possible
- A decision is made on the communication method in use based on the source address
- The source address must be the second byte of every packet received (the first byte should be the destination address)
- Some form of configuration is required to indicate which source addresses are "dumb"

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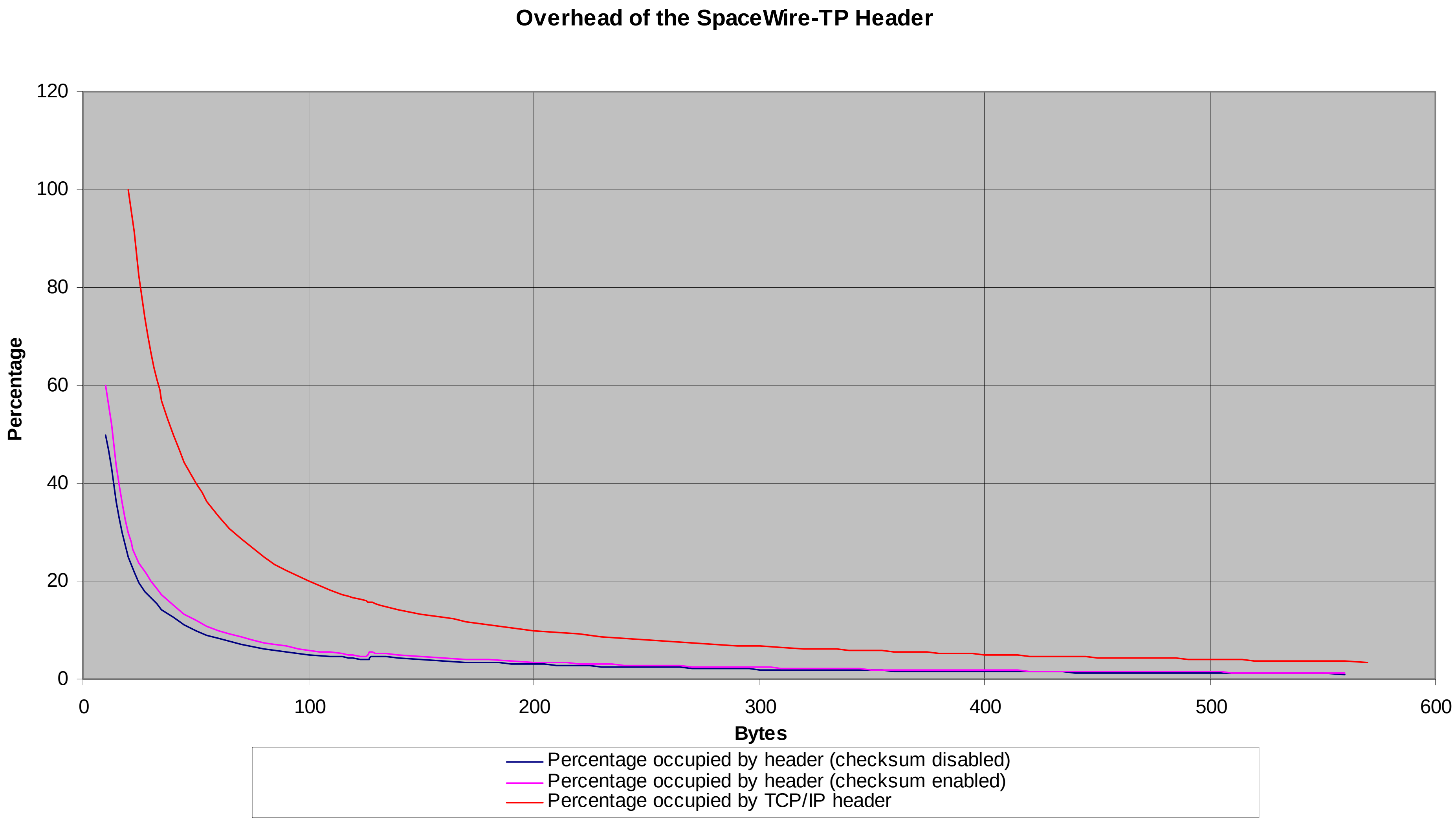
SpaceWire-TP Overheads



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Summary

- TCP/IP can be used to provide Network and Transport Layer functionality over SpaceWire
- Has a number of limitations
- SpaceWire-TP will solve many of these problems
- Currently in prototyping stage
- But should be considered for addition to the SpaceWire standard in future