BriMon

Design and Implementation of Railway Bridge Monitoring Application

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And
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BriMon **Project**

Agenda

- § Introduction to the Problem
- § Application Design
- § Transport Protocol
- § Routing Protocol
- § Current Status

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- Introduction to the Problem
  - Motivation
  - Problem Statement
  - Related Work
  - Introduction
- Application Design
- Transport Protocol
- Routing Protocol
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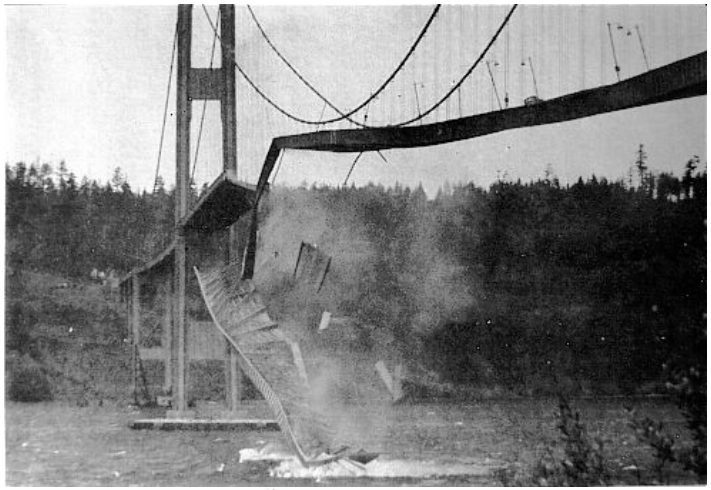
Motivation

- 1.20 lakh railway bridges in India of which 43 per cent are 100 years old and 57 per cent 80 years old
- Current State : Monitoring using huge equipment, takes days to setup.
- Analysis done online , data cannot be easily stored.
- Frequent Monitoring next to impossible..

Protocols, Hardware and design may be reusable

Deployments will enable faster Industry adoption



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Problem Statement

"The structural response (readings of the accelerometer) of the bridge have to be reliably delivered to a central location for further processing."

Analysis

- Readings from **piers** of the bridge
- No significant **loss** of data
- System should be **fault tolerant**
- Kinds of Vibrations
  - Forced Vibrations
  - Ambient Vibrations
  - Free Vibrations

Constraints

- Equipment to run on **battery** power.
- Hostile Environment.
- **Unreliable** hardware
- No straight forward way to detect passage of train.

Our goal is to build a working prototype

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Related Work

Habitat Monitoring

- **long term sensor network deployment of 32 Mica2 nodes**
- **aims to monitor seabird nesting environments**
- **monitors temperature, pressure , humidity etc,**

Industrial Sensor Network :

- **predictive equipment maintenance**
- **aims to replace expensive wireless sytems**
- **measures acceleration,**
- **single hop and multi hop.**
- **long term deployment on micaZ and imotes .**

WISDEN :

- **multi-hop WSN**
- **monitoring large structures**
- **to replace existing wired systems**
- **14 micaZ nodes**
- **measures acceleration**
- **sampling rate 200-250Hz**

ØSingle hop wireless solutions for bridge monitoring available

ØUsing WiFi.

ØVery expensive

ØRecent efforts by UCLA using sensor nodes and DAQs

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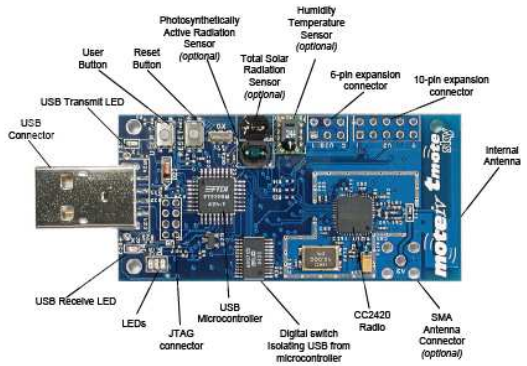
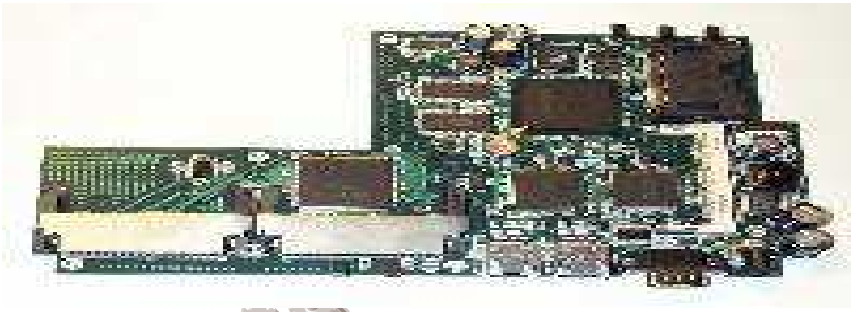
Introduction

- MoteIV's Tmote-sky
  - CC2420, 256Kbps
  - 10KB RAM
  - 1MB Flash.



- TinyOS and NesC
  - C like syntax
  - Components
  - Interfaces and Implementation
  - Event based programming.

- Soekris
  - Single board computer
  - Ethernet, WiFi, Serialport
  - Pebble linux



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Agenda

- Introduction to the Problem
- Application Design
  - Overview
  - Sequence of Events.
  - Data Organization and Layering
  - Alternatives and feasibility
  - Hardware Design
- Transport Protocol
- Routing Protocol
- Current Status

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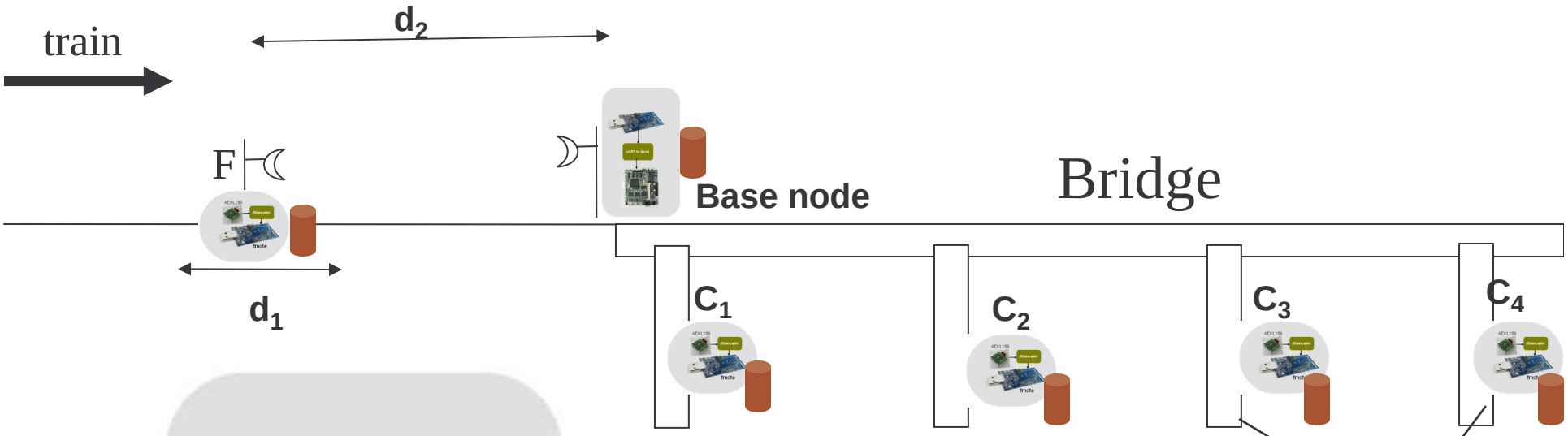
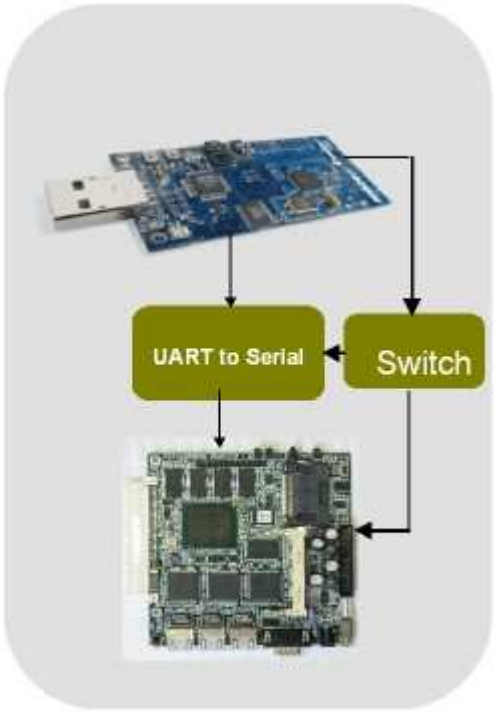
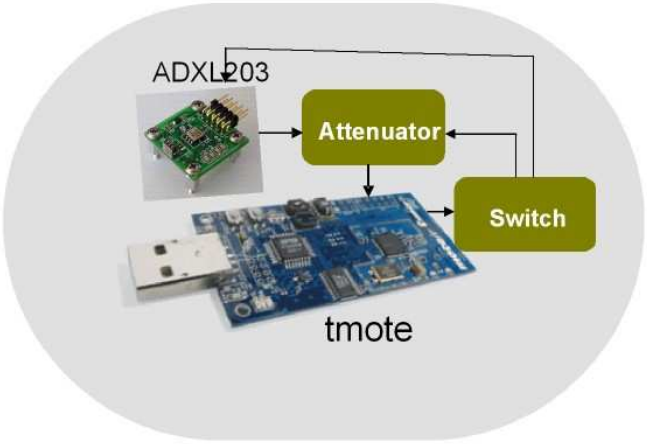
Application Design : Overview





Base Node



Ordinary Node

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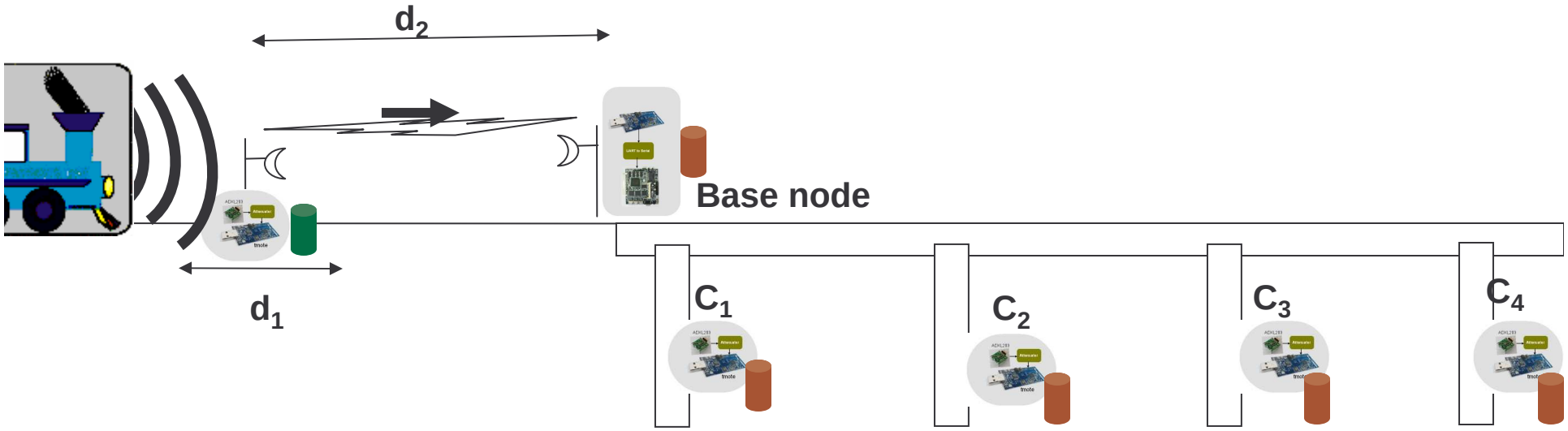
Application Design : Overview



802.11

Wake-On-WLan

802.15.4

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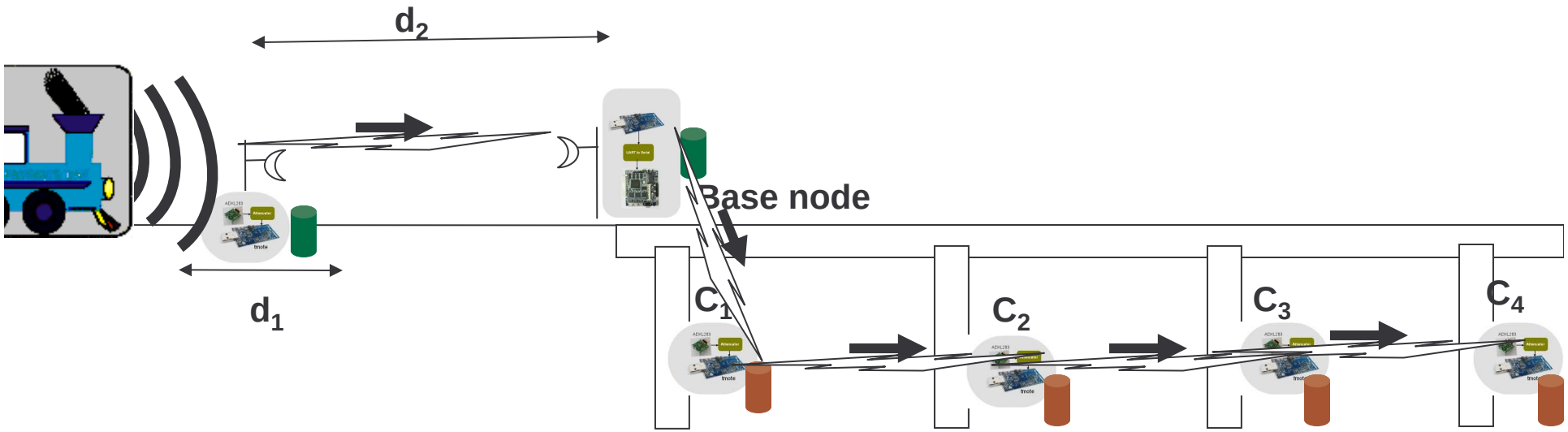

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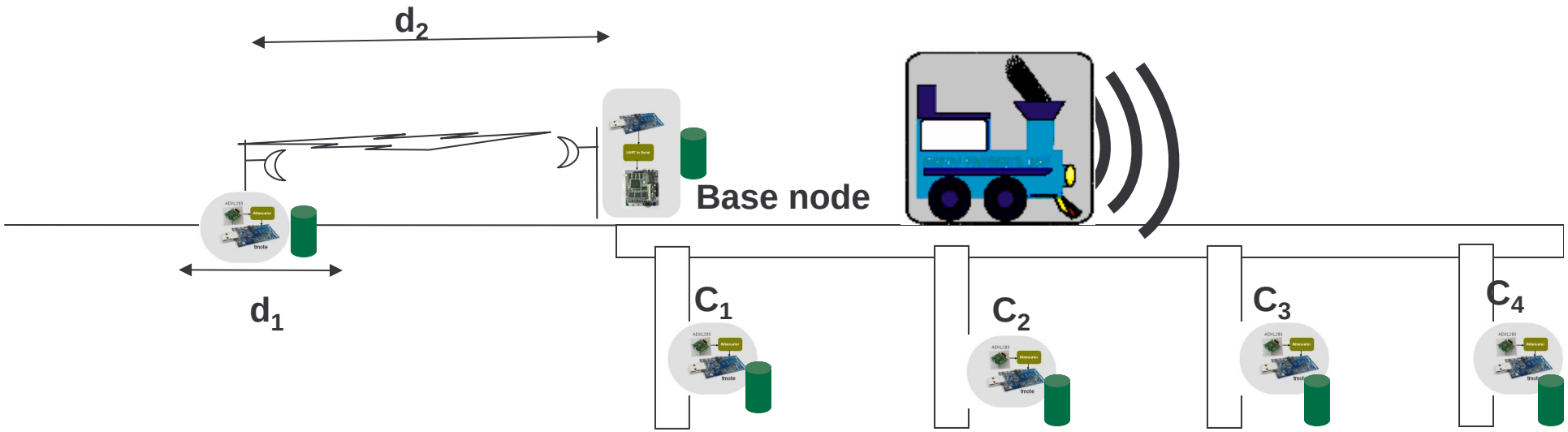

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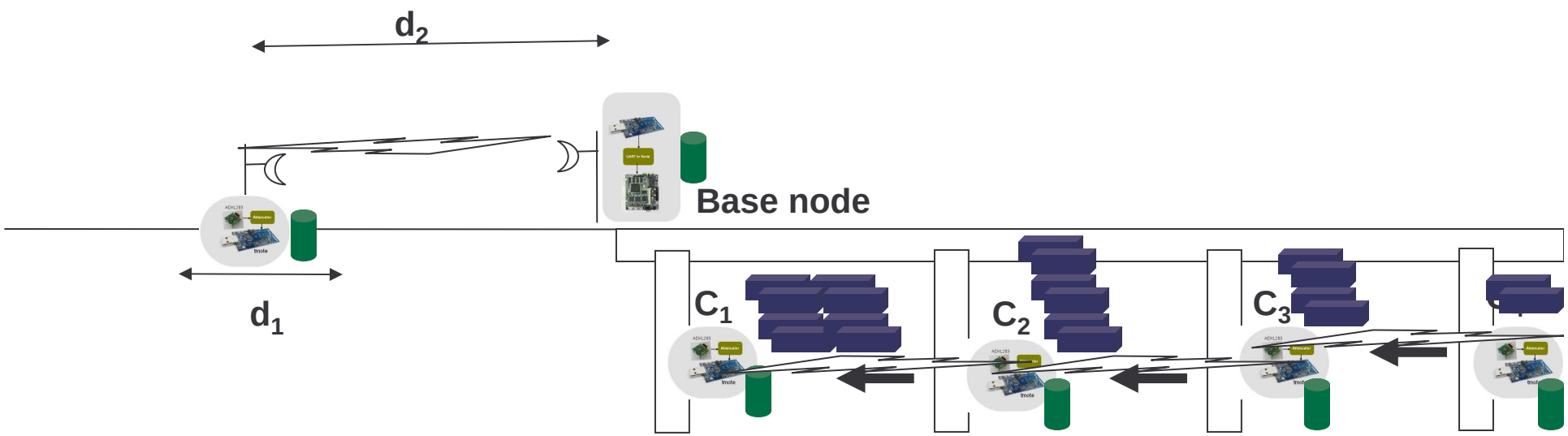

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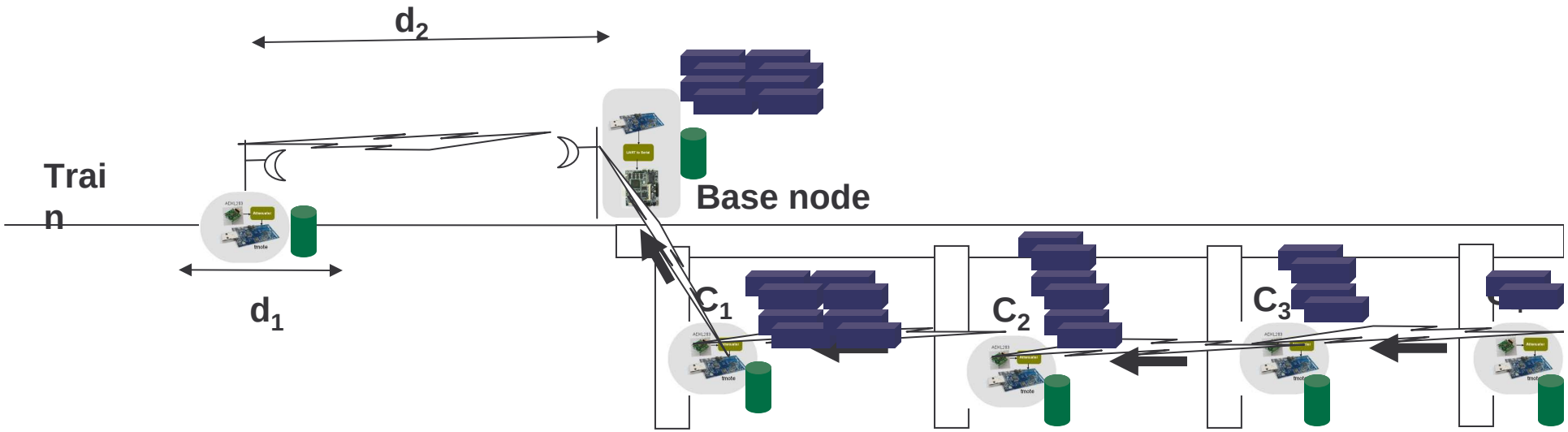

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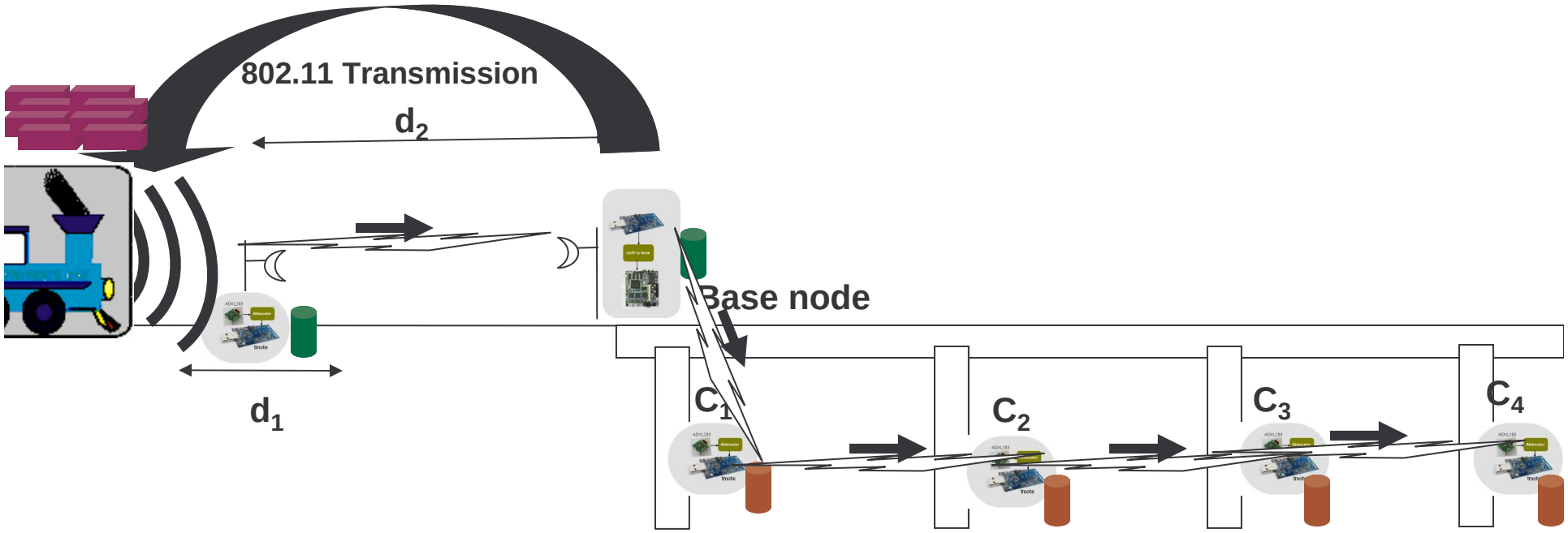

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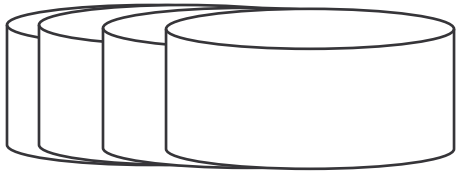
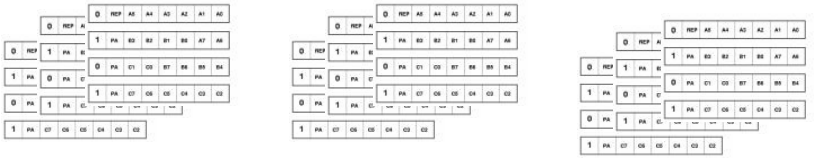
Data Organization

30 KB of Data

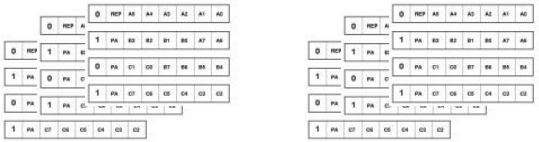


Why do we need such organization ?

5 files of 6Kb each



200 x 5 packets
Of 30 bytes eack



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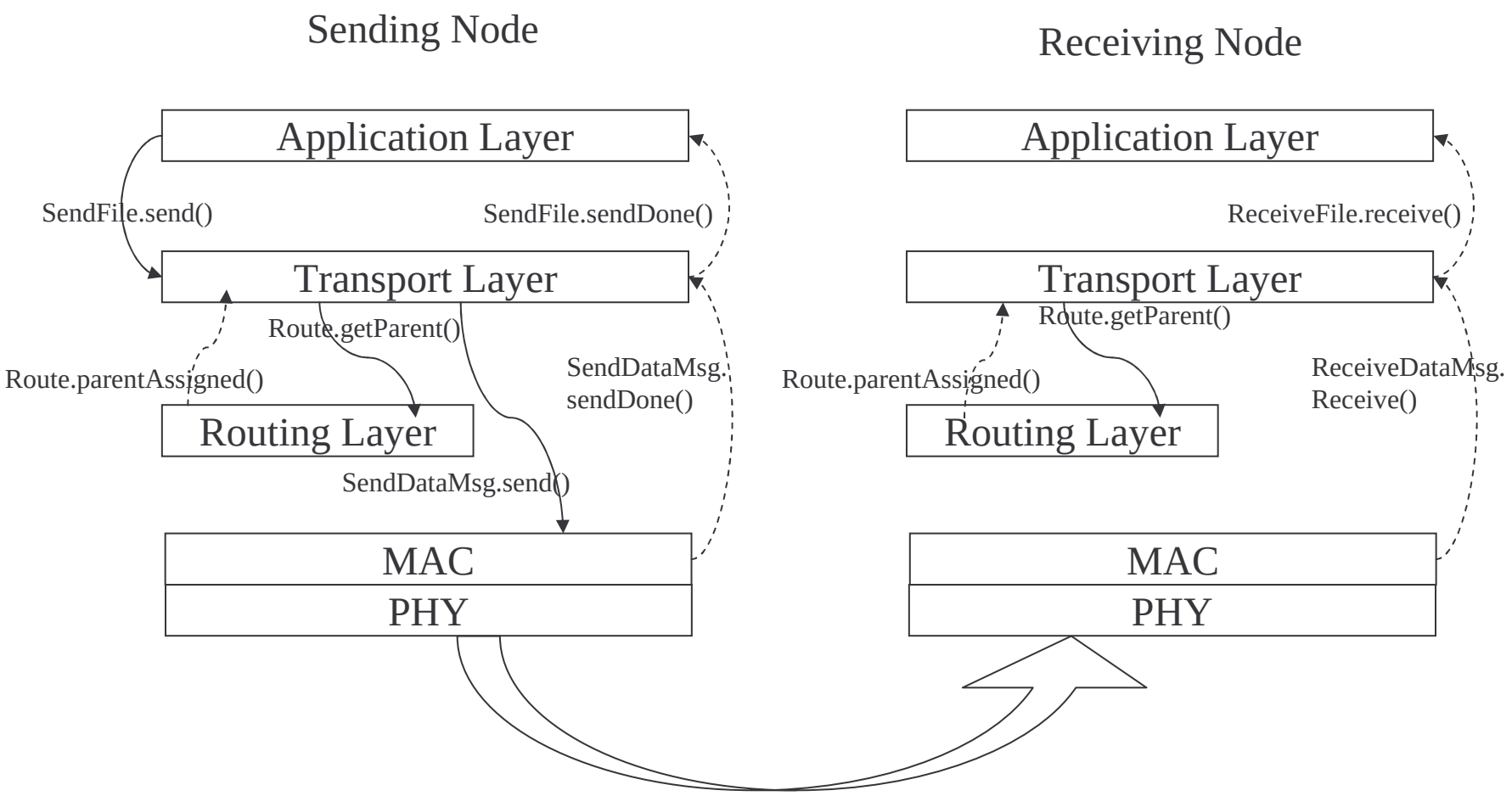
Layering



Common practice for networking applications

Why do we need layering?

Tiny OS encourages it

An example is use of AM_ messages

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Design Alternatives

- Why not draw power from electric lines on tracks?
  - Not all tracks are electrified.
  - Monitoring needed when bridge getting built.
  - Feasibility not known.
- Use GPRS for data transfer.
  - GPRS not available at most places.
- Use mechanical switch to detect arrival of train
  - Not our area of expertise
  - Still we need another system/device to transfer data.
- Using GPS for synchronization
  - Using GPS at every node is expensive.
  - A GPS device at the base node is feasible

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Feasibility

- Earlier deployments on other hardware have run for months.
- Current hardware is better.
- Man power to replace batteries once every 3-6months available.
- WOW tested on long distance link.
- Sensor nodes also tested on 500m link with external antenna.
- Data transfer using WiFi at speeds of 70mph is achieved

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Hardware Design

- Accelerometer
  - Is it possible that a MEMS accelerometer replace existing expensive accelerometers?
  - Range 0-50Hz
  - Low power, low noise, high sensitivity.
  - MMA7260Q and ADXL203
  - Fabrication of MMA7260 application circuit (PCB Library)
- Attenuator Circuit.
  - To solve the clipping problem

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Hardware Design

- Switch Circuit
  - Other devices cannot be shutoff by using a command.
- Is it possible to transfer data from the tmote to the Soekris?
  - USB to Serial ?
  - UART to Serial converter
- Power Circuit

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  - § Choice of Protocol
  - § Overview
  - § Protocol description
- § Routing Protocol
- § Current Status

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Transport Protocol : Overview

- Existing Protocols
  - PSFQ
  - RMST
  - ESRT
- RMST and ESRT – no implementation.
- PSFQ – implementation for mica, and PSFQ known to perform badly in our setting

- Reliably transfers a file from a node to its parent
- Store, Wait and Forward
- NACK based reliability
- Tight integration with read and write Flash operation
- Only hop-by-hop reliability

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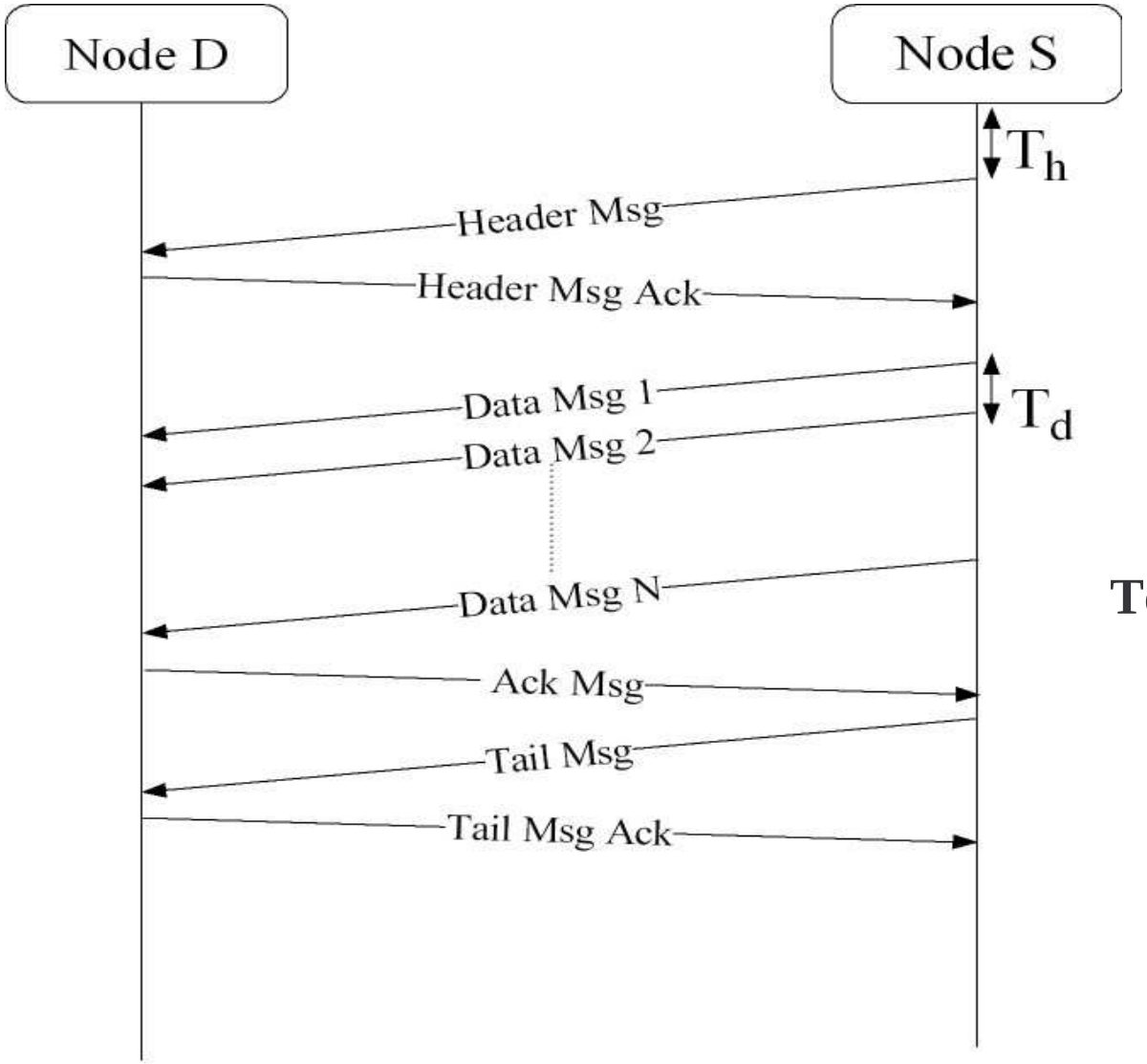
Transport Protocol



T_h is the inter file transfer interval

Inserted for handling SPI conflict b/w radio and flash

Td is the inter packet interval

zero packet loss

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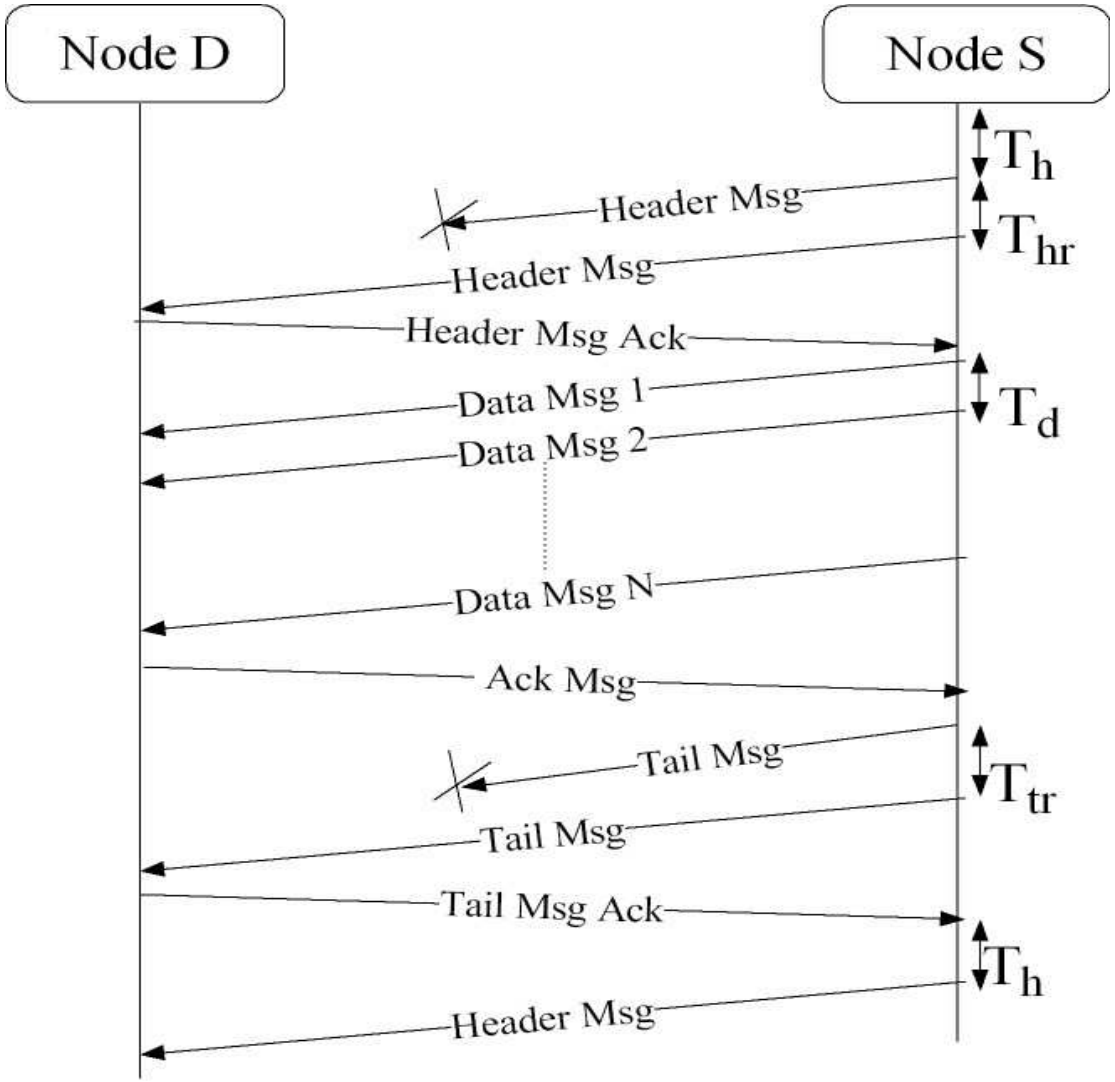
Transport Protocol



$$T_{hr} = T_{tr}$$

Header and Tail messages lost

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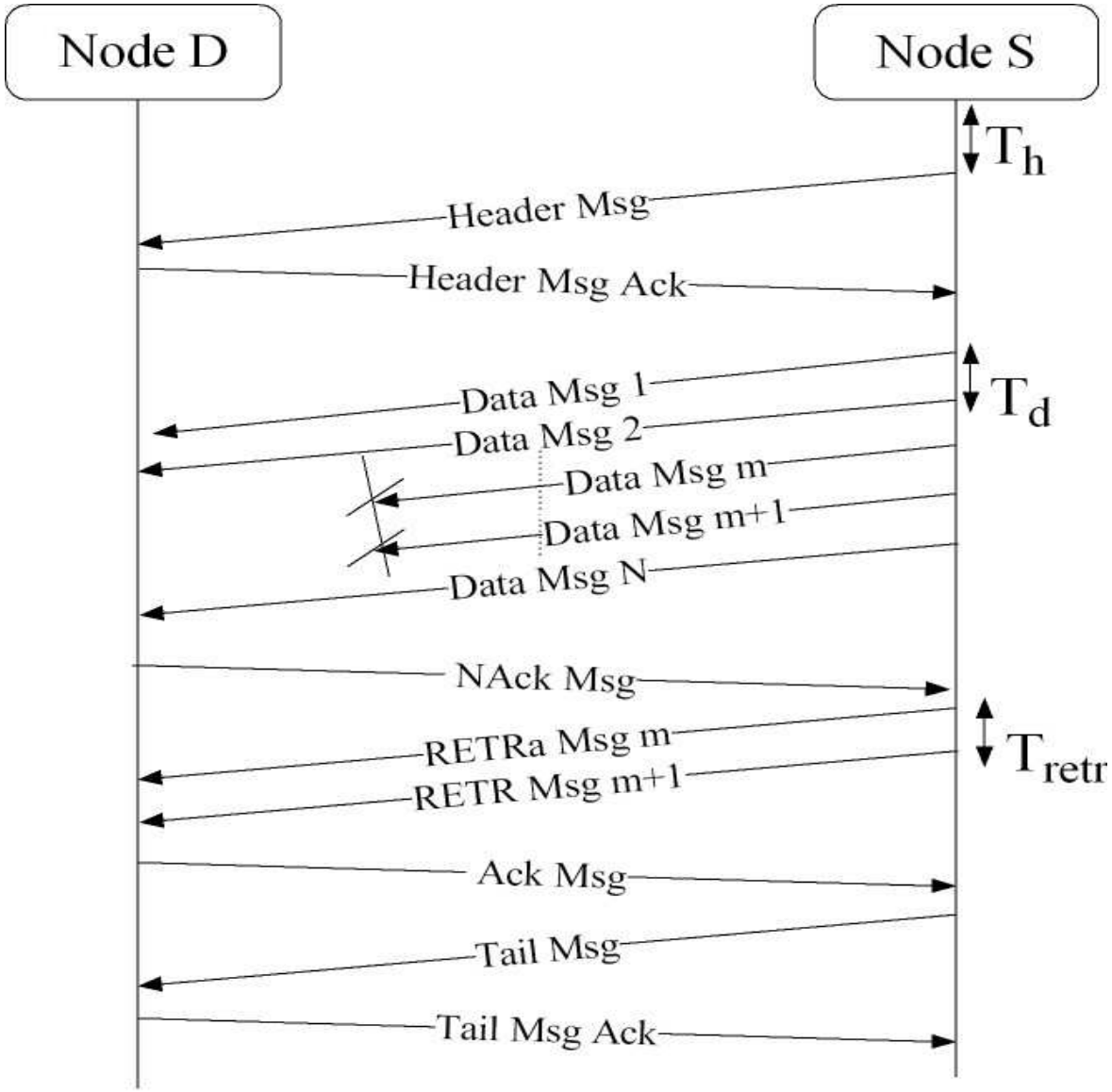
Transport Protocol



Data Messages getting lost

$$T_d = T_{retr}$$

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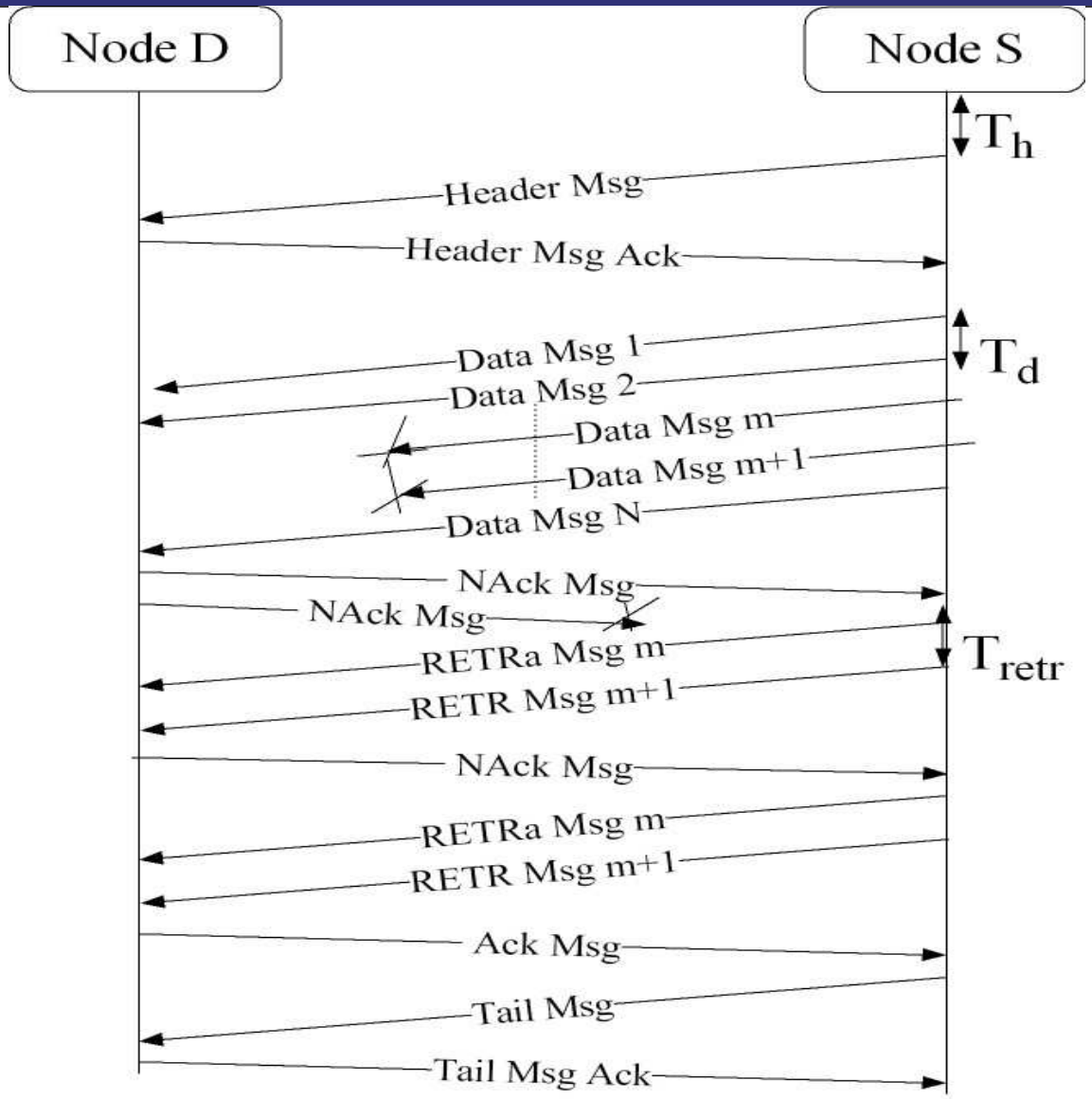

NACK messages getting lost

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Routing Protocol :Overview

- Existing Protocols
  - Single Destination DSDV
  - MultiHopLQI
  - MintRoute

- All nodes start transmitting beacons simultaneously and continue doing so.

- Metric used as LQI, but LQI is not a good measure of packet loss

- Base Node starts the routing process

- The protocol does not go on forever.

- Packet loss is the metric.

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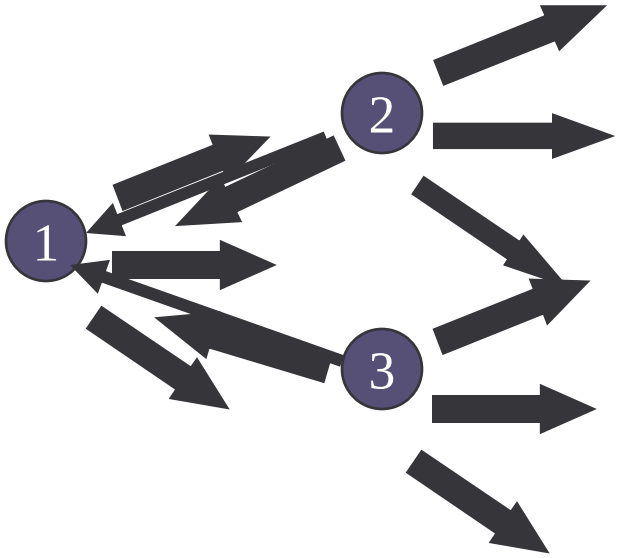
Routing Protocol: Brief Description



2 NODE_LISTEN

2 NODE_TRANSMIT

2 NODE_IDLE

2 NODE_LEAF

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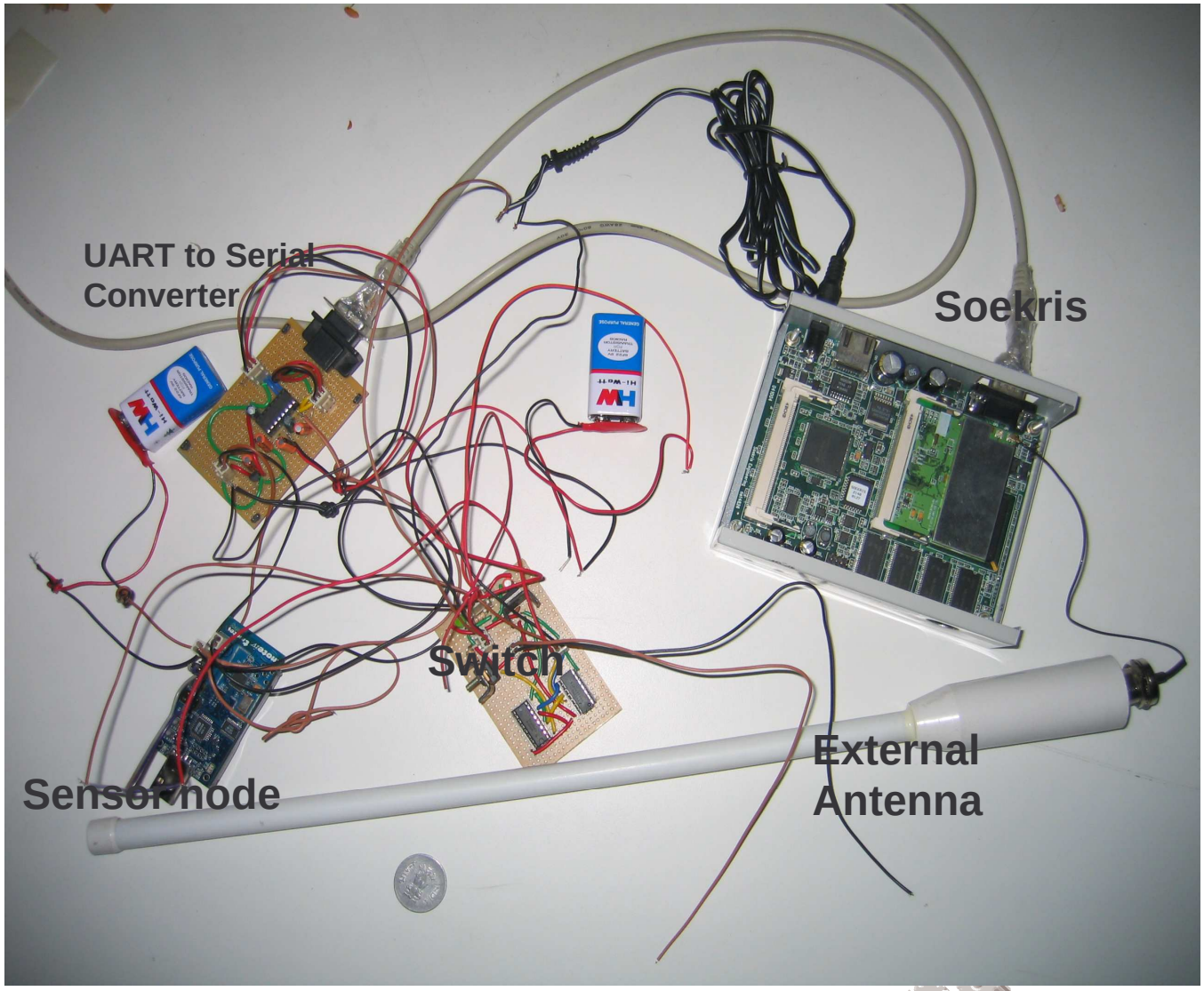
Status



Base Node

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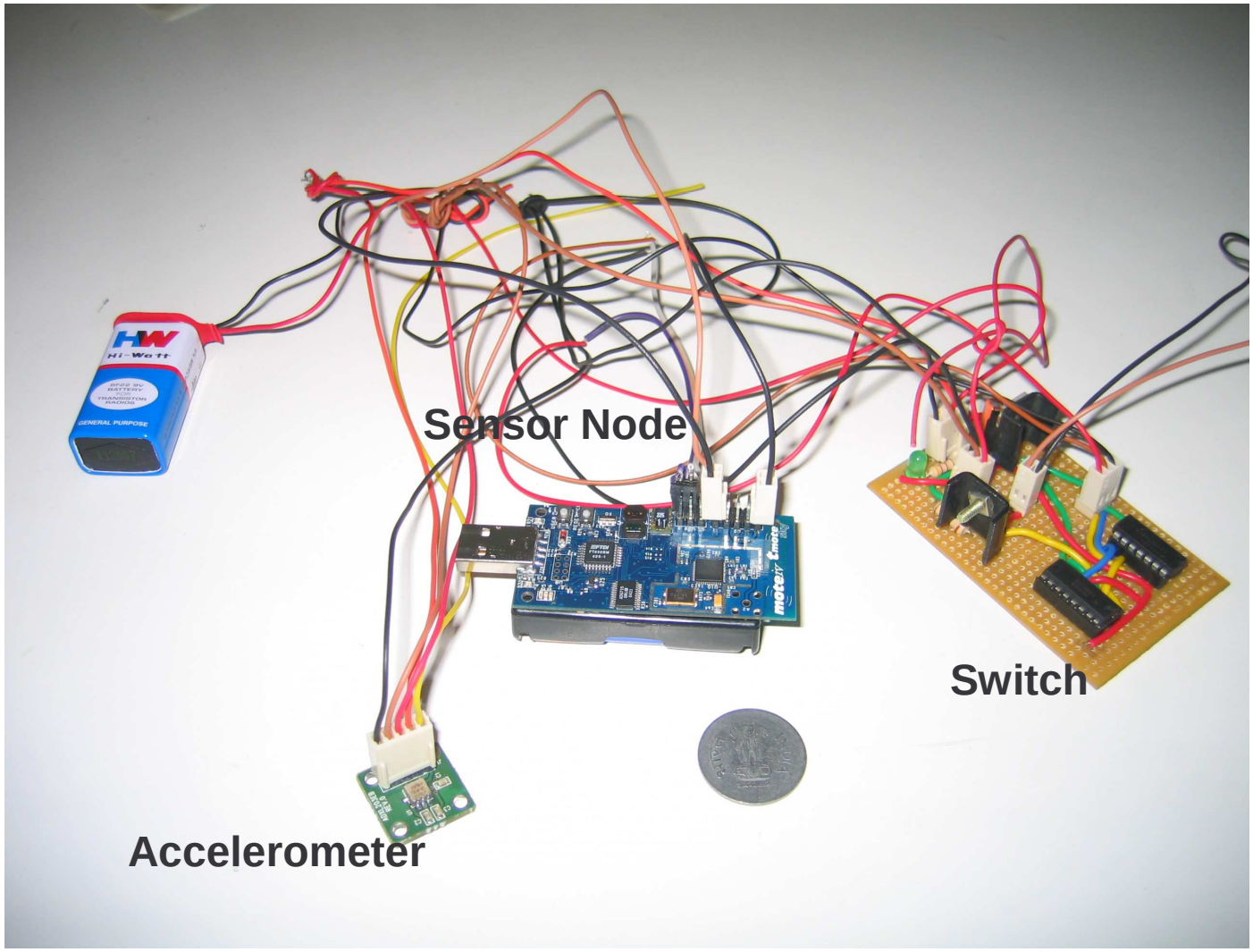
Status



Ordinary Nodes

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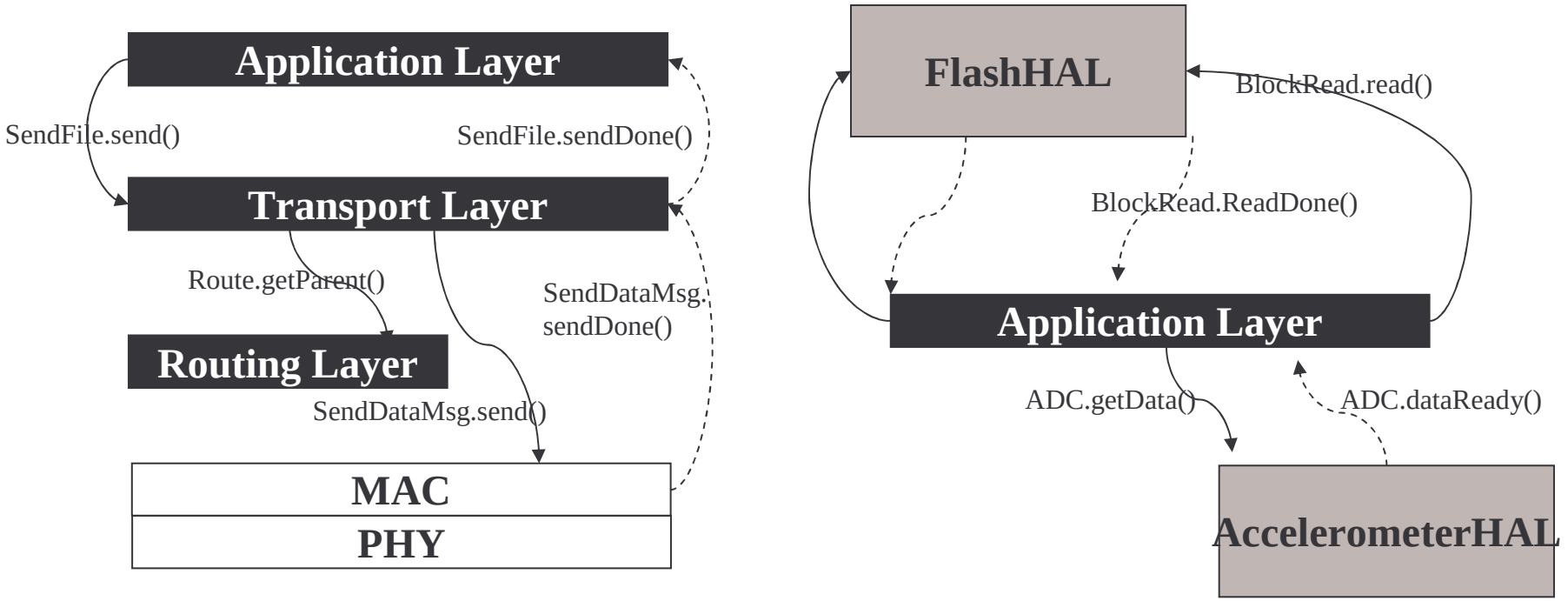
Software Components



Completely developed In house

Used existing code in the stack

Had to be tweaked or changed

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Conclusion

- Developed various Hardware and Software components required.
- Successfully able to collect data to a central server (soekris) from the WSN.
- Application is reliable as per our testing so far.
- Protocols developed found almost direct use in WiBeam project.
- Application Design and protocols were used in several CS725 course projects.

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Future Work

- Integrating all components.
- Documenting the design and the code.
- Initial outdoor testing.
- Testing on an actual bridge.
- Long term deployment on a bridge.

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Thank You

Questions?

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