Research Consortium in Speckled Computing

Free Space Optical Networking on ENS Platforms

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Overview

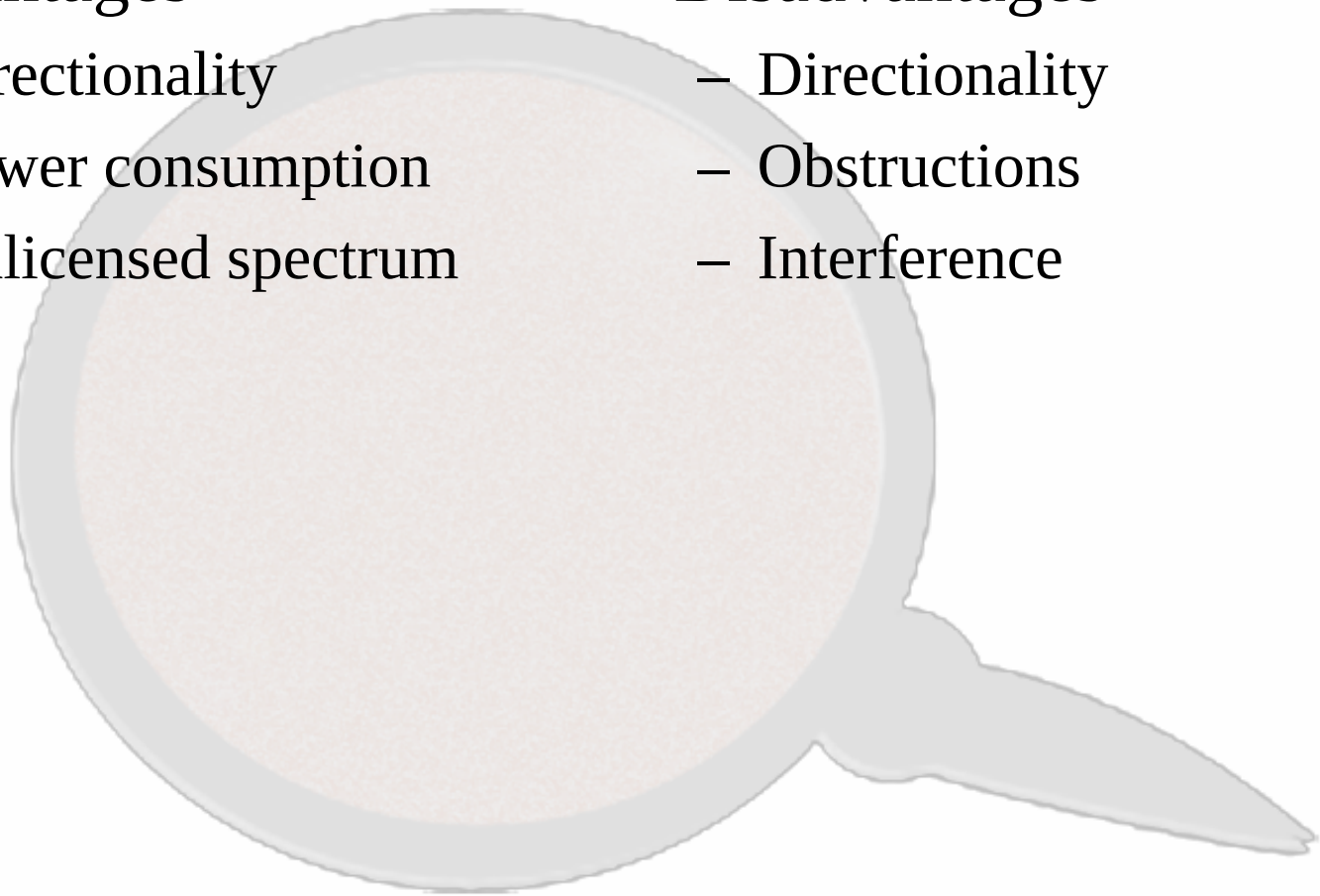
- What are Free Space Optics
- Our motivation
- Simple transceiver design
- What FSO does for EN applications
- Deployment issues
- Description of the demonstration

Free Space Optics

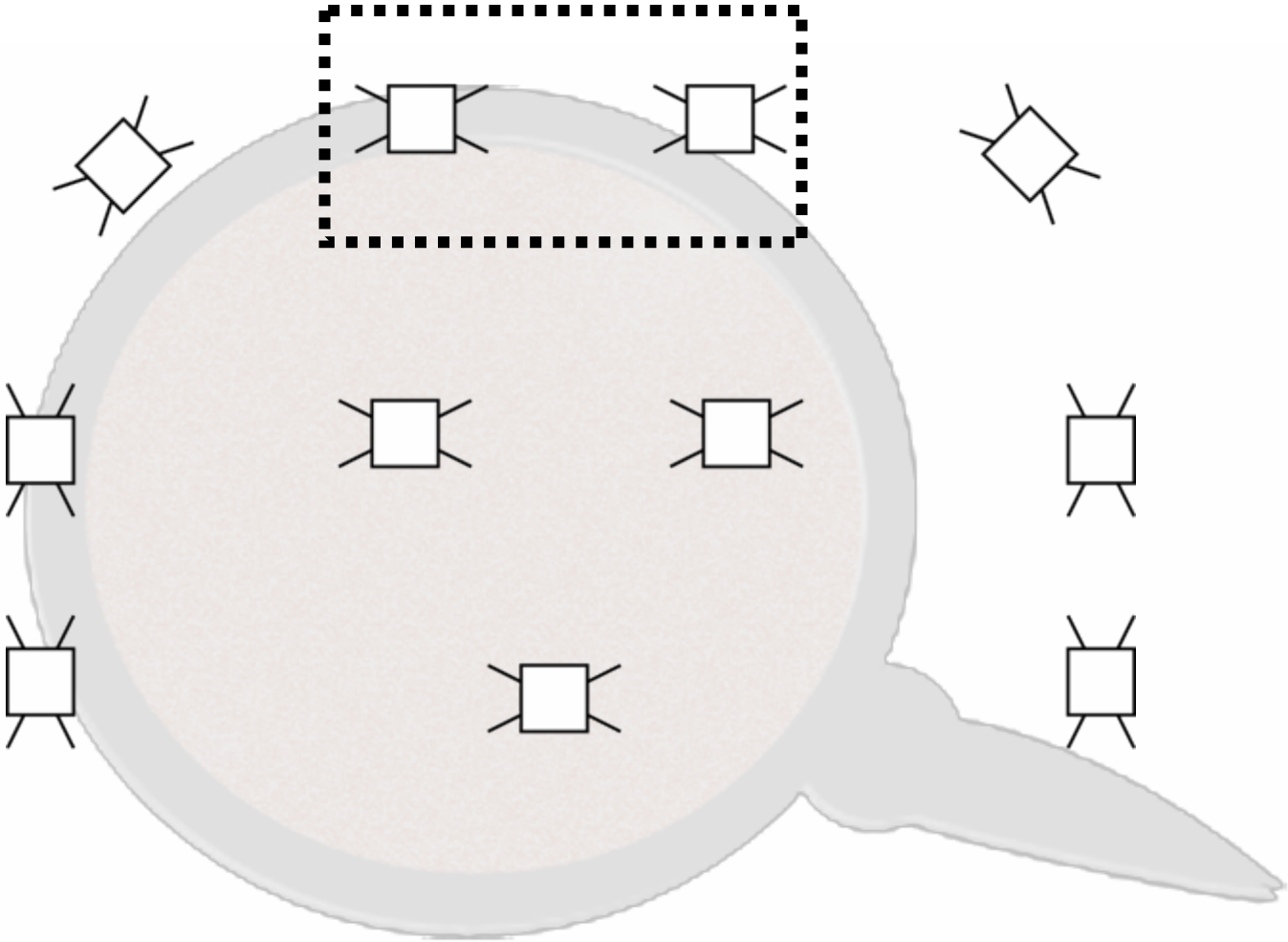
- Modulating light, transmitting through free space to send data
  - Not through fibre optic cables
  - Remote Controls
- Traditionally used in Metropolitan area networks

Free Space Optics

- Advantages
  - Directionality
  - Power consumption
  - Unlicensed spectrum
- Disadvantages
  - Directionality
  - Obstructions
  - Interference



Our Motivation



Our Motivation

- Divergence
- Output Power
- Data Rate
- Efficiency
- Wavelength
- Spot size
- Distance
- Coding scheme

- Acceptance
- Sensitivity
- Filters
- Idle Power
- Spectral response
- Detector area
- Rotation
- Digital circuitry

Our Motivation

- That's a lot of parameters, big design space.
- Focus on one aspect of this.
- As Mat said:
  - Wireless node with a solar panel
  - Used in indoor monitoring
  - Solar panel charges battery
  - Limited power budget, indoor lighting
  - 100uA for communication
- So let's work around a power budget of 100uA

Our Motivation

Name	Tx Current	Rx Current
CC1101	15mA	14mA
CC2500	12.8mA	21.6mA
CC2420	17.4mA	19.7mA

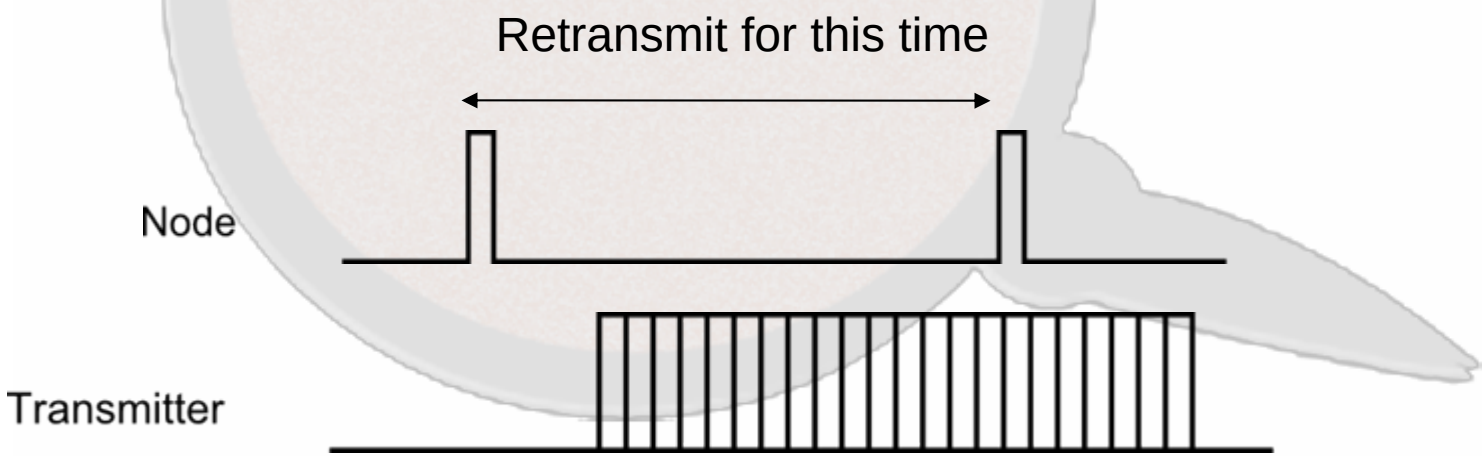
Power consumption for WSN radios

Our Motivation

- Synchronised data collection:
  - Use TDMA schedule
- Asynchronous events:
  - Low power asynchronous MAC protocols
    - SpeckMAC, B-MAC
  - High latency
    - Bad in emergency response applications

Low power listen MAC protocols

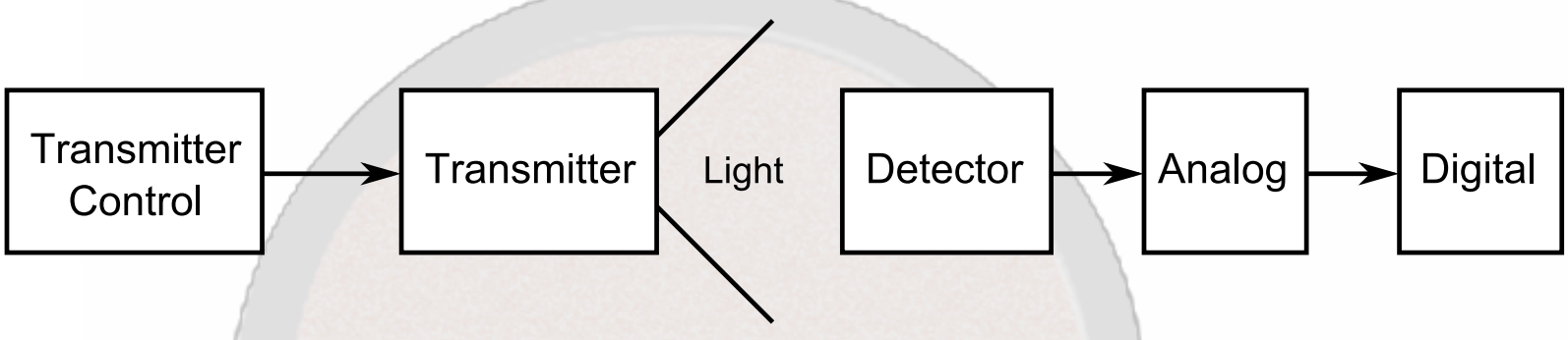
- All work on the same principle
  - Carrier sense every so often
  - Some sort of transmission scheme



Our Motivation

- To use Speck-MAC we need a duty cycle of 0.005 with the CC2420
  - A sleep time of 400ms
- Long delays through unsynchronised nodes
- Can we design an optical receiver that uses less than 100uA?
  - Yes.
- Does it reduce our latency?
  - Yes

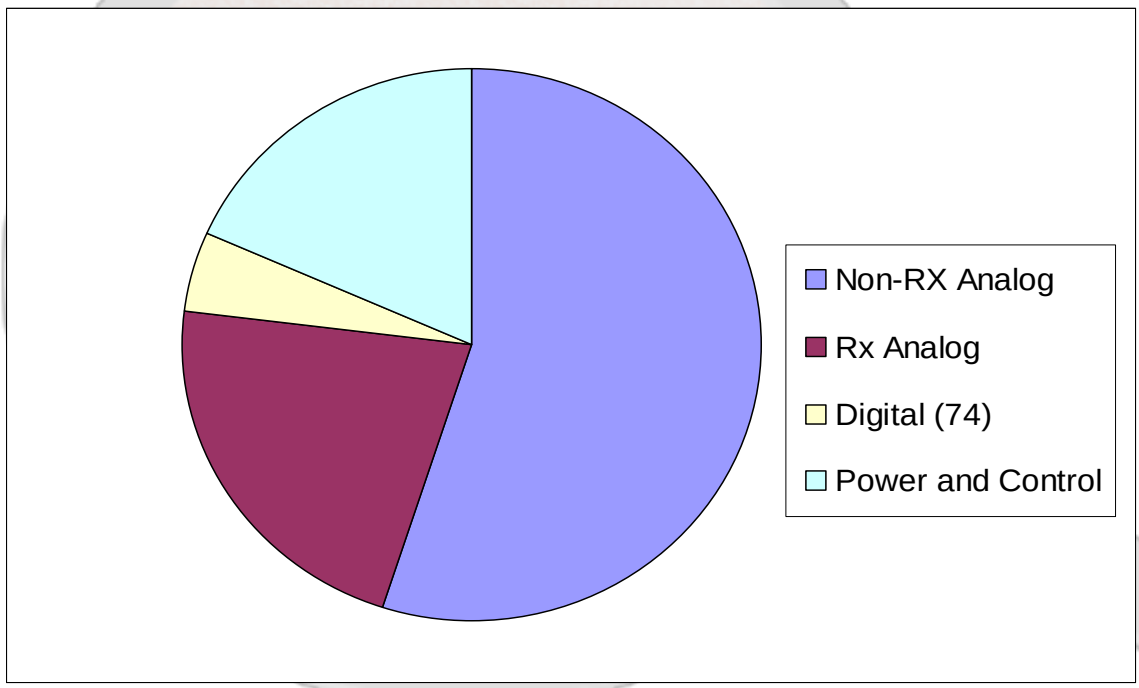
Simple transceiver design



- Transmitting Manchester
- Detector + Analog converts light to usable signal
- Digital decodes Manchester, and looks for a Start of Frame Delimiter (SFD)

Simple transceiver design

Breakdown of Receiver power consumptions as a proportion of the worst cast



Simple transceiver design

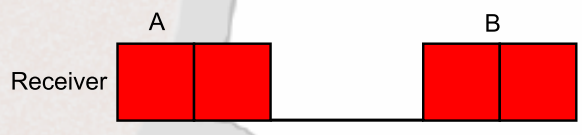
- That's just a generic coms model
- To get to low power
  - Use low power amplifiers
  - Lower data rate to 2Kbaud
- Trade off between data rate and power consumption
- Not a replacement for the radio

Simple transceiver design

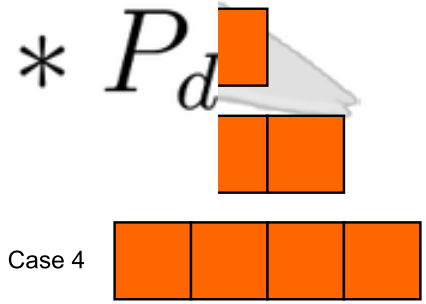
- To send a wakeup we send a 1 byte SFD
- With 3 bytes of preamble to bias filters
- Digital circuitry has a compare on a shift register. Will raise a signal when SFD is detected
- Total transmit time – 16ms

Simple transceiver design

- We need multiple receivers to get coverage on more than one side.
- But we don't have the power to keep them all active.
- Duty cycle, repeated transmissions
- Increases delay

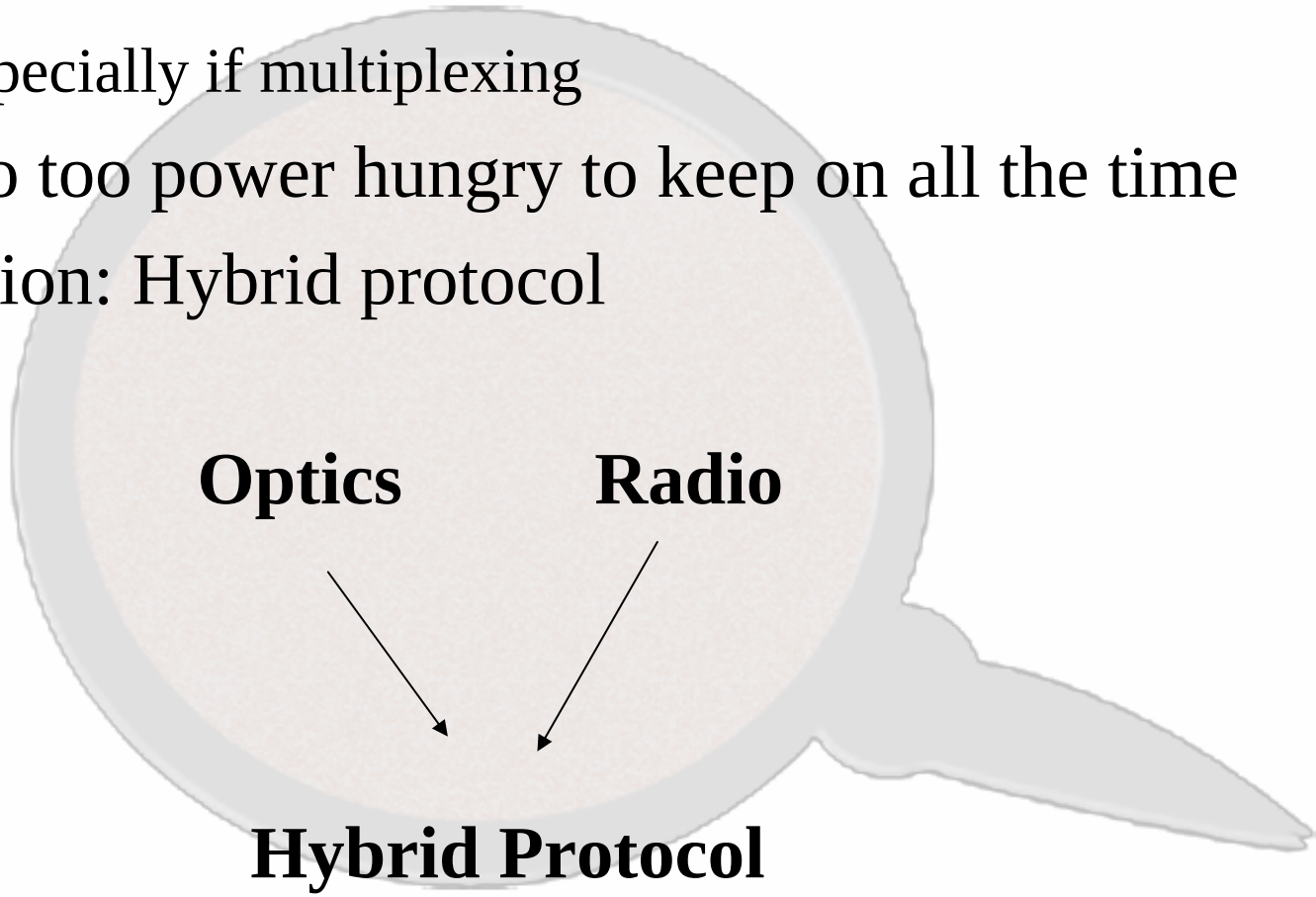


$$L_{avg} = \frac{(\sum_{n=1}^{T_{repeats}} n)}{T_{repeats}} * P_d$$



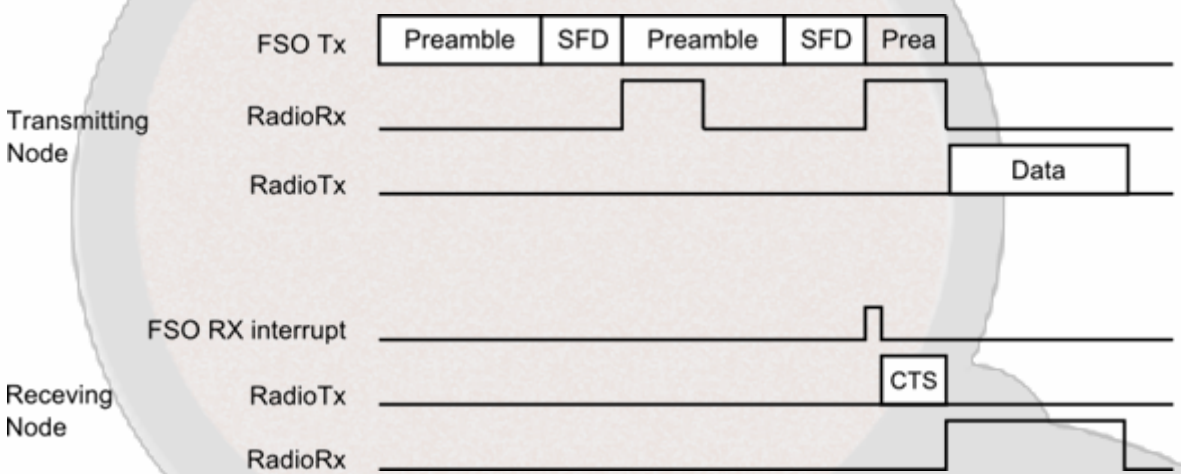
MAC protocol

- Optics too slow to send data
  - Especially if multiplexing
- Radio too power hungry to keep on all the time
- Solution: Hybrid protocol



MAC protocol

- To transmit larger data:
  - Use FSO to signal
  - Use radio to transmit data



- No need to keep radio in RX
- Adds only constant time to our latency

MAC protocol

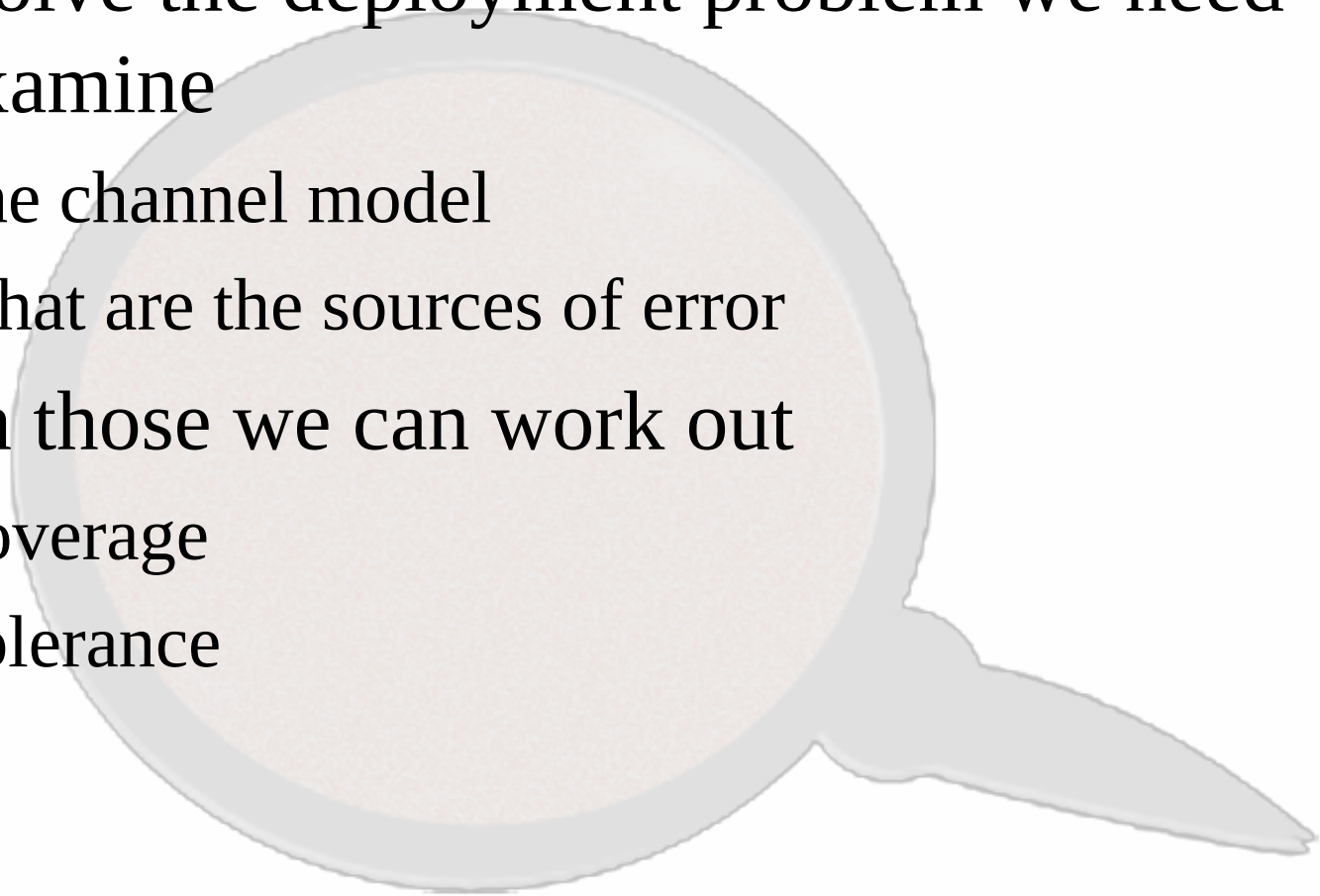
- Transmit a 20 byte packet across 4 nodes, each with 2 transecivers.
- SpeckMAC time
  - 1.4s
- OptiMAC (Optics only)
  - 1.144s
- OptiMAC-data (Optics and radio)
  - 142.35ms

Deployment

- First question that pops into people mind when you mention FSO
  - "Don't you need Line of Sight (LOS), doesn't that restrict you?"
- Short answer "Yes"
- Long answer "Yes, but…."
  - Not trying to hit a 1cm2 detector with a laser pointer
  - Not just aligning so that they point at each other

Deployment

- To solve the deployment problem we need to examine
  - The channel model
  - What are the sources of error
- With those we can work out
  - Coverage
  - Tolerance

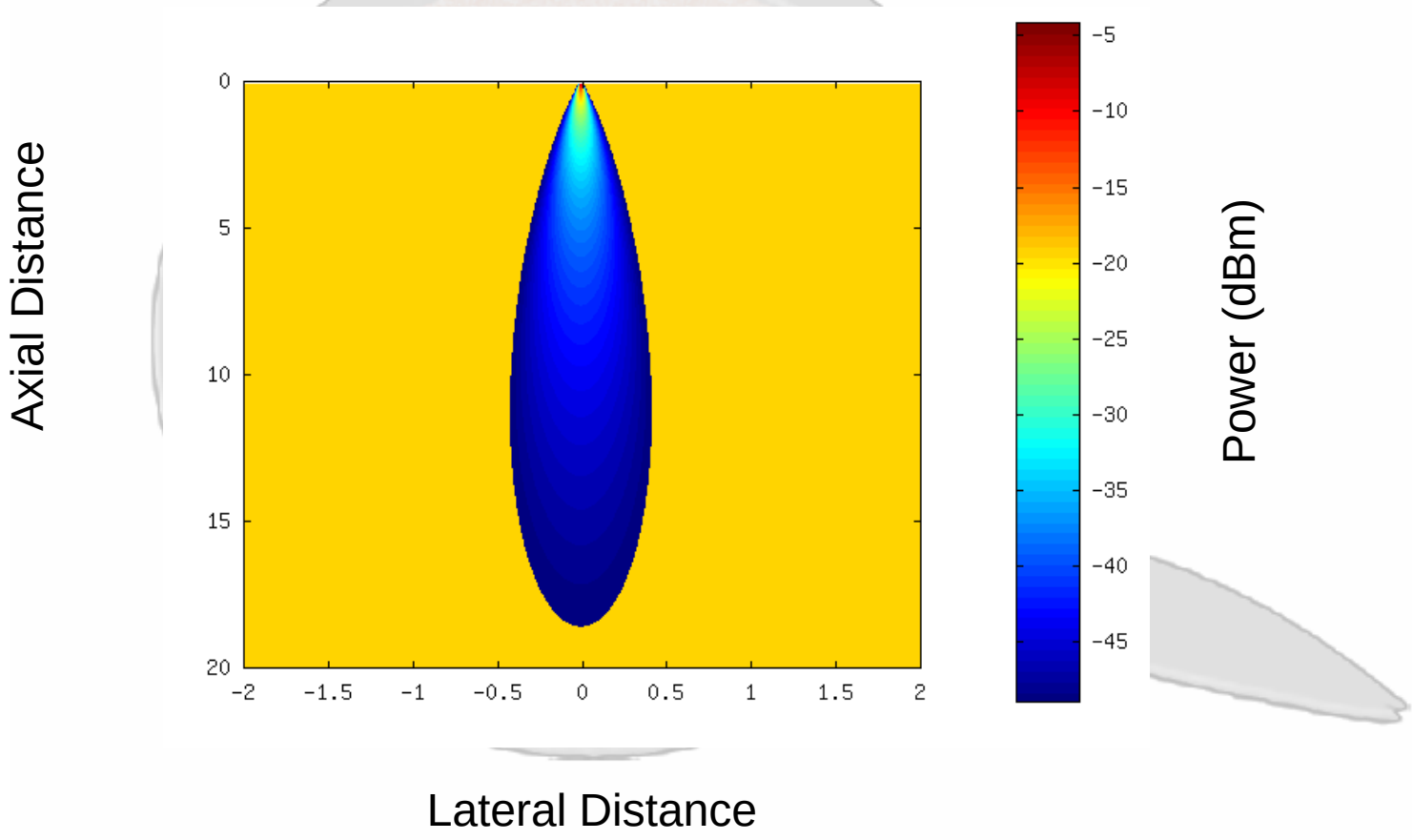


Deployment

- When a detector is placed pointing at a transmitter there are 3 parameters
  - Axial offset
  - Lateral offset
  - Detector rotation

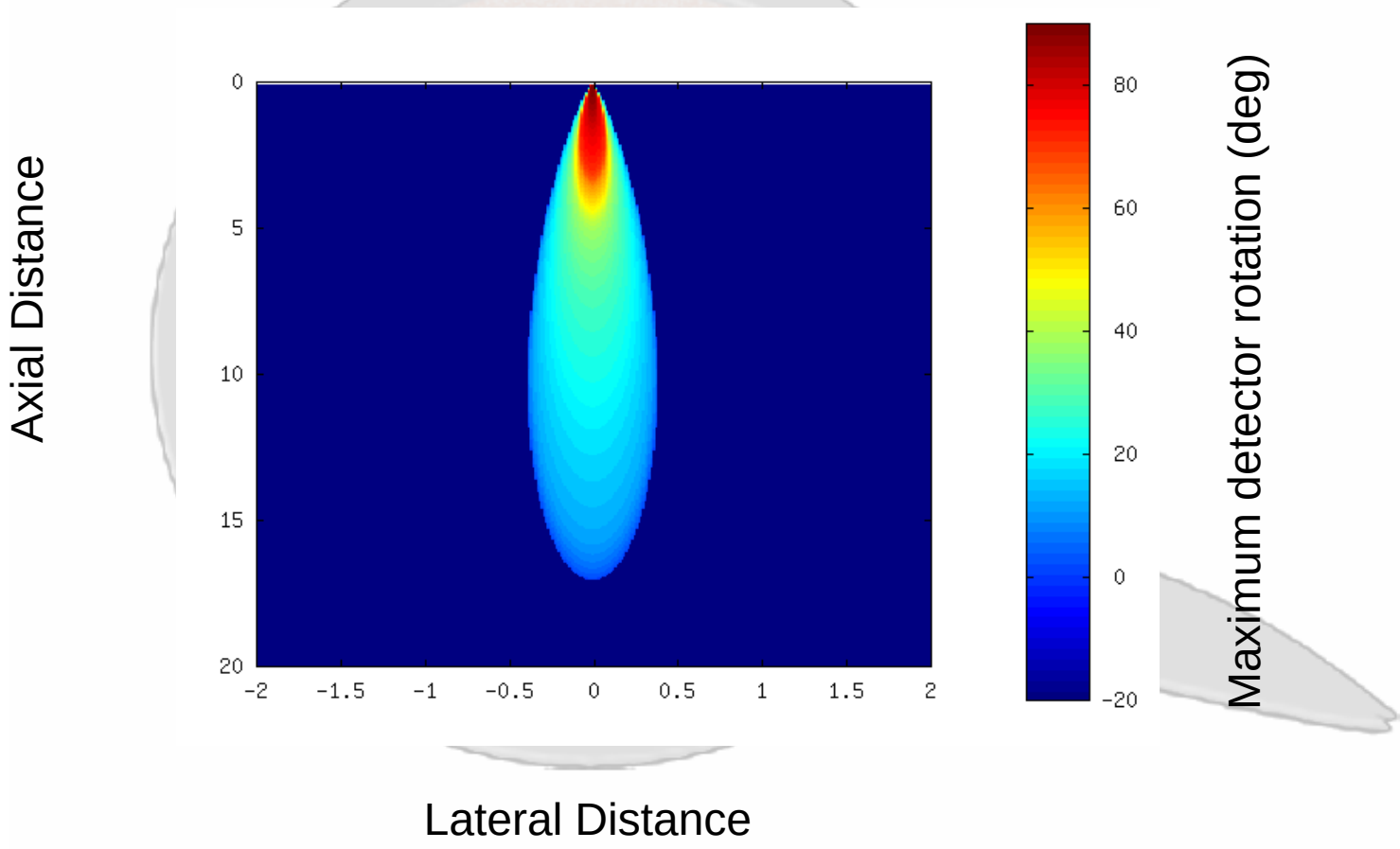
Deployment

Power distribution 1.5mW laser with 3 degree divergence



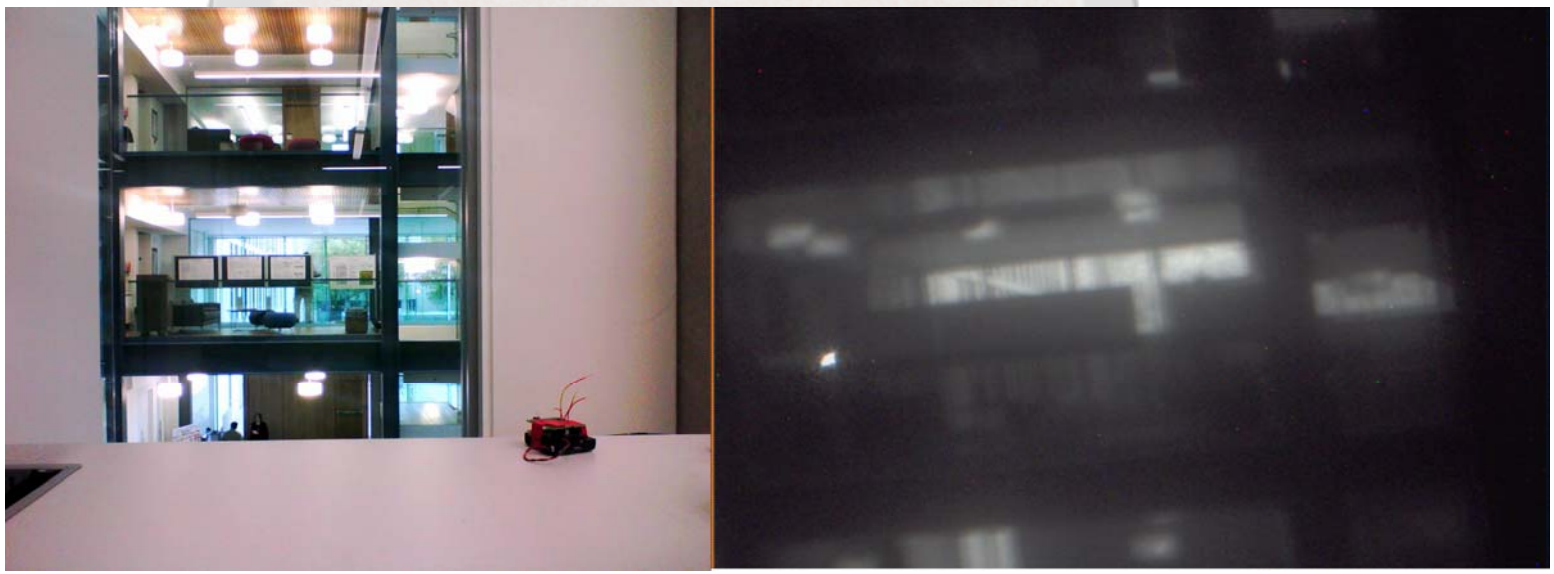
Deployment

Rotational tolerance 1.5mW laser with 3 degree divergence



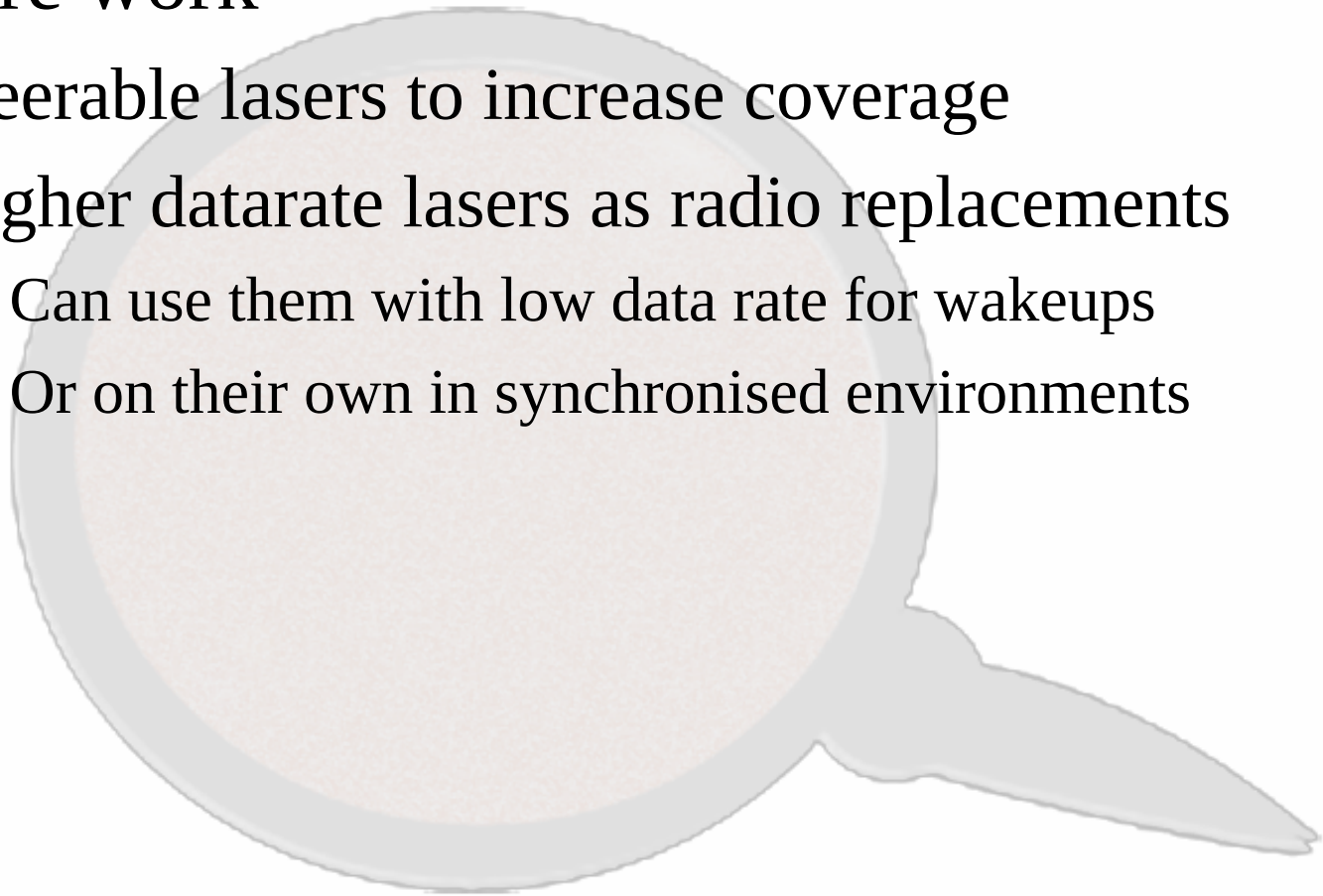
Deployment

- Sources of error
  - Misalignment of nodes
- Quantify?
  - Deployment tests



Free Space Optics

- Future work
  - Steerable lasers to increase coverage
  - Higher datarate lasers as radio replacements
    - Can use them with low data rate for wakeups
    - Or on their own in synchronised environments



Description of the demo

- Two simulated networks
- Connected by real network.
- Messages pass between each other through a small deployment of real nodes.