# Comprehensive Structural Health Monitoring of Wind Energy Infrastrastructure Using Wireless Sensor Networks

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# About Me

- First year PhD student
- Undergrad at ISU - Computer Engineering and Performing Arts
- Worked last two years at Epic
- Home department: Electrical and Computer Engineering
- Two major professors:
  - Dr. Daji Qiao (ECpE)
  - Dr. Halil Ceylan (CCEE)

# Agenda

# Structural Health Monitoring (SHM)

SHM is what it sounds like

- Using sensors to gather data relevant to the health of a structure
  - Strain
  - Moisture
  - Temperature
  - Vibrations
  - Electrical properties
  - Acoustic emissions
  - You name it
- Analyzing that data to draw useful conclusions
  - Pattern recognition
  - Baseline comparison

# Useful Conclusions

- Remote damage detection
- Helps improve:
  - structure lifetime predictions.
  - maintenance schedules.
  - reliability.
  - designs.
- Lowers costs and improves safety

# Top 5 Wind Energy Claims


## Wind Energy Claims

As the leading insurer of renewable energy projects for over 25 years, we have seen it all. **We have paid over 1,200 claims since 2008 totaling over $200,000,000.** That's more than any other renewable energy insurance provider has paid.

In our continuing effort to define industry standards, we performed a review of the reported 2012 wind farm losses in the U.S. This information has been compiled into the Top 5 components damaged and the Top 5 causes of loss.

Feel free to contact us to learn more about how we can support your wind energy insurance needs.

GCube Insurance Services, Inc.

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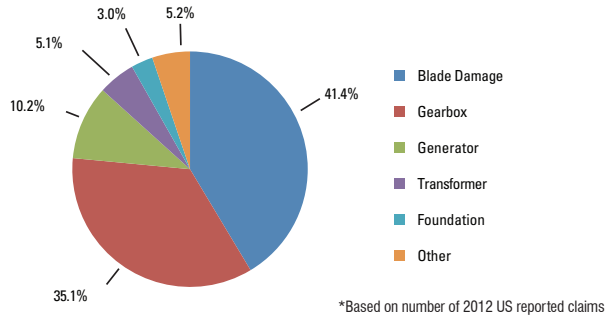
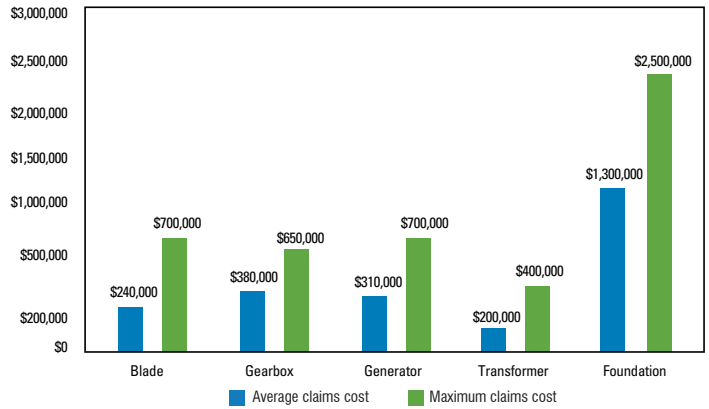
### Most Frequently Reported Component Damage*



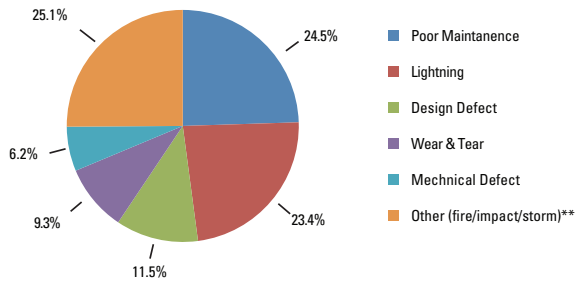

*Based on number of 2012 US reported claims

### Average & Maximum Claims Cost for Component Damage*




*Value of claim includes business interruption and all other related fees and expenses before the insured's deductible is applied

### Most Frequently Reported Cause of Loss/Failure Mode*




*Based on number of 2012 US reported claims
**Although low in frequency, cause of loss due to fire ranks #1 in total indemnity payments

# Applying to Wind Energy

For a wind turbine, "comprehensive" could mean monitoring

- structural soundness and/or stresses.
  - Concrete foundation
  - Composite blades
  - Steel tower
- component health.
  - Gearbox
  - Generator
  - Electrical
- efficiency.
  - Blade surface damage
  - Conversion system
- environmental conditions.
  - Wind speed
  - Temperature
  - Humidity

# Takeaways

- Lots of pieces
- Varying materials
- Varying scope
- Varying maturity of technologies
- Heterogeneous system $\rightarrow$ heterogeneous solution?

# Wireless Sensor Networks (WSNs)

WSNs are also what they sound like

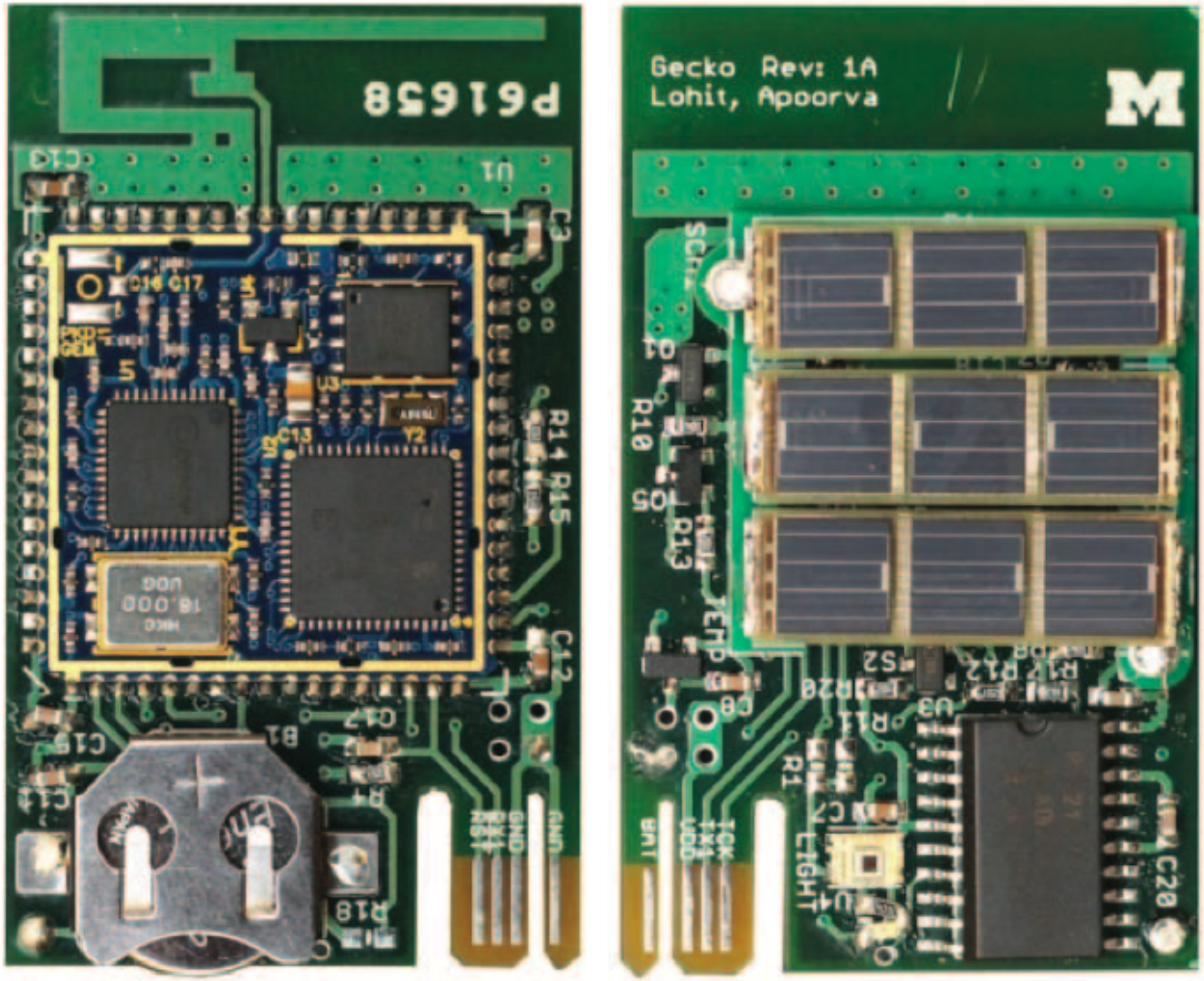
- Network of sensor nodes (motes)
- Communicate wirelessly
- Generally relay data to central location

# Sensor Nodes

Network building blocks, consisting of:

- Sensor
- Controller
- Wireless communication unit
- Timer
- Power source
- Software

# Gecko WSN node (Yerva et al., 2011)



# Operation

1. Sensor gathers data
2. Controller processes data
3. Node relays data

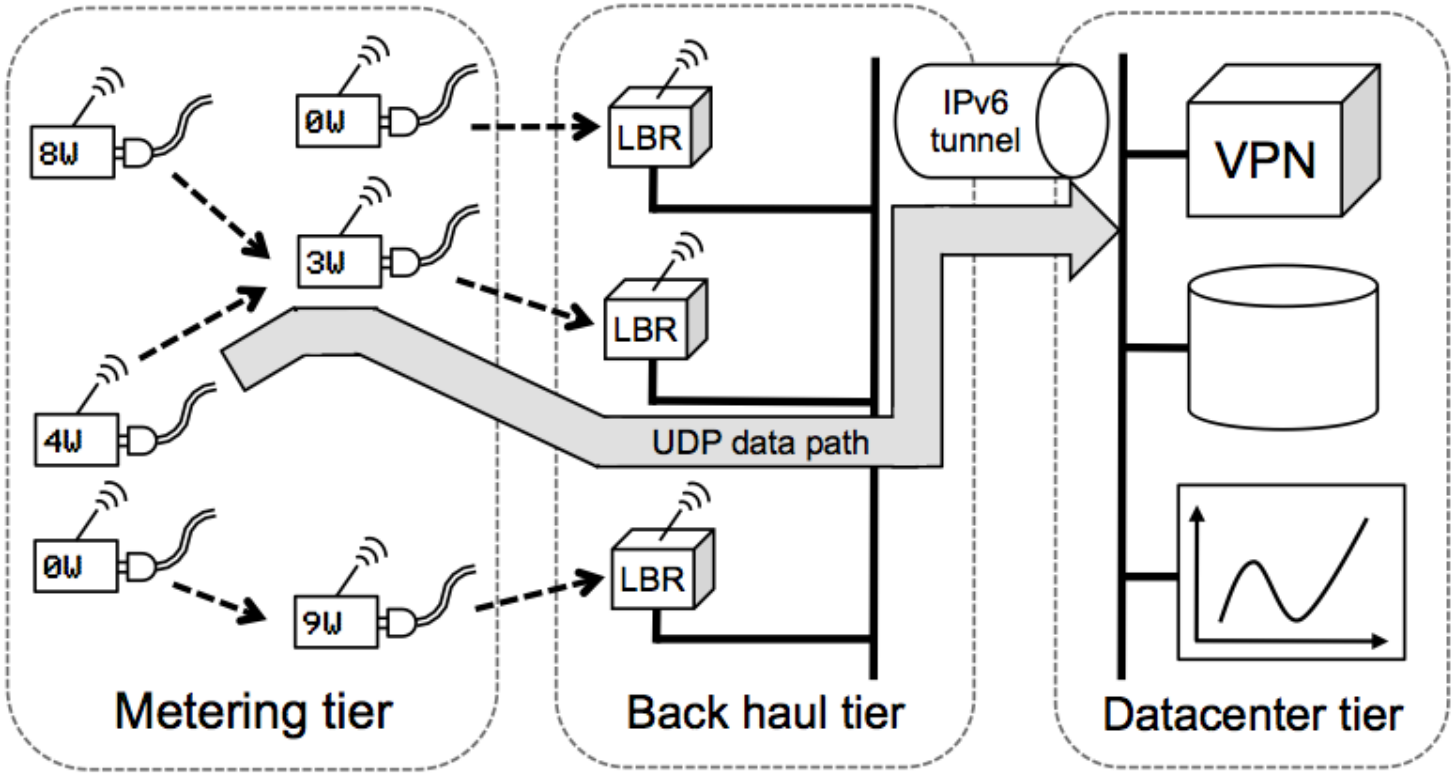


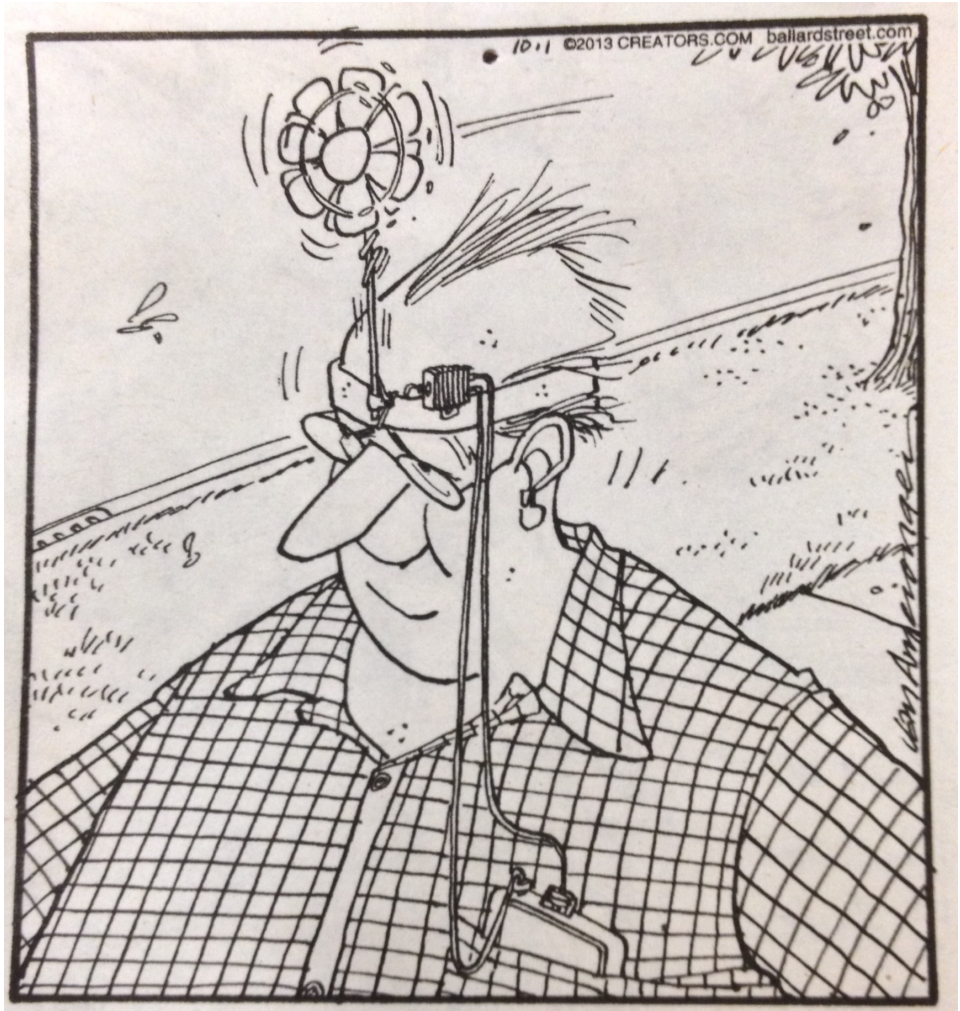

Figure: Sample WSN architecture (Dawson-Haggerty et al., 2012)

# Power Source

WSNs are often energy-constrained, depending on power source:

- Grid - not wireless
- Battery - must be changed or charged
- Harvesting - most constraining
  - Solar
  - Vibrations
  - Thermal
  - Air current

# Harvesting example (Amerongen, 2013)



# Wireless Communication

WSN communication protocols are a hot research topic

- Network architecture
  - Routing or flooding?
  - Multihop?
  - Predetermined or dynamic?
- Timing/duty cycling

# Duty Cycling

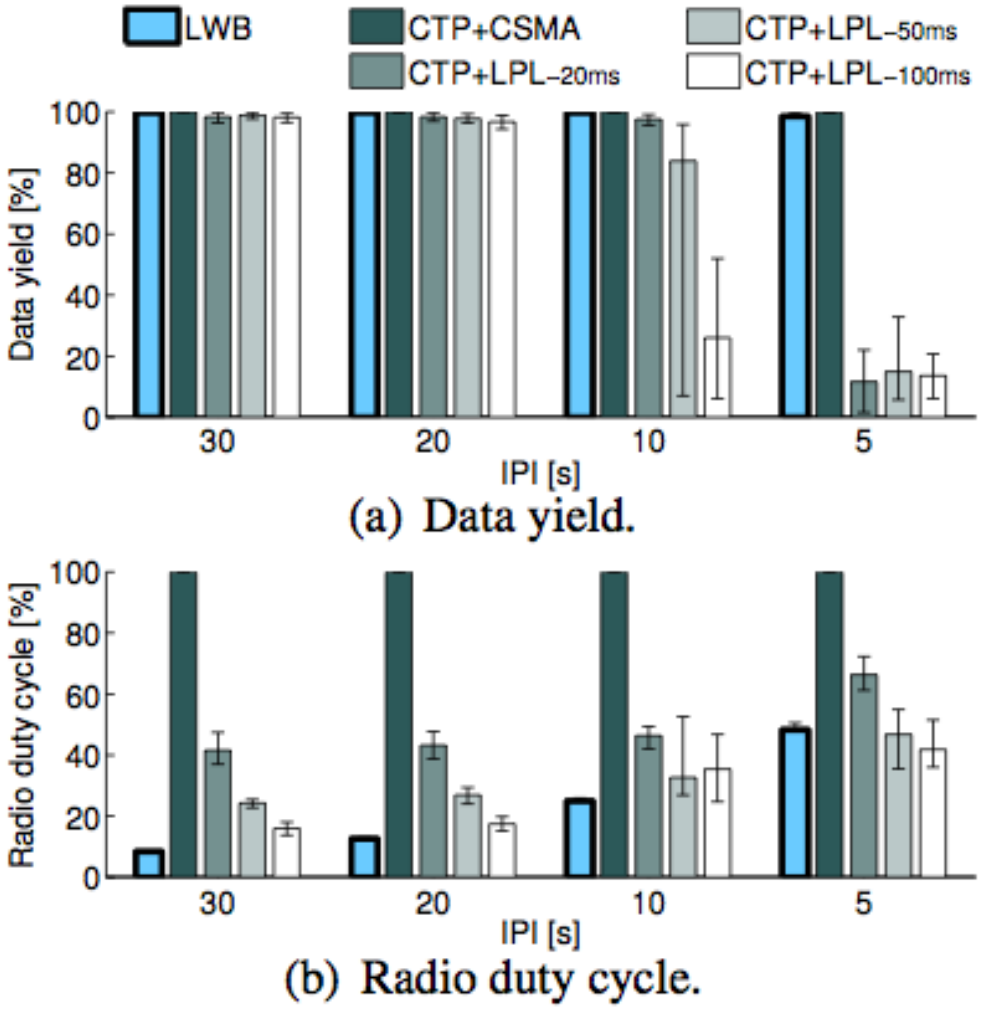



Figure: Duty cycling as a measure of efficiency (Ferrari et al, 2012)

# Applying to Wind Energy

- System of systems approach
- Heterogenous systems, again
- Energy constraints
- Size/placement constraints
- Durability/longevity

Figure: Instrumented blade ready for loading (Sundaresan, 2002)

# Takeaways

- Not your mama's WiFi
- Tough constraints
- Developing technologies

# Agenda

# Methodology

- Literature/Industry Review
  - Damage detection technologies
  - Wind energy needs
  - Potential for WSN
- Design
- Prototype
- Test (iCUBE Sensors Application Laboratory)

# Agenda

# Current Status

- Literature/Industry review
- Project refinement
- Share with me!

# Questions?

I have significant hearing loss, so I apologize in advance if I ask you to repeat yourself!