WiBeaM : Design and Implementation of Wireless Bearing Monitoring System

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29th June 2006

Outline

Wireless Sensor Networks

A collection of sensor nodes that are deployed to perform a specific action.

Characterestics/Challenges of WSN

- Small Processing power.
- Limited Memory.
- Radio to transmit /Recieve data.
- Ability to run on batteries.

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Condition Based Maintenance

To Monitor and assess the health of an equipment

Common Parameters Measured

- temperature
- vibration
- various other machine specific parameters

WiBeaM

Bearing Monitoring

WiBeaM

Thesis Definition

Develop a cheap and reliable sensor network application to monitor the bearing vibration of induction motors in a ship

Thesis Goals

- Find a suitable vibration sensor
- Form a network of sensor nodes
- Ensure reliable transfer of data
- Storage of measured readings on the node
- Conserve the battery power
- Process the measured signal and capture relevant vibration data

Background

Defects in Ball Bearings

- Outer race defect
- Inner race defect
- Ball defect

Bearing Anatomy

Existing Methods

Manual Methods

Automatic/semi-automatic Methods

- Shock Pulse Measurement
- Vibration measurement
- Stator Transient current analysis

Drawbacks of Manual Methods

- Large number of machinery
- Hidden costs
  - More man hours expended
  - No lead time
  - Book keeping
  - Costly Hand held scopes

Proposed Solution

- Develop a network of Wireless Sensor Nodes
- Should measure the vibrations automatically

Theory of Bearing Measurement

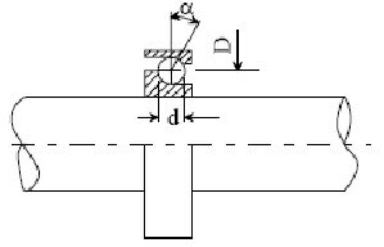
Outer,inner and ball race defects

$$\left[F_{ord} = \left\{ \frac{N \cdot RPM}{2} \right\} \times \left\{ 1 - \left(\frac{d_{ball}}{D_{pitch}} \right) \times cos\alpha \right\} \right]$$

$$\left[F_{ird} = \left\{ \frac{N \cdot RPM}{2} \right\} \times \left\{ 1 + \left(\frac{d_{ball}}{D_{pitch}} \right) \times cos\alpha \right\} \right]$$

$$\left[F_{ball} = \left\{ \frac{RPM}{2} \right\} \times \left\{ \left(\frac{D_{pitch}}{d_{ball}} \right) - \left(\frac{d_{ball}}{D_{pitch}} \right) \times (cos\alpha)^2 \right\} \right]$$

Bearing Geometry



Related Work

Structural Monitoring

Monitor Structures

Habitat Monitoring

Great Duck Island

CodeBlue

Application for hospital care

North-sea Deployment

Similar to what we have done

BriMon

Bridge Monitoring System for railway bridges

Comparison Table

	Habitat Monitoring	*WISDEN*	*North Sea Deployment*	*BriMon*	*CODEBLUE*	**WiBeam**
Deployment	Long Term	Short Term	Long Term	Long Term	Long Term	Long Term
Hardware	Mica2	Mica2 MicaZ	MicaZ	Tmotes Telos	Mica2,MicaZ	Tmotes
System Replaced	manual	wired	Expensive wireless	manual	Medical Electronics	manual
Architecture	Tiered	Flat	Tiered	Tiered	Tiered	Tiered
Sensor	Temp erature Pressure	accelero meter	accelero meter	acclero meter MEMS	Pulse oximeter EKG	accelero meter MEMS
Compression	YES	YES	NO	NO	NO	NO

Design Overview

Operaton Cycle of Motors

- Important - Fire fighting system, AC Plant , Ref plant etc.
- Less Important - Cooling motors, Fuel supply motors for Engines
- Unimportant - Ventilation, Sewage Motors

Duty Cycle

- Motors are run in a cycle of 6 hours on/off in a day
- Nodes may wakeup once in every four hours and check for activity
- One measurement in a day is sufficient
- Latency upto one day is acceptable

Design Overview

Comparison between various Accelerometers

	Power	Range	Freq Band	Sensitivity	Noise	Cost
ADXL105 MEMS	$2-5V$	$\pm 5g$	$0-12Khz$	$225-275mv/g$	$225mg$	$14USD$
CXL04 XBow	$\pm 5V$	$\pm 4g$	$0-100Hz$	$500mv/g$	$10mg$	$185USD$
SKF CMSS786A	$18-30V$	$\pm 80g$	$0.5-14Khz$	$95-105mv/g$	$20mg$	$120USD$
CMCP-1100	$8-12V$	$\pm 50g$	$0.3-10Khz$	$100mv/g$	$4-8ug$	$130USD$
Wilcoxon 786A	$18-30V$	80g	30Khz	$100mv/g$	not specified	185USD

Hardware Selection

Comparison between various Sensor Nodes

Model	Radio	Data Rates	RAM	Processor	I/OInterface
Tmote Sky	2.4Ghz	250kbps	10KB	msp430	10 Pin
Intel	Bluetooth	750kbps	64KB	ARM7TDMI	USB-slave mode
Mica2	916MHZ	38.4kbps	4KB	Atmega128	51-pin
Micaz	2.4Ghz	250kbps	4KB	Atmega128	51-pin

Design Overview

Operating System

TinyOS

- Component based operating system
- Developed by U/C at Berkeley
- Has lot of sample applications and code
- Freely downloadable

Design Overview

Software design

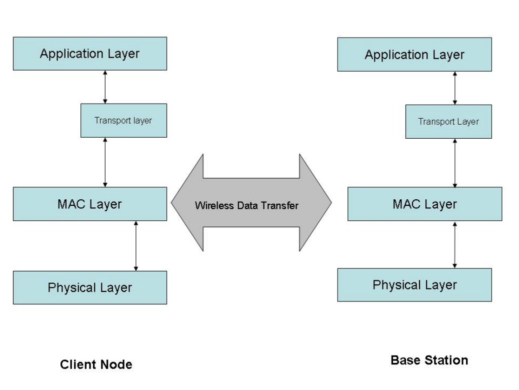
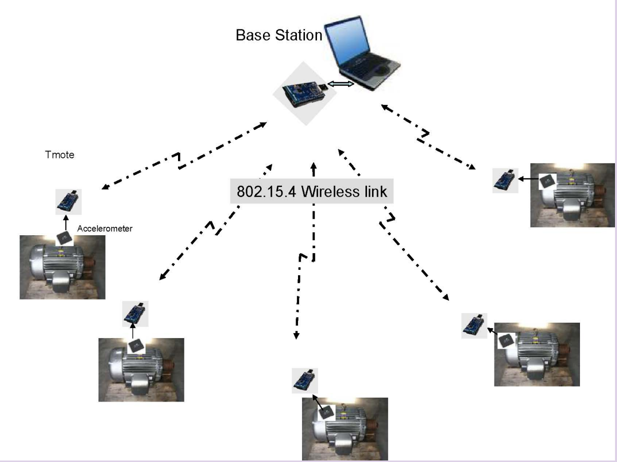


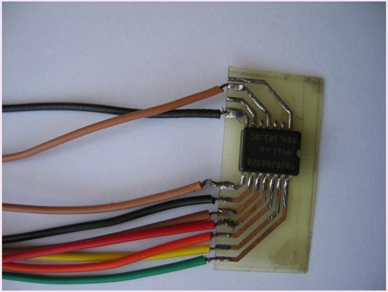
Figure: Layered design

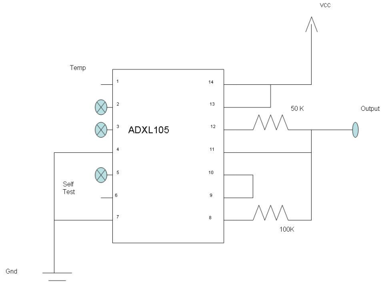
Design Overview

Overall System design

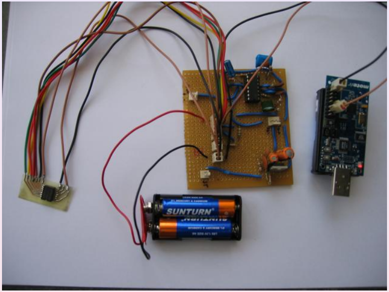


Hardware Implementation



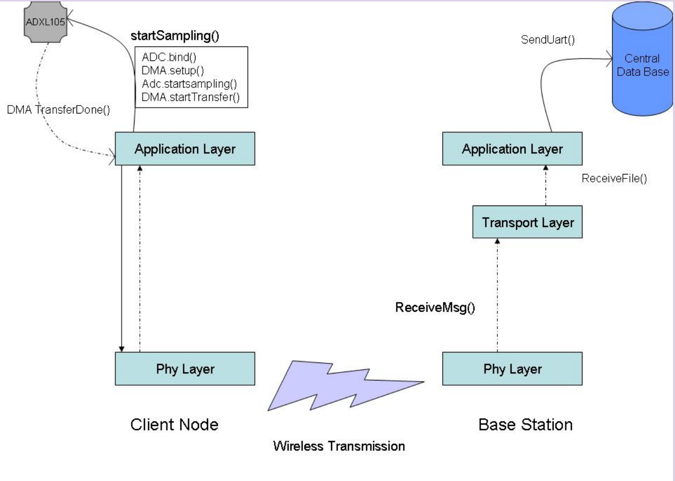


Implementation Details

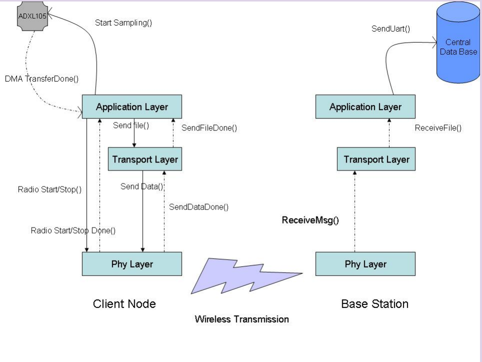


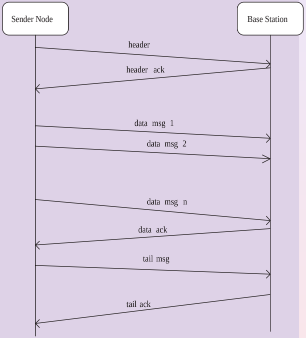
Implementation Details

Data Measurement

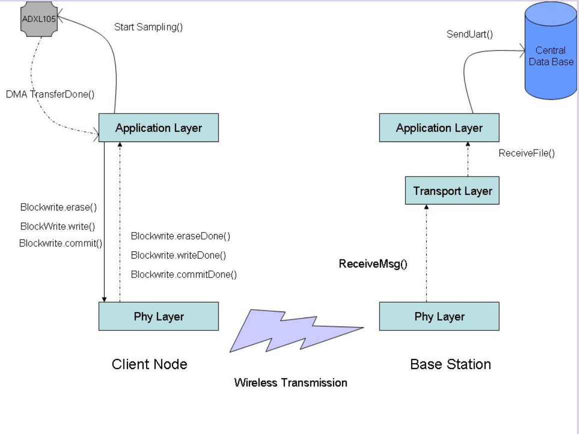


Reliable Data Transfer

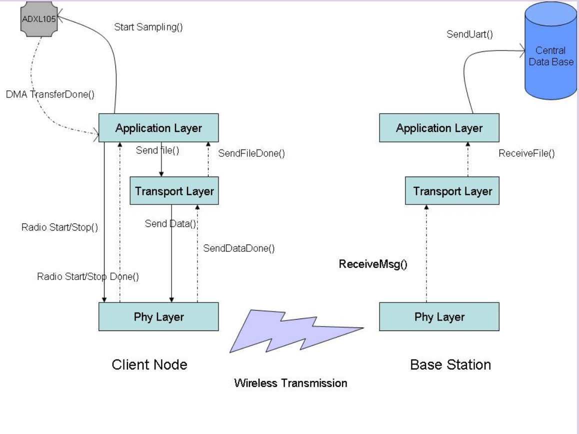




Flash Storage

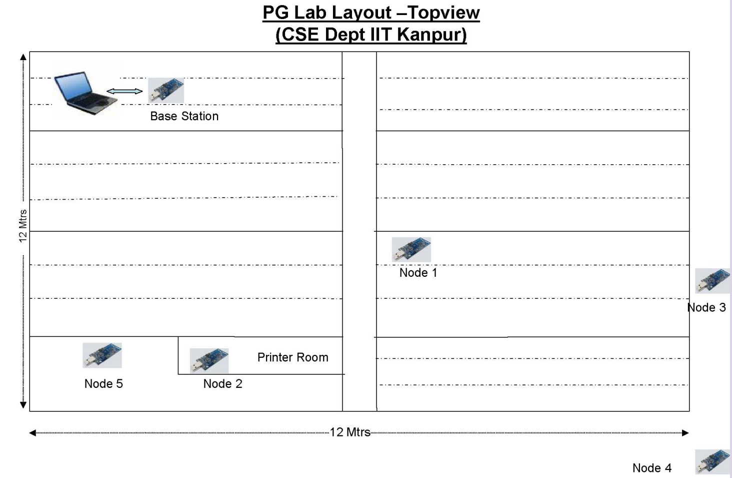


Power Consumption



Performance Analysis

Singlehop Vs Multihop



CC2420 Transmit Power Vs Power Consumption

TinyOS Power Value	Transmit Power(dBm)	Current Consumption(mA)
31	0	17.4
27	-1	16.5
23	-3	15.2
19	-5	13.9
15	-7	12.5
11	-10	11.2
7	-15	9.9
3	-25	8.5

Table: Source - CC2420 Datasheet

Powers After running Power Negotiation Algorithm

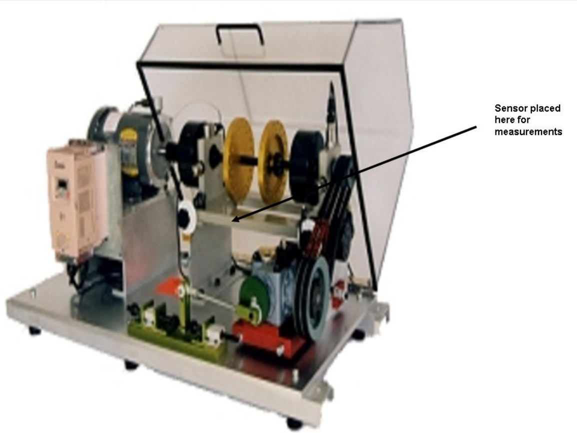
Node ID	Transmit Power(dBm)
1	-25
2	-9
3	-12
4	-18
5	0

Data Transfer with 4 nodes

Delay(msec)	Throughput(kbps)	%Packet Loss(per file)
10	17.5	4
5	23	6
2	32	8
1	35	9

Table: Throughput and Packet loss at various delay intervals

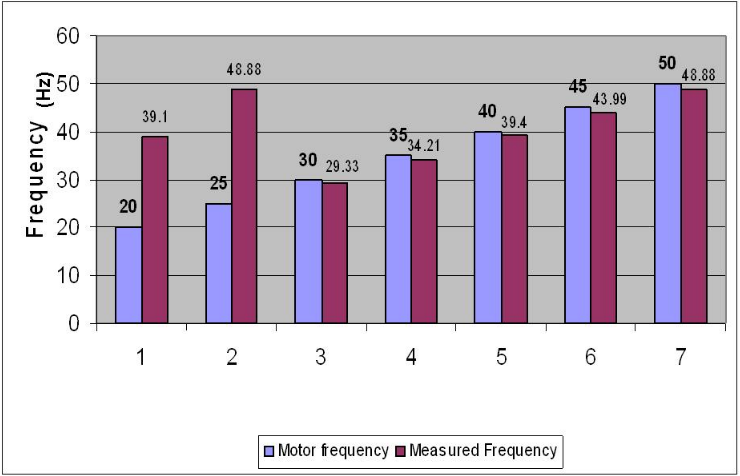
Testbed for Trials



Measurement Settings

- Sampling Frequency = 20KHz
- No of data points measured = 4096
- $\delta F = \frac{1}{(\delta T \times N)}$
- δF is the desired frequency resolution
- δT is the time between two samples(depends on the sampling rate)
- $\delta F = \frac{1}{(50 \times 10^{-6} \times 4096)} = 4.88 Hz$
- No of Frequencies checked = 7
- No of measurements obtained at each frequency = 5

Vibration Measurements



Future Work

- Data Compression
- Packaging
- Industry Trials
- Site Survey
- Security
- Low power operation (switch off Microcontroller)
- User Interface

Conclusion

- Wireless solutions are ideal to ships environment
- Extendable to other equipment like Engines and Generators etc

Questions ?

Please ask, it may improve the standard of my work