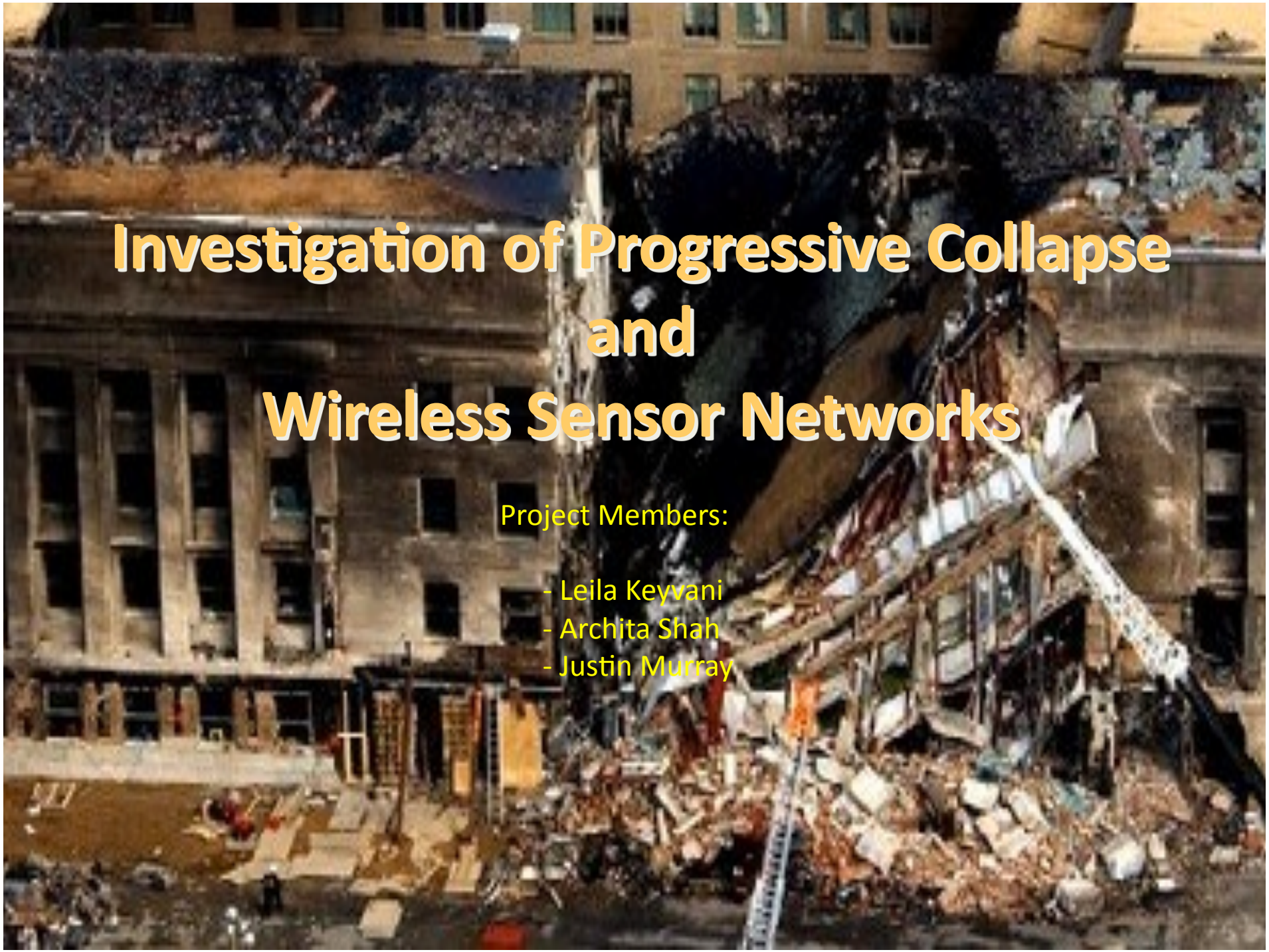


Investigation of Progressive Collapse and Wireless Sensor Networks

Project Members:

- Leila Keyvani
- Archita Shah
- Justin Murray

Outline

- Introduction
- Why Progressive Collapse
- National Educational Competition on P.C.
- Ideal Project Characteristics
- Protocol: ZigBee
- Technical Limitations
- Possible Architectures
- Project Characteristics
- Testing with ZigBee
- Conclusion
- Future Enhancements

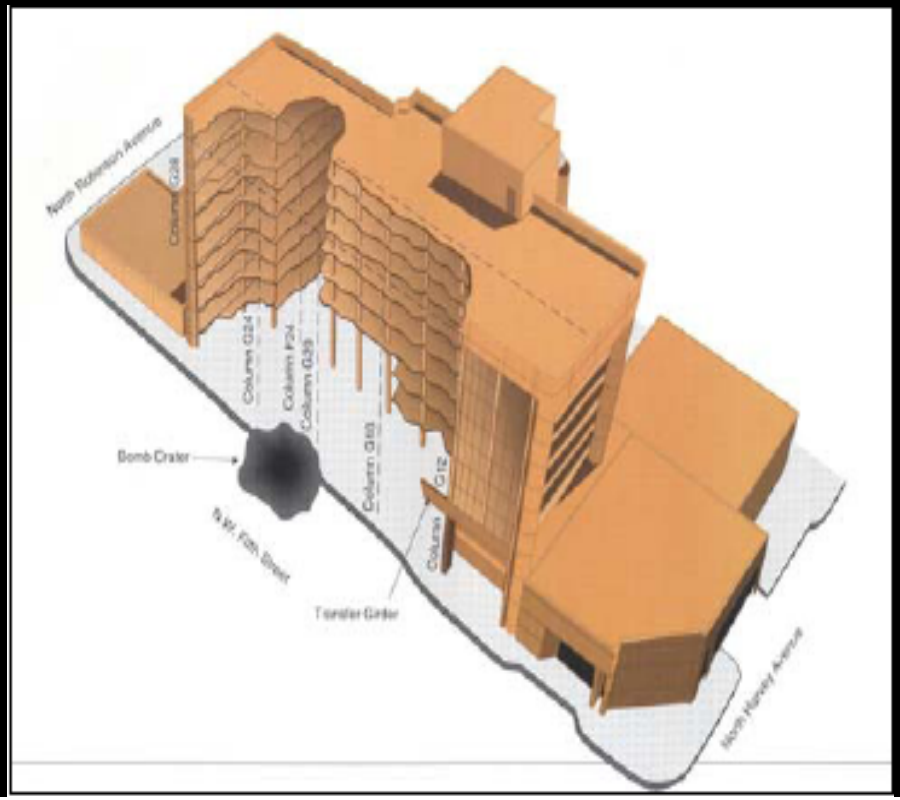
Collapse

s following damage to
tion of a structure

First sample of progressive collapse in London1968

Samples of Progressive Collapse

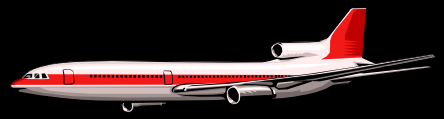
- Alfred P.Murrah Building
- Oklahoma city
- Explosion of a truck in front of the building



What type of loads initiates Progressive collapse?

Man-made hazards

Natural hazards
Earthquake ، wind, …



impact

Investigation of Potential for Progressive Collapse

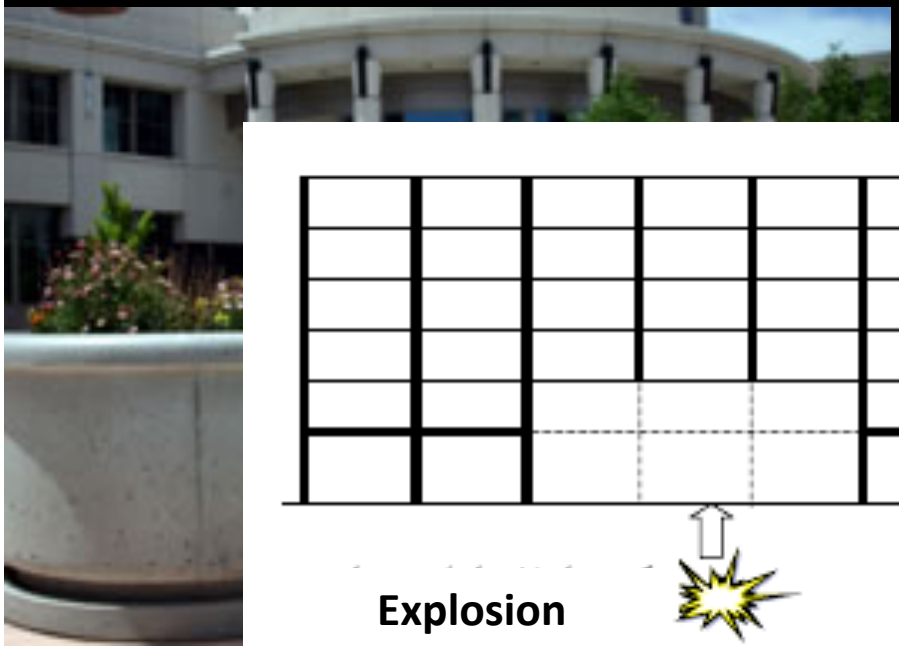
Site Investigation

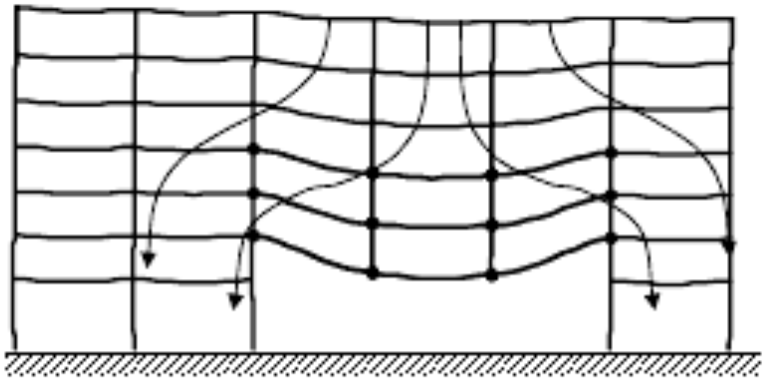
Structural Investigation

Explosion, Impact,...

Investigation of the stability of Structures after damage

Alternate Load Path Method





National Educational Competition on Predicting progressive collapse resistance of structural systems (2007)

(www.pcrc2007.neu.edu)

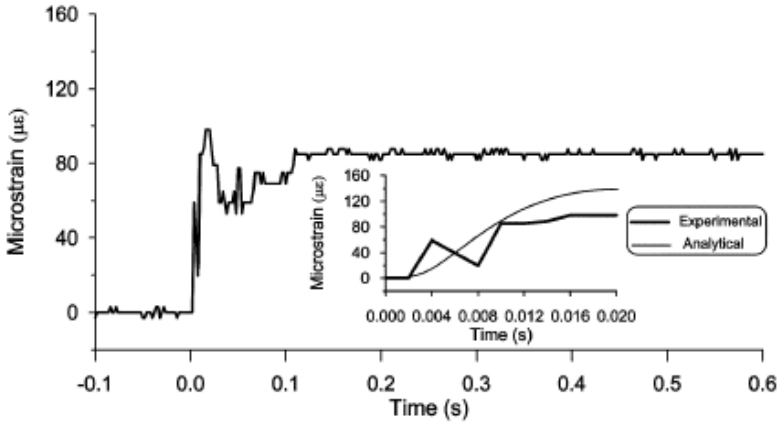
Discovery Channel Segment on Progressive Collapse

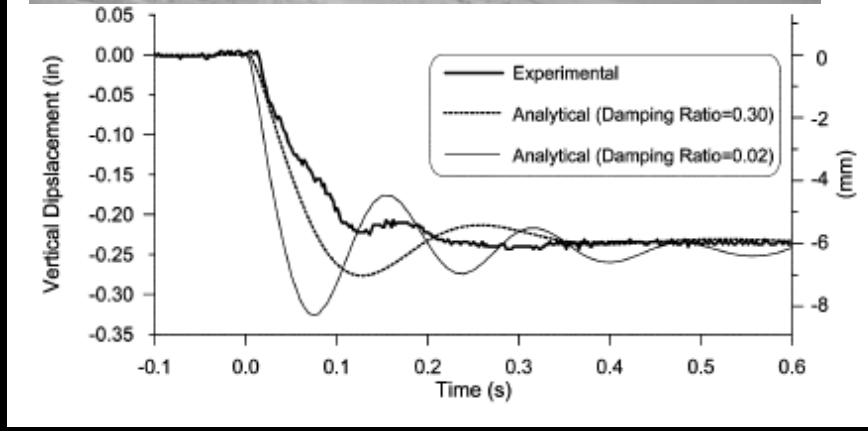
http://www.pcrc2007.neu.edu/discoverybranch.php

Experimentally and Analytically

University of Arkansas Medical Center dormitory by Sasani, Bazan, and Sagiroglu

- Sensors are deployed In buildings for experimental data collection.
- Analytical models are verified with experimental data
- Verified analytical models are evaluated for further understanding of behavior

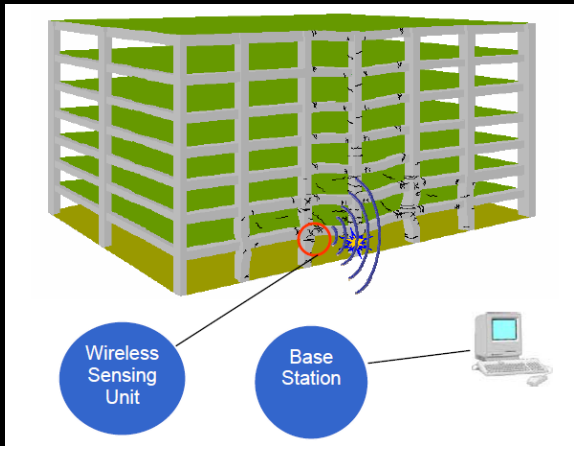




Experimental data acquisition system

- Wired systems :
  1. Cumbersome in installation for large scaled building
  2. Cost of maintenance of wired systems
  3. Damages in buildings could lead to loss of data!
- Wireless systems:
  1. Addresses problems with wired systems specially cost and installation
  2. Can handle large number of sensing units
  3. Main objective: to be installed in important buildings

  as a real time data acquisition system for predicting the possible collapse



Ideal Project Characteristics

- Wireless, self-powered sensor network
- Capable of remaining dormant on battery power for years
- Low cost (due to high number of sensors and possible damage to them)
- Large number of sensors throughout a structure
- High data rate, in the range of 1 kHz per sensor
- Capable of monitoring various building characteristics in real time
- Data can be used to predict/warn of progressive collapse
- Commercially viable to be used in all large-scale structures around the world
- Information can be read and interpreted remotely at long distances
- This would be considered an “Alert System” or the Phase 3 for our uses of this technology.

Possible Architectures

- Small-scale experimentation (Phase 1)
- Mid-scale experimentation (Phase 2)
- Large scale alert/monitoring system (Phase 3)

Phase 1

- In-building experiment with small amount of induced damage
- Small number of sensors concentrated around the damage site
- Very high sampling rate for detailed analysis

Phase 2

- In-building experiment with larger amount of damage than in phase 1
- Capable of causing significant changes within the structure
- Data needs to transmit out of the building, as after the test, it may be unsafe to enter
- High data rate with small number of sensors in various areas of the building.

Phase 3

- Large-scale monitoring system, for use during a catastrophic event
- Large number of sensors monitoring all structural components of the system
- Lower sample rate needed to accommodate high traffic on each channel
- Wi-fi or Ethernet backbone needed to handle high amount of data
- Data can be interpreted remotely from across the country or globe

Protocol: ZigBee

- ZigBee is a specification for a suite of high level communication protocols using small, low-power digital radios based on the IEEE 802.15.4-2003 standard for Low-Rate Wireless Personal Area Networks (LR-WPANs)

- ZigBee is targeted at radio-frequency(RF) applications that require a low data rate, long battery life, and secure networking

ZigBee Characteristics

- Low-cost
- Low-power consumption
- Capable for multi hop
- Maximum data rates allowed are: 250 kbps@2.4 GHz, 40kbps@915MHz, 20kbps@868MHz
- Intended for use in embedded applications
- Fully reliable “hand-shaked” data transfer protocol
- Frequency: 2.4GHz ,915MHz and 868MHz
- Channels: 16 channels@2.4 GHz, 10 channels@915MHz, 1 channel@868MHz
- Multiple topologies: star, peer-to-peer, mesh

Effectiveness of ZigBee

- ZigBee channels are capable of supporting the data rates necessary for the "Phase 1" and "Phase 2" uses of this sensor system
- Reliable transmission rates and accuracy
- Effective over short-to-medium distances (around 50 m)
- Distance requirements in Phase 1 and Phase 2 are generally short
- Several useful channels that do not interfere with Wi-fi
- Low power consumption (long battery life)

ZigBee Shortcomings

- Cannot handle long distance transmission
- Small amount of internal data storage (possible overwritten data)
- Cannot transmit through various obstacles, particularly concrete floors
- Cannot provide data rates high enough for use in “Phase 3” system
  - Requires some sort of wi-fi or ethernet backbone
- Larger buildings present more problems due to congested channels
- Cannot operate at full speed with other wireless interference present
- Not all channels are useful due to Wi-fi interference and overlapping of frequency bands

In this project …

- focus on the application of wireless networks to facilitate data collection from sensors installed in buildings under various conditions
- The type of network chosen for this investigation relies on the IEEE ZigBee wireless protocol
- use available features of hardware components for a complete and reliable system
- Multiple sender and receiver nodes would be handled with appropriate sensors attached
- Running the system on batteries to simulate the field experimental condition
- High rate of sampling per sensor (1KHz) almost in the range of channel capacity
- Considering transmission in the range of 100 feet
- Using available hardware from TI for communication

Communication Characteristics in Our Project

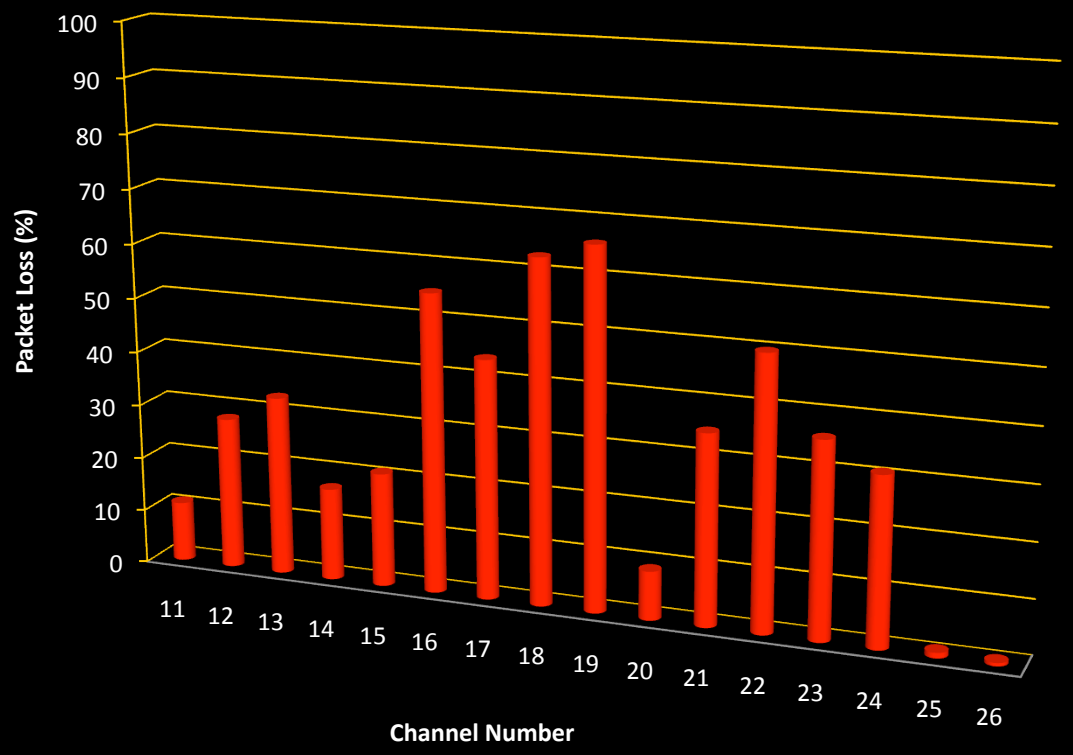
- All ZigBee communication is single-hop
  - Multi-hop system would reduce data rate considerably
- Retransmission: reduces packet loss, limited to 3 retransmissions to get real-time data
- Acknowledgement: verifies that the packet is received before sending next packet

Equipments and Features Used

1. CC2530 from TI : a “System-on-Chip”
   - ZigBee transmitter/receiver
   - eight channel ADC
   - 32MHz XOSC system clocks
   - Timer1 Channel 0
   - DMA
2. Interfacing with programming software on the PC:
   - Evaluation Board (EB) ,Battery board (BB)
3. FT232R Breakout from SparkFun
4. UART
5. Sensor: Potentiometer

Testing with ZigBee

- Evaluation of 16 available channels for 2.4 GHz band in terms of efficiency (Packet loss, Transmission rate)
- No interference (in terms of traffic) with Wi-Fi

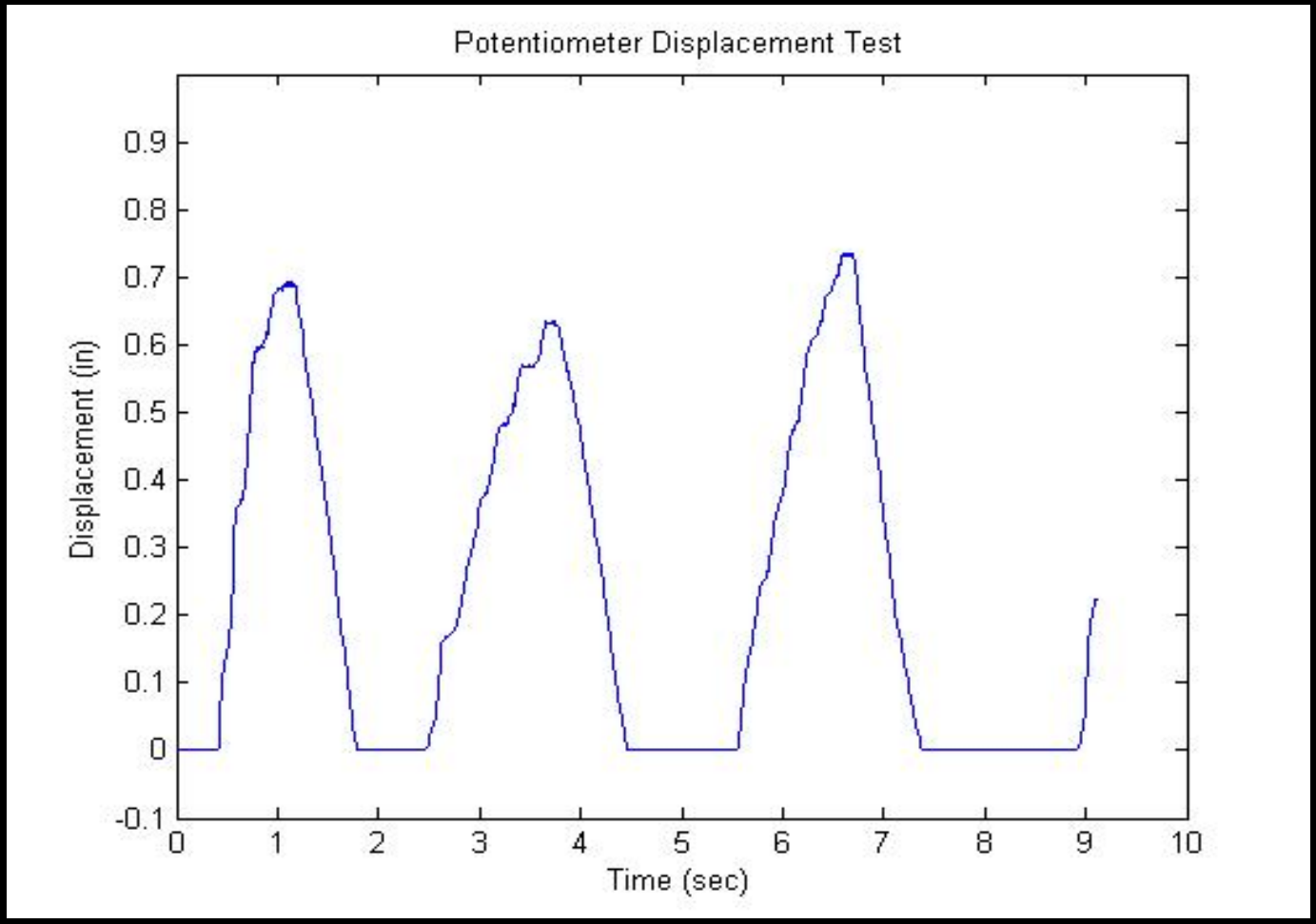


Cont'd….

- Evaluation of combination of two channels:
  1. Two close channels [25&26] : Caused overlapping problem, 50% packet loss for both
  2. Two far away channels [26&20]: No overlap, 66% packet loss in channel 20, 5% packet loss for channel 26

- Used Booster antenna with channel 26:
  - Drop in packet loss rate from 10% to 1% at the same position
  - No transmission w/o at some particular positions

Test results for Potentiometer



Project Schedule

- Investigate the potential for using ZigBee wireless devices in conjunction with sensors to monitor structural behavior in a matter of seconds
  - Configuration of ADC for one analog and single-ended input
  - Receiver code to receive and send over UART
  - Serial reader program at the base PC
  - Evaluation of reliability of received data
  - Increasing the robustness of the sender and receiver code

  Feb.

  - Adjusting sensing time intervals and recording every time step
  - Increasing systems speed in sensing, sending , receiving, and interpreting
  - Using real sensing devices such as potentiometer
  - Increasing systems capacity in sensing data by improving codes and using more sensors
  - Collecting the data from different senders
  - Setting a small-scaled experiment for testing of system in reality
  - Evaluating data based on experiment

  March ½ April
- Use tens of sensors to monitor important data from a structure

  ½ April
- Use advanced knowledge of structural behavior along with the data from the sensors to save lives after a significant catastrophic event

Conclusion

- ZigBee channels can provide the data rates and accuracy needed for structural measurement purposes
- It is suitable for structural analysis purposes because it is low cost and low power
- Due to a limited number of useable channels and range limitations, results are not easily scalable to larger structures
- Wi-Fi or other high-data rate technology would be needed to coordinate large amounts of data in full structure

Future Enhancements

- Synchronizing sender data for analysis purposes
- CCA (CSMA/CA): transmitting data from multiple senders on one receiver
- Using strain gauges with ZigBee
- Using external temperature sensors
- Configuring Wi-Fi/ethernet back bone
- Using USB Hub to manage many receiver nodes on a single PC

Questions???