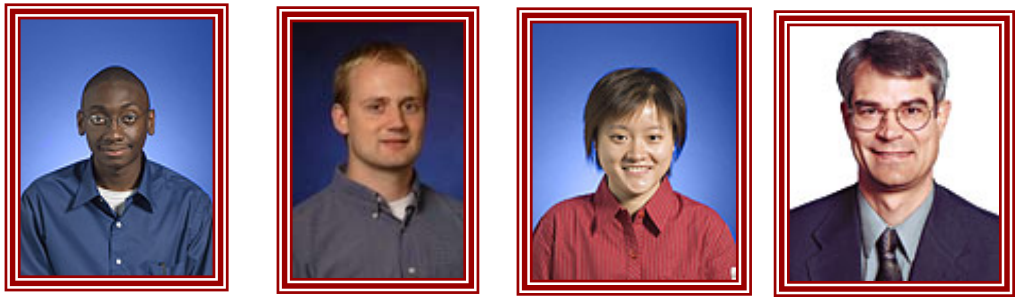
2008 Smart Radio Challenge

Automated Spectrum Mapping



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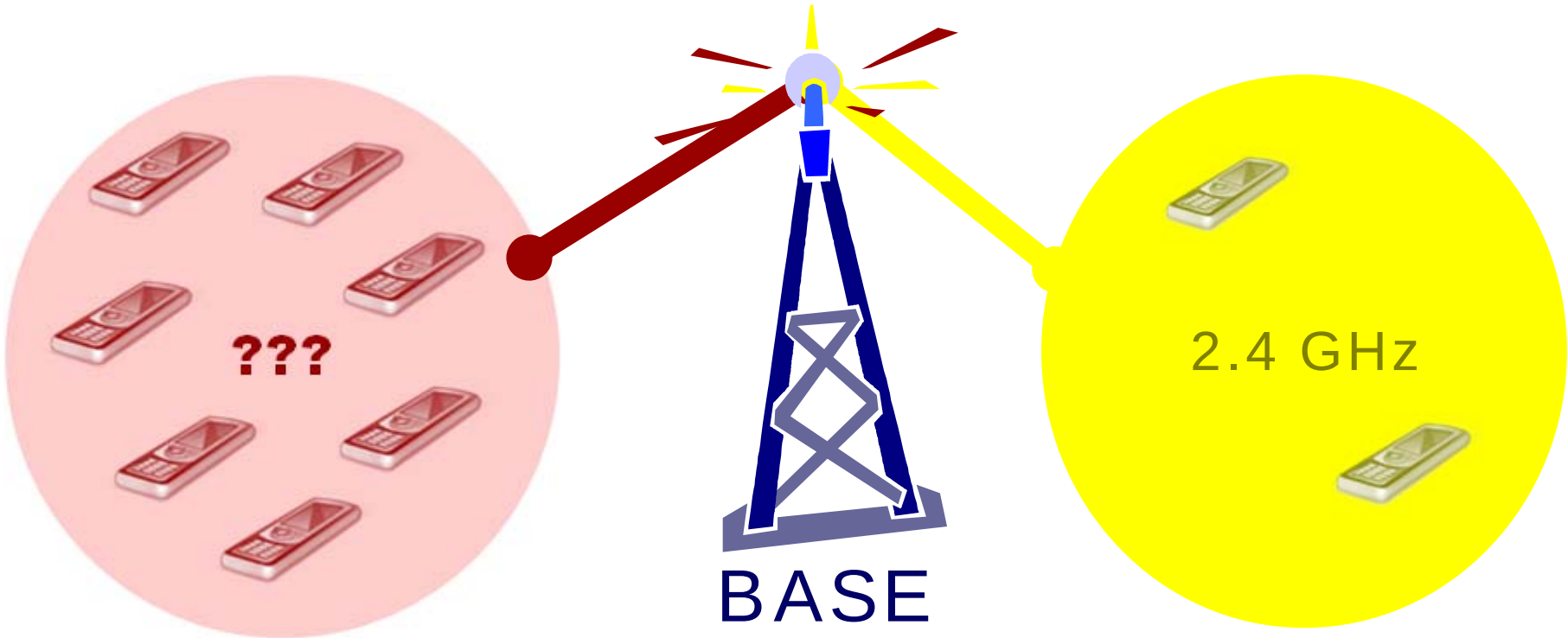
Advisor: Dr. Dan Stancil
Date: Dec1-4, 2009

Electrical & Computer ENGINEERING

Outline

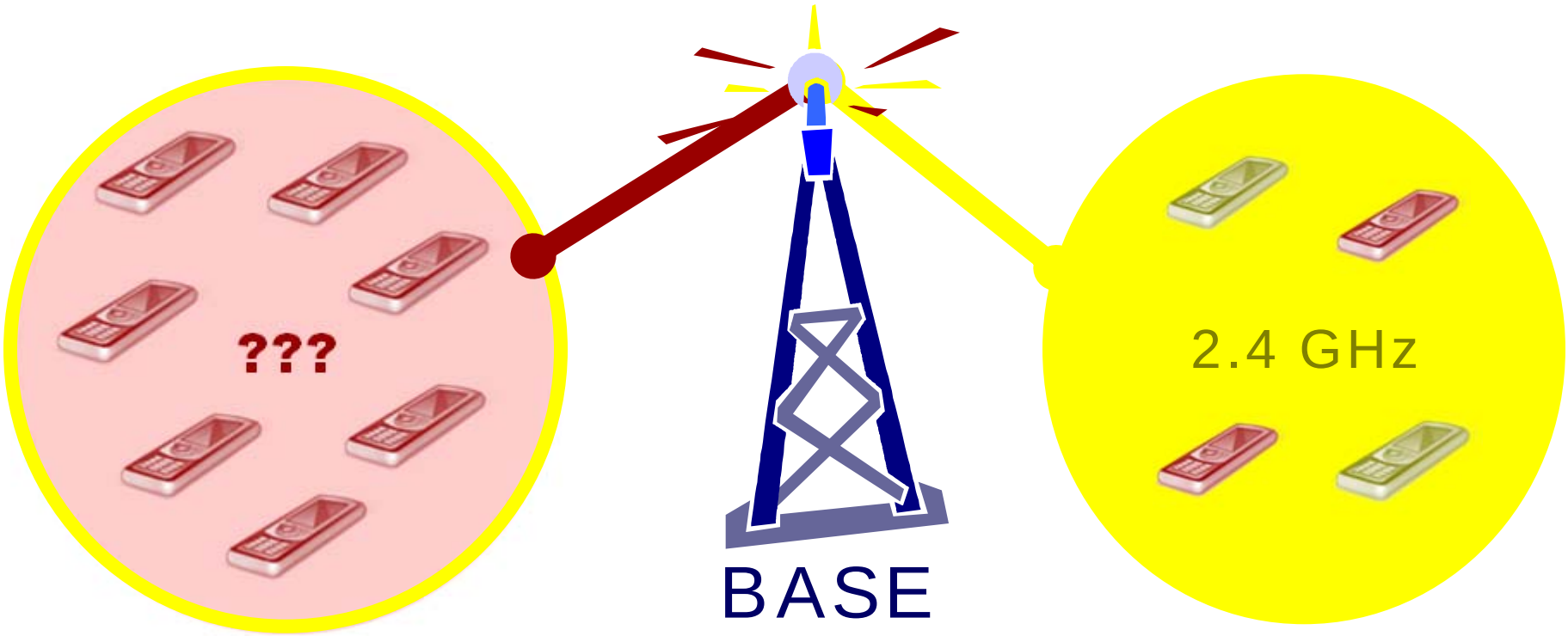
- Problem Scenario
- System Design and Overview
  - Hardware
  - Software
  - Sensing and Learning
  - Interference Avoidance
- Application

Problem Scenario



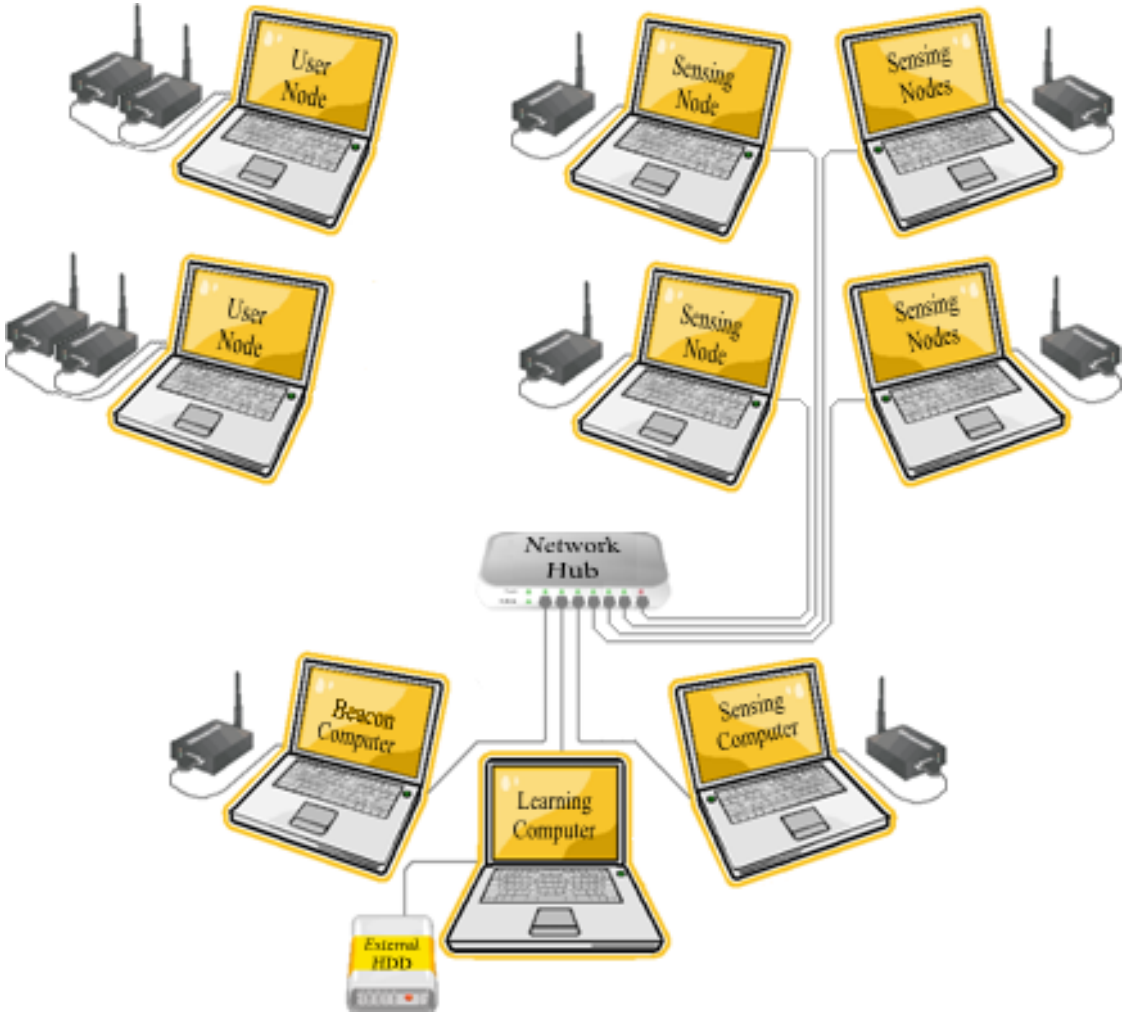
- **There is a crowed area of spectrum that your network is in, and QoS has gone down, but you have new users that want to join the network.**
- **You see that other individuals have radios in another network that are not experiencing the same ailments as your radio.**

Problem Scenario



- **Map the Spectrum in the 2.4 GHz ISM Band**
- **Operate as Secondary User in the Band**

System Design & Overview



Ettus Research

GNU Radio
the gnu software radio

MATLAB

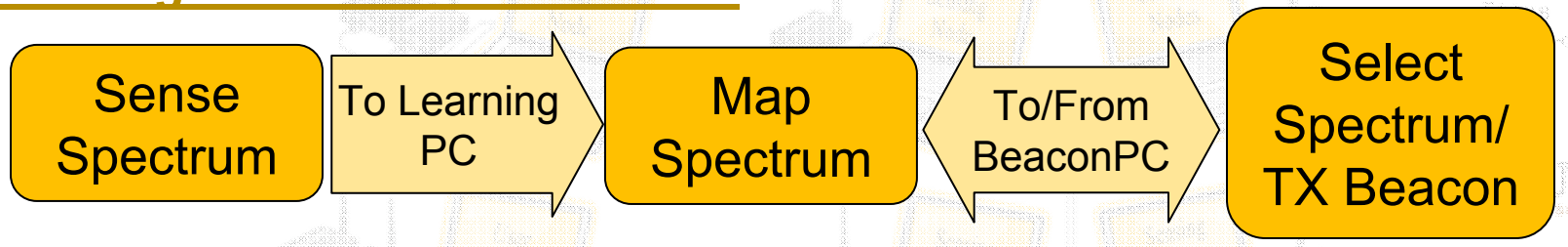
python

ubuntu

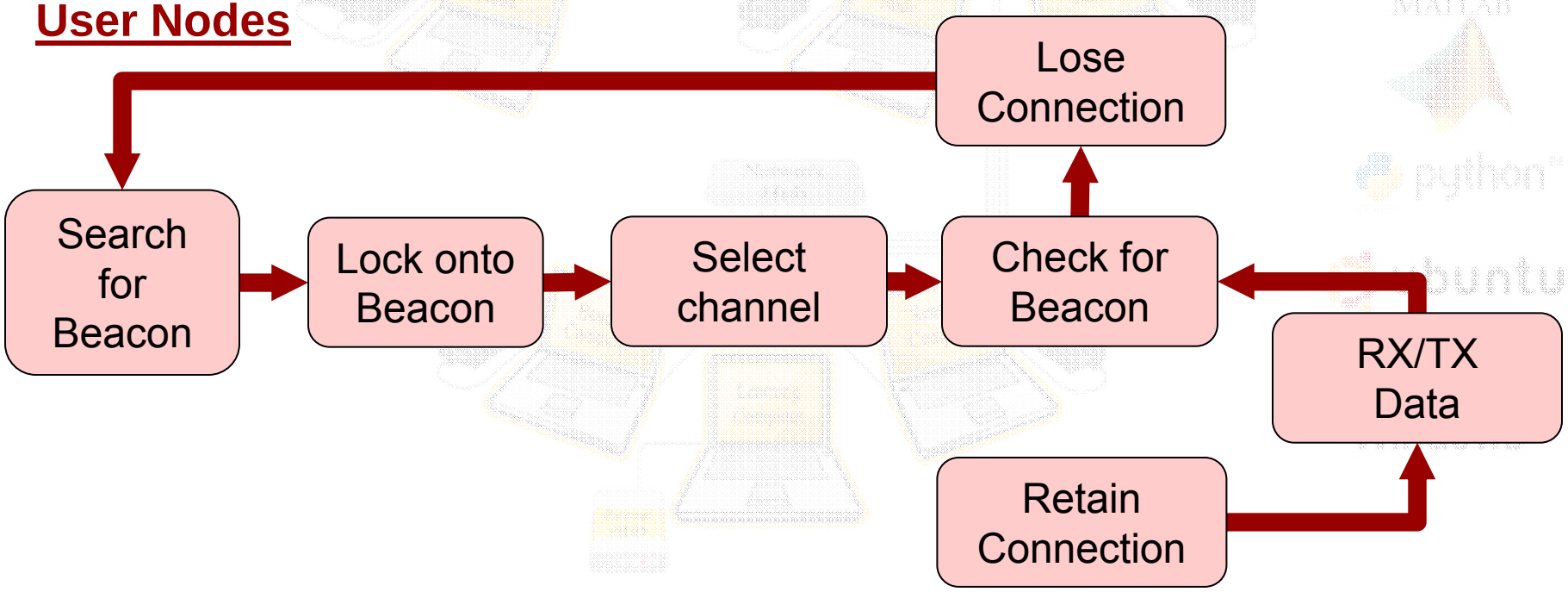
Microsoft Windows xp

System Design & Overview

Sensing Nodes & Base Station



User Nodes



System Design & Overview

Sensing Nodes

- Radio – USRPs
- Software – Pipeline
- Connection to Base Station – Ethernet
- Purpose – Constantly sense the spectrum through 3 64 MHz sweeps
- Represents the users in the crowded Network

System Design & Overview

Base Station: Sensing Computer

- Radio – Signal Conversion Module (SCM)
- Software – Custom C++ Code
- Purpose – Constantly Sense the spectrum. Takes one sweep the entire 2.4 GHZ ISM band with frequency resolution of 1.14 kHz

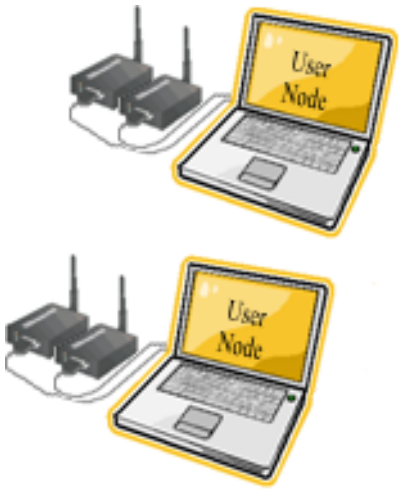
System Design & Overview

Base Station: Learning Computer

- Software – MATLAB

- Purpose – Perform all of the Learning (i.e. Energy Detection, Temporal Detection etc..)
  - Stores Sensing data
  - Locate Unused Spectrum
  - Allocate secondary user channels.

System Design & Overview



Base Station: Beacon Computer

- Purpose – transmits the beacon signifying the channel allocated by the Learning computer

User Nodes

- Radio – 2 USRPs
- Software – Pipeline/MATLAB
- The user nodes performs three applications on the allocated channel

Hardware

USRPs 1

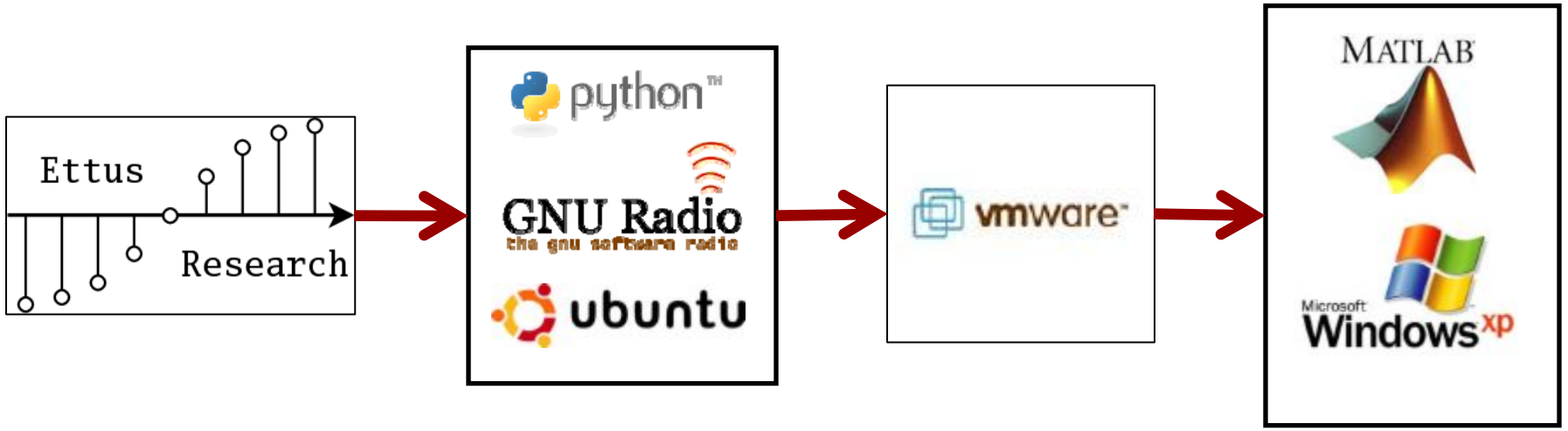
- Streams IQ data at 8Msps
- Reprogrammed to record high BW sweeps
  - 64MHz BW (32 MHz reliable BW)
  - 62.5 kHz Resolution
  - 250 ms refresh time per sweep

Hardware

Custom Signal Conversion Module

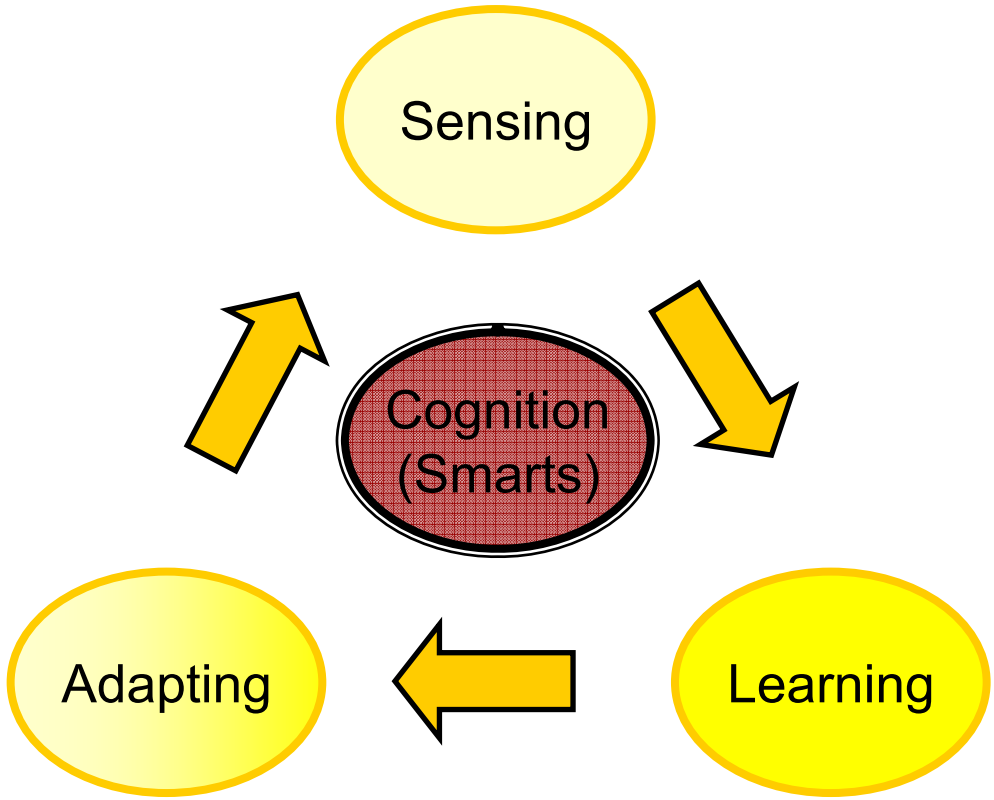
- High performance receiver
  - Sensitive RF front end
  - 100 MHz BW
  - 1.14 kHz Resolution
  - 1.2 s refresh time

Software



- **Pipeline** – Moves data collected in GNUradio to MATLAB
- **Custom C++** – Captures Data from the SCM
- **MATLAB** – Several GUIs and algorithms for sensing, learning, and implementing user node applications

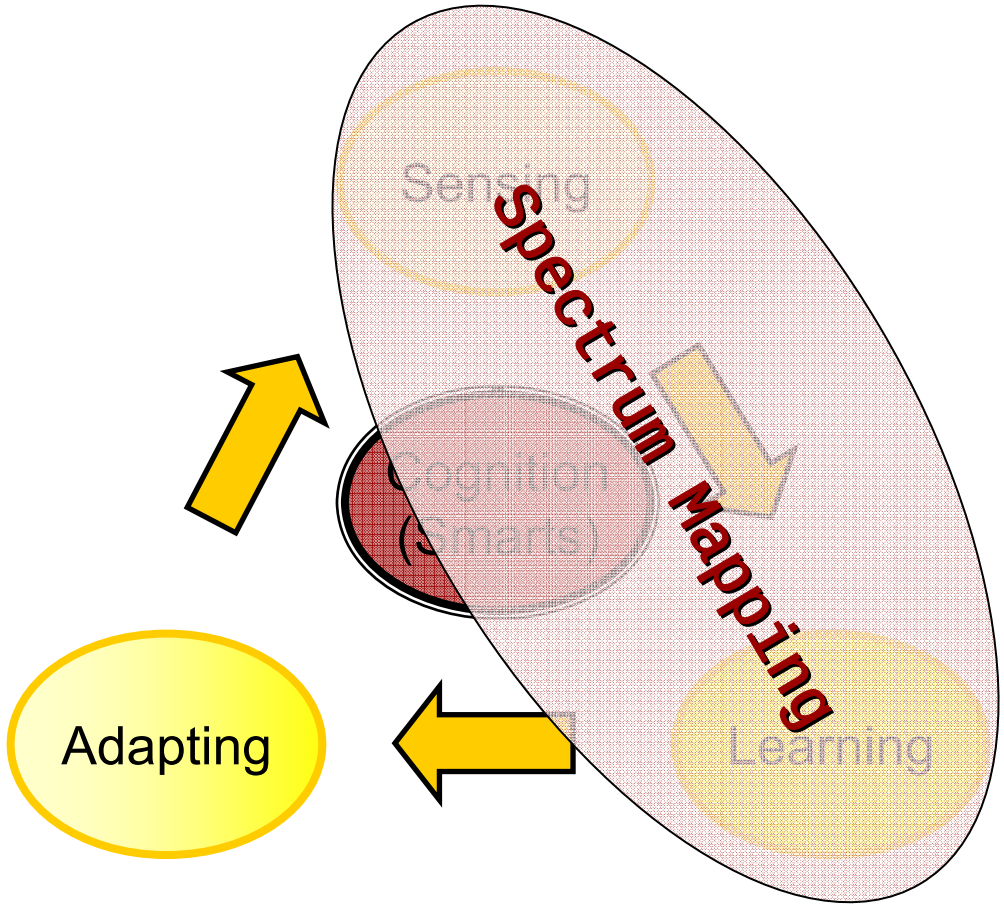
Sensing and Learning



Basic Definition of a Cognitive Radio/Network

A radio or network of radios that can **ADAPT** by changing its radio/network parameters based on what it **LEARNED** through **SENSING** and interacting with the environment in which it operates.

Sensing and Learning



Spectrum Mapping

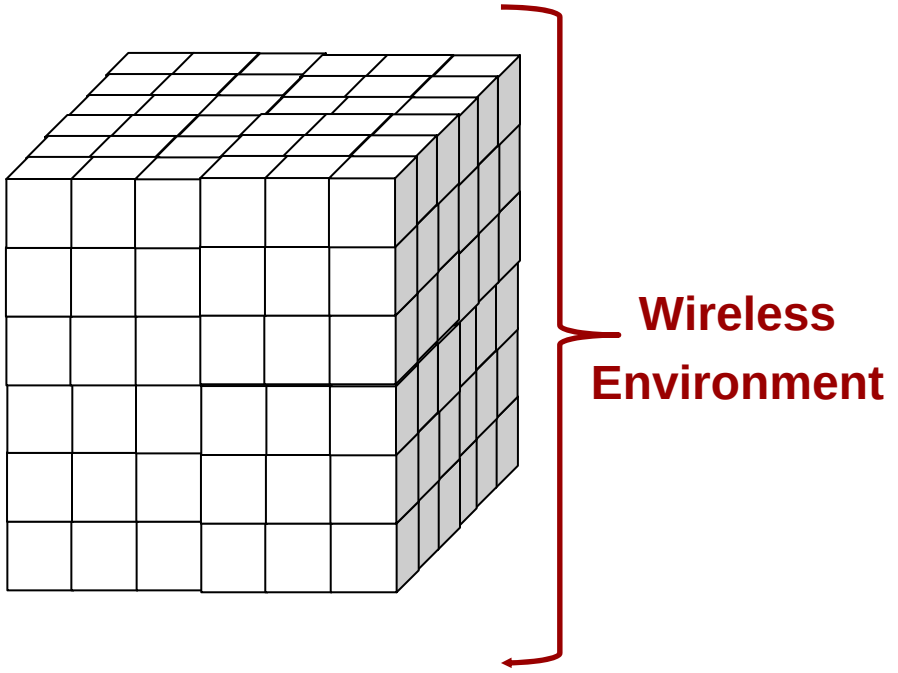
Spectrum mapping is performed in the sensing and learning stage

Sensing and Learning

Spectrum Mapping – Sensing Stage

Wireless Environment

sensing – obtain spectral information about the wireless environment

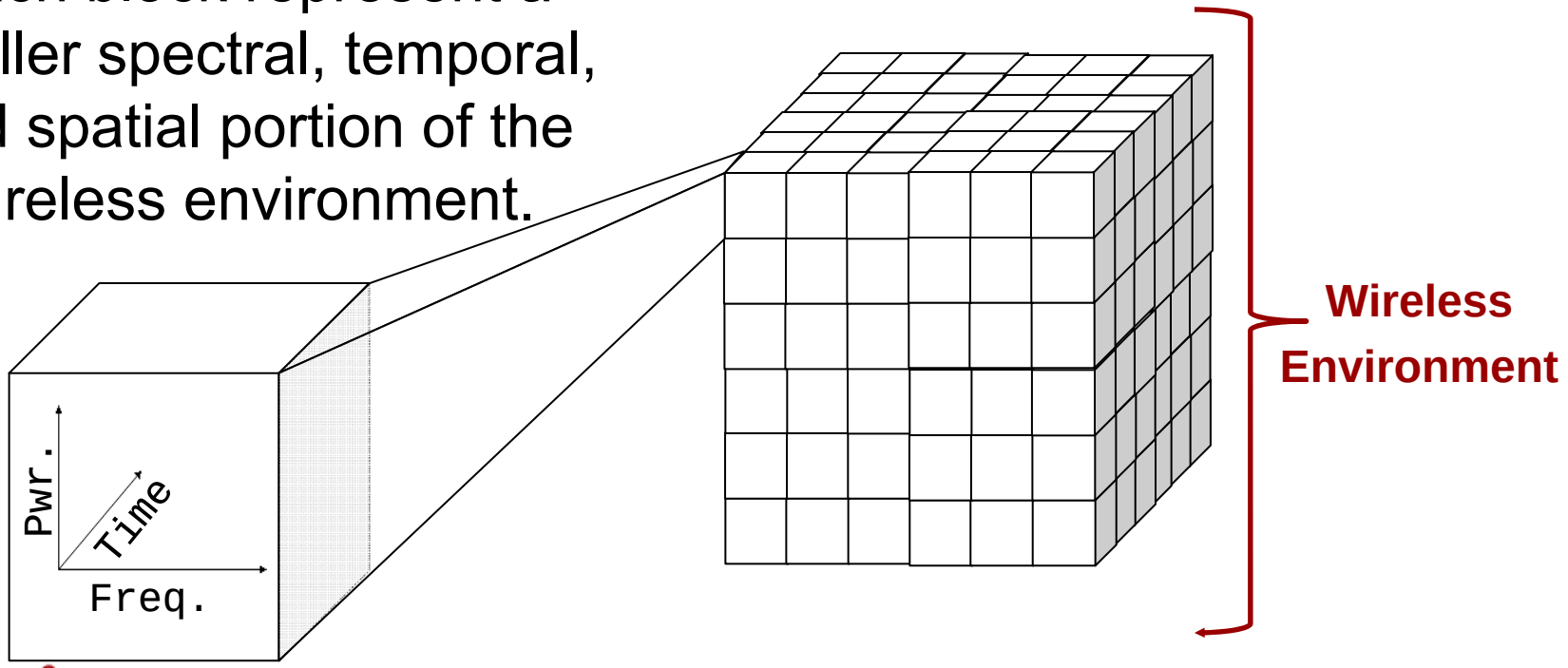


Sensing and Learning

Spectrum Mapping – Sensing Stage

Wireless Environment Blocks

Each block represent a smaller spectral, temporal, and spatial portion of the wireless environment.



Sensing and Learning

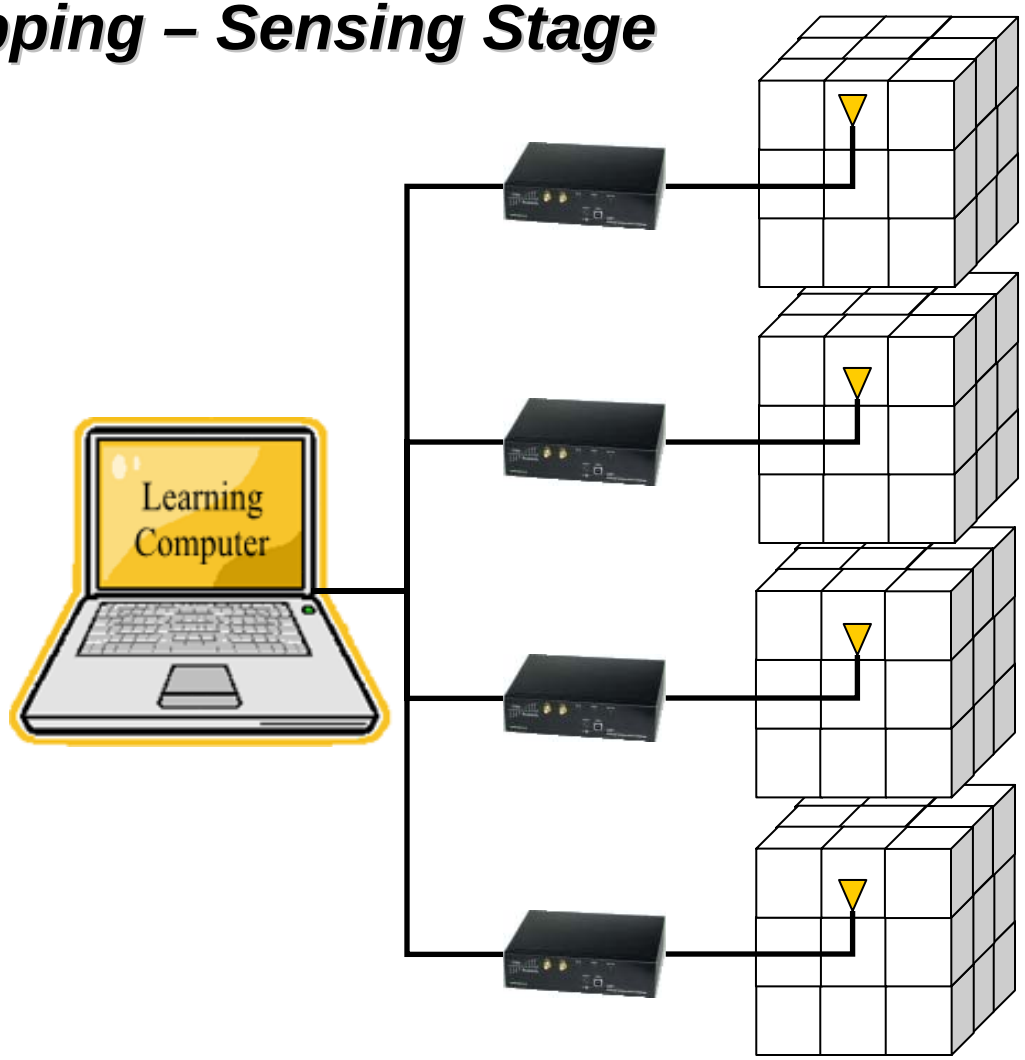
Spectrum Mapping – Sensing Stage

Smaller Environments

•We break the environment into smaller subsections.

•And each of the sensor nodes senses in the respective sub section of space, time, and or frequency

•The sensing data is sent to the learning computer to reduce the amount of processing needed at the sensing nodes



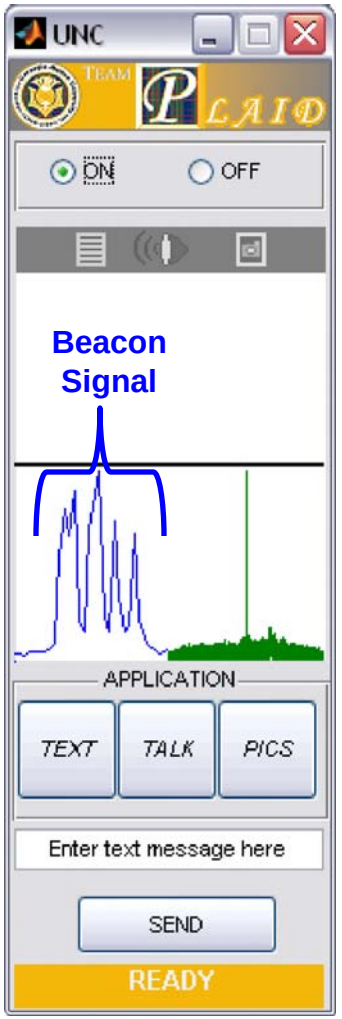
Sensing and Learning

Spectrum Mapping – Learning Stage

- **Energy Detection**
  - Used a predetermined noise floor
  - Based on peak energy values
  - Bandwidth and center frequency are used to classify the signal
- **Localization**
  - Uses the ratios of receive signal powers
- **Duty Cycle**

Interference Avoidance

- Detects interference by monitoring the beacon signal
- Beacon Signal
  - On-off-keying modulation
  - low detection threshold to increase sensitivity
- If excessive errors are observed on the beacon signal the channel is abandoned

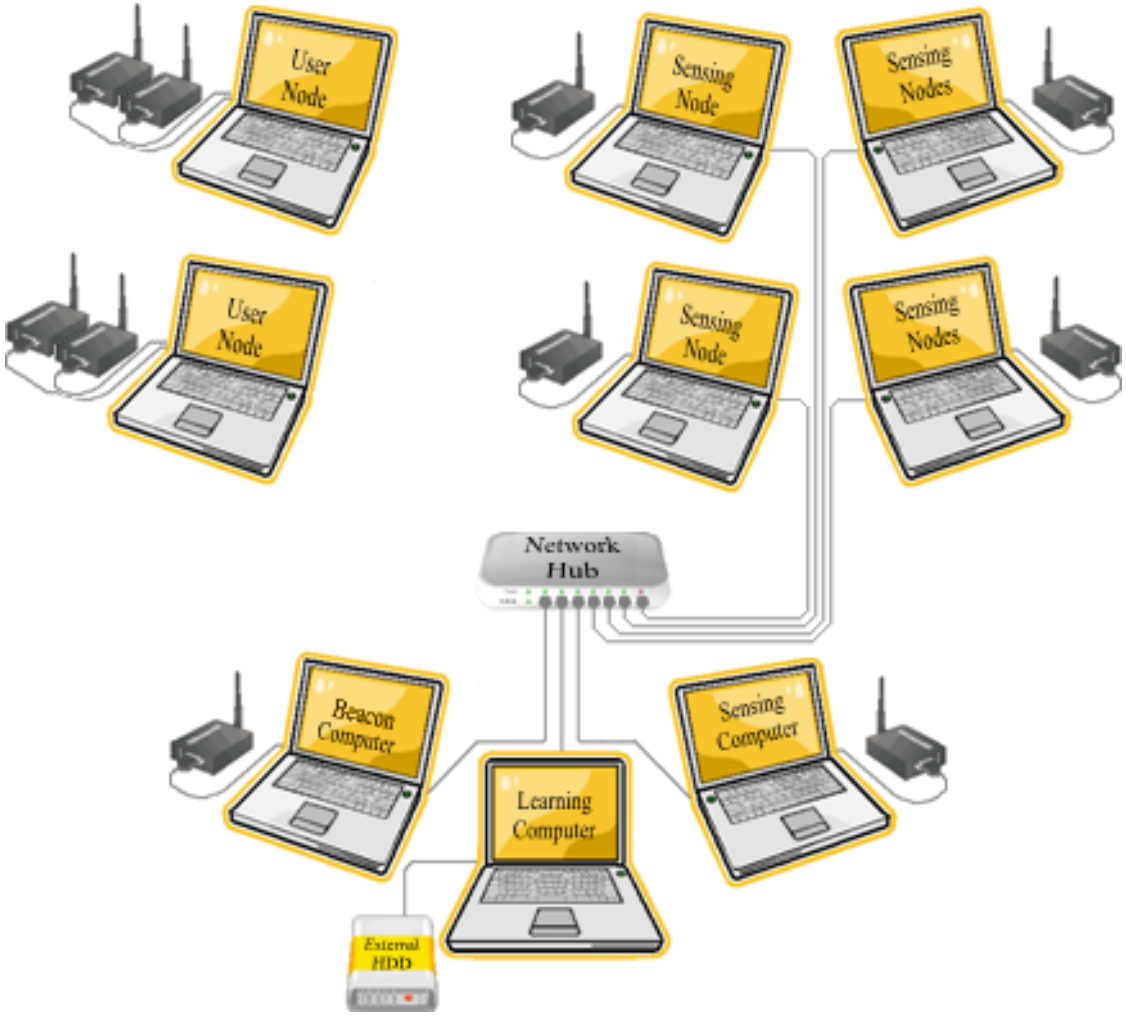


Applications

- **Simple Text Messages:** Send a text string, in ASCII format, to another user node
- **Voice messaging:** records a 10-second voicemail locally, and send the voice message to another user node.
- **"Real-Time" Picture Sharing:** Captures pictures periodically and send the latest capture to the other user.

- **User nodes use MSK for modulation.**
- **MAC layer, the user use a predetermined channel setup.**

Conclusion/Summary



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Microsoft Windows xp