On sensing and communicating using off-the-shelf devices

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Applications of IoT
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View from my office

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Talk summary

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- Exploiting EFI vehicle sensors
- Mobile convoy communication
- A small example of spectrum sensing
- Using sound
- Innovations for Poverty Alleviation Lab

Technology and **R**esearch in **E**merging **N**etworks and **D**istributed **S**ystems (**TRENDS**) Lab

Electronic Fuel Injection (EFI) Vehicle

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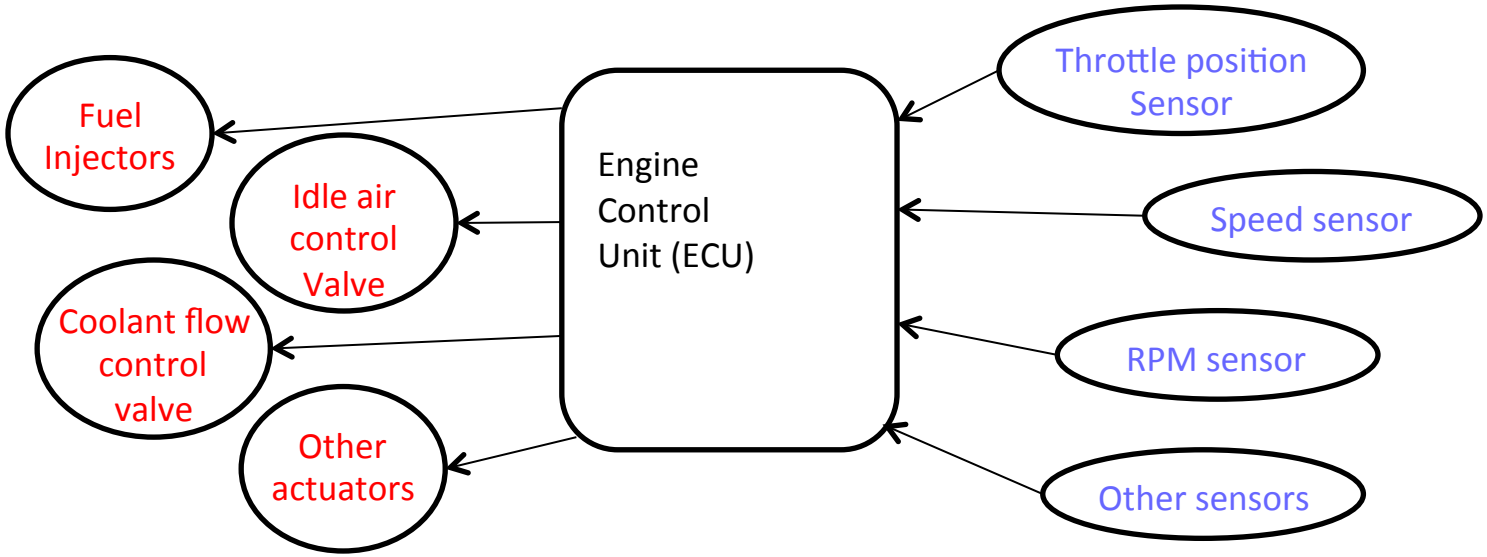
- EFI system injects exact amount of fuel needed to have different air/fuel ratios at different loads, to have efficient combustion. This is electronically controlled.
- EFI engine consists of 3 types of components
  1. **Sensors**: accelerator position, rpm sensor, speed sensor, etc
  2. **Engine Control Unit (ECU)**: On board computer
  3. **Actuators**: fuel injectors, Idle Air control Valve, coolant flow control valve



Sensors in an EFI vehicle

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1. Engine RPM sensor
2. Throttle Position Sensor (TPS)
3. Vehicle Speed Sensor (VSS)
4. Manifold Absolute Pressure (MAP) Sensor (calculate engine load)
5. Mass Air Flow Sensor (MAF) (calculates the amount of air going into the enine)
6. Crank/Cam Position (calculate ignition timing advance)
7. Knock sensor
8. Coolant Temperature Sensor (CTS)
9. Intake Air Temperature (IAT) sensor
10. Oxygen sensor (provides feedback to maintain a proper air/fuel ratio)

Examining sensors on throttle body

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Sensors on a throttle body

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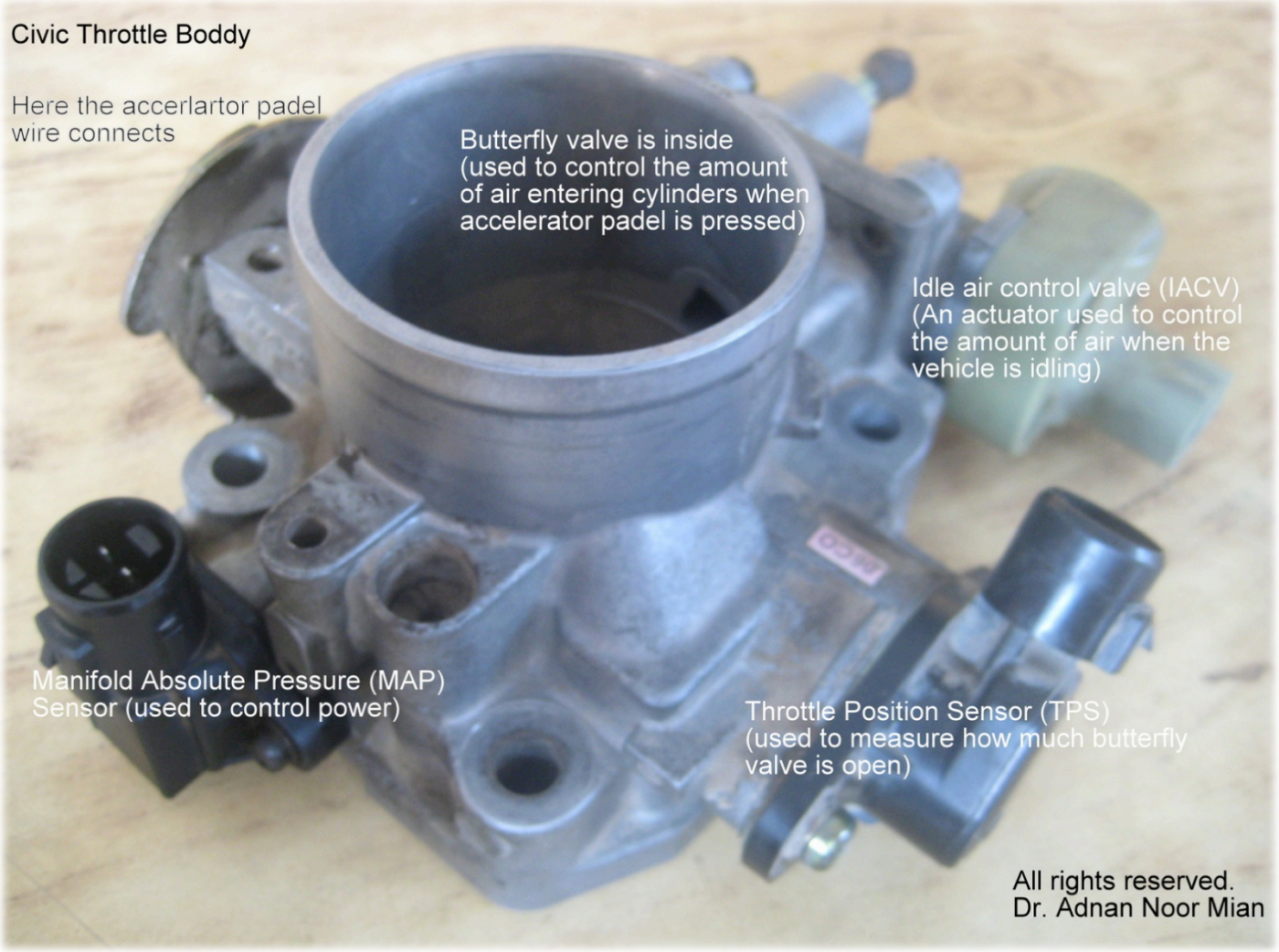

Sensors on a throttle body

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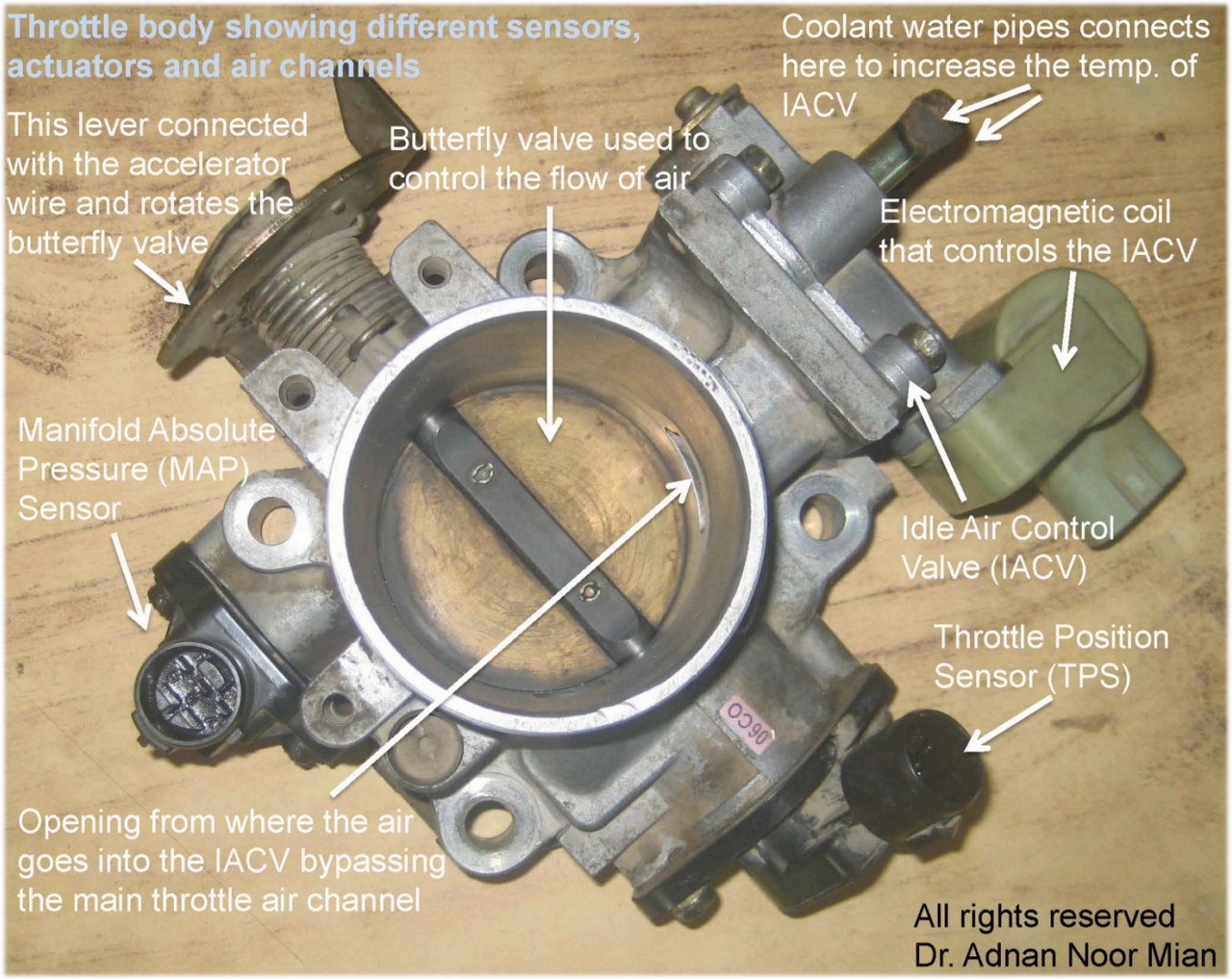

MAP Sensors in an EFI vehicle

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Sensors in a smart phone

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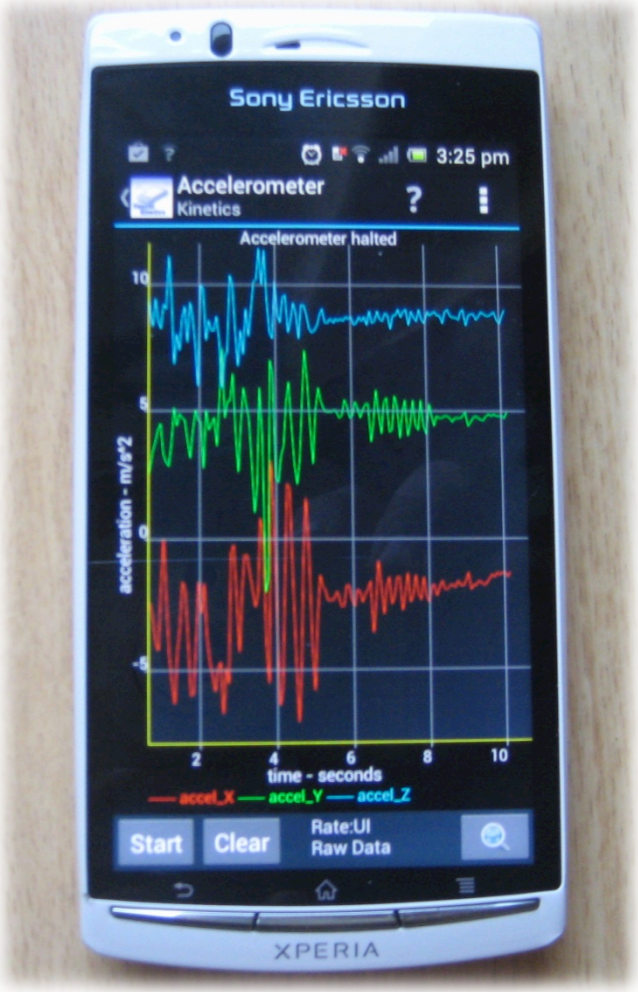
1. Accelerometer
2. Gyroscope/orientation sensor
3. Magnetic field sensor
4. GPS sensor
5. Proximity sensor
6. Light sensor
7. Temperature sensor
8. Pressure sensor
9. Humidity sensor
10. Soud sensor (microphone)
11. Camera for detecting movements



Sensors, all around and free !

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In a modern driving environmnet, a driver is surrounded by lots of sensors

Camera

Accelerometer

GPS sensor

Mass air flow sensor

RPM sensor

Speed sensor

Magnetic field sensor

Throttle position sensor

Intake air temp. sensor

Knock sensor

Crank/camshaft position sensor

Manifor absolute pressure sensor

Sound sensor

O2 sensor

Coolant temperature sensor

Humidity Sensor

Getting data from EFI vehicle sensors?

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- We can get data from the vehicle sensors using the On Board Diagnostics (OBDII).
- OBDII port is a 16 pin port usually on the driver side of the vehicle
- Many different protocols are used to communicate with the engine. Often used is ISO 9141 protocol.
- ELM 327 based tool makes task of communication with engine easy and inexpensive. It is OBD-to-RS232 (serial port) converter that abstracts the low-level protocols and presents a simple interface.
- To access data we send Parameter ID (PID) to the ECU via serial port/ bluetooth and the port replies with the value of the parameter.

Getting data from EFI vehicle sensors?

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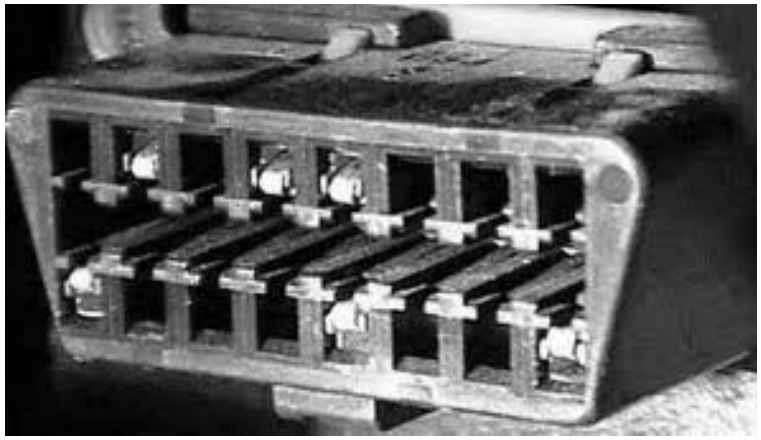

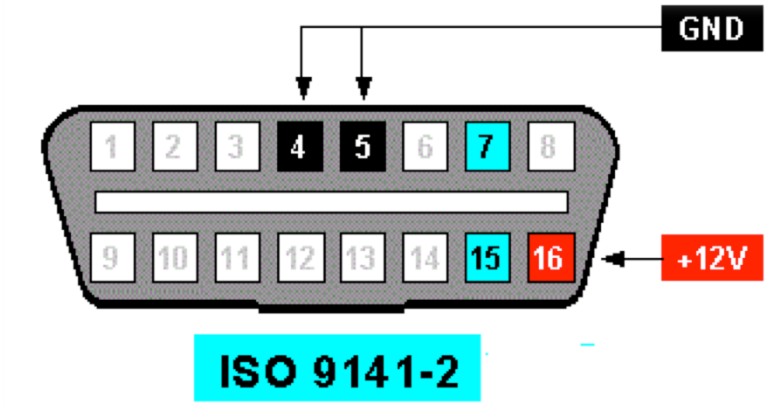

Getting data from EFI vehicle sensors?

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- Example: Mode: 0×01 -> request live data, PID: 0×0C -> request rpm value

  request frame sent: 01 0C (2 byte frame sent)

  reply frame received: 41 0C 0F A0

  0×41 means a response to mode 0×01 and 0x0C means that the response is for PID 0x0C.

  0F 0A are the value of rpm. The exact rpm value is calculated using formula:

  A: 0x0F = 15 and B: 0xA0 = 160

  (A*256)+B)/4=1000rpm

- There are more than 200 standard PIDs to get different values. Not all PIDs are active in all vehicles. In addition to standard PIDs, some are proprietery.

Sensing, computing and communicating

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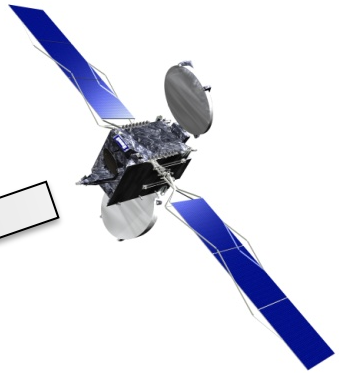
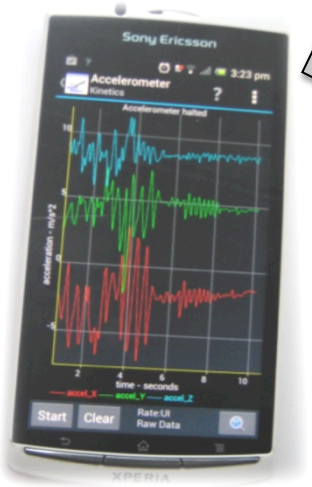
16 pin OBDII interface
using ISO 9141 protocol

Wire,
Bluetooth,
or WLAN

PID request /
reply



GPS



Server/
Cloud

GPRS, 3G, LTE

Internet

DB

What characteristics can we measure?

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The primary purpose of OBD is diagnosis. We exploit it find:

- Diagnostic Trouble Codes (directly accessed from OBDII)
- Fuel consumption (speed, MAP, RPM sensors)
- Fuel remaining (either fuel sensor or estimated using fuel consuption)
- Hard application of brakes and high acceleration (speed sensor)
- Right left movement of vehicle (accelerometer, magnetic field sensors)
- Condition of road, smooth or bumpy (accelerometer, magnetic field sensors)
- Overspeeding (speed sensor)
- Remote logs Mobile oil change alerts (distance travelled recorded in ECU)
- Driving gear (Speed, RPM sensors)
- Driver compliance to traffic signals (camera)
- Position of the vehicle on map (GPS sensor)
- ...many more.

What can we determine?

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- **Road related**
  - Road physical conditions - how much is the road bumpy? Needs repair?
  - Road traffic conditions: congestion, free running, etc. - vehicle are visible on maps
- **Vehicle related**
  - Fleet management: Keeping a record of different parameters to determine when vehicle tuning is needed?, when to change mobile oil?, etc
  - Remote assistance in case of malfunction - sending vehicle info to an expert
- **Driver related**
  - Driver profiling and evaluation … *(next slide)*

Driver profiling/evaluation/identification

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- How the Driver takes turn?
- How driver move through traffic?
- How the driver uses brakes to stop the vehicle?
- How the driver accelerates/decelerate?
- How much is the driver economical/greener?
- How he cross the speed breaker?
- When he shifts the gear?
- .... etc.

Who are would be interested?

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- **Driving licensing issuance authorities:** To evaluate the driving skills of a person objectively and discover weak points in driving.
- **Insurance companies:** To decide which type of insurance plan they want to give a particular driver depending on driver's driving.
- **Driving Learner**: To use this system to evaluate and improve his own driving before actually going for a driving test.
- **Fleet Management System:** To manage large fleet of vehicles by maintaining their logs automatically.
- **Metropolitan management authorities:**
  - To know the conditions of the road and emissions
  - Interested in knowing the unusual driving pattern (drunkenness or disability) etc. to determine beforehand any likelihood of future problem.
- **Analysts:** would like to analyse the data to find peculiarites in driving habits, traffic conditions, etc.

Challenges/Issues

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- How much computation Vs. communication on a smart Phone?
- How to get around with limited PIDs or sensors are in vehicles sold in asia ?
- Application of AI techniques to improve the system
- Plan to develop a real time game having a reward mechanism in which there is a competetion between drivers who would try to get scores based on their performances
- Developing an application for commercial purpose in collaboration with a software house. A cement factory having >300 vehicles have shown interest for their fleet management.
- Big data analysis for driver identification (in collaboration with Univ. of Cambridge)

Mobile convoy communication

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- Interested Punjab Information Technology board to provide for protocol/escort convoy of high profile people.
- Old Walke talkes are used, all hear
- Can use a portable base stations but that would need license. Portable Jammers often not jam wifi

Mobile convoy communication

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- One solution is using a GSM potable base station
- But it requires license band
- With the availability of low cost, long distance Wi-Fi technology with state of the art encryption mechanisms and the android based smart phones, we can replace the traditional Walkie talkie based communication.
- The domestic solution is preferred over the products available in the market to avoid the chance of any spying feature intentionally embedded in specialized solutions.

Mobile convoy communication

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Proposed Solution

- Use of multiple ISM bands frequencies with Wi-Fi protocols.
- Vehicles will be connected together by 5GHz Ubiquiti devices with Omni directional antenna that provides up to 2 KM connectivity.
- The range of the network will be extended by the intermediate vehicles of the convoy. Each vehicle will also have a Wi-Fi access point for connecting the android based mobile phones held by the security officials.
- The android phones will be equipped with a secure VoIP application like Voxer and Zello that provide secure voice, video and group text messaging feature.

Mobile convoy communication

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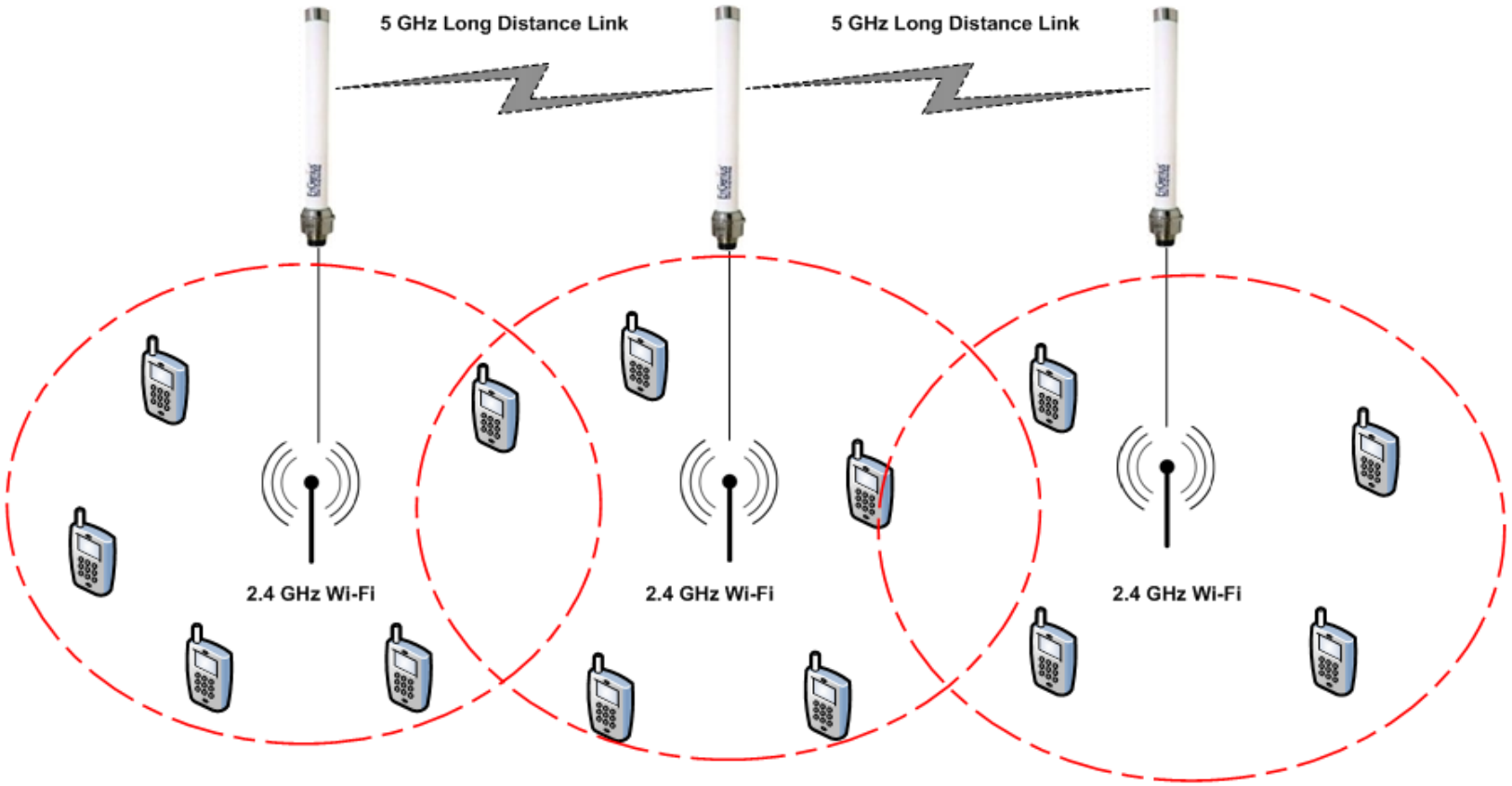

Mobile convoy communication

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Challenges

- One long range Vs small short range with a back haul
- Mobility response of Ubiquity devices
- In mobility 5GHz or 2.4 Ghz band for back haul
- How many voice calls simultaneously it can handle?

Spectrum Sensing & wireless mouse

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- Observation: 2.4 GHz band Wifi link often used to drop when used with wireless mouse
- Used spectrum analyzer wispy
- Found wireless mouse transmit very near to channel 1 of wifi. If wifi channel is set, then there is interference
- Solution: set wifi channel 6

Using sound

- Using sound to send data between an android phones (softmodem) using OFDM
  - No pairing required, multicast
  - Can be used to send/broadcast short text
  - opening locks using acoustics, might not be secure
- Also looking into:
  - acoustic spectrometry using android phone to estimate surface hardness

Innovations for Poverty Alleviations lab

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WATER QUALITY MEASURMENT UNIT

- Electrical Conductivity Sensor to measure total dissolved solids (TDS)
- Turbidity + Residual Chlorine Sensors
- Dashboard to view Water Quality

WATER DISPENSING UNIT

- Arduino controlled solenoid valve
- A flow sensor that measures quantity of water dispensed at each transaction
- GSM shield to upload data in real time

STUDENT PROJECTS

- Student Projects on Soil Moisture Level Detector, Flood Early Warning System + Air Quality Sensing System
- Water level detected via Comp Vision

BIOMETRICS ATTENDANCE SYSTEM

- Customized Biometric + QR code based attendance system
- Tamper Proof + Fast Data Entry
- Raspberry Pi + GSM + DB on SD Card

This work is done by my colleague, Mustafa

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Thankyou

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