INDEPENDENT PROJECT

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Introduction

What is Wi-Fi sensing ??

- `Wi-Fi sensing` is the use, by a Wi-Fi sensing capable STA(s), of received Wi-Fi signals to detect feature(s) of an intended target(s) in a given environment
- Features : motion, presence or proximity, gesture, people counting, geometry, velocity, etc.
- Target : object, human, animal, etc.
- Environment : Within a few centimeters/meters of a device, room, house/enterprise, etc.
- Some of applications of Wi-Fi sensing include:
  - Gesture recognition
  - Room sensing and presence detection
  - Activity detection
  - Facial or body recognititon
  - Gaming control
  - Robot 3D vision

- Wi-Fi is ubiquitous in homes and enterprises.
- Expand the use of Wi-Fi to applications beyond just communication.
- New functionalities for 802.11-enabled devices (TV, speaker, router, IoT devices) and facilities (stadiums, halls, rooms, warehouse, factory).
- Need no dedicated hardware. Any 802.11-compliant device (including our demo devices) can potentially implement any 802.11 sensing functionalities using only software upgrade.
- Wi-Fi can overcome drawbacks from alternative technologies
  - Camera: field of view, privacy, power consumption
  - Ultrasonic/laser: objects can block

- 802.11 sensing, or WiFi sensing, [1] is the use of 802.11 signals to sense (e.g. detect) events/changes in the environment. Often with signal processing and machine learning.
- Briefly, here is why Wi-Fi sensing would work:
  - A STA (Tx) transmits 802.11 signal to a STA (Rx) in a multipath-rich venue.
  - 802.11 signal bounces back and forth in the venue generating lots of multipaths.
  - Although undesirable to communications, the bouncing of the 802.11 signal effectively "scan" or "sense" the venue.
  - By monitoring the multipaths , it is possible to detect target events and changes in the venue.

- As said before, the bouncing of 802.11 signals creates multipaths which effectively scan or sense the environment - including any object motions, events and changes. The multipaths are captured in channel state information (CSI)
- Detection of some features require ML, but many can be achieved with signal processing.
- To start with we are going to use RSSI as an indicator to predict gestures performed.

Introduction

- - Channel State Information or Continous wave radar
  - Action/gesture could be classified/recognized by both CSI and CW radar based schemes.
  - The performance of cooperation of three nodes is better than the performance of a single node.
- - Monostatic and Multi-static Radar
  - Why extend beyond monostatic radar ?
- - Introduction
  - Feasibility
  - Standardization
- - Device free localization and tracking
  - DFL Los + Multipath components (MPC) simple
  - DFL Los + Multipath components (MPC) enhanced

OFDM

Orthogonal frequency division multiplexing

- It is a method of digital signal modulation in which a single data stream is split across several separate narrowband channels at different frequencies to reduce interference and crosstalk.
- Crosstalk is disturbance caused by electric or magnetic fields corresponding to telecommunication signal of adjacent circuit.
- In a conventional single-channel modulation scheme datastream bits would be sent serially.
- In ODFM datastream bits are transmitted in parallel (several at once on separate channels) but at lower speed in each substream (a stream within another stream) relative to the original signal.
- Symbols sent in the substreams are longer and spaced farther apart.
- OFDM is used in Wi-Fi, DSL internet access, 4G wireless communications, and digital television and radio broadcast services.

- Wi-Fi is a term for certain types of wireless local area networks (WLAN) that use specifications in the 802.11 family.
- A Wi-Fi network uses radio waves to wirelessly transmit information across a LAN.
- Wi-Fi's signals are transmitted in frequencies of between 2.5 and 5 gigahertz (GHz).

RSSI

Relative Signal Strength Indicator

- RSSI is an estimated measurement of how good a device can hear from any access point or router.
- It helps to determine if a signal is sufficient to establish a connection .
- Its typical range is from 0 to -120 (although it differs from chipset manufacturers.)
- RSSI indicates the received power level after any possible loss at the antennas . Hence , the higher the value of RSSI ,the stronger the signal.

CSI

Channel State Information

- CSI describes how a signal propagates from transmitter to receiver.
- It helps to adapt transmissions to current channel for better reliable communication.
- CSI needs to be estimated at the receiver end and usually quantized and fed back to transmitter.
- In a MIMO - natural flat fading channel , the system is modelled as

$$\mathbf{y} = \mathbf{H}\mathbf{x} + \mathbf{n}$$

  y , x are the receive and transmit vectors ,
  H and n are channel and noise matrices.
- Different kinds of CSI :
  - Instantaneous CSI
  - Statistical CSI

Different kinds of CSI

Instataneous CSI (short term CSI)

- It means that the current channel conditions are known , which can be seen as knowing the impulse response of a digital filter.
- The channel matrix H is known perfectly.

$$\text{vec}(\mathbf{H}_{\text{estimate}}) \sim \mathcal{CN}(\text{vec}(\mathbf{H}), \mathbf{R}_{\text{error}})$$

where $\mathbf{H}_{\text{estimate}}$ is the channel estimate
where $\mathbf{R}_{\text{error}}$ is the error estimation covariance matrix.

Different kinds of CSI

Statistical CSI (long term CSI)

- It means that the statistical characterization is known and it includes the type of fading distribution .
- The statistics of H are known.For a Rayleigh fading channel , this corresponds to :

$$\text{vec}(\mathbf{H}) \sim \mathcal{CN}(0,\, \mathbf{R})$$

where **R** is the channel covariance matrix R