# Integrated Sensing and Communications

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# Sensing

- To detect the location, motion of mobile devices, vehicles or human
- Sensing may improve the communication efficiency
- Sensing may also provide services other than communications

# IEEE 802.11bf

- “802.11bf is a new Task Group about WLAN sensing within the IEEE 802.11 working group.”

- “WLAN sensing is the use, by a WLAN sensing capable STA(s), of received WLAN signals to detect feature(s) of an intended target(s) in a given environment.”

# IEEE 802.11bf

## WLAN sensing

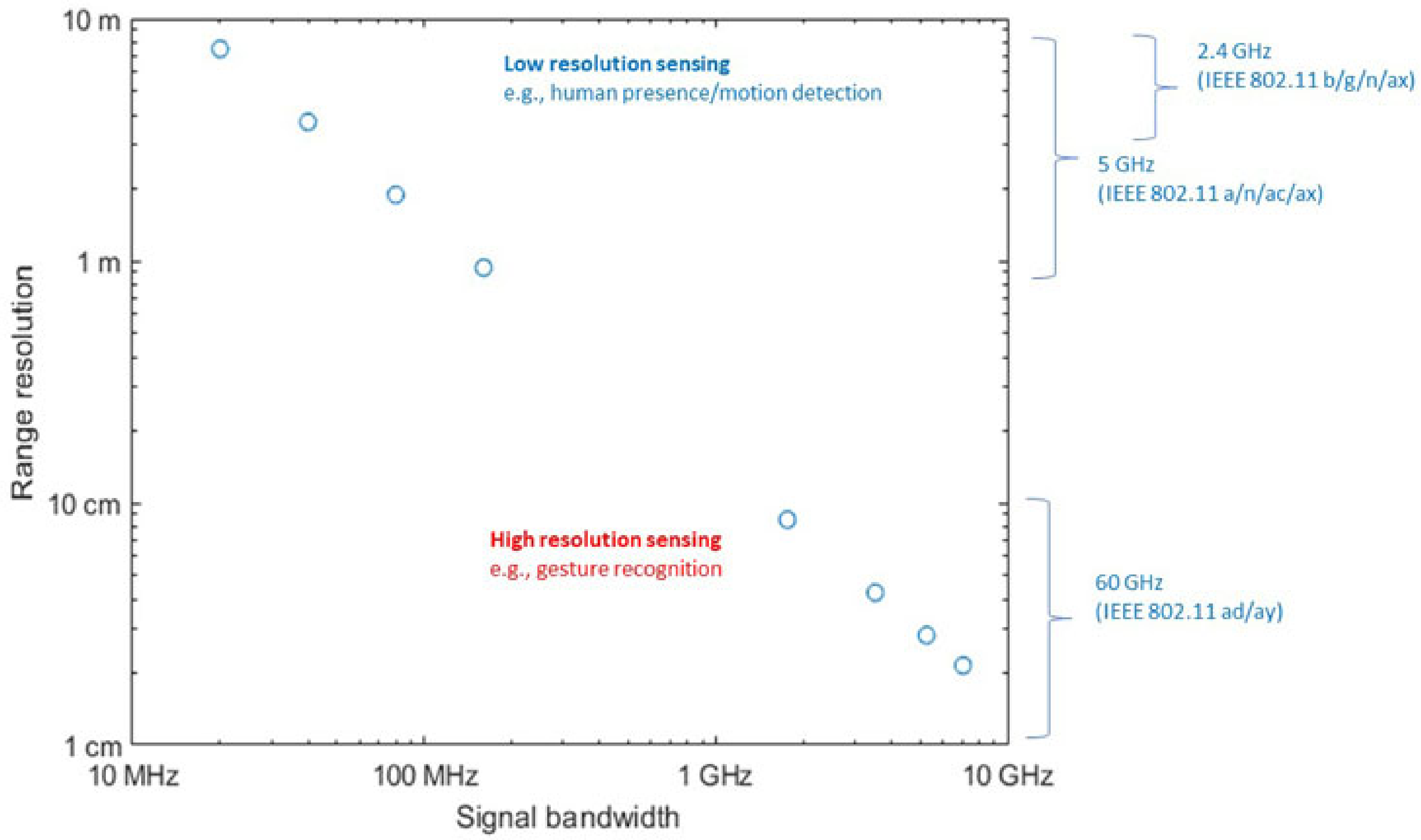
**Use case example 1**

- **Multiple devices diversity: Makes use of 802.11 devices found in various locations inside the house**
  - Different rooms/floors could be "sensed"
  - High level of device diversity, wide coverage
- **Applications**
  - Home security and safety
  - Energy management and control
    - HVAC, light, device power save
  - Home elderly care and assisted living

**Use case example 2**

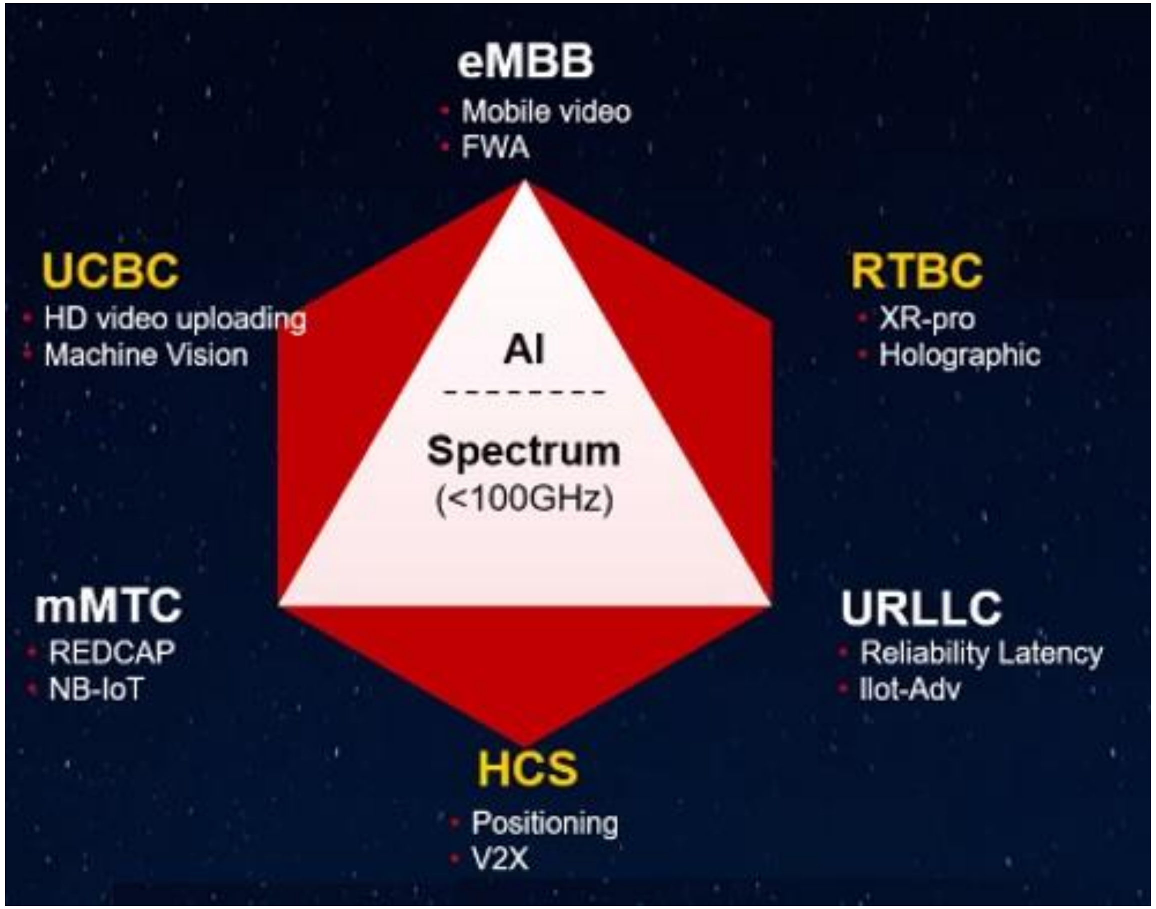
- **mmWave: 60 GHz 802.11 technology offers better performance to detect/track movement**
  - Higher resolution
  - Higher accuracy
- **Applications**
  - More than just a teleconferencing tool to speak with your physician, upon consent, your laptop could also be able to provide your physician with vital data, both historical and in real time

# IEEE 802.11bf



# Sensing in 3GPP

- Currently, 5G is not so successful in applications
- Industry tries to define new application scenarios for cellular systems
- Huawei: 5.5G

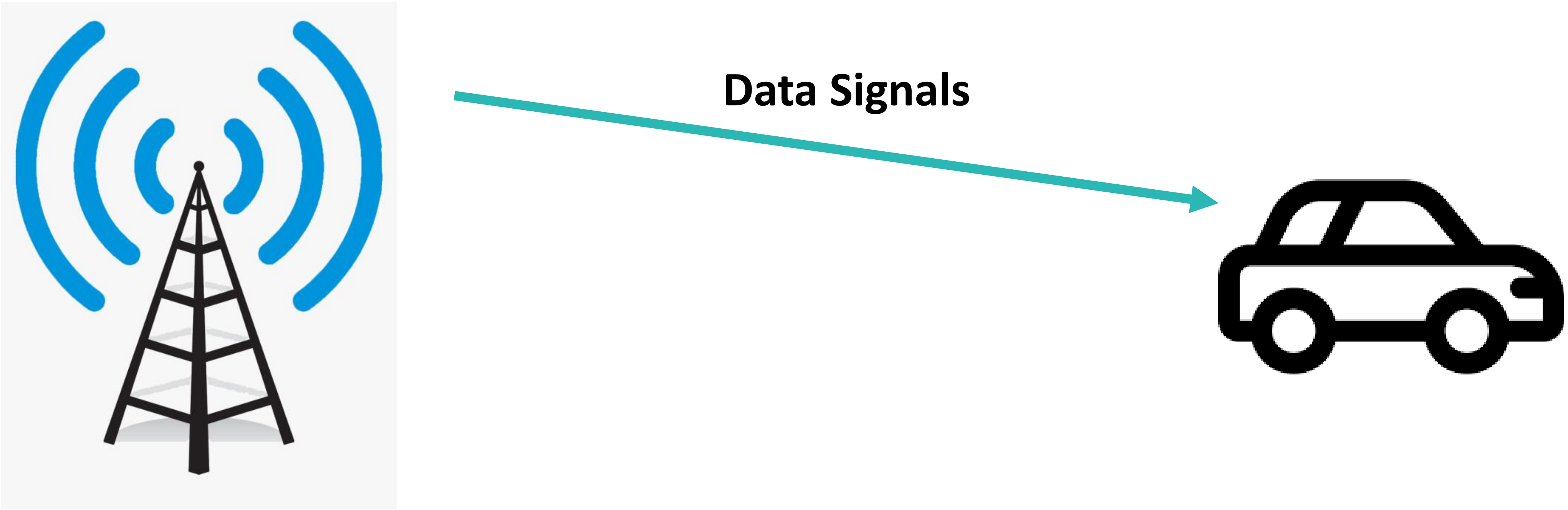


# Sensing Modes and Parameters

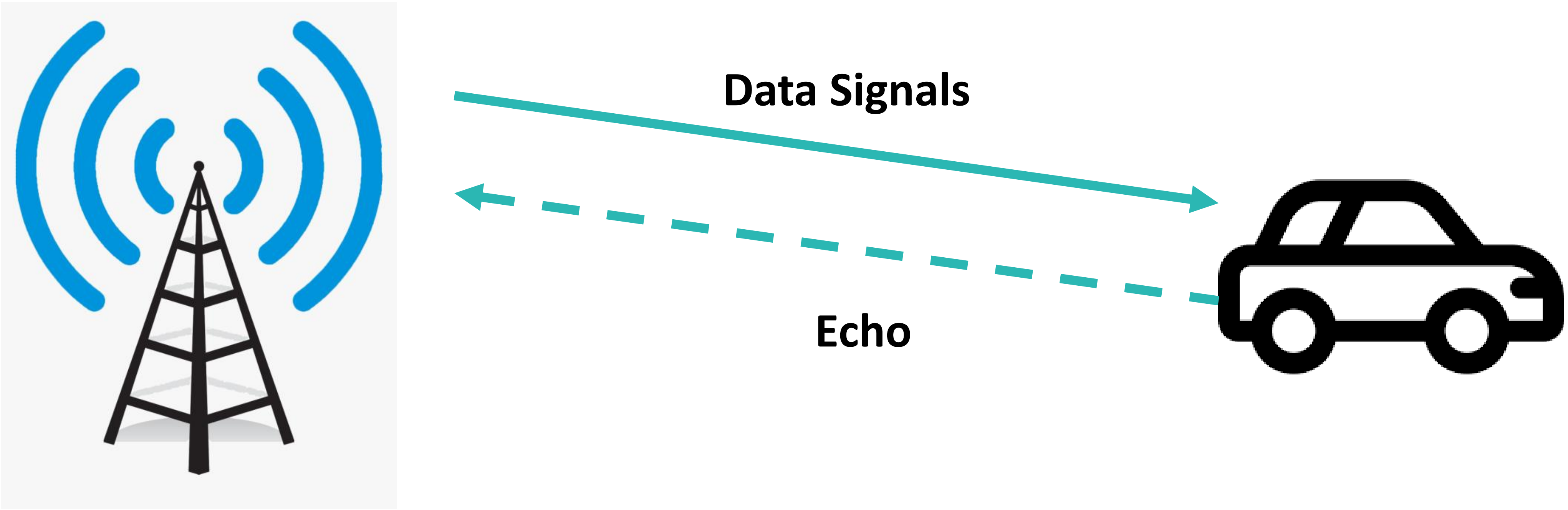
- Distance to the BS or mobile devices
- Angles
- Velocity
- Motion

- Proactive and passive

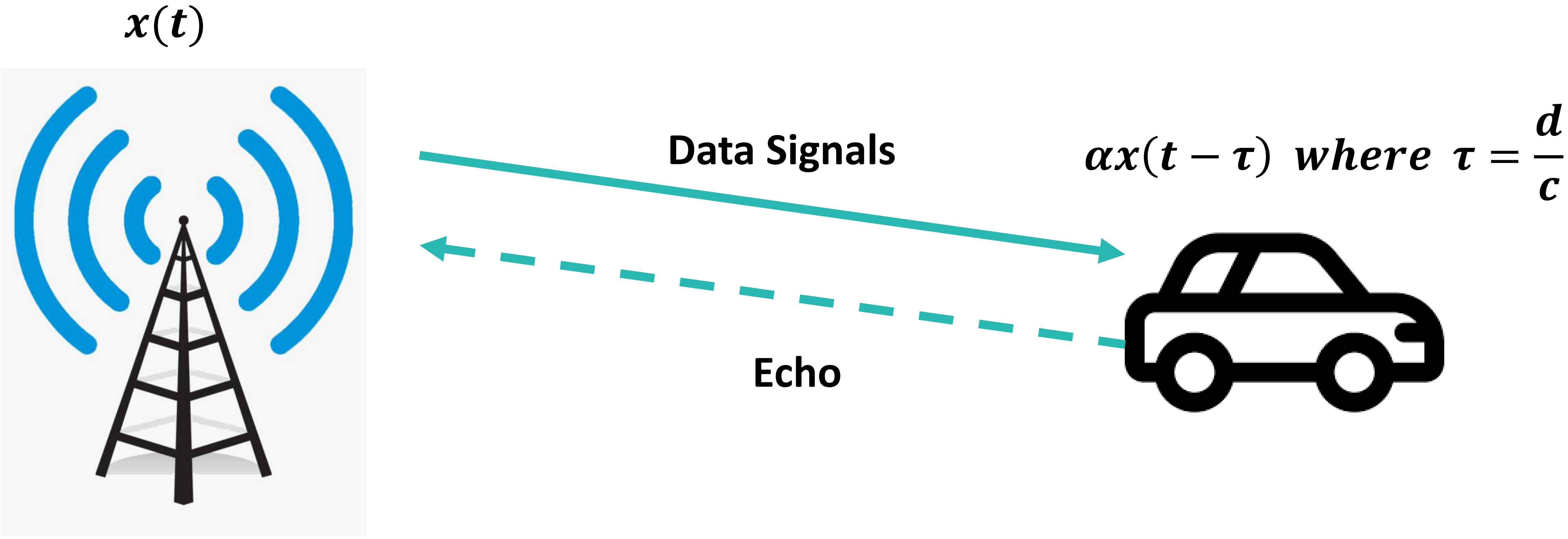
# Proactive Sensing



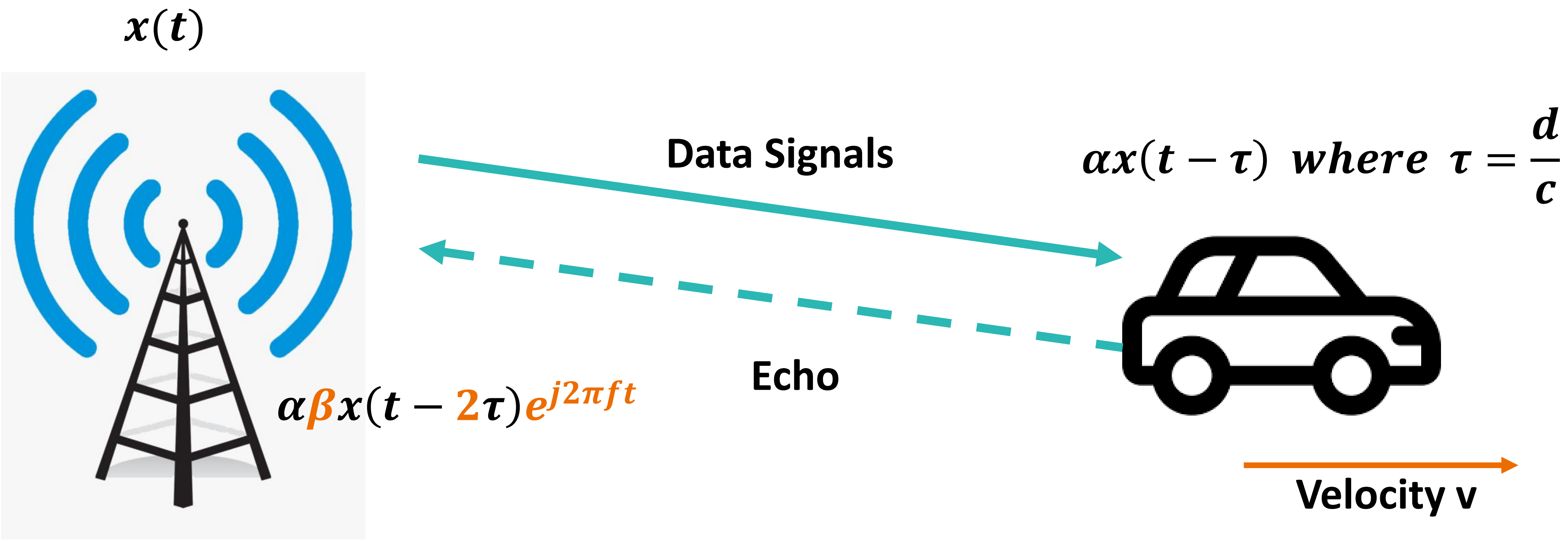
# Proactive Sensing



# Proactive Sensing



# Proactive Sensing




- $\beta$ is due to the pathloss of echo path + radar cross-section (RCS)
- $f$ is the Doppler frequency = $\frac{2vf_c}{c}$

# Proactive Sensing

$\boldsymbol{x(t)}$

$$\boldsymbol{y(t) = \alpha\beta x(t - 2\tau)e^{j2\pi f t}}$$

- If the BS knows y(t)
- Define $Cor(c,d) = \int x(t-2c)e^{j2\pi dt}y^*(t)\,dt$
- The estimation of $(\tau, f)$:

$$(\hat{\tau}, \hat{f}) = arg \max_{c,d} Cor(c,d)$$

# Proactive Sensing: Analysis

$\boldsymbol{x(t)}$

$\boldsymbol{y(t) = \alpha\beta x(t - 2\tau)e^{j2\pi ft}}$

- If is $\tau$ known, $Cor(\tau, d) = \int x(t - 2\tau)e^{j2\pi dt}y^*(t)\, dt$
- The estimation of $f$:

$$\hat{f} = \underset{d}{arg\max}\, Cor(\tau, d)$$

$$= \underset{d}{arg\max} \int x(t - 2\tau)e^{j2\pi dt}\alpha^*\beta^* x(t - 2\tau)^* e^{-j2\pi ft} dt$$

$$= \underset{d}{arg\max}\ \alpha^*\beta^* \int |x(t - 2\tau)|^2 e^{j2\pi(d-f)t} dt$$

# Proactive Sensing: Analysis

$\boldsymbol{x(t)}$

$\boldsymbol{y(t) = \alpha\beta x(t - 2\tau)e^{j2\pi f t}}$

- If is $f$ known, $Cor(c, f) = \int x(t - 2c)e^{j2\pi f t}y^*(t)\, dt$
- The estimation of $\tau$:

$$\hat{\tau} = \arg\max_c Cor(c, f)$$
$$= \arg\max_c \int x(t - 2c)e^{j2\pi f t}\alpha^*\beta^* x(t - 2\tau)^* e^{-j2\pi f t} dt$$
$$= \arg\max_c \alpha^*\beta^* \int x(t - 2c)x(t - 2\tau)^* dt$$

# Proactive Sensing: Full Duplexing

$\boldsymbol{x(t)}$

$$\boldsymbol{y(t) = \alpha\beta x(t - 2\tau)e^{j2\pi f t}}$$

- The BS should knows y(t)
- BS is sending x(t) => It must be full duplex
- Full duplex is currently a huge challenge for data transceiver design

# Proactive Sensing: TDMA

$\boldsymbol{x(t)}$

$$\boldsymbol{y(t) = \alpha\beta x(t - 2\tau)e^{j2\pi ft}}$$

- The BS sends the radar and data waves in different time
- Radar wave: Frequency Modulated Continuous Wave (FMCW)
- Only require full duplexing in FMCW transmission – Easy-peasy