Wireless Networking

Course code: CS4222/5422, Tutorial session: #2

Brief Instructions regarding the tutorial session

1. The attendance to tutorial sessions would contribute towards the determination of final grade
2. Please review the questions before coming to the tutorial session
3. Make an effort to solve the questions before attending tutorial. The teaching assistants will help in case of issues
4. The designated time for the tutorial session is one hour. Please contact the teaching assistants or the instructor if you need any further clarification regarding the tutorials outside the allocated period. Please send them an email.

Question 1: What is whitespace networking? What frequency bands are used for the broadcasting of television and FM radio signals in Singapore and United States? What unoccupied bandwidth is available in these frequency bands for wireless communication? Can we use these frequency bands for communication between IoT devices?

Answer 1:

Whitespace networking implies using the frequency bands that are allocated for television broadcast for communication. This includes using these frequency bands for communication between electronics and computer communication devices.

We can only use such unoccupied band for communication if they are allowed by the authorities. In several countries of the world, governments, and regulations, allows the usage of these bands for device communication. Hence, the short answer for using these bands for IOT devices: depends, and likely yes.

Television in USA:

VHF: 54 to 216 MHz
UHF: 470 to 700 MHz

FM in USA:

88 MHz to 108 MHz

Television in Singapore:

174 to 230 MHz

And

494 to 790 MHz

FM in Singapore:

Broadcasting: 88 to 108 MHz

IMDA is an authority in Singapore responsible for the allocation of the radio spectrum. You can look at the allocation in the following link.

https://www.imda.gov.sg/-/media/imda/files/regulation-licensing-and-consultations/frameworks-and-policies/spectrum-management-and-coordination/spectrumchart.pdf

And

https://www.imda.gov.sg/-/media/imda/files/regulation-licensing-and-consultations/frameworks-and-policies/spectrum-management-and-coordination/spectrummgmthb.pdf

For calculation of unoccupied, you can look at present radio/television station and the remaining spectrum left that is unoccupied (this is given as a homework for students).

Question 2: You designed a temperature sensor that is programmed to transmit in the 2.4 GHz band with an antenna gain (both receive and transmit) of 2 dBi and a transmit power of 10 dBm at the sensor. The application requires a communication range of 100 meters from temperature sensor to edge device. Please answer the following question.

a) Considering 100 meters is the maximum achievable range. What is the receive sensitivity of the radio transceiver at the edge device?

b) If you employ the 100 MHz frequency band instead of the 2.4 GHz band, what transmit power would suffice to support a range of 100 meters?

c) How does the size of the antenna change (between 100 MHz and 2.4 GHz)? Please assume that you are using a monopole antenna for communication?

d) What is the impact on battery lifespan when operating at the 100 MHz frequency band compared to the earlier case when the sensor was transmitting at 2.4 GHz?

Answer 2:
Let us recall the Friis propagation equation:

$$P_r = G_r G_t \left(\frac{c}{4\pi f_c d} \right)^{\alpha} P_t$$

$$1]\quad P_{rx} = P_{tx} G_{tx} G_{rx} \left(\frac{c}{4\pi D_r f_0} \right)^2$$

$$2]\quad P_{rx}(dB) = P_{tx} + G_{tx} + G_{rx} + 20\log_{10}\left(\frac{\lambda}{4\pi D_r} \right)$$

For the sake of simplicity, let us consider the value of the parameter alpha to be 2.

a) Since the question mentions that maximum range is 100 meters. This means that the radio transceiver at the edge device is receiving at the sensitivity levels.

D = 100 meters
Gt=Gr= 2 dBi
F(frequency) = 2400 MHz
Pt = 10 dBm
Pr = Receiver Sensitivity

Plugging the value in equation 2), we can estimate the Pr or receiver sensitivity to be -66.05 dBm

b) Let us assume the receiver sensitivity is the same: -66 dBm

We want to ensure Pr > -66 dBm

D = 100 meter
Frequency = 100 MHz
Gt=Gr = 2 dB

Again plugging the value in the equation 2 and solving the equation for Ptx.

c) The antenna size becomes larger for 100 MHz when compared to 2.4 GHz

d) As the radiated power required to reach a distance of 100 meters reduces at 100 MHz. Consequently, the battery lifespan improves significantly.

Question 3: You are designing a wireless transmitter and considering the use of On-Off Keying (OOK), Frequency Shift Keying (FSK), or Chirp Spread Spectrum (CSS) as potential modulation schemes. For each specific application scenario, please select the most suitable modulation scheme and provide reasoning for your choice.

Application	Description
Urban deployment of sensors	Sensors communicate over distances of hundreds of meters in a complex urban environment. It consists of roads, buildings and vegetation.
Remote control	Communication between remote control and air conditioner or a television set
Simple sensors for agriculture monitoring	Simple, energy-harvesting sensors, communicating over long distances for monitoring soil.

Answer 3:

Application	Description
Urban deployment of sensors	Chirp Spread Spectrum owing to better sensitivity and range. FSK can also be used as it supports large range and simple devices are being deployed. Both are commonly employed for communication with sensors located at large distances. CSS reaches the maximum range for same transmit power.
Remote control	Short range, simple devices. Consequently, we may use OOK as a scheme.
Simple sensors for agriculture monitoring	Since the sensors are simple and we also want large range, we would employ FSK. It hits the perfect balance between complexity required for implementation and the communication range.