Wireless Networking CS4222/5422

Tutorial 8

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Q1

(a) On the average, there are 17 students in a tutorial session. What is the probability that at least two students have the same birthday (assume 365 days)?

(b) For the entire class, there are 141 students. What is the probability that no two students have the same birthday (assume 365 days)?

What is the probability two people in a group have the same birthday?

Birthday Problem

In a group of n randomly chosen people, what is the probability that two share the same birthday?

P(at least two people among n sharing birthday)

= 1 - P(n students have birthdays on different days)

$$= 1 - \frac{365}{365} \times \frac{364}{365} \times \frac{363}{365} \times \quad \ldots \quad \times \frac{349}{365}$$

$$= 1 - \frac{365!}{365^n \times (365-n)!}$$

Q1a) Group size = 17

In a group of n randomly chosen people, what is the probability that two share the same birthday?

P(at least two people among n sharing birthday)

$$= 1 - \frac{365!}{365^{n} \text{ X } (365-n)!}$$

$$= 1 - \frac{365!}{365^{17} \text{ X } (365\text{-}17)!} \sim \mathbf{0.315}$$

Q1b) Group size = 141. No two students share same birthday

In a group of n randomly chosen people, what is the probability that two share the same birthday?

P(no two people among n sharing birthday)

$$= \frac{365!}{365^n \text{ X } (365-n)!}$$

$$= \frac{365!}{365^{141} \text{ X } (365\text{-}141)!} \sim \mathbf{2.3 \text{ X } 10^{-14}}$$

Q2

Whitespace frequencies allows wireless communication in an unused part of the television spectrum.

(a) Discuss the pros and cons of utilizing the TV spectrum for wireless communication.

(b) Identify applications that could significantly benefit from the implementation of whitespace networking.

(c) How does whitespace frequency availability differ between urban and rural settings?

(d) Explain how databases play a critical role in managing whitespace frequencies for wireless communication.

(e) Describe the regulatory hurdles and requirements for using whitespace frequencies.

(f) What are the TV frequency bands allocated in Singapore? Assuming you want to use the Bluetooth standard (Transmitting at 0 dBm, RX Sensitivity: -100 dBm) within the whitespace frequency band, how would the range improve compared to operating at the 2.4 GHz frequency band? What could be a potential drawback?

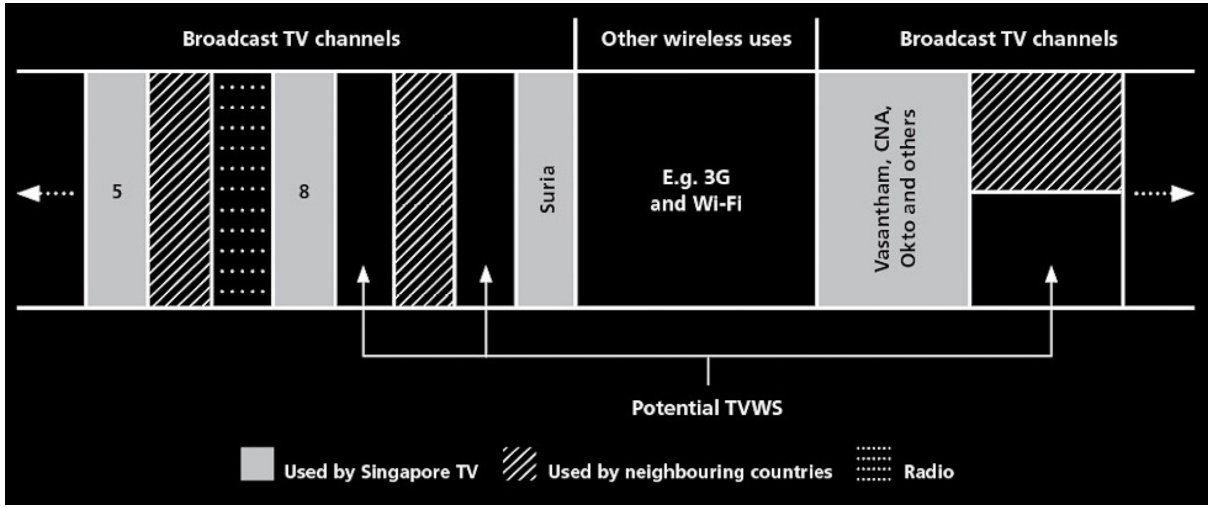
Q2a) Whitespace frequencies – Pros and Cons

Pros:

- Better propagation characteristics owing to lower frequency
- Less interference from other wireless devices
- Alleviate congestion in existing frequency bands, improve network capacity

Cons:

- May not be available in every part of the world.
- Authorities need to allow the use
- Commodity radio hardware may not be designed for Whitespace frequencies



Q2b) Identify Applications for Whitespace Frequencies

Numerous applications:

- Internet connectivity in rural areas
- Sensor data collection for monitoring sites

Pilot programs already running in Singapore:

- TVWS enabled sensors installed in "smart" rubbish bins to alert cleaners when they are full
- NUS leveraged TVWS' range and ability to design a smart grid to charge hostel residents on a pay-per-use model.

Q2c) Whitespace Frequency – Urban vs Rural

Urban Areas

- the demand for wireless connectivity is typically high, available spectrum is often heavily utilized.
- Whitespace frequencies limited in urban settings.

Rural Areas

- Fewer incumbent license holders, which can result in more whitespace frequency availability.
- Attractive option for providing high-speed internet access in rural areas where traditional wired infrastructure is not available.

Q2d) Explain role of databases

The availability of whitespace frequencies may change depending on both location and time.

Using a geo-location database alerts TVWS devices and back-end users such as service providers when there is available spectrum at its nearby location

Q2e) Explain regulatory hurdles

- Relevant authorities must grant permission for the utilization of unused TV spectrum.
- Regulations may differ from region to region, and some countries might not permit transmissions on such frequency bands.
- This contrasts with ISM bands, which do not require such approvals.

Q2f) What are the TV frequency bands allocated in Singapore? Bluetooth standard within the whitespace frequency band, how would the range improve compared to operating at the 2.4 GHz frequency band? Drawback?

Channel No.	Center Frequency	Frequency Range	System
29	538 MHz	534 MHz–542 MHz	DVB-T2
31	554 MHz	550 MHz–558 MHz	DVB-T2
33	570 MHz	566 MHz–574 MHz	DVB-T2
35	586 MHz	582 MHz–590 MHz	DVB-T2
38	610 MHz	606 MHz–614 MHz	DVB-T

Recall the Friss propagation equation

$$P_r = G_r G_t \left(\frac{c}{4\pi f_c d} \right)^{\alpha} P_t \longrightarrow d \propto \frac{1}{f_c}$$

- ✓ Better propagation Characteristics
- ✓ Reduced interference given wider band

Drawbacks:

- larger antenna sizes in IoT devices
- commodity radio chipsets may not support operation on TV whitespace frequencies.

Q3

In the project assignment, we are using a time-slotted neighbour discovery mechanism. For this kind of neighbour discovery mechanism, please answer and reason the following questions:

(a) Let’s assume that time is divided into slots of duration 200ms. In each time slot, a node wakes up with a probability of 0.1. What is the **average time taken for two such nodes to select a common slot to wake up**?

(b) In the project, beacon transmissions to announce a node’s presence are transmitted once at the beginning and once at the end of an active time slot. **Should transmissions be performed more often to improve chances of discovery**?

Q3a) Time is divided into slots of 200ms. In each slot, a node wakes up with probability 0.1. Average time taken for two such nodes to select a common slot?

Event A = both nodes wake up at a certain time slot

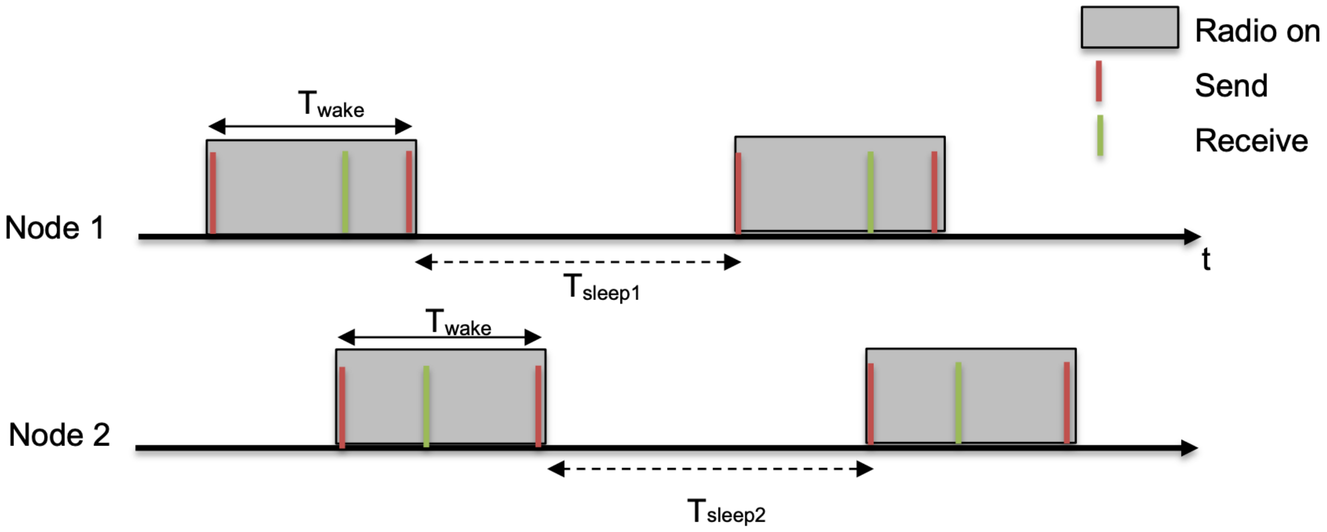
P(A) = 0.1 X 0.1 = 0.01

Expected number of time slots taken for both to wake up

$$= \frac{1}{P(A)} = \frac{1}{0.01} = 100 \text{ time slots}$$

Hence, expected time = 100 X 0.2 = **20 sec**

Q3b) Beacon transmissions to announce a node's presence are transmitted once at the beginning and once at the end of an active time slot. Should transmissions be performed more often to improve chances of discovery?



Pros

- May improve discovery when no. of nodes ('n') is small

Cons

- Can lead to frequent collisions when 'n' is large

Q4

Assuming you are deploying a network of air quality sensors in a city and need to make decisions regarding the selection of wireless networks, please answer the following questions:

(a) What data rate should be expected for these sensors? Which wireless networks would you choose and why?

(b) If you are selecting between 2-FSK (narrow bandwidth transmitter) occupying 125 kHz bandwidth and the LoRa standard using the CSS modulation scheme, consider the following: You have been allocated 3 MHz of spectrum in the unlicensed frequency band. What are the pros and cons of each option? How many air quality sensors can be supported using these standards?

Note: For the sake of calculation, time division multiplexing is not considered in this question

Q4a) Deploying a network of AQI sensors and need to select a wireless network, what data rate should be expected for these sensors? Which wireless networks would you choose and why?

Network Requirements:

Few bytes per reading → **Datarate: < 10 Kbps**

Transmit to distant gateway → **Range: 2-5 Kms**

Nodes deployed with limited battery → **Lifetime: 5-10 Years**

LP-WANs !!

LoRa® NB-IoT™ sigfox

- ☑ **Long Range** – Up to 15 km LOS
- ☑ **Low Power** Consumption
- ☑ Low Data Rate – Less than 100kbps

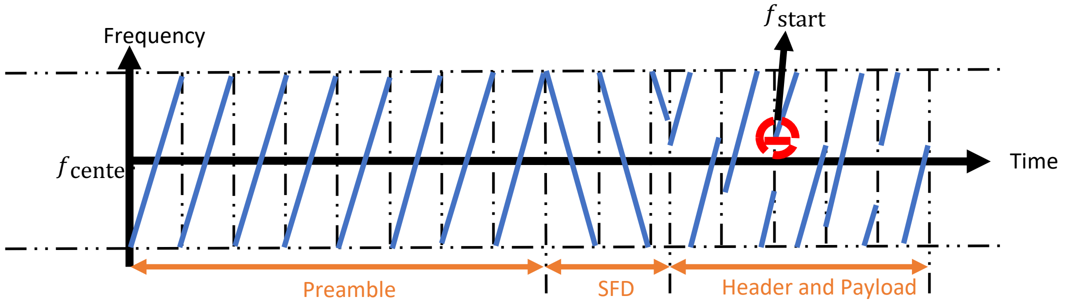
Q4b) 2-FSK vs LoRa. What are the pros and cons of each option?

Pros

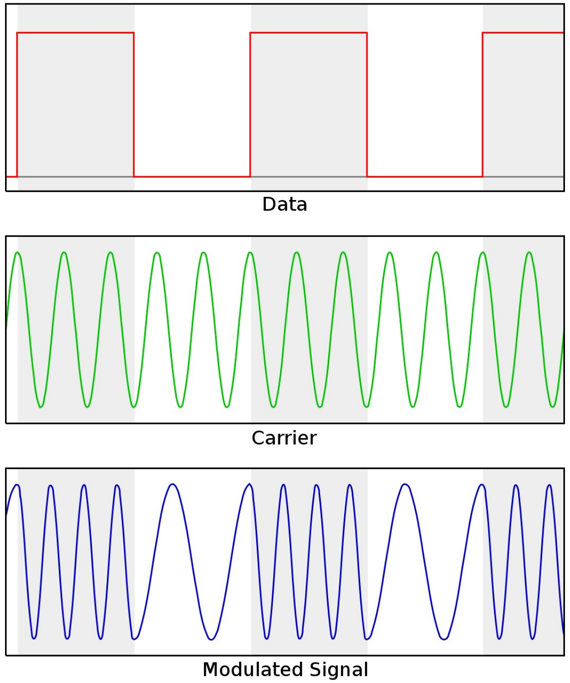
- LoRa provides a **high range** and **robustness**
- Operating in an unlicensed band, LoRa avoids the need for costly licenses and permits.
- Numerous network service providers deploying LoRa networks, the existing infrastructure can be easily reused, reducing costs and streamlining implementation.

Cons

- Limited throughput capabilities, restricting volume of data transmitted.
- As a commercial standard, some aspects of LoRa are proprietary, limiting accessibility and customization.
- More complex than 2-FSK, which could lead to increased implementation challenges and maintenance requirements.



Q4b) 2-FSK vs LoRa. What are the pros and cons of each option?



Pros

- Straightforward modulation
- enjoys widespread support among radio chipsets ➔ highly accessible.
- As it is not tied to any commercial network, maximum flexibility for network designers, eliminates the need for subscription fees.
- Capable of supporting high data throughputs, 2-FSK can handle a large volume of information.

Cons

- When compared to CSS-based transceivers, 2-FSK has a shorter range
- Fails to offer orthogonality, only few simultaneous transmissions

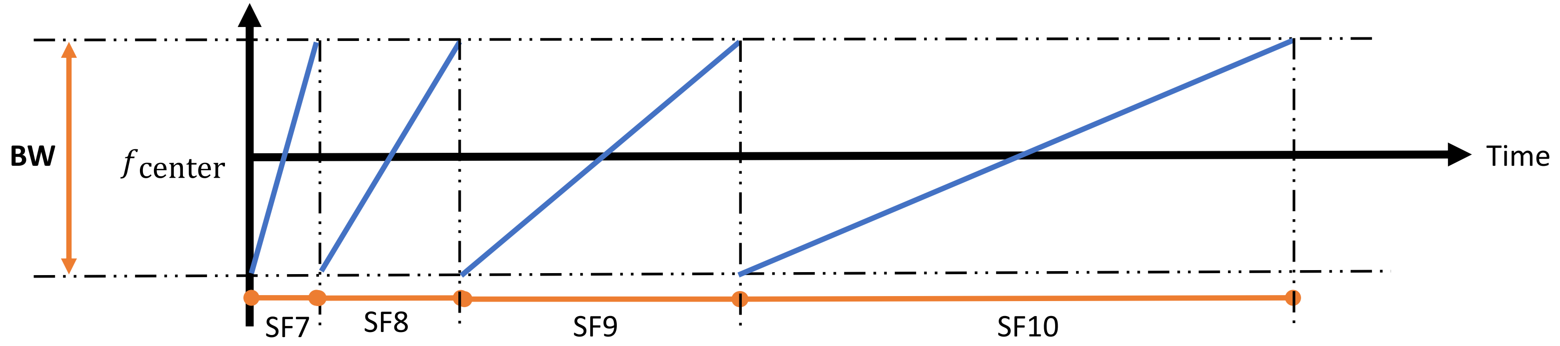
Q4b) 2-FSK vs LoRa. How many air quality sensors can be supported using these standards? Bandwidth: 125 kHz; Spectrum 3MHz

2-FSK transmission:

- Number of Transmission:
  - $\frac{\text{Available Spectrum Width}}{\text{Occupied Bandwidth}} = \frac{3\ MHz}{125\ kHz}$ = 24

LoRa:

- orthogonal spreading factors, we can have much larger number of transmitters than 2-FSK.



Q5

Technology	Bitrate	Transmit Current (mA) @ 3 Volts
WiFi (802.11b)	11 Mbps	170 mA (at 17 dBm TX strength)
ZigBee	250 kbps	9.1 mA (5 dBm)
LoRa	27 kbps	87 mA (at 17 dBm TX Strength)

Assume you have an IoT device equipped with ZigBee, LoRa, and Wi-Fi radios, powered by a coin cell battery with a capacity of 240 mAh. Given the radio configurations below, please calculate the energy per bit for each technology. Based on the results, discuss the advantages and disadvantages of each wireless communication method

For the following applications, which technology would you use:

- Sensor in agriculture setting (base station located 300 meters from soil sensor)
- Smoke alarms in home talking to each other and a Hub
- Security camera

Q5) Given the radio configurations below, please calculate the energy per bit for each technology

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Energy per bit = $\frac{\text{Energy Consumed per Second}}{\text{Bits transfered per Second}} = \frac{V \times A}{\text{Bitrate}}$

- WiFi

$$= \frac{V \times A}{\text{Bitrate}} = \frac{170 * 10^{-3} \times 3}{11 \times 10^{6}} = 46.36 \text{ nJ/bit}$$

- ZigBee

$$= \frac{V \times A}{\text{Bitrate}} = \frac{9.1 * 10^{-3} \times 3}{250 \times 10^{3}} = 109.2 \text{ nJ/bit}$$

- LoRa

$$= \frac{V \times A}{\text{Bitrate}} = \frac{87 * 10^{-3} \times 3}{27 \times 10^{3}} = 9667 \text{ nJ/bit}$$

Q5) Discuss the advantages and disadvantages of each technology

WiFi

- Lowest energy per bit
- However, it has short range
- Good for applications transmitting lot of data over short distances

Zigbee

- Mediocre datarate
- Slightly more range than WiFi.
- Commonly used in battery-powered IoT devices. Can also be used for mesh networks

LoRa

- Low datarate
- Very high range
- Good for applications requiring transmission of small amounts of data over hundreds of meters of distances

Q5) Choose the technology for given applications

Sensors in Agriculture

- Long Range
- Low Data Load

→ LoRa®

Smoke Alarm

- Short Range
- Low Data Load
- Battery Operated

→ zigbee

Security Camera

- Short Range
- High Data Load

→ Wi Fi™

Thank you

Feel free to contact me at kanav.sabharwal@u.nus.edu for any clarifications