Wireless Networking

Course code: CS4222/5422, Tutorial session: #6 (Answers)

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.

Answer 1: There are various strategies that can be employed. Since, predominantly the user is stationary. Hence, we would not want to use GPS too often. This would increase the energy consumption of the device.

We can use the accelerometer to keep track of the motion of the user. The accelerometer data can also be used to estimate when the user walks and roughly distanced traversed. These can then be used to trigger GPS periodically to calibrate the readings.

Thus, by using accelerometer to switch on more power consuming gps, and also using accelerometer for tracking, we can make the device to be more energy efficient.

Answer 2:

(a). For Bluetooth Radio:

Bitrate = 1.2 Mb/s = 1.2 * 10^6 bits/second
Voltage = 1.8 Volts
Transmit current = 60 mA

Time required to transmit 1 bit = 1/(1.2 * 10^6)
Energy consumed to transmit 1 bit = 1.8 * 60 * 1/(1.2 * 10^6) mJ

You can estimate in a similar manner for other radios.

For ZigBee:

Energy consumed to transmit 1 bit = 3 * 30 * 1/(0.25 * 10^6) mJ

For Wi-Fi:

Energy consumed to transmit 1 bit = 3 * 30 * 1/(54 * 10^6) mJ

For LoRa:

Energy consumed to transmit 1 bit = 3 * 30 * 1/(0.027 * 10^6) mJ

For Backscatter:

Energy consumed to transmit 1 bit = 3 * 30 * 1/(0.003 * 10^6) mJ

For judo:

Energy consumed to transmit 1 bit = 3 * 30 * 1/(0.1 * 10^6) mJ

(b)

Let us look at Bluetooth:

Data transmitted = 1000 bytes = 1000 * 8 bits
Energy required to transmit 1 bit = 1.8 * 60 * 1/(1.2 * 10^6) mJ
Total energy used to transmit 8000 bit = 8000 * 1.8 * 60 * 1/(1.2 * 10^6) mJ

For ZigBee: 3 * 30 * 1/(0.25 * 10^6) mJ * 8000
For Wi-Fi: 3 * 30 * 1/(54 * 10^6) mJ * 8000
For LoRa: 3 * 30 * 1/(0.027 * 10^6) * 8000
For Backscatter: 3 * 30 * 1/(0.003 * 10^6) * 8000
For Judo: 3 * 30 * 1/(0.1 * 10^6) * 8000

(c)

If the bit error rate is 30%, it means out of 1000 bits transmitted, 300 bits are corrupt.
To transmit 1000 bits successfully, you would need to transmit (1000/700*1000) bits

For bit error rate 5%
To transmit 1000 bits successfully, you would need to transmit (1000/950*1000) bits

For bit error rate 1%
To transmit 1000 bits successfully, you would need to transmit (1000/990*1000) bits

For bit error rate 40%
To transmit 1000 bits successfully, you would need to transmit (1000/600*1000) bits

To calculate energy consumed in case of backscatter: 3 * 30 * 1/(0.003 * 10^6) * (1000/600*1000)

You can calculate similarly for other technologies.

(d) No, this would depend on the application. The technology may not be able to support sufficient range of throughput to support application despite having a lower energy per bit. It is a complex task to determine what would be the appropriate technology for an application.

e) WiFI supports higher bitrate. Cameras require transmitting large amounts of information. It could be an application that may prefer Wi-Fi over ZigBee.

f) backscatter is low-power consumption. For applications requiring operation on small batteries or harvested energy.

Answer 3:

Let us list down some of the important parameters from the question.

The operating voltage is: 3 volts, The battery capacity: 120 mAh

Radio transceiver bitrate is 100 kilobits/second
Frequency: 2.4 GHz
Antenna gain (transmit and receiver): 2 dBi

Power consumption for radio transceiver

Transceiver Mode	Current Consumption
Sleep	10 microampere
Idle	5 milliampere
Receive	10 milliampere

Radio Transmit Power	Current Consumption
-10 dBm	10 milliamperes
0 dBm	15 milliamperes
5 dBm	20 milliamperes
15 dBm	30 milliamperes

Microcontroller is always active. Hence, the total current consumption will always include the current consumed by the microcontroller which is 2 milliamperes.

Time to transmit one packet (50 bytes) = 50 * 8/ 100*(1000) = 4 milliseconds

a) We would transmit to distance of 100 meters and 500 meters. We just need sufficient signal strength to reach the distant with stated powered consumption. Thus, if we estimate the received signal strength, it should be above -85 dBm.

For 100 meters: A transmit power of 0 dBm should be sufficient
For 500 meters: A transmit power of 15 dBm should be sufficient

You can estimate above with the link budget formula discussed earlier.

b) Power consumption for various states

If we consider a cycle of 1 seconds:

Various states for the device:

<u>State 1: Radio sleep + Microcontroller active</u>

Duration: 1000 - 50 - 4 - 4 = 942 milliseconds

Current consumption: 2 mA + 0.01 mA
Power consumption: 2.01 X 3 = 6.03 milliwatts

<u>State 2: Radio Idle + Microcontroller active</u>

Duration: 50 milliseconds
Current consumption: 2 + 5 = 7 mA
Power consumption: 7 * 3 = 21 milliwatts

<u>State 3: Radio Transmit + Microcontroller active</u>

Radio Transmit (100 meters) + Radio Transmit (500 meters) + Microcontroller active
Duration: 8 milliseconds

Power consumption for 100 meters transmission: (15+2) * 3 = 51 milliwatts
Power consumption for 500 meters transmission: (30+2) * 3 = 96 milliwatts

c)

Let us look at charge consumed in each state:

State 1: (2.01 * 0.942) mA-s
State 2: (7 * 0.05) mA-s
State 3: (17 * 0.004) mA-s
State 4: (32 * 0.004) mA-s

Average current =. Total Charge/Total time
= ((2.01 * 0.942) + (7 * 0.05) + (17 * 0.004) + (32 * 0.004))/1 second
= 2.439 mA

Lifespan = 120 mAH/2.439 = 49.2 hours