Exercise set: 4
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Introduction to IoT: fourth set of exercises

First exercise

The requested code has been attached to my submission in the file: "firstExercise.txt". The code has comments that help to understand it.

Second exercise - first application (enterprise IoT)

1. The first application I have selected is smart trashing and the smart object is a big smart bin that have to be placed in a rubbish dump. The operators can put the rubbish inside the bin without sorting it because the main functionality of the bin is to sort the rubbish by itself. How does it work? When the rubbish is put inside the bin a camera is able to identify rubbish types: this is possible thanks to a complex computer vision algorithm that works behind the camera. After rubbish identification a robotic arm takes each item and puts it inside the correct bin. In fact, inside this big bin there are different smaller bins, one per rubbish type. Finally, through a touch screen it is possible to manage the big bin and to visualize useful information about its state (updates, faults). For example, when one of the smaller bin inside the smart object is full, the screen will visualize this information. It is possible to connect the smart object to the network of the rubbish dump in such a way that the bin can send notifications to the operators when something goes wrong. Since the garbage types are really difficult to detect using only a camera, other sensors have to be used to make the detection more accurate:
    a. sounds sensor: when the item is put inside the bin it emits sounds that could differ from the other types of garbage, so it could be useful to use a sounds sensor to obtain an higher accuracy in classification. To make an example the paper is usually not loud like a piece of glass or metal;
    b. weight scale: it is possible to put a weight scale inside the bin, in this way it is easier for the algorithm to understand which type of item is put inside of it, in fact the different types of garbage have different weights, for example the paper is really light and the glass is really heavy;
    c. humidity sensor: this particular sensor is really useful to detect biodegradable waste, in fact a camera, the weight scale and sounds sensor aren't probably enough to understand about the biodegradable waste. I said this because the biodegradable waste includes a lot of waste types that look really different, have different sounds and also a different weight.
2. These are characteristics that are highly related to the network technology used for the smart object connectivity. Since I would use Narrowband IoT these are the requirements that the object imposes to the network technology:
    a. Frequency: 200 kHz;
    b. Range: 1 - 10 km;
    c. Bandwidth: 250 kbps;

d. Modulation: OFDMA, SC-FDMA;
e. Power: low/medium, the consumptions aren't a problem because the bin is directly connected to the main power supply of the rubbish dump.

3. I would use a Narrowband IoT network technology because:
   a. the rubbish dump network is a WAN cause of its size, so a WAN network technology is needed;
   b. as I said before, since the smart object is directly connected to the main power supply of the rubbish dump there aren't constraints on the consumptions of the device, so it is possible to use the network technology that reaches the best performances;
   c. since this is an enterprise IoT application we are highly interested in providing the best network services, so we need Quality of Services;
   d. we need the best latency performances because the inference algorithm of the bin could be offloaded in cyber-foraging if the computational power of the bin isn't enough to perform garbage type detection. Moreover we need to offload the deep learning model training to the cloud computing;
   e. LTE is the best standard for mobile devices that are the majority of the devices connected to the network of the rubbish dump.

   I would use a combination of infrastructure-based and ad hoc network architectures. The bin is connected by wire to the network of the rubbish dump that is directly connected to a LTE base station. Through this station it is possible to reach the server cloud for the training of the deep learning algorithm that works inside the bin. The notifications that have to be sent to the operators when something goes wrong could be sent using an ad hoc with single hop architecture, in fact the bin sends the notification to the nearest device and then the notification is propagated by the devices themselves.

   As I said before, a network range for a WAN has to be used in this application and since we are using Narrowband IoT the network range is 1 - 10 km. Depending on the size of the rubbish dump it is probably possible to use a Campus Area Network instead of the Wide Area Network.

Second exercise - second application (consumer level IoT)

1. The second application I have selected is smart home and the smart object is a smart fridge. This fridge has a camera that keeps track of the food inside of it. Through this camera the fridge is able to learn what the user eat in a period of time in such a way that it can order the food by itself. Moreover, it is able to buy the food in an intelligent way: if a product is finishing or expiring the fridge will order the product. To be able to perform these checks it needs computer vision algorithms. With these functionalities the user doesn't need to go buy something or to check the fridge. It is possible to configure the fridge through a touch screen. With this trouch screen the user can disabilitate the machine learning algorithm that learns the foods in such a way that he can decide which types of food to order by himself. Then, it is possible to make subscription to retailer such as Amazon to organize food ordering and delivering. In conclusion, the fridge is connected to the network in such a way that it can send

useful notifications about its state to the user’s device and it can connect to other IoT devices such as oven or weight scale.

2. These are characteristics that are highly related to the network technology used for the smart object connectivity. Since I would use ZigBee these are the requirements that the object imposes to the network technology:
    a. Frequency: 868 MHz, 2.4 GHz;
    b. Range: 10 - 100 m;
    c. Bandwidth: 20 kbps - 250 kbps;
    d. Modulation: DSSS, O-QPSK;
    e. Power: low (10 - 100 mW).
3. I would use ZigBee network technology because:
    a. since the fridge works inside a smart home it isn’t necessary to use WAN netowork technologies, in fact a range of 100 m it is enough for the majority of the houses;
    b. it is true that ZigBee works in the same band of the WiFi and that there could be interferences with the other devices in the home but since the fridge hasn’t critical functionalities it could be enough to retransmit loss data if it will be necessary;
    c. the other PAN technology presented was BLE that has a range that is too small for this application.

    I would use an ad hoc network architecture with single hop because the fridge can connect directly to the devices (oven, weight scale) in the house and to the smartphone of its owner. The infrastructuered based network architecture has to be used only to order products on Amazon and send notifications to the user when he is not at home.

    As I said before, a network range of 100 m it is enough to cover the majority of the houses considering that it is the range for a single hop.

Third exercise

I’ve chosen the second application and these are the information requested:

1. These are characteristics that are highly related to the network technology used for the smart object connectivity. Since I would use Lora these are the requirements that the object imposes to the network technology:
    a. Frequency: 863 - 928 MHz;
    b. Range: 2 - 10 km;
    c. Bandwidth: 250 bps - 50 kbps;
    d. Modulation: CSS;
    e. Power: low.
2. I’ve decided to use Lora network technology for this car, because:
    a. it has a low power comsuption;
    b. it has enough bandwidth to send data from sensors to the server cloud for their processing;
    c. it has a range that is enough large for normal driving conditions (city, highway and not inside of the forest or in the middle of the desert);

d. it has a latency performance that is better than SigFox and since we need to offload the data processing to the server cloud we want the response to arrive in reasonable time because this is an application where the safety of the driver is at the first place.

For this application an infrastructured based network architecture has to be used, in fact the car needs to be connected directly to the base stations to be able to contact the server cloud for the data processing.

I would like to have a better network range (40 km) because sometimes there aren't many base stations in remote areas of the world but we are constrained by the chosen network technology.

3. In this application the cloud computing offloading model has to be used, in fact it isn't possible to use edge computing because we aren't in a Personal Area Network and we can't use fog computing because we aren't in a Local Area Network. The car has to be connected directly to a base station that is connected to the Internet that allows to the car to connect to the server cloud. The only task it is useful to offload is the processing of the sensors data to be able to check the state of the vehicle because this is the task that requires more power, in fact an inference algorithm has to be performed. Since the information about the state of the vehicle haven't to arrive in real time we can wait for the latency related to the server cloud connection. The energy requested by the task is related to the energy of the network technology used, that is low. In conclusion, if we assume that this car check has to be performed every 24 hours, the sensors data recorded that have to be sent aren't too much and the computation costs required are limited because they depend on the amount of data that have to be processed.

Bonus exercise

The optimal bandwidth for this application is 6 bits per second because we can start the calibration of the measurements just after we have performed the measurements. Since the cooling of the MOX gas sensor is performed in parallel with the calibration of the measurements we need a bandwidth of 5 bits (calibration) + 1 bit (cooling) per second. There aren't other functionalities that can be performed in parallel so this application will reach a data rate of maximum 6 bits per second. The throughput varies between the day and the night hours. During night hours the throughput is 5.94 bits per second, while during day hours it is 5.82 bits per second.