IOTPA

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1 Multiple Access protocols

Any signal occupies a range of frequencies in a given period of time (void for phone applications 0-4KHz). Multiple access: several users that want to occupy a channel. Need to establish a rule to synchronize multiple users to access a shared channel. The first solution used id Frequency Division Multiple Access.

1.1 FDMA

Different users occupy different frequencies. They transmit simultaneously on different frequency. To receive information from a user use a filter that get only the frequency from one user. Orthogonal access to the channel, each user has a different resource of the channel. Can work on analog signal.

1.2 TDMA

Time Division Multiple Access works only on digital signals. Each user has a different time slot. Time is partitioned in different frames, each divided in slots. Each time slot is assigned to a different user based on some decision on the scheduling. Doesn't work on analog because it need to store the signal. To do this multiple access scheme all the transmitters need to synchronize the clocks. Need to do some work to synchronize the clocks, done by a coordinator or by the users. Need additional bits transmitted with the data to synchronize. TDMA has some overhead.

1.3 CDMA

Code Division Multiple Access transmit overlapping time and frequencies. Each user has a code that identifies it.

1.4 Contention Based MA

If there a lot of sensors that not always transmit using previous MA protocols there is a waste of resources as they need to allocate resources. With contention based, multiple sensors transmit when they need. They don't occupy a resource. In case of collision they retransmit. Also there is no overhead to synchronized the clocks. The power for TX is used for transmitting only the data and not for the overhead. Examples of contentions protocols:

- ALOHA: as soon as a node has a packet it transmit, usually the receiver send an ACK. In case of collision transmit again.
- Slotted ALOHA: need to reduce collision probability without introducing overhead. Time is divided in slots but they are not assigned. When a node need to transmit, do it in a slot. Collision might occur, but only with total overlapping
- CSMA: Carrier Sense Multiple Access, when the node need to transmit, listen to the channel (in receiver mode) to understand if someone else is transmitting. If channel is free transmit, if is busy transmit when it is free. Collision might occur when multiple channel are waiting for the channel. Also listening the channel consume energy.
- CSMA\CA: wait random time when channel is free to prevent previous case, but it introduces latency. Need to verify that for the current application the latency is not important.
- CSMA\CA RTS\CTS: Hidden Terminal Problem: one terminal cannot listen to an hidden terminal. When they are transmitting might collide. With WiFi there is the introduction of RTS and CTS. Request To Send and Clear To Send (see slide). Lots of overhead for this MA protocol. Exposure terminal problem still remains (see slides). Previous protocol can fail if some configuration of node is present. When transmitting lots amount of data there is no problem, but for WSN that transmit few bytes there is an issue.

For WSN there are other protocols more suited for the use case. Usually schedule protocols are more efficient. A tradeoff is using random access to schedule a transmitting slot. Then transmit using schedule protocols.

1.5 Exercise 1

1 Node that generates 10 Bytes each 16 milliseconds. The overhead is 25 bytes. The communication technology transmit at a speed of 250 Kbps. The power consumption is 50 mW. The energy in the battery is 10^4 Joules. Consumed energy is P * TTX = 56 * 10

$$bits = 35 * 8 = 280 bits \tag{1}$$

$$T_{TX} = 25 * 8/250 * 10^3 = 1.12 ms \tag{2}$$

$$E_{tx} = P * T_{TX} = 56 * 10^{-6} J \tag{3}$$

$$Lifetime = \frac{E_{battery}}{E_{TX} * T_{round}} = N_{rounds} * 16ms \quad (4)$$

If double the time between each round doubling the data it is more efficient. Because the overhead is applied to more data.

dB Measuring power in communication systems is common to use the dB. Assume to measure the power measured in W, use the ration of the power and a reference power.

$$dB = 10log_{10}\frac{P}{P_{ref}} \quad (5)$$

Usually the reference power is 1 W. In the case of 10 W the result is 10 dBW. 100 W is 20 dBW. In the case on the dBm the reference power is 1 mW, used when using low power levels. $0dBm = 1mW$

2 WSN

2.1 Energy Efficiency

Energy efficiency is one the main challenge of WSN. $ConsumedPower = absorbedpower * voltage$ To transmit there is a need for a determined level of minimum current. Reducing the output power does not affect much the current control.

Even going from sleep mode to awake there is a power consumption. Waking up frequently uses lots of energy.

One cycle of a WSN consist in.

1. The sink node sends a trigger packet
2. Sensor node sense the channel to check when it can transmit
3. The sensor transmit the data
4. After some second the node goes to sleep
5. Periodically the sensors wake up to check if the trigger packet is transmitted

In conclusion it might be useful to perform more computing on the node to transmit less data, and to put the sensor in sleep mode as much as possible.

To improve the energy efficiency there are 3 approaches:

- Low duty cycle operations
- Data-driver approaches
- Mobility-based approaches

2.1.1 Duty cycling

Duty cycling is based on as much sleep as possible for the node. Two types Topology Control and Power Management.

In case of Topology Control only a subset of nodes is chosen to be active. Using redundant nodes. Two basic approaches Location driven and Connectivity Driven.

Location driven The area to be monitored is divided in virtual grids. A node know in which grid it is