Introduction to IoT: Autumn 2019

Home Exam

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Instructions All course participants are requested to submit their solutions (in English) electronically to the instructors Agustin Zuniga (agustin.zuniga at helsinki.fi) and Prof. Petteri Nurmi (petteri.nurmi at helsinki.fi) by the due date. Use the following subject in your email: *IoT_EXAM_[last name_first name]_[student number], (i.e. IoT_EXAM_Zuniga_Agustin_12345)*

Formatting Submissions should be formatted according to the ACM master template available from https://www.acm.org/publications/proceedings-template. Please use the single column formation option for the document class. Your resulting file should format similarly to how the exam has been formatted.

Tasks 1 and 2 are compulsory to everyone.

Task 1: Concepts (4 pts.)

Please describe what the following concepts mean and why they are relevant for the Internet of Things. For full points give an example (or examples) of the concepts in an IoT context. Do not copy the definitions from Wikipedia or other source, but explain the concepts in your own words and relate them with IoT.

(1) Modulation
(2) Preemption
(3) Duty Cycle
(4) Vertical and Horizontal Scaling
(5) Distributed File System
(6) Inversion Attack
(7) Cyber-Foraging
(8) Multi-Factor Authentication

Task 2: Smart objectes and IoT applications (6 pts.)

Read the description of the following IoT application: https://learn.sparkfun.com/tutorials/wireless-gesture-controlled-robot and answer to the questions below regarding features of the smart object:

(1) List the different peripherals used by the smart object and classify them as sensors or actuators.
(2) Which type of control unit would be best suited and why?

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(3) Which requirements would the objects impose on the operating system? Which operating system would you use?
(4) What power source would objects use and why?
(5) What kind of energy harvesting could be used as power source / supporting power source and why?

Please select one of the following two questions, i.e., Task 3 or Task 4.

Task 3: Sensing (4 pts.)

Google's self-driving cars integrate the following sensors: laser range finder (LIDAR), windshield-mounted camera, 4 radars mounted on front and rear bumpers, GPS receiver, ultrasonic sensors on rear wheels, altimeters, gyroscopes, tachymeters, and pre-loaded maps of the environment.

(1) Classify each sensor along the main sensor categories introduced during the course.
(2) The car uses the windshield-mounted camera to recognise traffic signs and to support detection of different objects in the environment. Please indicate: (a) what type of intelligence does the system correspond to? (b) what type of algorithms would be used internally?
(3) Assume the car is driving 120km/h along a snowy road. The object detection range of the LiDAR sensor is 200m. During these conditions, the braking distance from 120km/h to 0km/h is 189 meters. What should the duty cycle of the Lidar be so that the car has sufficient time to stop in case there is an obstacle?
(4) Assume that both Lidar and object detection from Lidar sensors operates with 5Hz frequency. Would the car have enough time to stop in time?

Task 4: Networking in IoT (4 pts.)

Connected cows is an IoT application that allows adopting smart technology at farms. The following report: https://www.ft.com/content/2db7e742-7204-11e7-93ff-99f383b09ff9 shows five sensors that can be used to obtain detailed information about cows (i.e location, health and level of productivity). A farmer wants to implement the complete IoT solution (all the five sensors) in 50 cows. Assume that cows are moving in a 5 km^2 farm, and the sizes of each sample are: 0.1 MB for necklaces, 0.05 MB for pedometers, 0.075MB for acid monitors, 0.025 MB udder sensors and 0.05 MB for tail movements. Assume also that samples from the necklace and pedometer are collected and transmitted every 30 minutes. In the case of acid monitor, tail movements and udder sensors the measurements are collected every 5 minutes, but transmitted every 15 minutes.

(1) Which networking technologies would be best for this application and why?
(2) Report the bandwidth used by the application.
(3) Report the throughput of the channel if you know that the percentage of packages that collide during the data transmission of the individual devices are: 5% for necklaces, 2% for pedometers, 10% for acid monitors, 1% udder sensors and 10% for tail movements.
(4) Assume the farm adopts a gateway that can process 4mb of measurements per minute (including operations performed on the data, i.e., storage, decryption, analysis etc.). Can all the data be processed in time? If not, how could the system be modified?

Please select one of the following two questions, i.e., Task 5 or Task 6.

Task 5: Data management in IoT (4 pts.)

Consider a company that rents bicycles to people at different locations of the city. Assume the company implements its system using a distributed sensor database schema, and that each station has a sensor that measures the number of bikes available every 5 minutes. The number of bikes is stored by attribute `bikes` which is supported by every station. Assume also that the station has storage for all returns within the past week, and that each station knows the postcode where it has been installed. How would you implement the following features to its system?

(1) Query for the average availability of bikes in postcode 00560 within the past hour?
(2) A repeating query that returns the number of bikes within any postcode starting 0056 every 15 minutes?

For a summary of different query operators and their meanings, please see Slide 45 of Lecture 9 or Table 4 in the following article: *Belfkih, A., Duvallet, C., Sadeg, B. (2019). A survey on wireless sensor network databases. Wireless Networks, 1-26.*

Assume another company wants to implement the same approach using a warehousing approach and a big data framework. In this case all data from all sensors would be sent to a central storage and processed there. How would you implement the same features in Map Reduce? What would be the Map and what would be the Reduce operation?

(3) Query for the average availability of bikes in postcode 00560 within the past hour?
(4) A query that returns the number of bikes within any postcode starting 0056 for the past 15 minutes?

Task 6: IoT Privacy and Security (4 pts.)

IoT cows applications offer a great opportunity to integrate IoT into farms. The following report: https://www.ft.com/content/2db7e742-7204-11e7-93ff-99f383b09ff9 shows five sensors that can be used to obtain detailed information about cows. The sensors are produced by different vendors, which can cause big privacy and security issues.

(1) Which IoT layer would be more exposed to security attacks at individual and group sensor level?
(2) What would be the effect of having a DDoS attack if all the information is transmitted at the same time? What would the effect if the information is transmitted at different time?
(3) Which method would you use to ensure that sensors' measurements are not corrupted?
(4) How could you create a secure communication channel between two cows?

Bonus (10 pts)

- Copy the file *cooja_home_exam.csc* (the file is included as part of the home exam email) to your Contiki's virtual machine.
- From the Cooja's menu select *File>Open simulation>Browse...*, and open *week2_task.csc* file.
- Once the file has been loaded (see Figure 1), you will see two different kind of nodes in the *Network* window. Green nodes correspond to Z1[1] type motes and the red ones to SKY[2] type. The nodes are distributed in three groups at different locations. Additionally, you will observe three *Sensor Data Collect* windows, each of them corresponding to one of the three *Collected View*[3][4] panels. *Sensor Data Collect* windows provides information of the interaction and performance of the nodes during the simulation. In this example, these windows give you insights about what is happening within the different node groups.

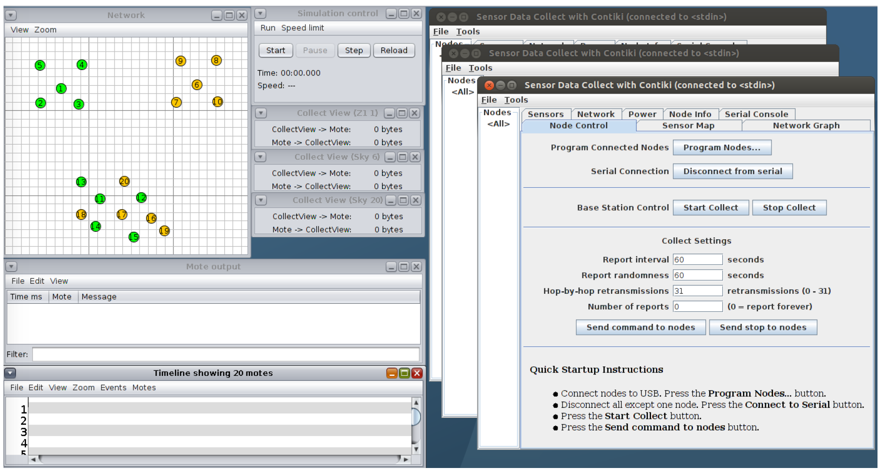

Fig. 1.

- Press the *Start* button in the *Simulation Control Panel* to begin the simulation.
- To start nodes data collection, repeat the following steps for the three *Sensor Data Collect* windows: In the *Node Control* tab, press the *Start Collect* button. Then, press the *Start Collect* button. The nodes will appear one by one in the *Nodes* area.
- Observe that each *Sensor Data Collect* window has different nodes. Now, you can identify the group of nodes corresponding to each window.
- Keep the simulation running for at least 5 minutes.
- Open the *Simulation Control Panel* that contains nodes 1 to 5. Select < *all* > in the *Nodes* area. Select the *Power* tab and examine the information about in *Instantaneous Power*, *Power History*, *Average Power* and *Radio Duty Cycle*. Repeat this step for the remaining windows, and answer the following questions (give justified arguments for maximum points, you can also include print screens of the tabs):

(1) Which type of nodes perform better respecting power consumption and why?
(2) How energy drain of the nodes is affected when they are deployed in groups of the same and different model?

[1] http://wiki.zolertia.com/wiki/index.php/Main_Page
[2] http://www.crew-project.eu/sites/default/files/tmote-sky-datasheet.pdf
[3] http://anrg.usc.edu/contiki/index.php/Collect_View
[4] http://contiki.sourceforge.net/docs/2.6/a00010.html