COMP 32412

Two hours

Please write your student ID on the supplementary sheet (Appendix A) attached to the exam. Return this with your answerbook used for Section A.

UNIVERSITY OF MANCHESTER
SCHOOL OF COMPUTER SCIENCE

The Internet of Things: Architectures and Applications

Date: Friday 25th May 2018

Time: 09:45 - 11:45

Please answer all Questions.

Use a SEPARATE answerbook for each SECTION

This is a CLOSED book examination

The use of electronic calculators is permitted provided they are not programmable and do not store text

[PTO]

Section A

Please answer ALL questions

1. Answer **ALL** parts of this question (20 marks).

a) Web communication technologies are essential to IoT systems where RESTful and Websocket services are widely used. Briefly describe the differences between these two approaches and present an example where one service is preferred over the other. (4 marks)

b) The developer of a smart home automation system has produced the Information Model of a virtual entity illustrated in Figure 1 representing a smoke detector that measures the level of carbon dioxide (CO_2) in a room of a home. The smoke detector records the level of CO_2 in the room every 60 seconds. Justify whether the provided Information Model is complete. If necessary, modify the given model to correctly reflect the information managed by this virtual entity. (3 marks)

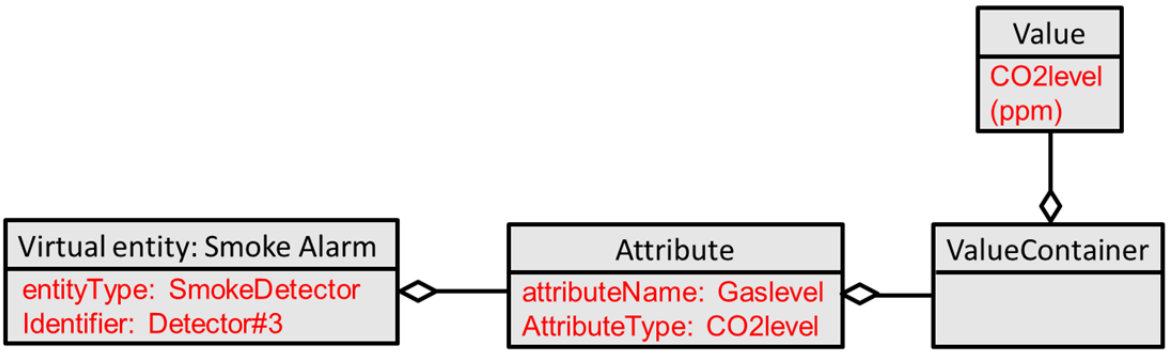

Figure 1: Information Model of the virtual entity.

c) A generic IoT Domain Model is depicted in Figure 2. For each class of the model, give its type (e.g., Software, Hardware…., etc). (Hint: you can either use a legend or annotate each class separately). Please use the separate sheet, provided as Appendix A, and staple it to the answer book. The cardinalities for the association relation between the Virtual Entity and Physical Entity class are also annotated on the Domain Model. Discuss whether these cardinalities are correct and, if not, provide the correct cardinality for the source and endpoint of this relation. (5 marks)

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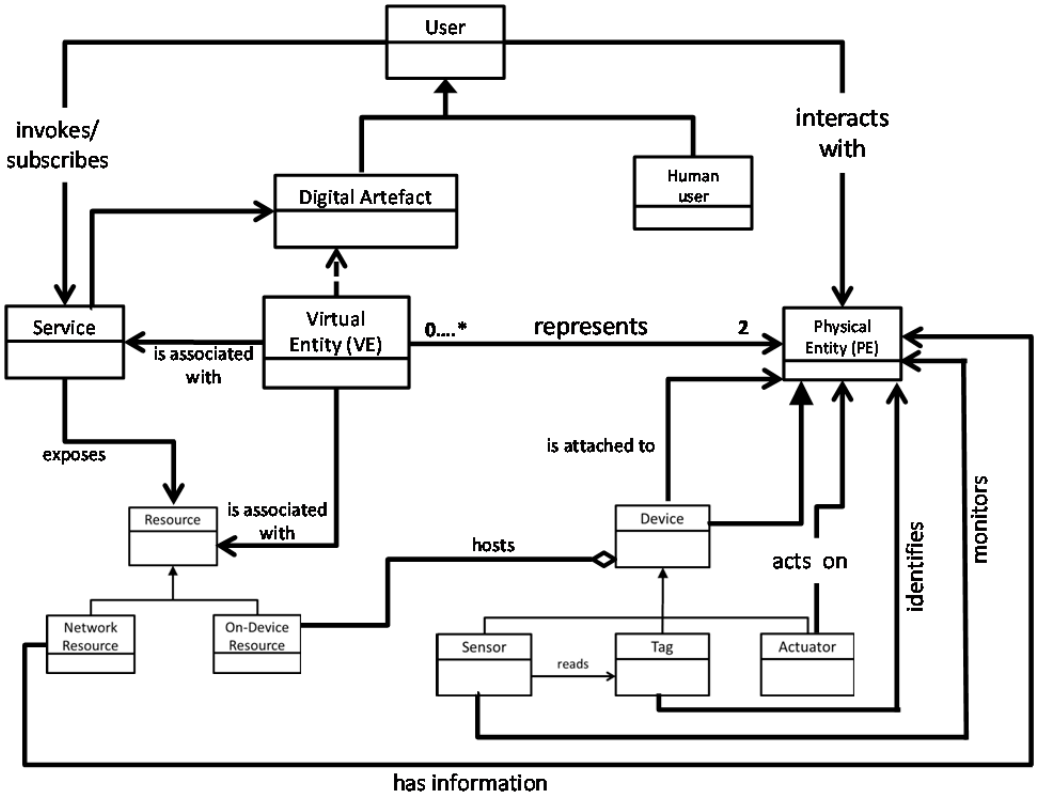

Figure 2: Generic IoT Domain Model.

d) A smart irrigation system is developed for a greenhouse. The smart irrigation system comprises two temperature sensors, one soil moisture sensor and two water valves for water supply. Data from the sensors and commands to the water valves are provided from a microcontroller board mounted on the greenhouse walls. The board also contains a GPS identification device. An application provides the sensor data to the farmer and the farmer can interact with the greenhouse through commands to turn on/off the water valves.

Develop a Domain Model for the irrigation system of the greenhouse (analogue to the example shown in Figure 2). All components of the irrigation system should be included in the Domain Model. In the Domain Model, indicate the type of each class (Hint: the use of a legend may simplify this task).

(8 marks)

2. Answer **ALL** parts of this question (20 marks).

a) Briefly describe how spread spectrum methods work and give the main advantage these techniques bring to wireless communication. (3 marks)

b) WLANs support communication among devices with two primary methods. The Basic Service Set (BSS), which requires the use of an access point (AP) and the Independent Basic Service Set (IBSS). What are the advantages of having an AP in networks based on BSS? What are the main characteristics of the networks that utilize the IBSS? (4 marks)

c) Considering the classic Bluetooth protocol, what is a Scatternet?
Assume that we want to construct a Scatternet consisting of 15 devices. How can we produce such a Scatternet? (you can either provide a textual answer or draw a diagram that reflects the required Scatternet). (5 marks)

d) Two wireless networks are active within an indoors personal operating space (POS). One of the wireless networks is a WLAN while the second network is deployed using Bluetooth. The master device of the Bluetooth network is physically located on a laptop of a user which is also connected to the WLAN network.

i) What is the appropriate type of mechanisms we can use in this scenario to avoid interference between the two networks? Give one example of these techniques used in systems supporting both WLAN and Bluetooth communication. (2 marks)

ii) Assume that this user disconnects from the Bluetooth network but remains connected to the WLAN. Both networks remain active within the POS. What are the mechanisms we can deploy in this scenario to avoid interference? (3 marks)

iii) If the path-loss exponent in this indoor environment is 6 and assuming that the interference at the WLAN device is considered negligible if the level of interference is less than -60 dB, what is the minimum distance that the WLAN device must have from the devices of the Bluetooth network? Give one example of these techniques. (3 marks)

The log-distance path loss model is assumed to describe power losses in this problem, given by

$$\overline{PL}(d) = \overline{PL}(d_0) + 10n\log\left(\frac{d}{d_0}\right).$$

Assume that the reference distance is 0.5 m and that the losses at this distance are 6 dB.

Section B

Please answer ALL questions

3. Answer **ALL** parts of this question (20 marks).

A house has a thermostat which keeps the internal temperature in the range

$$[T_{int}, T_{int} + \Theta] = [20^oC, 22^oC]. \quad (1)$$

When the heating system is switched off, the temperature T in the house declines in time t following Newton's law of cooling:

$$\frac{dT}{dt} = -\gamma_c(T - T_{ext}), \qquad T(0) = T_0, \quad (2)$$

where T_0 is the internal temperature at time $t = 0$ and T_{ext} is the external temperature. The analytical solution of (2) is given by

$$T(t) = T_{ext} + (T_0 - T_{ext})e^{-\gamma_c t}. \quad (3)$$

a) Assume that $T_0 = 22^oC$, $T_{ext} = 10^oC$ and $\gamma_c = 0.005 \left[\frac{1}{min}\right]$. Compute the time required for a home to cool down to $T_{int} = 20^oC$ using formula (3). (5 marks)

b) The exponential solution model (3) can be approximated by a linear model under the assumption $T - T_{int} \ll T_{int} - T_{ext}$. The linear model is obtained from (3) by replacing the exponential term with a linear Taylor expansion (hint: $e^{-x} \approx 1-x$). Apply the linearised formula obtained in this way to determine the time required for a home to cool down from $T_0 = 22^oC$ to $T_{int} = 20^oC$. Compare the result with that obtained in Part (a). What can be concluded? (5 marks)

c) Consider the case when the thermostat switches on periodically when the internal temperature in a house falls to $T_{int} = 20^oC$ and switches off when the temperature reaches $T_{int} + \Theta = 22^oC$ (see Figure 3).

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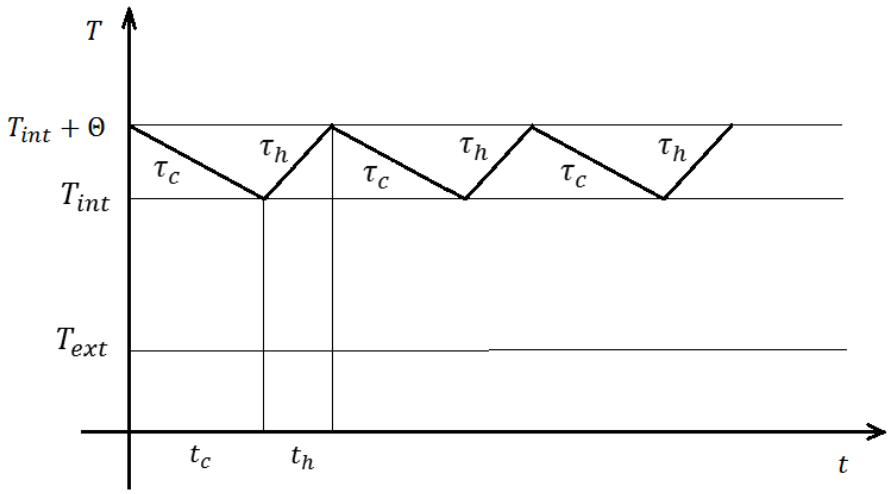
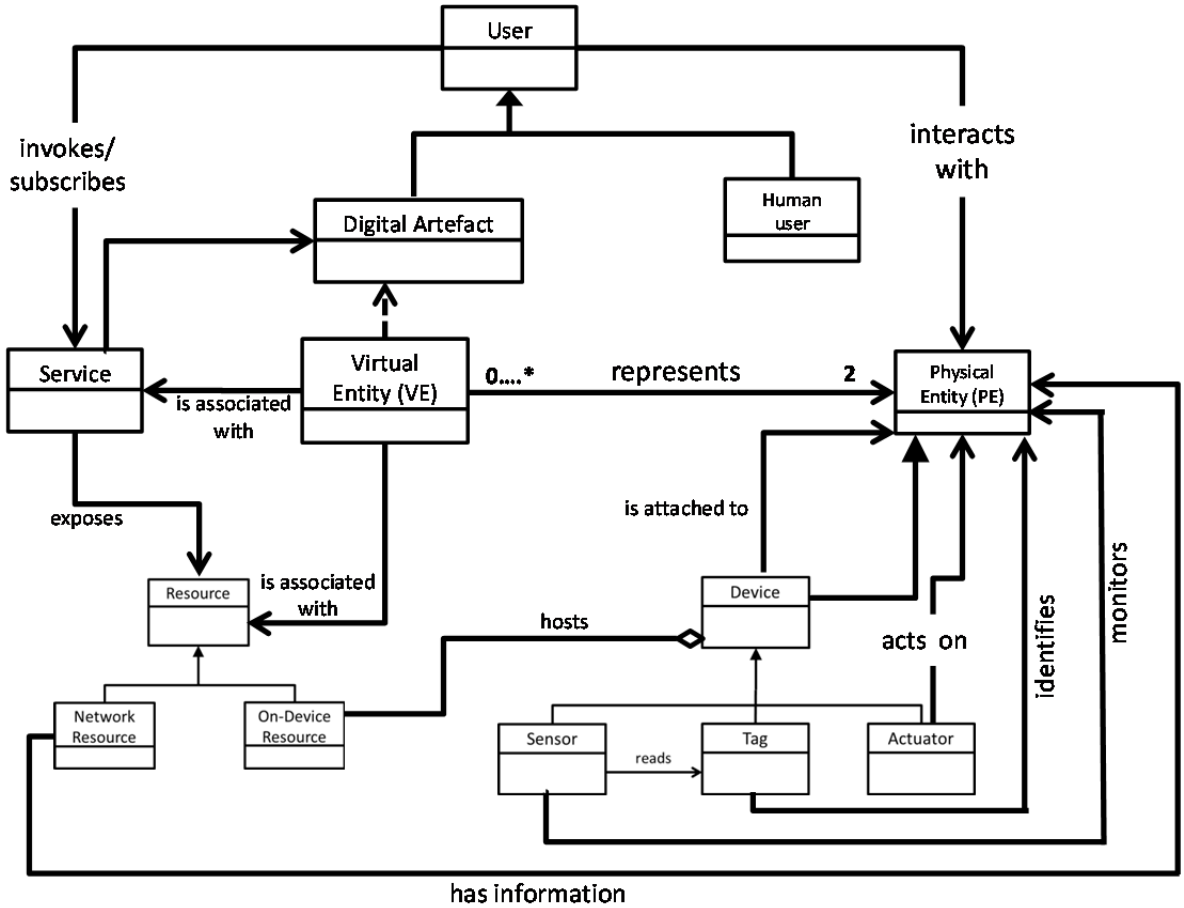


Figure 3: Temperature profile.

The power shedding policy is designed to reduce (shift) the original temperature band $[T_{int}, T_{int} + \Theta]$ by $\Delta T_{int} = 1^{o}$C. The power shedding mechanism switches off the thermostat at $t = 0$, regardless of the current temperature in a home, allowing it to cool down to the new low temperature $T_{int} - \Delta T_{int} = 19^{o}$C. After this, a normal switching rhythm is restored keeping the temperature in the interval $[T_{int} - \Delta T_{int}, T_{int} + \Theta - \Delta T_{int}] = [19^{o}\text{C}, 21^{o}\text{C}]$. Draw a diagram of the temperature as a function of time for both the case when no energy management is involved and when power shedding mechanism is deployed. In your answer assume that the simulation time is 6 hours and $\tau_c = 0.5^{o}$C/hour, $\tau_h = 2^{o}$C/hour. Assume in both cases that the temperature at $t = 0$ is 21°C, and that in the case of no power management the thermostat was switched off at $t = 0$ (i.e. a home was cooling down). How much time (out of 6 hours) is the thermostat switched on in both cases? Calculate the energy saving during the first 3 hours of the period when the energy management system is deployed. How can the change in the external temperature T_{ext} be accounted in the model? (10 marks)

Student ID:……. (To be used for answering Question 1, Part c)

NOTE: Please staple this page on the answer book used for Section A.



Copy of Figure 2 in the Exam paper.