EEE3095/6S Class Test 1

18 September 2023

Duration: 90 minutes Total: 80 marks

Empl ID: _____

Instructions:

- This is a closed-book test.
- There are four questions to this test, each of which contains sub-questions. You must answer **all** questions as each one corresponds to a Graduate Attribute on which EEE3096S students will be assessed.
- Use a **pen** to complete the test — pencil will only be marked for drawings. Values indicated on drawings must be written in pen. Please show all of your working and reasoning clearly — your method and approach matter.
- Keep all your answers **within** the allocated block(s) for each question; anything outside of these blocks may not be marked.
- This test assesses your understanding of the "Light-of-Things" (LoT) design problem. The LoT assignment and preparatory tasks were meant to clarify the system design being considered, and this test will focus on assessing approaches, methods and solutions that you would apply to address the assigned tasks. A summary of the LoT concept is provided on the next page.

Question	Available Marks	Grade
1	20	
2	20	
3	20	
4	20	
Total:	80	

Light-of-Things System Design

This test relates the "Light-of-Things" design concept that was proposed in the GA Assignment. As mentioned, the assignment is more of a conceptual assignment to explain a design topic of focus and to familiarise students with the system. Accordingly, the same system design description as provided previously is summarised here for this test.

The assignment concerns development considerations for a LoT sensor data transfer network. The baseline version, and the version that students are mainly going to be considering, utilises simplex communication in which a transmitter node sends data to a receiver node.

Figure 1 gives an example scenario of how such a network might be set up. In this scenario, there is a Central Receiver, the CR, to which data messages are sent via light beams. The sensor nodes, labelled SN-1 to SN-3 in the diagram, sample one or more physically attached sensors and transmit this sensor data by light signals back to the CR.

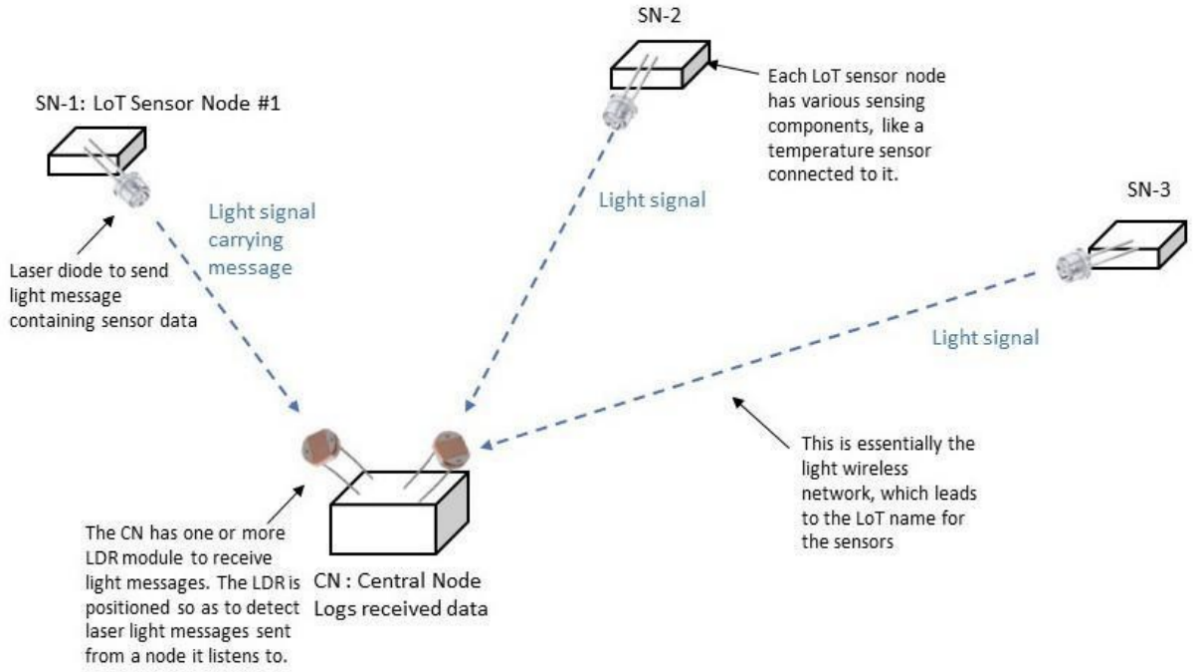

Figure 1: LoT laser light data transfer network

The data to be sent by a node is first packaged into a message package, and this package is appropriately encoded and transmitted by the sensor node's Light-Emitting Diode (LED) transmitter. In the standard configuration, each sensor node needs its LED to point directly at a Light Dependent Resistor (LDR) on the receiver side.

Based on the above (and the full GA Assignment that was handed out in the previous term), answer all of the following questions.

Question 1: Embedded Systems Design [20 marks]

GA aspect: "B.1 Embedded System design as a complex process"

a. Consider that you are the team leader for the development team constructing this LoT system, and you have been asked (by the client) to make a decision as to whether an Application Programming Interface (API) should be developed for the project.

(i) Write down what your response would be, providing motivation for whether or not an API would be advisable. (4)

(ii) Provide a brief description of the functions that you recommend for this API for the LoT system. (8)

b. The LoT receiver, on the central node, is connected to a microcontroller that controls it. But this controller needs to send received data on to another embedded platform (another STM board, for example) that will make use of the received data.

(i) If you are allowed to use either the I2C or SPI communication protocol for this, explain to the client two advantages of I2C over SPI and two advantages of SPI over I2C. (4)

(ii) If using SPI, is it necessary to have a common clock line between the devices for the purpose of receiving data? Why? And where would this signal be generated? (4)

Question 2: Design Diagrams [20 marks]
GA aspect: "B.2 Use of design diagrams"

The LoT transmitter needs to send out signals of light which need to follow a regular timing period, i.e., with each pulse lasting for a predetermined time period. For the data feed, the most basic item that the LoT transmitter needs to send is a byte (perhaps obtained from an ADC reading). But to improve reliability and sequencing, we could use a start bit (e.g., a logic-high bit, which turns on the LED for a certain period), then the 8 bits of data, then a parity bit, and then finally a stop bit (e.g., a logic-low bit, turning the LED off for a certain period).

a. Provide a labelled diagram (e.g., a flowchart or Finite State Machine) showing how you could go about taking a byte of data (input variable "X") and transform it into the final transmitted data that will be written to the LED, including the surrounding start, parity and stop bits. Assume even parity and show your logic in implementing the parity bit. (16)

b. Briefly explain how an odd-parity system would differ from the previous implementation. (4)

Question 3: Embedded Communications [20 marks]

GA aspect: "B.6 Use of standard embedded systems communication protocols"

a. Consider that your LoT sensor device can be connected as a master to some slave device via SPI or I2C. For this question you can choose to answer either one of the choices below depending on whether you are more comfortable with I2C or SPI. (10)

- **Choice 1 (SPI)**: Draw a labelled diagram showing the physical SPI interface (with a brief description of how it works) as well as the timing diagram/waveforms for sending the data byte 0xC2 from master to slave. Assume that SPI Mode 0 is being used and the most significant bit is transmitted first.

- **Choice 2 (I2C)**: Draw a labelled diagram showing the physical I2C interface (with a brief description of how it works) as well as the complete message structure for sending the data byte 0xC2 to a slave device (with a proposed ID/address for the slave).

b. Consider that you are tasked to construct a communication protocol for the LoT system. You are to allow up to 16 sensor nodes to send data packets to the central node. Assume each sensor is given a 4-bit ID that ranges from 0 to 15 (base-10). Each sensor is able to send up to 20 bytes of data, but not all the sensors need this much space and some sensors produce more sampled data than others.

(i) Decide and motivate for whether or not you think parity checks and/or any other error detection schedule would be advisable. (2)

(ii) Develop and describe a potential message structure for a sensor node to be able to transmit a block of data via the LoT light link, assuming that there is no clock line and that each bit would take 1 ms to transmit. Do this by proposing a possible schedule by which the 16 sensor nodes could be set up so that they can each transmit to the central receiver/LDR on the central node without doing so simultaneously; then, using your proposed schedule, compute how long it would take for all 16 sensors to transmit 20 bytes each (including all bits surrounding the data in your message). (8)

Note: This is an open-ended question and the marking is based on the logic and clarity of your explanation; think about synchronisation between devices, start/stop conditions, and reliability.

Question 4: ARM Tools [20 marks]

GA aspect: "B.5 Use (cross-)compiler for developing ES software"

Consider that you are involved in the development and debugging of the program code running on the central node receiver for the LoT system.

a. The LoT receiver is likely going to be detecting and processing signal pulses at a rather fast rate – perhaps at a few hundred kHz. Would there be any point in using a debugger for its code development, such as GDB? Motivate your answer with at least two reasons and include an example scenario where you may/may not want to use such a tool. (6)

b. The terms "runtime environment", "development environment" and "execution environment" do not refer to the same thing. Briefly explain the difference between these three terms in the context of embedded systems development. (9)

c. Provide a formal definition for a "cross-compiler toolchain", and give two examples of typical functions of a toolchain. (5)

END OF TEST