Q.1 (a) A taxi company that operates in an urban area wishes to use Internet of Things (IoT) technology to

(i) continuously monitor the condition of essential components of its taxis, e.g. engine, brakes and tyres;
(ii) measure the distances travelled with and without passengers, and determine the driving behaviours of taxi drivers from their average driving speeds and acceleration and deceleration characteristics, and
(iii) be notified about emergency conditions, e.g. major illness of passengers or drivers such as heart attack or stroke, accidents etc.

Specify with explanations which wireless IoT technology is suitable for each of these use cases.

(9 marks)

(b) Would edge computing be beneficial to the taxi company in part (a)? Explain your answer.

(6 marks)

(c) Table Q.1 shows the power consumption of a certain wireless sensor node at different states of operation s_k. The transition time to s_k from the active state s_0 is given by $\tau_{d,k}$ and the transition time from s_k to the active state s_0 is given by $\tau_{u,k}$.

State	P_k (mW)	$\tau_{d,k} = \tau_{u,k}$ (ms)
Active (s_0)	700	-
Ready (s_1)	270	5
Monitor (s_2)	180	15
Look (s_3)	130	20
Sleep (s_4)	7	40

Table Q.1

If the estimated time between the end of processing of the previous event and the arrival of the next event is 22 ms, determine the state that the wireless sensor node should go into between events in order to maximize energy saving.

(10 marks)

Q.2 (a) A wireless sensor network implements the LEACH protocol.

Sort the following events in the order from the smallest timescale (most frequent) to the largest timescale (least frequent):

A. The round number increases.
B. A node runs out of energy.
C. A particular node becomes a cluster head.
D. A particular node sends data to the cluster head.
E. New clusters are formed.
F. A cluster head sends data to the base station.

(6 marks)

(b) How does the LEACH protocol ensure that each sensor node becomes a cluster head exactly once in an interval of $1/P$ rounds, where P is the cluster head probability?

(6 marks)

(c) In a target tracking sensor network, sensor selection is done using a sensor geometry based information utility measure that is inversely proportional to the Mahalanobis distance. The current belief about the target position is Gaussian with mean $\hat{x}$ and covariance Σ.

The leader node is at position $x_l = \begin{bmatrix} 0 \\ 4 \end{bmatrix}$. One of two candidate sensor nodes, either sensor node S_1 at position $x_1 = \begin{bmatrix} 4 \\ 7 \end{bmatrix}$ or sensor node S_2 at position $x_2 = \begin{bmatrix} -3 \\ 5 \end{bmatrix}$, is to be selected so that its sensor readings can be incorporated into the current belief about the target position in order to improve the belief. The communication cost between the selected sensor node and the leader node needs to be taken into account.

Given that $\hat{x} = \begin{bmatrix} 1 \\ 2 \end{bmatrix}$ and $\Sigma = \begin{bmatrix} 0.7 & 0.8 \\ -0.5 & 1.3 \end{bmatrix}$, calculate the value of the composite objective function comprising a factor $\gamma = 0.7$ of information utility and $(1 - \gamma)$ of communication cost for each of the two candidate sensor nodes, and hence, determine which sensor node should be selected.

(13 marks)

END OF ASSESSMENT