Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER I
SESSION 2021/2022

COURSE NAME	:	SMART WSN TECHNOLOGIES
COURSE CODE	:	MET11103
PROGRAMME CODE	:	MET
EXAMINATION DATE	:	JANUARY 2022
DURATION	:	3 HOURS
INSTRUCTION	:	1. ANSWERS **ALL** QUESTIONS 2. THIS FINAL EXAMINATION IS AN **ONLINE** ASSESSMENT AND CONDUCTED VIA **OPEN BOOK.**

THIS QUESTION PAPER CONSISTS OF **SEVEN (7)** PAGES

Q1 **(a)** Consider the operation of the Smart WSN. Differentiate the operation of cluster head and ordinary node for one round operation using flow diagram.

(6 marks)

(b) Energy consumption is the main concern in the design of a Smart WSN, since it determines the node and network lifetimes. Consider the Smart WSN shown in **Figure Q1.** It consists of two clusters, CH1 and CH2. CH1 is connected to one ordinary node and CH2 to two ordinary nodes. Assume that the sources of energy consumption come from the ordinary nodes and cluster head activities given below.

Types of Node	Sources of Energy Consumption
Ordinary Nodes	Sensing and Transmitting
Cluster Head	Sensing, Receiving and Transmitting

Assume the free space fading with exponent 2 as the propagation model, the number of sensing bit is b and the cluster head weighting factor for sensing, transmitting or receiving only are given as, $\{ h_2 , h_3 \} = \{1.4, 1.6 \}$.

(i) Derive the total energy model for the network in terms of the variables concerned.

(12 marks)

(ii) Calculate the total energy consumed for the network using the parameters shown in **Table Q1.**

(7 marks)

Q2 Low Energy Adaptation Clustering Hierarchy (LEACH) algorithm is one of well-known WSN routing algorithms. It is hierarchical based and need to select a leader in each round of data transmission.

(a) Explain the characteristics of Low Energy Adaptation Clustering Hierarchy (LEACH) algorithm.

(4 marks)

(b) Examine in detail the operation of LEACH, including all of its phases involved and the flow diagrams.

(11 marks)

(c) Propose and design **TWO (2)** mechanisms for cluster head selection.

(10 marks)

Q3 **(a)** (i) Explain the need of time synchronization mechanisms in Smart WSN?

(3 marks)

(ii) State **THREE (3)** examples of the importance of time synchronization.

(6 marks)

(iii) Explain the difference between external and internal time synchronization. Identify **ONE (1)** example in each type.

(4 marks)

(b) Node A sends a synchronization request to Node B at 3150 (on the Node A clock). At 3250 node A receives the reply from node B with timestamp of 3120.

(i) What is node A's clock offset with respect to the time at node B (you can ignore any processing delays at either node). Which node's clock goes faster?

(6 marks)

(ii) How should the node with faster clock, adjust its clock?

(6 marks)

Q4 **(a)** Describe in general the working principle of reduction algorithm known as Adaptive Real-Time Payload Scheme (ARPS).

(6 marks)

(b) Consider the ARPS algorithm given in the **Figure Q4(b),** with the following sensed data collected from the sensor board of multiple sensors, n where n=4 sensors. The sensors are utilized, with the following sensed data, {Temperature (°C), Humidity (RH%), Voltage(V) and Light(Lux)}. At time t and $(t-1)$ the collected data is given as $\mathbf{S}_{1\times4}[\mathbf{t}]$= {22.50, 43.00, 2.6, 1050} and $\mathbf{S}_{1\times4}[\mathbf{t-1}] = \{22.90,43.01,2.5,1055\}$ respectively. Using the data provided, analyze the operation of the algorithm starting with the reduction phase, then the approximation phase.

(19 marks)

-END OF QUESTIONS –

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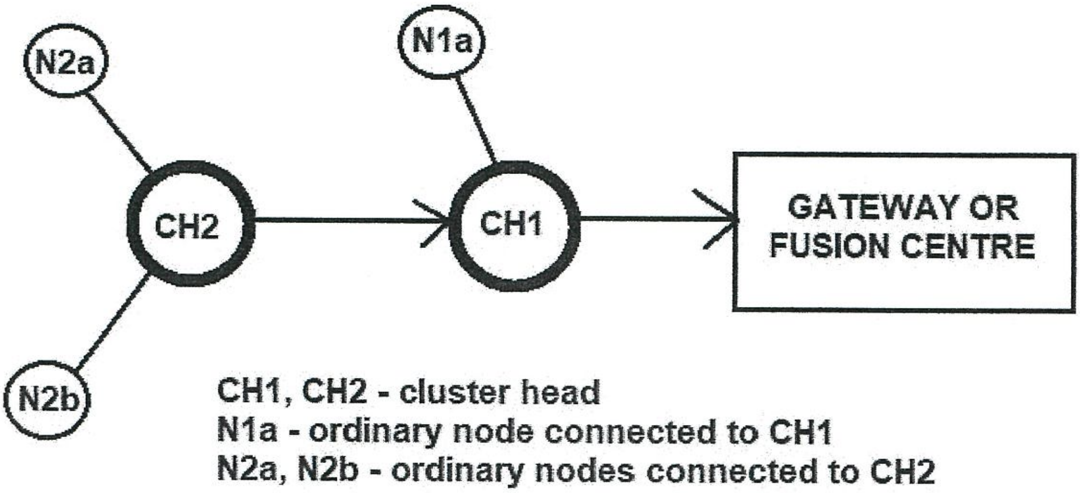

Figure Q1(a). A Smart WSN network Model

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Table Q3: Parameters for energy consumption calculation.

SYMBOL	DESCRIPTION	VALUE
N_{cyc}	Number of clock cycles per task	0.97 x 10^6.
C_{avg}	Average capacitance switch per cycle	22pF
V_{sup}	Supply voltage to sensor	2.7 V
f	Sensor frequency	191.42 MHz
n_p	Constant depending on the processor	21.26
n	Path loss exponent	2 or 4
I_o	Leakage current	1.196 mA
V_t	Thermal voltage	0.2 V
b	Transmit packet size	2048 bits
E_{elec}	Energy dissipation: electronics	50 nJ/bit
E_{amp}	Energy dissipation: power amplifier	100 pJ/bit/m^2
T_{tranON}	Time duration: sleep -> idle	2450 µs
$T_{tranOFF}$	Time duration: idle -> sleep	250 µs
I_A	Current: wakeup mode	8 mA
I_S	Current: sleeping mode	1 µA
T_A	Active Time	1 ms
T_S	Sleeping Time	299 ms
T_{tr}	Time between consecutive packets	300 ms
T_{sens}	Time duration: sensor node sensing	0.5 mS
I_{sens}	Current: sensing activity	25 mA
I_{write}	Current: flash writing 1 byte data	18.4 mA
I_{read}	Current: flash reading 1 byte data	6.2 mA
T_{write}	Time duration: flash writing	12.9 mS
T_{read}	Time duration: flash reading	565 µs
E_{actu}	Energy dissipation: actuation	0.02 mJ
h_1	CH weight factor, for processing	1.2
h_2	CH weight factor, for transmission and receiving.	1.4
h_3	CH weight factor, for sensing	1.6
h_4	CH weight factor, for sensor logging	1.8
d	Transmission range	30 m

// Setup phase

// Note: this phase only runs for one time

- **Read** only one sample $\boldsymbol{S_{1\times n}[t]} \in R^{1\times n}$
- **Send**$S_{1\times n}[t]$ to the fusion center // *Non-reduced mode*
- **Set**$S_{1\times n}[t-1] = S_{1\times n}[t]$; // *only use for first time in reduction phase* (Online)

Figure Q4(b). A data reduction model: Setup Phase

// **Reduction Phase(Online)** (Sensor Node Level with multiple sensors)

Input:$S_{1\times n}[t] \in R^{1\times n}$ // A new real-time sensed data at time *t*. *n* is the number of sensors at the node

$S_{1\times n}[t-1] \in R^{1\times n}$ // The last sensed data transmitted to the fusion center at time [*t-1*]

Output: $D[t] \in R^{1\times 1}$ // represents variable of real-time sensed data

Begin: //

Calculate $RD_{1\times n} \in R^{1\times n}$ // Relative difference vectorbetween $S_{1\times n}[t]$ and $S_{1\times n}[t-1]$is defined as

$$RD_i = \left\| \frac{(S_i[t]-S_i[t-1])}{(S_i[t]+S_i[t-1])*0.5} \times 10^2 \right\| \quad ; i=1, 2,\dots, n \quad (1)$$

If $\sum \; |RD_{1\times n}| \neq 0$ // *Decision phase in case* $\forall RD_{1\times n} = 0$ *notransmitted (off)*

- Calculate the required number of bits to represent $|RD_i|$ as the following //*maximum number of bits*

$$m = \lfloor log2(Max(|RD_{1\times n}|)) \rfloor + 1 \; // \quad (2)$$

- Calculate the total number of bits (L) required to represent relative difference $\pm RD_i$and defined as

$$L = m + 1 \quad (3)$$

- Estimate $Sb_{1\times n}$. In order to manage negative and non-negative RD tests, Eqn.(4)is applied

$$Sb_i = \begin{cases} 2^{((i\times L)-1)} & for\ positive\ change\ (+RD_i) \\ 0 & for\ negative\ change\ (-RD_i) \end{cases} \quad (4)$$

- Calculate the representation of the sensed data $D[t]$in realtime [t] as defined in Eqn. (5).

$$D[t] = \sum_{i=1}^{n} |RD_i| \times 2^{((i\times L)-L)} + sb_i) \quad (5)$$

- Send reduced sensed data **D[t]** to the fusion center
- Calculate the prediction of the sensed data $\hat{S}_{1\times n}[t]$at current time t as the following

$$\hat{S}_{1\times n}[t] = (S_{1\times n}[t-1] \,.\!\times (RD_{1\times n} \times 10^{-2})) + S_{1\times n}[t-1] \quad (6)$$

- Set $S_{1\times n}[t-1] = \hat{S}_{1\times n}[t]$ // for the next cycle

End if // End Algorithm

Figure Q4(b). A data reduction model: Reduction Phase

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// **Approximation Phase (Online)** **(Fusion Center Level)**

- **Receiving** reducessensed data D[t] from the sensor node at realtime t //
- **Determine** *the total number of bits for*D[t] that is defined as
  $$\boldsymbol{L1} = \lfloor log2(\mathrm{d[t]}\,)) \rfloor + 1 \quad (7)$$
- **Estimate** the number of bits for each sensor by applying $\boldsymbol{m} = \|\boldsymbol{L1/n}\|$, $\|\ \ \|$ denotes the nearest integer to m
- **Convert** $D[t]$ from decimal to binary basedon BCD code $Db = Dec2bin(D[t], m \times n)$ where $(m \times n)$the number of bits is and n is the number of sensors.
- **Predict** the relative difference for each sensorRD_i**by taking m-bits from right to left,**Db**is stated as the following**
  $$D_i = Db[(m \times i) + 1 - m : m \times i)], \quad (8)$$
- **Convert**D_i from binary to decimal
  $$RD_i = \begin{cases} \boldsymbol{Bin2Dec}(D_i) - 2^{m-1}, \boldsymbol{Bin2Dec}(D_i) > 2^{m-1} \\ \boldsymbol{Bin2Dec}(D_i) \times -1\,, \boldsymbol{Bin2Dec}(D_i) < 2^{m-1} \end{cases} \quad (9)$$
- **Finally**, predicts$\hat{S}_{1\times n}[t]$as the real-time sensed data at the time [t] at the sensor node level by applying the same Eqn(6) as the following
  $$\hat{S}_{1\times n}[t] = (S_{1\times n}[t-1] .\times (RD_{1\times n} \times \mathbf{10^{-2}})) + S_{1\times n}[t-1],$$
- **Set**$S_{1\times n}[t-1] = \hat{S}_{1\times n}[t]$ // for the next cycle

Figure Q4(b). A data reduction model: Approximation Phase