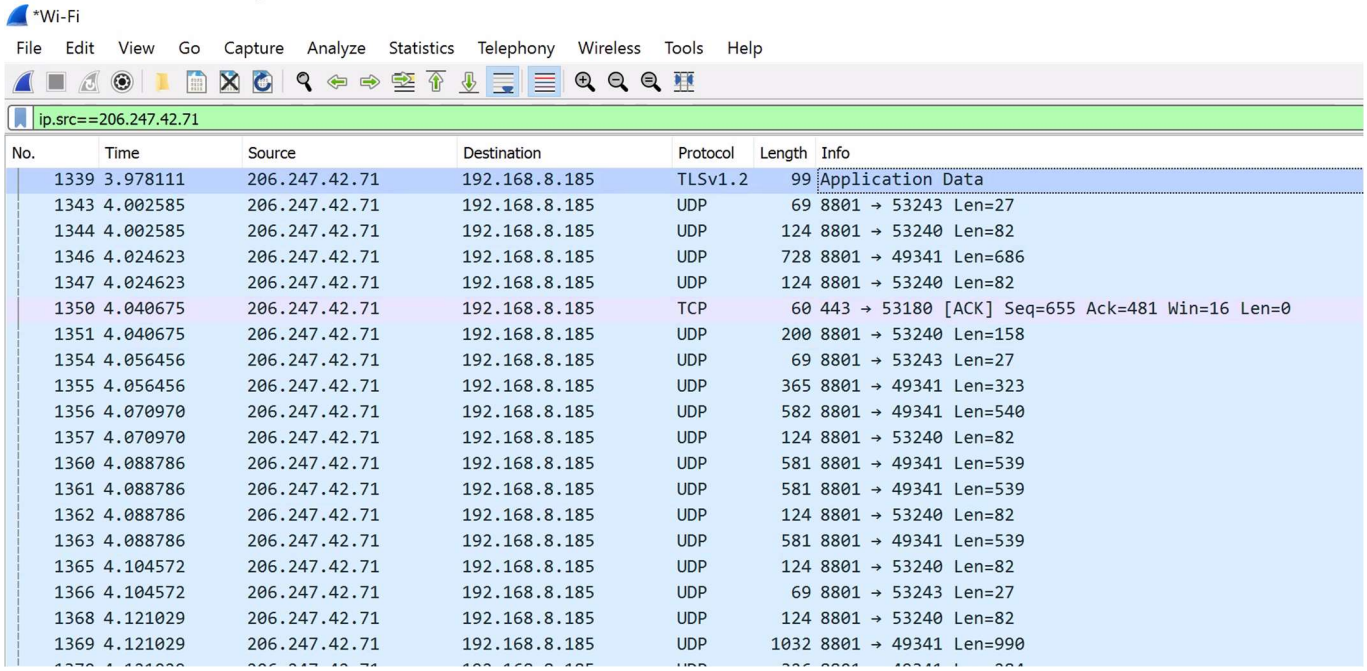
EID: Solution

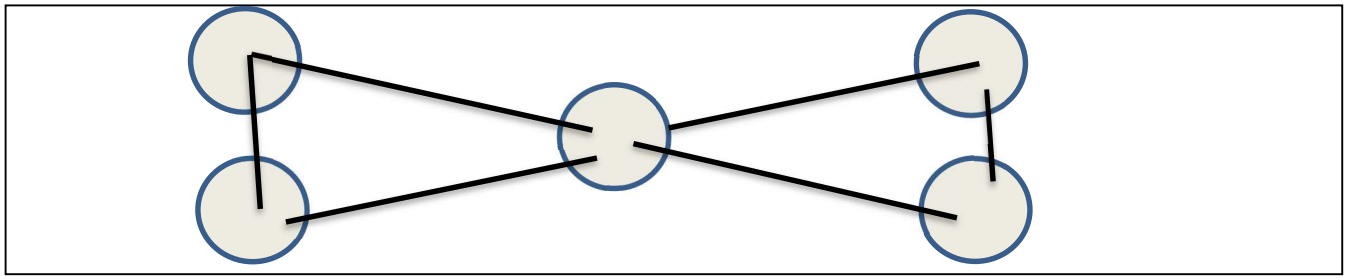
(10) Question 1. An unstable controller will not operate, and the vehicle will crash. It is a hard real time system because Δt must be less than a constant k.

(10) Question 2. It is ok to miss a few packets and we wish to maximize bandwidth, so UDP. If we were interested in security, we would use TCP. Zoom uses both



No.	Time	Source	Destination	Protocol	Length	Info
1339	3.978111	206.247.42.71	192.168.8.185	TLSv1.2	99	Application Data
1343	4.002585	206.247.42.71	192.168.8.185	UDP	69	8801 → 53243 Len=27
1344	4.002585	206.247.42.71	192.168.8.185	UDP	124	8801 → 53240 Len=82
1346	4.024623	206.247.42.71	192.168.8.185	UDP	728	8801 → 49341 Len=686
1347	4.024623	206.247.42.71	192.168.8.185	UDP	124	8801 → 53240 Len=82
1350	4.040675	206.247.42.71	192.168.8.185	TCP	60	443 → 53180 [ACK] Seq=655 Ack=481 Win=16 Len=0
1351	4.040675	206.247.42.71	192.168.8.185	UDP	200	8801 → 53240 Len=158
1354	4.056456	206.247.42.71	192.168.8.185	UDP	69	8801 → 53243 Len=27
1355	4.056456	206.247.42.71	192.168.8.185	UDP	365	8801 → 49341 Len=323
1356	4.070970	206.247.42.71	192.168.8.185	UDP	582	8801 → 49341 Len=540
1357	4.070970	206.247.42.71	192.168.8.185	UDP	124	8801 → 53240 Len=82
1360	4.088786	206.247.42.71	192.168.8.185	UDP	581	8801 → 49341 Len=539
1361	4.088786	206.247.42.71	192.168.8.185	UDP	581	8801 → 49341 Len=539
1362	4.088786	206.247.42.71	192.168.8.185	UDP	124	8801 → 53240 Len=82
1363	4.088786	206.247.42.71	192.168.8.185	UDP	581	8801 → 49341 Len=539
1365	4.104572	206.247.42.71	192.168.8.185	UDP	124	8801 → 53240 Len=82
1366	4.104572	206.247.42.71	192.168.8.185	UDP	69	8801 → 53243 Len=27
1368	4.121029	206.247.42.71	192.168.8.185	UDP	124	8801 → 53240 Len=82
1369	4.121029	206.247.42.71	192.168.8.185	UDP	1032	8801 → 49341 Len=990

(10) Question 3. A mesh topology.
(5) Part a) All nodes are connected one way or another, some node-node communication require intermediate node, central nodes, some node-node communication links have more than one possible path.



(5) Part b) More robust for node failure (fault tolerant), or distance between nodes larger than communication range. A mesh is not faster than a star; the above mesh is faster, but in general a mesh may need dozens of hops to reach the destination.

(10) Question 4. Looking at just current, we might be tempted to say number of nodes is I_{OH}/I_{IH} or I_{OL}/I_{IL}, which would calculate to 4000 slaves. However, the input capacitance will dominate the number of slaves allowed. Each slave adds 8pF and the total capacitance would be C=n*8pF, where n is the number of slave. Let R (3.3V/8mA about 400Ω) be the effective output impedance (open circuit voltage divided by short circuit current). To run at 115200 bits per second (about 9us/bit) the time constant of the RC circuit must be short compared to 9 µs. We limit RC < 1µs, $400*n*8*10^{-12} < 10^{-6}$, n < 312. **Input capacitance** will determine the maximum number of slaves allowed.

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(10) Question 5. We abandoned these instructions because they take a long time to execute. Terminating these instructions will reduce the interrupt latency (time from trigger to running the ISR).

(10) Question 6. *Note: there were two versions of the exam with different speaker resistances.* Loudness is a function of the power delivered to the speaker. $P = 0.5*V^2/R$. The 50% is because of the 50% duty cycle. Determine the voltage across the speaker

Speaker voltage	$V = (V_{BUS} - V_{DS}) = 4.5V$
Speaker current	$I = (V_{BUS} - V_{DS}) / R$
Speaker power	$P = 0.5*(V_{BUS} - V_{DS})^2 / R = 0.5*(4.5)^2 / R$
Version 1 Power ratio	32/8 (8ohm is 4 times louder than 32 ohm)
Version 2 Power ratio	32/16 (16ohm is 2 times louder than 32 ohm)

(10) Question 7. *Note: there were two versions of the exam with different priorities.*
Version 1 is both ISR are level 7
(5) Part a) No critical section because ISRs are atomic relative to each other
Version 2 is one ISR is level 5 and the other is level 6
(5) Part a) Yes critical section because the higher priority ISRcan interrupt the read-modify-write access to the same shared global (Port F date, The solution would have been to use bit banding or bit specific addressing.
(5) Part b) T1 is the time to execute `GPIO_PORTF_DATA_R ^= 0x04;` T2 is the time to execute `GPIO_PORTF_DATA_R ^= 0x04; Task1();`
The time to execute Task1 is T2-T1.

(10) Question 8. *Note: there were two versions of the exam with different speaker resistances.*
Version 1. Solve for resolution first.
Resolution of the value = 2cm/8 = 0.25 cm.
Minimum value = 0.00cm.
Precision = 8 bits or 256 alternatives.
Maximum value = 255/4 cm = 63.75cm.
Version 2. Solve for resolution first.
Resolution of the value = 4cm/8 = 0.5 cm.
Minimum value = 0.00cm.
Precision = 8 bits or 256 alternatives.
Maximum value = 255/2 cm = 127.5cm.

(10) Question 9. Consider an input device that uses a FIFO to pass data from ISR to the main program
(5) Part a) Since the FIFO is usually empty, software runs faster on average than the input hardware. It is **I/O bound**
(5) Part b) Even though it is I/O bound (average input rate is slower than the average software rate), there are some times that the input rate gets large and the FIFO becomes full. If an input occurs when the FIFO is full data will be lost. You should increase the size of the FIFO so no data are lost.
(10) Question 10) This is a tricky question because you CANNOT use Little's formula, $R=N/\lambda$. By definition, the average input rate (λ) is less than the maximum rate (λ_{max}). There is nothing useful you can say about R, given λ_{max}. $\lambda=N/R < \lambda_{max}$, so $R>N/\lambda_{max}$. For example, the average input rate might have been 1 byte per year and the average FIFO size might have been 1, so the average response time would be 2 years!