MIT 6.808 2022 – Mobile and Sensor Computing
Midterm Exam

There are 28 questions and 10 pages in this quiz booklet. To receive credit for a question, answer it according to the instructions given. *You can receive partial credit on questions.* You have **80 minutes** to answer the questions.

Don't forget to write your name on this cover sheet NOW!

If you find a question ambiguous, be sure to write down any assumptions you make. Be neat. If we can't understand your answer, we can't give you credit!

THIS IS A CLOSED-BOOK QUIZ.
YOU MAY USE TWO DOUBLE-SIDED PAGE OF NOTES.

Do not write in the boxes below

1-5 (20)	6-7 (10)	8-10 (13)	11-12 (9)	13-14 (9)
15 (5)	**16-17 (9)**	**18-19 (10)**	**20 (5)**	**Total (90)**

Name:

Localization and Positioning

1. *(4 points)* Order the relative accuracy of the following positioning technologies (from 1–4), in order from least (1) to most (4) precise.

   3 Wi-fi localization as with the Radar paper from Microsoft

   1 Triangulation using information from cellular radio signals.

   2 Global Positioning System (GPS).

   4 Cricket.

2. *(2 points)* To obtain a precise position estimate, a GPS receiver must obtain signals from at least 4 satellites, and use the received information to solve for the receiver's position coordinates as well as for time. (Fill in the two blanks.)

3. *(6 points)* RADAR, Cricket, and WiTrack are all indoor location/positioning systems. Circle True or False for each of these statements about these papers.

   (a) True / False RADAR requires no additional hardware infrastructure if the building has a wireless LAN deployed.

   (b) True / False WiTrack requires no additional hardware infrastructure if the building has a wireless LAN deployed.

   (c) True / False RADAR analyzes the phase information of radio signals to estimate distances and obtain location.

   (d) True / False WiTrack analyzes the phase information of radio signals to produce its inferences.

   (e) True / False Cricket uses time-of-flight of radio signals to estimate distances and obtain location.

   (f) True / False In Cricket, mobile devices transmit signals that are received by devices in the infrastructure to estimate distances.

4. *(3 points)* Ben Bitdiddle studies the **Cricket** paper and decides to *remove* the constraint that the Cricket listener discard ultrasonic signals that arrive without a concurrent radio reception. His modified system treats any ultrasonic reception as valid and associates that signal with the start time of the nearest previously observed radio reception. Circle True or False for these statements.

   multipath from a given radio

   (a) True / False In Ben's system some estimated distances between a given beacon-listener pair may be larger than in Cricket.

   (b) True / False In Ben's system, assuming no radio receptions are lost, some estimated distances between a given beacon-listener pair may be smaller than in Cricket.

   (c) True / False In Ben's system, assuming no ultrasonic signals arrive at the listener after being reflected from things in the environment, most estimated distances between a given beacon-listener pair are likely to be the same as in Cricket.

   if multipath from previous radio

Localization with Phase and FMCW

Isaac built a device that localizes people based on their reflections. The device transmits a wireless signal and measures its reflection of the human body. Answer the questions below about different ways of measuring the person's location.

16. *(2 points)* Isaac wants to use the phase of the wireless reflection to measure the person's location. The equation of phase as a function of distance is: $\phi = 2\pi \frac{d}{\lambda} \pmod{2\pi}$

17. *(1 points)* Which of the following is true about getting distance from phase:

    (a) True / False The phase can be used to obtain a unique distance measurement.

    (b) True / False The phase can be used to accurately track changes in distance

18. *(2 points)* Isaac is frustrated with the confusion in distances that arises from phases, and he decides to use FMCW to obtain the exact distance to the person. He wants to measure distances with a resolution of 0.5 meters. The equation of resolution as a function of bandwidth is: $r = C/2B$. Plugging in the parameters, the bandwidth required is: 300 MHz. (Fill in both blanks.)

19. *(3 points)* Isaac now wants to localize the person's reflection in 2D, rather than just computing distance. Isaac wants to use one transmitter and multiple receivers to do that. All the antennas he uses are omnidirectional (i.e., they can receive signals from all sides).

    - The minimum number of receive antennas that Isaac needs is 3.

    - Draw how using 1 transmit antenna and the number of receiver antennas you highlighted above (each antenna is separate), Isaac can localize a person in 2D. Briefly explain your reasoning.

RFIDs, IMUs, Vital-Radio, and BackDoor

5. *(6 points)* Circle True or False for each of these statements about **RFIDs**:

   (a) True / False The RFID in the MIT ID card has a tiny built-in battery.

   (b) True / False RFIDs that require tapping harvest power from the vibration caused by tapping.

   (c) True / False Far-field RFIDs power up via inductive coupling.

   (d) True / False The slotted Aloha protocol (used in EPC Gen2) can achieve over 50% efficiency when the number of tags is known in advance.

   (e) True / False In the paper "Hacking RFIDs for Fun and Profit", the authors modify an RFID by cutting its antenna and attaching a sensor instead of the region they cut out.

   (f) True / False E-Toll transponders have a MAC protocol that ensures only one transponder replies at any point in time, even if many transponders are within radio range.

6. *(4 points)* Circle True or False for each of these statements about **IMUs**:

   (a) True / False Accelerometers are used to measure rotational acceleration of a mobile device.

   (b) True / False Gyroscopes operate using the Coriolis effect.

   (c) True / False In gyroscope integration, an error that arises from bias is usually Gaussian with zero mean.

   (d) True / False It is possible to fool accelerometer readings using acoustic waves.

7. *(4 points)* Circle True or False for each of these statements about the **Vital-Radio** paper:

   (a) True / False It needs FMCW to separate the reflections from people at different distances.

   (b) True / False It can only capture someone's heart rate if they are holding their breath.

   (c) True / False It can measure someone's breathing rate even if they are facing their back to its antenna.

   (d) True / False It uses ultrasonic signals.

8. *(4 points)* Circle True or False for each of these statements about **Backdoor** paper:

   (a) True / False It Uses near-ultrasound waves to inject inaudible commands

   (b) True / False It exploits the non-linearity of the microphone diaphragm (amplifies)

   (c) True / False The attacker can use standard acoustic speakers, such as those in a laptop, to launch the attack. (needs ultrasonic)

   (d) True / False The attacker needs to transmit sound at exactly two center frequencies. (ultrasound) ↳ at least

Network Connectivity

9. *(4 points)* Circle True or False for each of these statements about IoT network technologies.

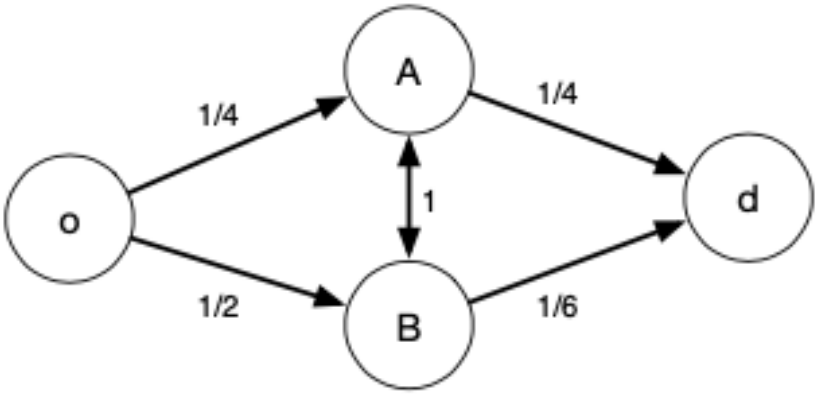
   (a) True / False Bluetooth Low Energy (BLE) senders wake up at specified time slots to transmit or receive data, sleeping the rest of the time.

   (b) True / False BLE nodes learn about each other when the central node advertises services that peripheral nodes can hear about.

   (c) True / False The connectivity range of BLE radios on smartphones is comparable to Wi-Fi.

   (d) True / False The data rate of BLE radios on smartphones is comparable to Wi-Fi.

10. *(6 points)* Consider the network topology below for a network using Wi-Fi links below. Suppose node o wants to send a message to d, and o and d cannot communicate directly. The number on each edge is the probability that a forward transmission and an acknowledgment are successfully received on the link, i.e., it is the bidirectional probability of successful packet delivery. The network uses the ETX metric, which can be computed using the link success probabilities given.



Which path would the network use to send data between o and d? What is the ETX metric of this path?

ETX of: OAd : 4+4=8

OABd : 4+1+6 = 11

OBAd: 2+1+4=7

OBd : 2+6=8

Pothole Patrol, Crash Maps, and Glimpse

11. *(3 points)* The Pothole Patrol paper the ratio of the x to z acceleration magnitudes, filtering out values lower / higher (circle one of the two underlined choices) than a threshold to avoid distinguish potholes from door slams / expansion joints / manholes / speed bumps (circle one or more of the underlined choices).

12. *(4 points)* Circle True or False for each of these statements about the paper by Songtao He et al. on estimating crash rates on road networks.

    (a) True / False It estimates crash rates at a 5-meter granularity.

    (b) True / False It uses satellite imagery as an input.

    (c) True / False It uses historic information of road crashes only to train the neural network, but not as an input to the neural network.

    (d) True / False It uses position and velocity data from GPS traces of vehicles driving on roads as an input to the neural network.

13. *(2 points)* Circle True or False for each of these statements about the Glimpse system by Chen et al.

    (a) True / False It uses an "active cache" on the mobile device to improve the accuracy of tracking identified objects.

    (b) True / False It uses "trigger frames" to improve the end-to-end latency of tracking.

Farmbeats

Answer the following questions about the farmbeats paper:

14. *(2 points)* Name the two insights that the model uses in order to fill in gaps in measurements from deployed sensors:

    (a) Spatial smoothing

    (b) visual smoothing.

15. *(4 points)* Circle True or False for each of the below statements on why the Farmbeats project it uses TV whitespaces for connectivity to the Farm:

    (a) True / False Whitespace connectivity requires lower power than WiFi.

    (b) True / False Whitespace frequencies can travel through crops and canopies.

    (c) True / False It is particularly easy to form mesh networks using whitespace connectivity.

    (d) True / False Large chunks of TV spectrum is available in rural areas.

Underwater Backscatter

20. *(2 points)* The underwater backscatter technology uses piezoelectric material in order to enable underwater communication via backscatter.

21. *(7 points)* Circle True or False for each of the below statements on the materials that underwater backscatter uses:

    (a) True / False These materials are very low power
    (b) True / False The materials can transform electrical to mechanical energy.
    (c) True / False The materials can transform mechanical to electrical energy.
    (d) True / False The materials can transform sound to electricity.
    (e) True / False The materials can transform electricity to sound.
    (f) True / False The materials can be used to reflect sound.
    (g) True / False The materials can be used to modulate the reflection of sound.

22. *(2 points)* Circle True or False about what happens to acoustic signals impinging (i.e., arriving) at an underwater backcatter node in the different states:

    (a) True / False The signal is reflected when the switch is open.
    (b) True / False The signal is reflected when the switch is closed.

23. *(3 points)* Maya builds an underwater backscatter node with a microcontroller, which consumes 500 micro-Watts of power when it is running. The microcontroller needs to run for 3 seconds every time it needs to transmit a single sensor measurement. The node is deployed in a certain underwater location where it can harvest 30 micro-Watts of power. How long does the node need to harvest energy before it can transmit each sensor measurement? Show your work. (one micro-Watt = 10^{-6} Watts) (1pt)

each measurement needs: $E = Pt$

$\Rightarrow E_{harvest} = E_{tx}$ (1pt)

$t_{harvest} = \frac{500 \times 3}{30} = 50$ seconds (1pt)

24. *(2 points)* Bob decides that instead of underwater backscatter, he wants his sensor to use a traditional underwater modem. The modem needs 50 Watts of power, and also needs to run for 3 seconds in order to transmit a single sensor measurement. The node is deployed in a certain underwater location where it can harvest 30 microWatts of power. How long does the node need to harvest energy before it can transmit its sensor data? Show your work.

$t = \frac{50 \times 3}{30 \times 10^{-6}} = 5,000,000\text{s} \approx 57.8$ days

25. *(5 points)* Laura wants to build an underwater backscatter device that doesn't rely on energy harvesting altogether. She wants to do that so that the node can run independent of the amount of power that is available for harvesting. She wants to use a 3 Volt 250 mAh coin cell battery. Her idea is to use underwater backscatter to send each sensor measurement (which takes 3 seconds, same as before, and consumes 500 micro-Watts of power). She envisions that her device needs to send a measurement once every hour (and is in sleep mode otherwise). How long can her device last before it needs its battery to be replaced in the following two scenarios (Show your work):

- Assume the sensor does not consume any energy when it is sleeping

note: it is NOT running continuously

(1 pt) $E = V \cdot \text{"mAh"} = 3 \times 250 \times 10^{-3} \times 3600$ (1 for plugging in correctly)

(1 pt) $E = 500\,\mu W \times 3$, once per hour

(1 pt) $\#\text{hrs} = \frac{E}{E_{\text{per hr}}} = 180{,}000 \text{ hours} \approx 20.5 \text{ years}$

- Assume the sensor draws 6 micro-amperes from the battery when it is sleeping.

$E_{\text{per hour}} = 500\,\mu W \times 3 + 6\,\mu A \times 3V \times (3600 - 3)$

$\#\text{hours} = \frac{E_{\text{tot}}}{E_{\text{per hr}}} = 698 \text{ days or } 4.6 \text{ years}$

26. *(1 points)* Finally, let us go back to Bob's design which uses a standard underwater modem. How long would the node last if it sends a measurement once per hour, and assuming it does not consume any energy when it is sleeping

18 hours

Class Feedback (Bonus)

27. *(1 points)* What was/were your favorite lecture(s)/topic(s) in this class?

28. *(1 points)* What was/were your least favorite lecture(s)/topic(s) in this class?

End of quiz!