Introduction to Embedded Systems Research
Final Exam

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Closed book. Closed notes. No calculators or other computers.
If you write lightly with pencil, I may not see your answers or work.

Name:

Sign below to acknowledge the Engineering Honor Code: "I have neither given nor received aid on this examination, nor have I concealed a violation of the Honor Code."

Using at most one sentence, each, describe the main contribution of each of these five research papers.

5   1. Y. Zhu, A. Samajdar, M. Mattina, and P. Whatmough, "Euphrates: Algorithm-SoC co-design for low-power mobile continuous vision," arXiv, Tech. Rep., Apr. 2018.

5   2. E. Ronen, A. Shamir, A.-O. Weingarten, and C. O'Flynn, "IoT goes nuclear: Creating a ZigBee chain reaction," in *Proc. Symp. on Security and Privacy*, May 2017.

5   3. P. M. Sheridan, F. Cai, C. Du, W. Ma, Z. Zhang, and W. D. Lu, "Sparse coding with memristor networks," *Nature Nanotechnology*, vol. 12, Aug. 2017.
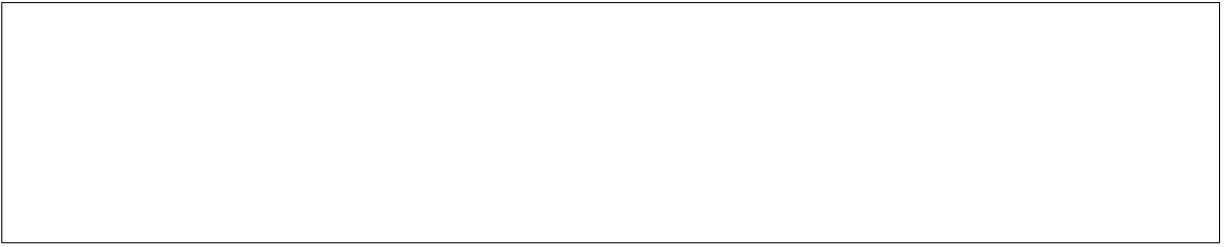
5   4. P. Coussy, C. Chavet, H. Wouafo, and L. Conde-Canecia, "Fully binary neural network model and optimized hardware architectures for associative memories," *ACM J. on Emerging Technologies in Computing Systems*, vol. 11, no. 4, Apr. 2015.
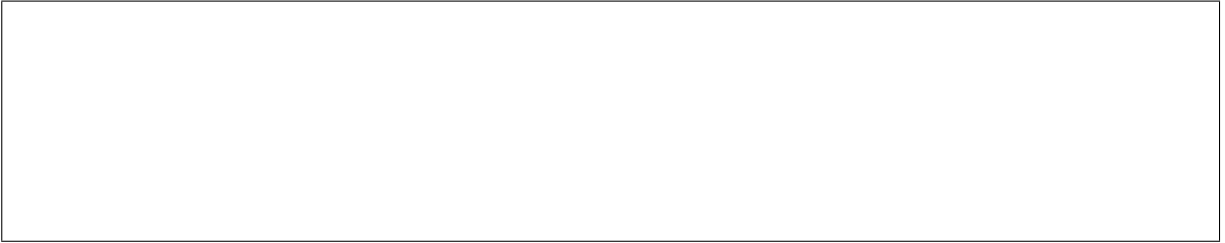
5   5. L. Zhang, B. Tiwana, Z. Qian, Z. Wang, R. P. Dick, Z. M. Mao, and L. Yang, "Accurate online power estimation and automatic battery behavior based power model generation for smartphones," in *Proc. Int. Conf. Hardware/Software Codesign and System Synthesis*, Oct. 2010, pp. 105–114.
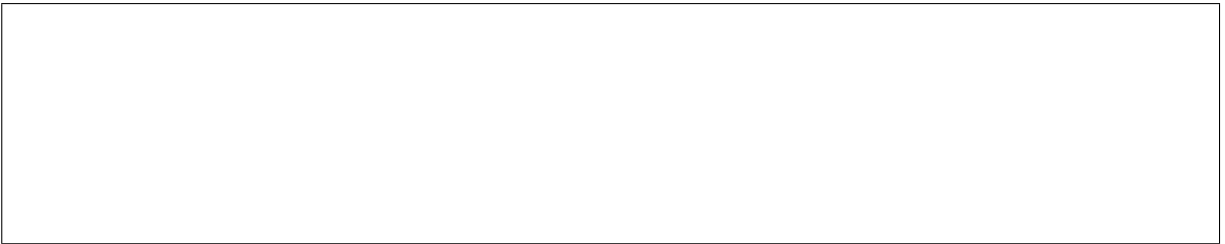
5   6. For the student project on using parallel recombinative simulated annealing to design printed circuit board trace antennas, a single optimization run took many hours. Why? In other words, what was the majority of time spent on?

      ◯ Calculating the results of Boltzmann trials.

      ◯ Random number generation.

      ◯ Running an electromagnetics simulator.

      ◯ Calculating interactions with printed circuit board traces used for power distribution.

5   7. Which of the following errors can be detected via model checking?

      ◯ Failure of the design to always meet the requirements in the specifications.

      ◯ Hardware component faults resulting from manufacturing process variation.

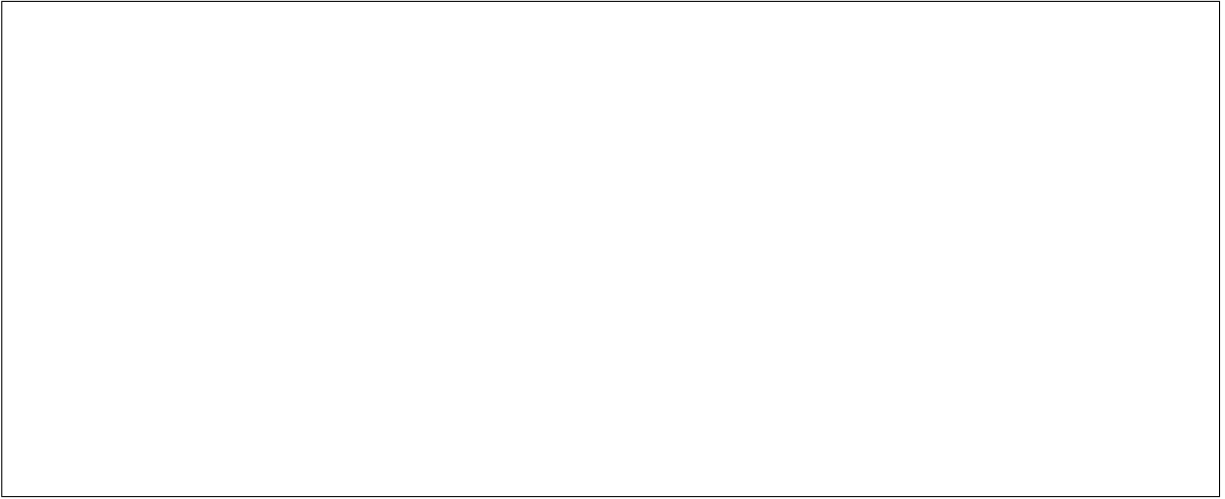   ◯ Mismatches between specification and designer intentions.

10 8. List three reasons (a few words each, at most) that high power consumption can cause problems in embedded systems. Helpful note: Rephrasing the same reason doesn't turn it into different reasons.
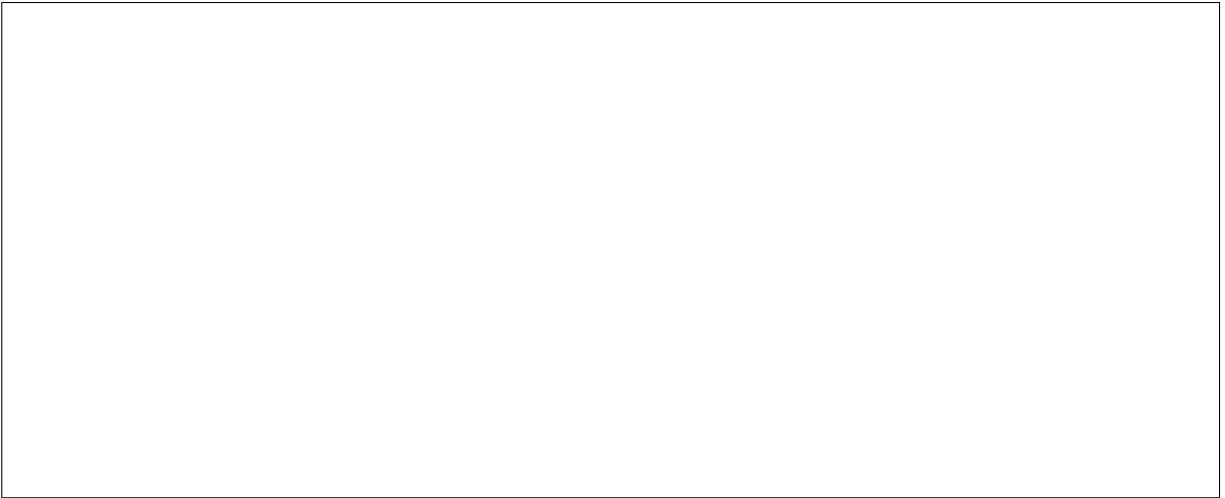
5 9. Consider the following table.

Wireless Communication Technologies

Technology	Power (mW)	Range (m)	Typical rate (kb/s)
4G	1,000	70,000	10,000
5G	1,000	40,000	100,000
WiFi / 802.11(g)	250	140	20,000
Zigbee / 802.15.4	50	10–1,500	100
LoRaWAN	10	15,000	20
NB-IoT	100	15,000	250

Which communication technology is most energy efficient per bit, and what is its energy cost per bit? Show your work.

5 10. List four methods of improving the energy efficiencies of deep neural networks, using at most a few words each.

5 11. In a convolutional neural network, how many multiply-accumulate operations are required to apply a 5×5 kernel to a 100×100 two-dimensional image? You may neglect computations related to indexing operations. Assume a stride length of 1.

5 12. In a convolutional neural network, how many multiply-accumulate operations are required to evaluate a single neuron in the second of two fully-connected layers, each containing 1,000 neurons? You may neglect computation related to applying the activation function to the sum.