COMPUTER SCIENCE TRIPOS Part II – 2020 – Paper 9

11 Mobile and Sensor Systems (rkh23)

A company manufactures small location tags containing a speaker and a Bluetooth radio designed to be attached to personal effects such as keys. A Bluetooth-enabled smartphone can instruct the device to make an audible noise to aid in finding it when lost. The company wishes to support *background* location estimation of the tags relative to the phone.

(*a*) They propose to use Bluetooth 5.1, which supports an antenna array for direction finding from Bluetooth packet exchanges.

   (*i*) Explain how an antenna array enables direction finding. Discuss any practical challenges in direction finding indoors. [4 marks]

   (*ii*) State and justify the upper bound on the spacing between antenna array elements and estimate this value in metres for Bluetooth. Comment on the practicality of your estimate. Is there any disadvantage to having closer spacing? [4 marks]

   (*iii*) The antenna array could be on the phone or on the location tag or both. Discuss the commercial trade-offs of these options. [3 marks]

(*b*) In addition to direction, the system must estimate the distance to the tag from the phone.

   (*i*) Discuss how feasible it is to use Received Signal Strength (RSS) measurements to estimate distance in this context. [1 mark]

   (*ii*) Explain how WiFi 802.11mc Fine Timing Meansurement estimates distance. Discuss whether an analogous scheme could be implemented using standard Bluetooth 5.1 hardware for this application. [5 marks]

   (*iii*) Given that the speakers and microphones on smartphones and on the tags can produce and receive ultrasonic audio, describe an approach to estimating distance. How would you optimise your system for the power-sensitive location tags? [3 marks]