Wireless Networking

Course code: CS4222/5422, Assignment #4/Project

Important Instructions: This assignment must be completed collaboratively by all members of the group. A statement of work detailing the contributions of each member to the assignment, along with the source code, must be uploaded to Canvas.

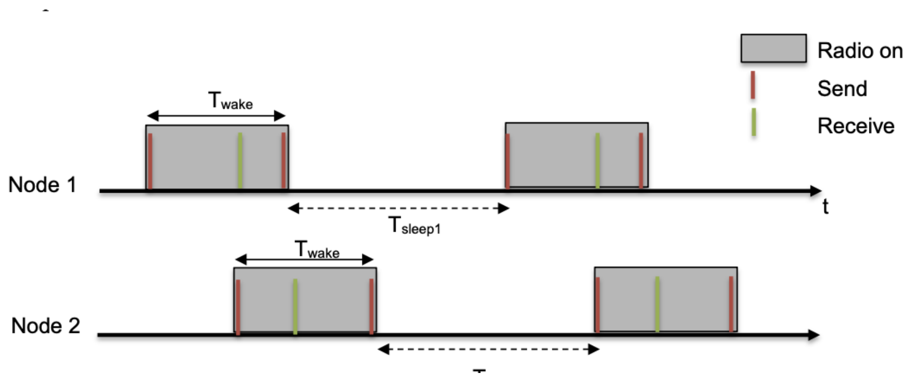
Objective

You will apply various concepts learned in the course and assignments, including sensor interfacing, proximity detection using received signal strength, delay-tolerant networking, and neighbor discovery. The project is structured into two parts:

- You will implement a neighbor discovery mechanism based on "birthday protocol."
- You will enhance this neighbor discovery mechanism to establish a delay-tolerant sensing application. In particular, you will investigate estimating link metrics.

Introduction

You are provided a program that implements"birthday protocol." In this protocol, each node wakes up at random intervals to transmit data and listen for transmissions from nearby devices. The following illustration demonstrates the steps involved in protocol's operation:



The identical code is executed on all nodes. Each node wakes up for a duration of Twake, sending two packets: one at the beginning of the wake-up period and another at the end, just before returning to sleep. Following the initial transmission, the node keeps its radio on to listen for potential incoming messages.

In the illustration above, Node 1 and Node 2 operate based on their timers. The intervals between two consecutive wake-up slots (**Tsleep1 and Tsleep2** in the figure) are randomly selected from a uniform distribution, sharing the same mean **Tsleep** value.

Adjusting **Twake and Tsleep** will influence the latency experienced by nodes when discovering neighboring devices and the radio energy consumption. The radio's duty cycle can be calculated using the formula: **Twake / (Twake + Tsleep)**

You are provided with a C program, "nbr.c," which implements the fundamental logic outlined above. The modifiable parameters in the program are as follows:

WAKE_TIME (Twake): The default value is set to (RTIMER_SECOND / 10) or 100ms.

The maximum duration of a single sleep interval is constrained by the RTIMER count wraparound. Therefore, the total sleep interval between two wake-up periods is calculated as the product of the duration of a single sleep (SLEEP_SLOT) and the number of sleep cycles (SLEEP_CYCLE).

- **SLEEP_SLOT:** The default value is the same as WAKE_TIME.
- **SLEEP_CYCLE:** This represents the average number of sleep cycles, with a default value of 9. The duty cycle is calculated using the formula: WAKE_TIME / (WAKE_TIME + SLEEP_CYCLE * SLEEP_SLOT).

Task 1:

Please try out various settings and observe your results while performing the tasks:

a) Using the default settings, observe and record how long the devices take to discover each other. Pick one of the devices as A and plot the cumulative distribution of the intervals between packet receptions on device A hearing from device B.

b) Reset device B and observe how long it takes for device A to hear from device B after device B reboots. You may need to modify the given code to observe this duration. Perform the experiments at least 10 times and plot the cumulative distribution.

Next, please modify the program (nbr.c) so that two-way discovery (A hears from B AND B hears from A) can be completed in a deterministic manner within 10 seconds. You should choose settings so that the radio power consumption is "minimized".

You must include the following in the report (detailed instructions below in the document):
a) The algorithm you have implemented
b) The parameters chosen
c) The maximum two-way latency observed

Important: Please note that the two-way latency is the time it takes for node A to hear from node B, and then for node B to hear from A. In other words, it is the time it takes for performing two-way neighbor discovery.

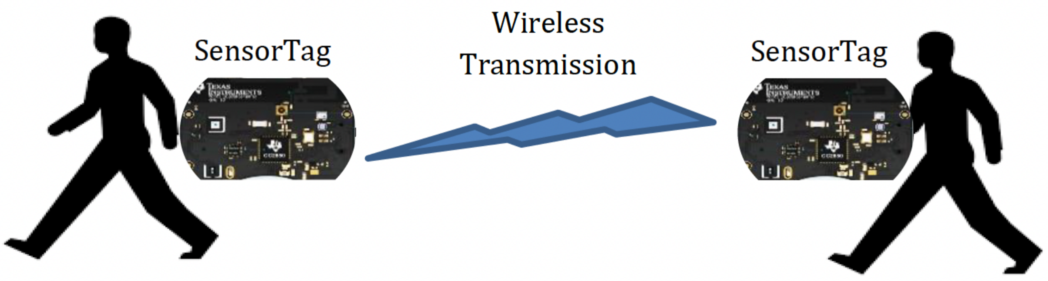
Setting up Contiki

- Extract provided neighbour.zip in the contiki-ng/examples directory
- Compile the program using command “make TARGET=cc26x0-cc13x0 BOARD=sensortag/cc2650” in the directory “contiki-ng/examples/nbr”.
- Use uniflash program to burn the binary file to the SensorTag.
- Observe the output of the program through the USB serial port.

You need to run the program on 2 devices to perform the experiment.

Task 2:

There has been significant interest in backhaul networks. These are useful for offloading sensor data from scenarios where traditional network connectivity, such as cellular towers, may not be available. In these networks, nearby devices, like smartphones, laptops, and tablets, pick up transmissions from sensors and offload them to a cloud-based server whenever connected to a traditional network. Examples of such networks are Apple AirTags and the Find My network. In this case, nearby Apple devices act as relays to track the AirTag's location using Bluetooth and ultra-wideband technology. This allows AirTag to be located even when out of range of its paired device.



In this project, you will design a basic implementation of such a network. One node will sense light readings whenever there is motion and collect them in an array. Next, another node will discover this node and then receive the accumulated light readings whenever the link quality between nodes is good. We describe these tasks in much greater detail next. One of the sensor tags should be programmed to collect light sensor readings whenever there is significant motion. These light sensor readings should be stored in an array. You may decide on an appropriate size for the array. Please refer to the second assignment for details regarding the sampling of the light sensor. The next step involves the other sensor tag discovering the particular sensortag (holding light readings). After discovery, the tag should transmit the light readings. The transfer should start when the link quality is good.

There are different ways to determine that the link quality is good; it could be that the RSSI is sufficiently high for received packets, or the Packet Received Ratio or ETX is high. You can use an appropriate metric, but please justify your choice in the report. Furthermore, please also justify any threshold used. If you use signal strength, what RSSI value would you consider to indicate a good link with sufficiently strong signals? Explain these choices in the report, and we will account for your answers when grading you for particular task.

Your code should output (write to stdout using printf) the time a device first detects another device in the following format:

Timestamp (in seconds) DETECT nodeID

DETECT is a keyword for the detection of a NEW node.
A single whitespace separates the fields.

For example: 123 DETECT 34567
This means that at 123 seconds, a node with ID 34567 is detected.

When the node determines that the link quality is good and it is ready to perform transmission of collected sensor data, please print the information in the following format:

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345 TRANSFER 34567
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This means that at 345 seconds, the node with ID 34567 is in the vicinity with good link quality and is ready for the transfer of sensor data.

Notes:

- TRANSFER is only printed when the node has determined that the link quality between nodes is good.
- Please keep the energy consumption for performing the neighbor discovery and other tasks as low as possible.

Finally, after the node has been successfully detected, also print the light sensor readings that were transferred. Please print them as follows:

"Light: Reading 1, Reading 2, ..., Reading 10"

Demonstration, Submission Guidelines and Deadline

The deadline for submission of the assignment is April 26th, 2024. This assignment needs to be done with members of the designated group. We provide implementation of neighbour discovery program here: neighbour.zip
You would need atleast two nodes for this assignment. Please pick one as a light-sensor and another as a receiver (data mule). We will evaluate your system using different scenarios based on metric such as those listed below:

- Detection accuracy. This includes detection of new node, existing node moving away, and the times it take to detect these events.
- Steps taken to reduce energy consumption
- What was the logic for transferring light readings?
- How did you determine that link quality was good?
- Creativity of the proposed solution

Submit a single zip file named group-number-project.zip to CANVAS with following files:

- A single pdf file (report.pdf)
- The neighbor discovery protocol you have implemented to “duty-cycle” your radio in order to reduce power consumption.
- The logic that you have implemented for link quality detection
- Results showing the evaluation of your system
- What was the logic of the code to sense motion, capture light readings and transfer these captured light readings to another sensor tag
- Your code in a single directory named source-code
- Your code must be able to compile to run SensorTag
- A README file to compile and execute your program(s).

You can submit after due date of 26th April 2024 without penalty till 30th April 2024. Afterwards, we will not accept the submission.