ECE9047: Laboratory 4 Report

Objective

This lab is about designing a wireless sensor network to perform a specific task within certain design constraints. It is required to design a wireless sensor network to track an animal population and monitor environmental conditions in a given habitat.

design philosophy

- Due to the use of Zigbee, the network is heterogeneous. Some nodes are equipped with sensors to collect specific data, while others function solely as relay nodes for data transmission. As a result, their hardware configurations differ.
- The network will follow a structured, deterministic deployment strategy rather than a random placement of nodes.
- Given Zigbee's limited communication range of 10 meters, numerous nodes are connected to only one neighboring node. Consequently, the network exhibits a k-connectivity of 1. This makes such nodes vulnerable to single points of failure, as the disconnection of their only link could lead to a complete loss of connectivity for parts of the system.
- Assuming the pressure sensor takes 1000 measurements, and two high-capacity batteries can support 100,000 transmissions, the system is estimated to operate continuously for approximately 100 days—equivalent to one academic semester.
- The maintenance strategy involves replacing the entire hardware unit when necessary. The associated costs for these replacements are accounted for in the project budget.

Sensor coverage

For sensor radius, it is assumed that light and humidity levels are relatively uniform throughout an indoor room environment. Therefore, for the light and humidity sensors, precise spatial coverage is not critical, as the goal is to obtain representative measurements for the entire room. A sensing radius of 15 meters is selected, which ensures coverage of at least half of the room area, deemed sufficient for reliable environmental monitoring.

For pressure sensors, which are primarily used to detect movement at doorways, the corridor width of approximately 2.5 meters is considered. Consequently, a sensing radius of 2 meters is assigned to each pressure sensor, which effectively covers standard room entrances. Due to the larger entrance of the Café, three pressure sensors are deployed to ensure complete coverage of this wider area.

As for the coverage since the light and humidity sensors share identical sensing characteristics and deployment locations, their sensing areas are equivalent. While not all regions are within sensing range, the measurement objective tolerates this limitation, and thus the k-coverage is defined as 0. However, this does not significantly affect the validity of the collected data. In contrast, pressure sensors have a much more limited sensing range, focused exclusively on doorways. As a result, most indoor areas remain outside their detection zones, leading to a k-coverage of 0 for this sensor type as well.

Construction of the nodes

In this system, only Zigbee wireless hardware is used for communication protocol. The following table shows the specific information for the nodes.

Node type (Zigbee)	Location	Sensor	Power	Functionality
Control center	Wall	Light sensor, humidity sensor	Power outlet	Work as a light and humidity detection. It communicates with the outside world via ethernet.
Router (Pressure)	Floor	Pressure sensor	High-Capacity Battery*2	Measuring migrations patterns of undergraduate students and relay information.
Router (Relay)	Ceiling	N/A	High-Capacity Battery*2	Only relaying information.
End (Pressure)	Floor	Pressure sensor	High-Capacity Battery*2	Measuring migrations patterns of undergraduate students.
End (light, humidity). power	Wall	Light sensor, humidity sensor	Power outlet	Measuring light and humidity in a room with power outlet.

End (light, humidity). battery	Wall	Light sensor, humidity sensor	Medium Capacity Battery	Measuring light and humidity in a room without power outlet.

deployment of the network

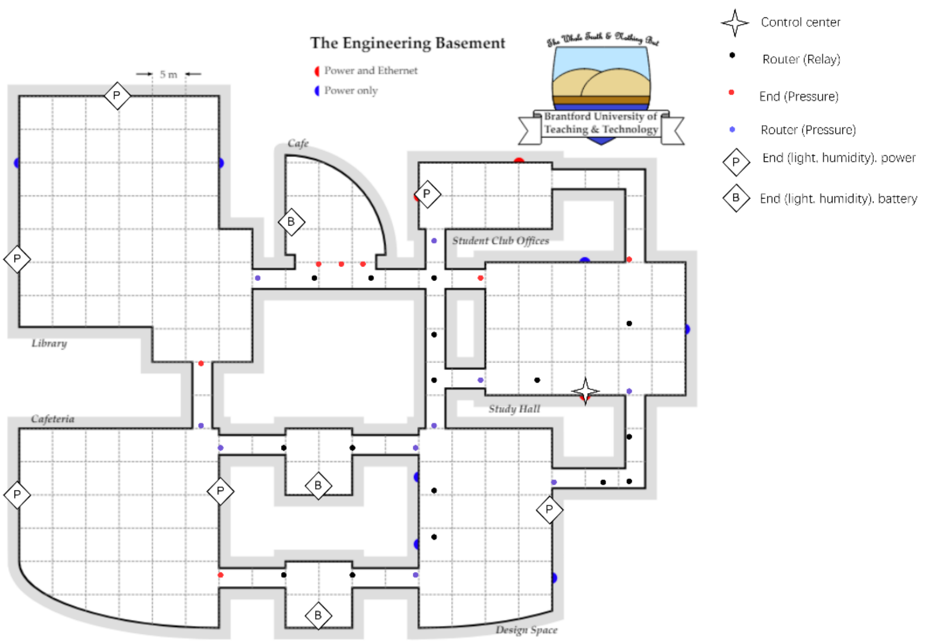

Fig1. Node Deployment

The mounting positions for each node type are listed in the table above. The rationale for these placements is as follows:

1. Light and Humidity Sensors: Nodes equipped with light and humidity sensors are mounted on the wall, approximately at the average height of undergraduate students. This decision is based on the need to avoid environmental interference that may occur at floor level. For instance, when individuals walk over floor-mounted sensors, the light sensor readings may be obstructed by shadows, resulting in inaccurate data. Similarly, water brought in by footwear on rainy days can artificially elevate floor-level humidity readings. Wall-mounted placement ensures more stable and representative measurements of room conditions.
2. Pressure Sensors: Pressure sensors are installed directly on the floor, as they are intended to detect the presence and movement of individuals via foot pressure. Accurate timestamping of footsteps requires direct contact, which justifies this positioning.

3. Relay Nodes (Routers): Router nodes, which are solely responsible for data transmission and do not perform any sensing functions, are mounted on the ceiling. This placement minimizes interference with human activities and ensures a secure and unobtrusive installation, while maintaining line-of-sight communication paths with other nodes.

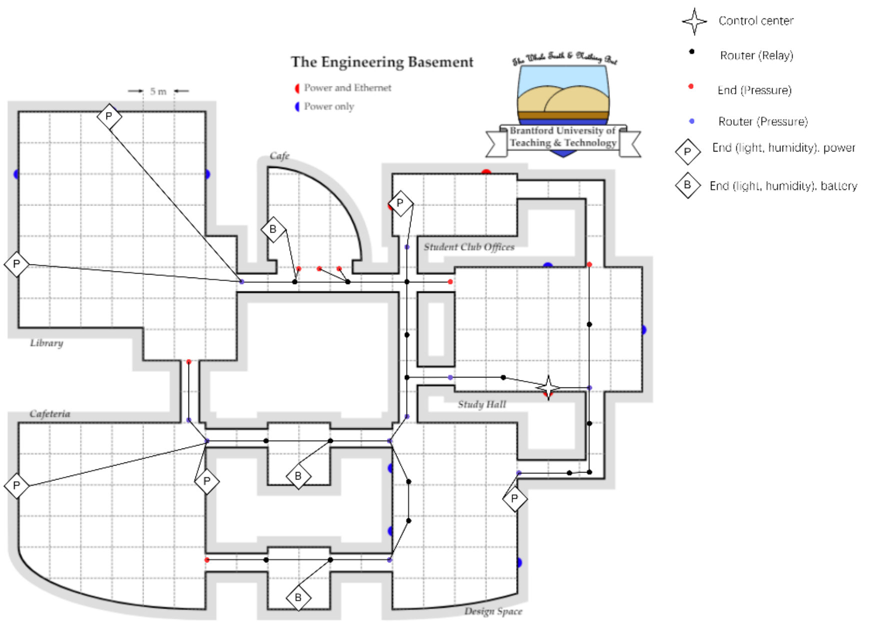

Fig2. Communication Channels

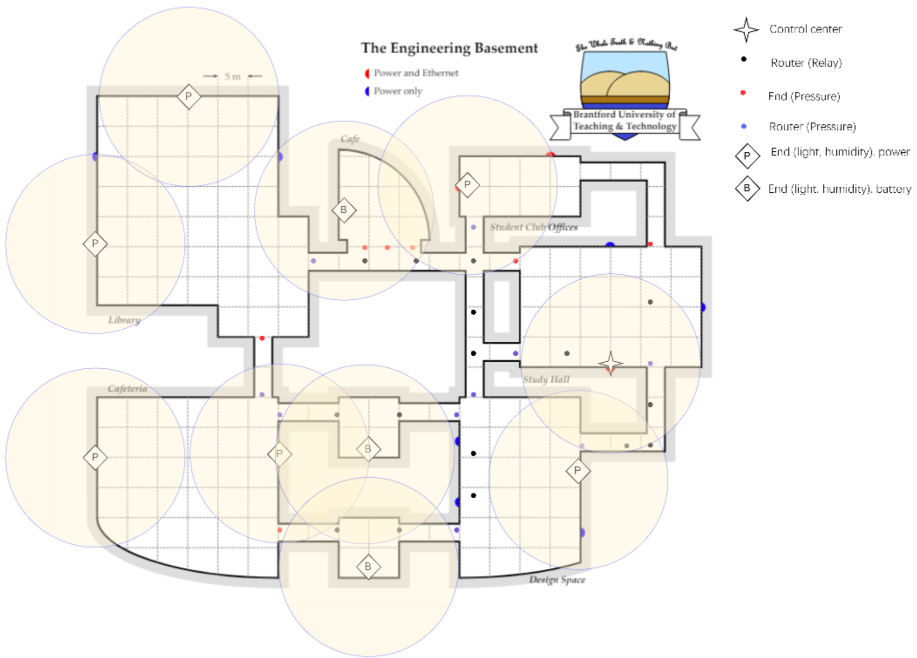

Fig3. Sensing area for light and humidity sensor

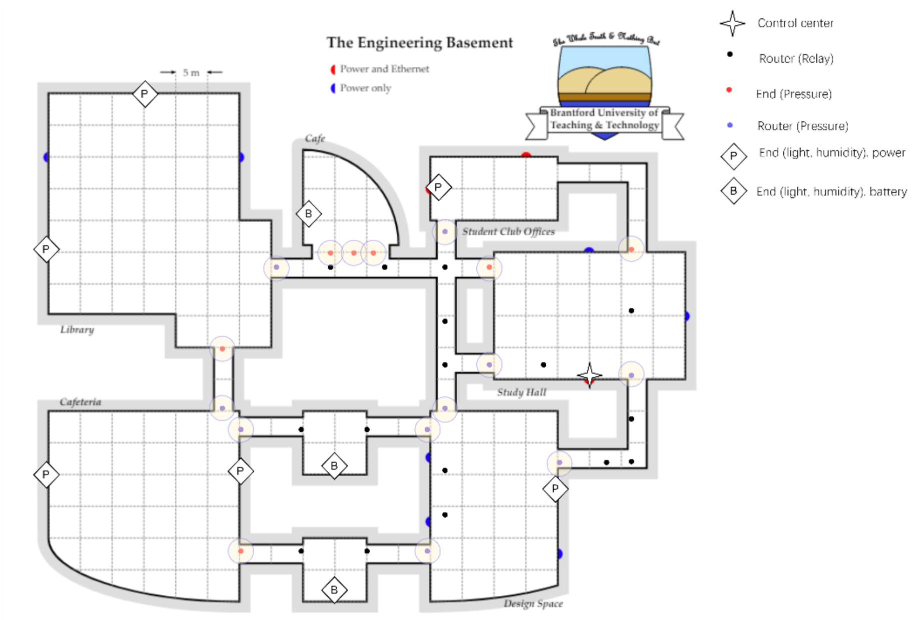

Fig4. Sensing area for pressure sensor

operating procedure

- The light and humidity sensor acquires data at every 2-hour intervals. The pressure sensor acquires data when there is an interrupt (Someone steps on it).
- Interference between the sensors is successfully prevented. light and humidity sensors which are placed on the walk will not influence each other.
- The light and humidity sensor record data with specific levels such as light sensor reads 200lx and humidity sensor reads 45%RH. The pressure sensor records the timestamp when the weight on it passes 40 kilograms.
- The data in light and humidity sensors can directly tell the light and humidity level in a room while the timestamp in pressure sensors can be compared to derive the route of a student. For instance, the closest timestamp in pressure sensors which are placed on two side of the corridor can derive the direction of a student's congregation. The entrance with earlier timestamp states the starting point and the other means the end point.

strengths/weaknesses

- It is unlikely for an undergraduate student to bypass a pressure sensor unnoticed, as the sensing area has a diameter of 4 meters—unless someone is intentionally jumping over it.
- A key weakness of the system is its low *k*-connectivity; the failure of several nodes could result in network disconnection.
- One major strength is its efficient use of hardware resources. Unlike Z-Wave devices, each component within a node serves a specific function. This design

reduces redundancy and simplifies maintenance, as replacing a node does not require purchasing additional, unnecessary hardware to maintain system uniformity.

Budget for the WSN

Node	Control center			
Category	Description	Value ($)	Number	Cost
Base	Microcontroller	10	1	10
Sensor	Light Sensor	2	1	2
	Humidity Sensor	2	1	2
	Pressure Sensor	2	0	0
Power Source	Low-Capacity Battery	5	0	0
	Medium-Capacity Batt	15	0	0
	High-Capacity Battery	25	0	0
	Power Converter	5	1	5
Communications	Zigbee Controller (ZC)	25	1	25
	Zigbee Router (ZR)	10	0	0
	Zigbee End Device (ZED)	5	0	0
	Z-Wave Transmitter	20	0	0
	Ethernet Port	5	1	5
			Total Cost one node	49
			Number	1
			Total Cost	49

Node	Router (Relay)			
Category	Description	Value ($)	Number	Cost
Base	Microcontroller	10	1	10
Sensor	Light Sensor	2	0	0
	Humidity Sensor	2	0	0
	Pressure Sensor	2	0	0
Power Source	Low-Capacity Battery	5	0	0
	Medium-Capacity Batt	15	0	0
	High-Capacity Battery	25	2	50
	Power Converter	5	0	0
Communications	Zigbee Controller (ZC)	25	0	0
	Zigbee Router (ZR)	10	1	10
	Zigbee End Device (ZED)	5	0	0
	Z-Wave Transmitter	20	0	0
	Ethernet Port	5	0	0
			Total Cost one node	70
			Number	16
			Total Cost	1120

Node	Router (Pressure)			
Category	Description	Value ($)	Number	Cost
Base	Microcontroller	10	1	10
Sensor	Light Sensor	2	0	0
	Humidity Sensor	2	0	0
	Pressure Sensor	2	1	2
Power Source	Low-Capacity Battery	5	0	0
	Medium-Capacity Batt	15	0	0
	High-Capacity Battery	25	2	50
	Power Converter	5	0	0
Communications	Zigbee Controller (ZC)	25	0	0
	Zigbee Router (ZR)	10	1	10
	Zigbee End Device (ZED)	5	0	0
	Z-Wave Transmitter	20	0	0
	Ethernet Port	5	0	0
			Total Cost one node	72
			Number	10
			Total Cost	720

Node	End (Pressure)			
Category	Description	Value ($)	Number	Cost
Base	Microcontroller	10	1	10
Sensor	Light Sensor	2	0	0
	Humidity Sensor	2	0	0
	Pressure Sensor	2	1	2
Power Source	Low-Capacity Battery	5	0	0
	Medium-Capacity Batt	15	0	0
	High-Capacity Battery	25	2	50
	Power Converter	5	0	0
Communications	Zigbee Controller (ZC)	25	0	0
	Zigbee Router (ZR)	10	0	0
	Zigbee End Device (ZED)	5	1	5
	Z-Wave Transmitter	20	0	0
	Ethernet Port	5	0	0
			Total Cost one node	67
			Number	7
			Total Cost	469

Node	End (light, humidity). Power			
Category	Description	Value ($)	Number	Cost
Base	Microcontroller	10	1	10
Sensor	Light Sensor	2	1	2
	Humidity Sensor	2	1	2
	Pressure Sensor	2	0	0
Power Source	Low-Capacity Battery	5	0	0
	Medium-Capacity Batt	15	0	0
	High-Capacity Battery	25	0	0
	Power Converter	5	1	5
Communications	Zigbee Controller (ZC)	25	0	0
	Zigbee Router (ZR)	10	0	0
	Zigbee End Device (ZED)	5	1	5
	Z-Wave Transmitter	20	0	0
	Ethernet Port	5	0	0
			Total Cost one node	24
			Number	6
			Total Cost	144

Node	End (light, humidity). Battery			
Category	Description	Value ($)	Number	Cost
Base	Microcontroller	10	1	10
Sensor	Light Sensor	2	1	2
	Humidity Sensor	2	1	2
	Pressure Sensor	2	0	0
Power Source	Low-Capacity Battery	5	0	0
	Medium-Capacity Batt	15	1	15
	High-Capacity Battery	25	0	0
	Power Converter	5	0	0
Communications	Zigbee Controller (ZC)	25	0	0
	Zigbee Router (ZR)	10	0	0
	Zigbee End Device (ZED)	5	1	5
	Z-Wave Transmitter	20	0	0
	Ethernet Port	5	0	0
			Total Cost one node	34
			Number	3
			Total Cost	102

Budget	Budget for Replacement
2604	396