

Advanced Occupancy System

Mitch Williams
Adam Winter
Shane Woolwine



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Mission Statement

In the market today, there is a need for a robust and easy to implement sensor system that allows a system operator to remotely determine the availability of an area of interest. Currently, there are no non-invasive occupancy detection and verification systems that require minimal amounts of user time and effort. The Advanced Occupancy System has been developed primarily as a method for companies to save time and money by improving their organizational capacity.

The Advanced Occupancy System is marketable toward any organization in which conference rooms or study spaces are limited or frequently interrupted. Additionally, this system can easily be adapted to work with aeration systems to cut the costs of heating or cooling offices that are not frequently used. Target markets for the Advanced Occupancy System are companies with large organizational hierarchies or organizations that employ/support a large number of individuals with limited work space. Secondary target markets include public venues that entertain many individuals such as restaurants, theaters, or the public library.

The occupancy sensor must be able to run well on battery power for an extended period of time, more than 2-5 days. Also, to improve versatility the system must have the ability to communicate wirelessly with other sensors. A target price of \$150 - \$200 is optimal for this product.

Motivation

- Our motivation for this product is to increase consumer efficiency by developing a product that will improve a company's organization and time management capacity.
- Currently methods for determining and monitoring the availability of areas of interest require large amounts of wasted time and effort.
- Research has identified three situations concerning the state of occupancy for an area of interest that will be addressed by the Advanced Occupancy System
 - An individual is located in an AOI.
 - Objects or possessions have been left in an AOI.
 - The AOI is unoccupied

Customer Needs

- **Display**
 - The ability to view information from a remote location
- **Privacy**
 - The system does not invade consumer privacy, i.e. no cameras
- **Appearance**
 - Does not interfere with normal activity
- **Reliability**
 - The system requires minimal user intervention
- **Versatility**
 - System is extensible and expandable
 - Can be implemented in a variety of locations
- **Accuracy**
 - Can adjust for different occupancy scenarios
- **Cost**
 - The system is priced affordably

Needs Survey

1. What information would you like an occupancy sensor system to collect in your organization? For example, would you like it to tell you how many people are in a room/table or just if the room/table are being used?
2. How do you believe your company/organization can benefit from an occupancy sensor system? Do you think it would save time?
3. In what ways does the lack of an occupancy sensor system detrimentally affect your company/organization?
4. Does an occupancy sensor system provoke concerns about invasion of privacy? If yes, what constraints/limitations must be placed on the system to calm your concerns?
5. Are there any limitations to the physical dimensions of an occupancy sensor system?
6. Would you prefer a system that operates using battery power or a hard-line connection to the building's power system? (Note: A battery power systems may be more versatile, but requires routine maintenance.)
7. Would you consider a wireless sensor system or a wired system to be more useful. Keep in mind that a wireless system would be much more versatile.
8. How long do you believe an occupancy sensor system should last operating on battery power?
9. Where would you place the sensors of the system?

Priority of Customer Needs

#	Need Statement	Importance
	Display	
1	The system information is viewable from remote locations	1
2	The system displays numerical data	2
3	The display gives a graphical representation of where occupants are located	4
4	Information is given in real time	3
	Privacy Concerns	
5	The system displays occupancy data in a way that respects a person's sense of privacy.	1
6	The system is implemented in a way that makes users aware of it's presence	3
7	The system communications are secure	3
	Cost	
8	One piece of equipment can detect occupancy of more than one area of occupant interest	2
9	The system uses readily available hardware	3
10	The system is priced affordably	2
	Power	
11	A power saving software scheme is used	3
12	The system can adjust for a variety of power sources	2
	Appearance	
13	The system is designed to create a minimum level of distraction	5
14	The system intergrates with the user environment	4
	Reliability	
15	The system notifies users of required maintenance	2
16	The system requires minimal user intervention	2
17	The system is tamper proof	3
	Accuracy	
18	The sensor resolution accurately determines the number of occupants in an area of interest	3
19	The software is written to adjust for different occupancy situations	2
	Versatility	
20	The system is extensible and expandable	2
21	The system can implemented in a variety of locations	1
	Operation	
22	The system utilizes a variety of sensor systems	1
23	The system is user friendly	1
24	Supports user input	5
25	System information is collected in real time	3
26	Occupancy contains a verifcation system	1
27	The system correlates with other types of data	4
28	The system is not limited to person detection	3

Occupancy Need Metrics

#	Need #	Metric	Importance	units	Competition Comparison		
					Sensource PC-VD105	Sensource PC-2QS06	Sensource PCW-2TB06
1	1, 2, 3	Electronic Information	1	mb	900	900	
2	4, 24	Delay	3	s	0	0	
3	13, 14, 19, 23	Customer Satisfaction Accuracy	1	%			
4	7, 17	Resiliency from attacks	5	%			
5	8, 20	# Occupant areas to equipment ratio	3	n	1	1	
6	9, 10	Cost of hardware	2	\$	\$455/unit	\$545/unit	\$735/
7	11,12	Power	3	V DC	12V DC	12V DC	3.6V
8	13	Noise Level	4	dB			
9	13	Heat Dissipation	4	J			
10	13, 14	Sensor module dimension	4	inches	5.1"L x 3.1"W x 1.8D"	3.7"L x 2.5"W x 2.25"D	6.3L" x 2"
11	15, 16	Average maintenance time	3	hr/wk			
12	15	Upkeep cost	2	\$/year			
13	18	Occupants per area	3	n/m ²	n/65	unlimited	unlim
14	20	Coverage area	2	m ²	65	unlimited	unlim
15	21	Environmental Effectiveness	5	%	80	80	
16	22	Multiple sensor systems	2	n	1	1	
17	25	Verification	1	%	0	0	
18	26	Integration multiple data sources	4	n	0	0	
19	27	Multiple types of object detection	3	n	1	1	
20	5,6	Customer Satisfaction Privacy	1	%	20	99	

Sources

Sensource PC-VD105

http://www.sensourceinc.com/PDF/PC-VDI05_Brochure.pdf

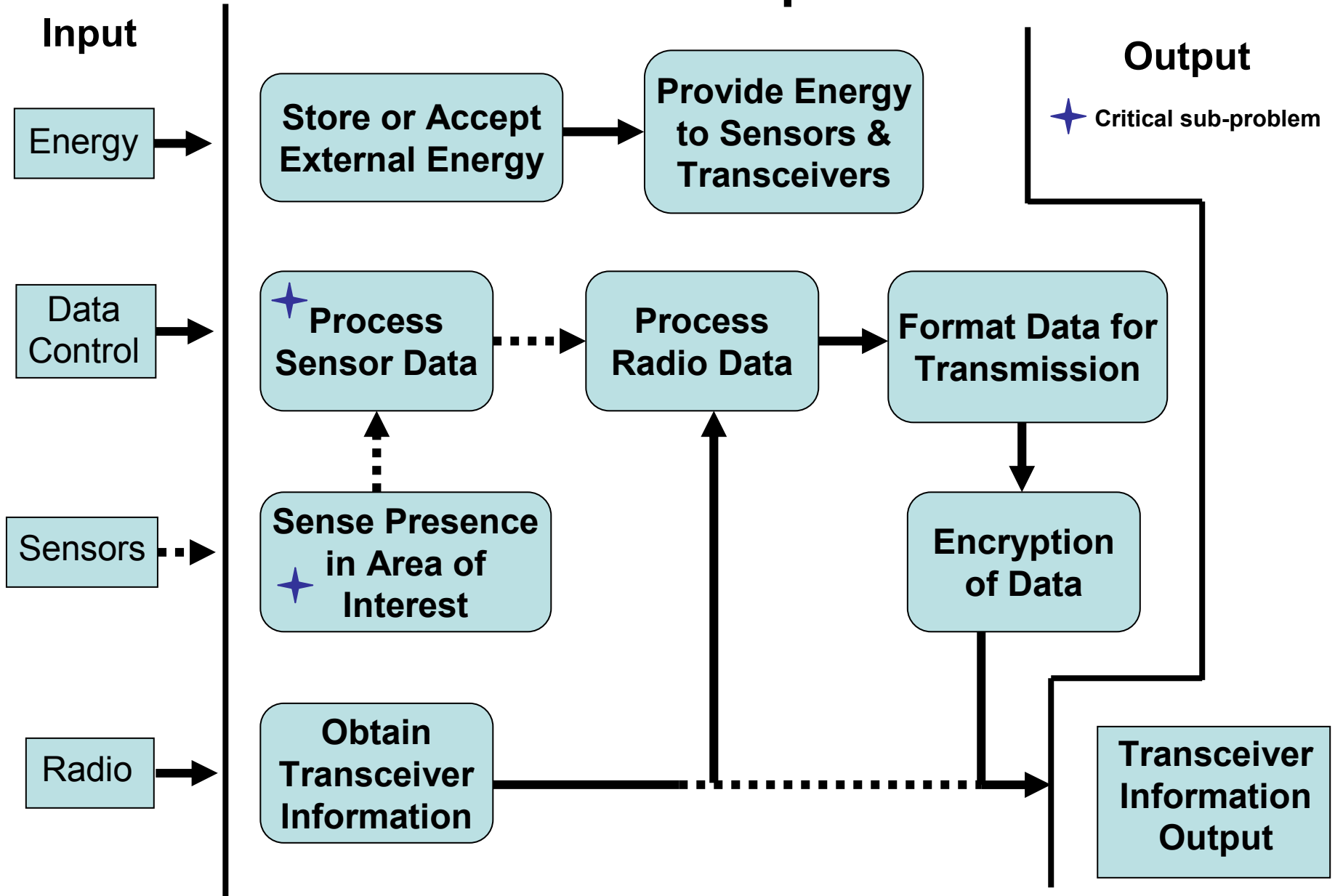
Sensource PC-2QS06

<http://www.sensourceinc.com/PDF/PC-2QS06%20-%20Brochure.pdf>

Sensource PCW-2TB06

<http://www.sensourceinc.com/PDF/PCW-2TB06%20-%20Brochure.pdf>

Product Decomposition



Solution Concepts

Sensors

- Motion Sensor:
 - Active IR, Radar, and Photosensor technologies detect the presence of individuals using active technology to continuously monitor environmental discrepancies in a controlled environment. An environmental discrepancy alters standard signal reception and alerts the system to the presence of an individual in the range of operation.
- Air Sonar:
 - Two types: Active and Passive
 - Active sonar emits ultrasonic bursts in a medium to determine the distance to an object using echolocation. Significant variation in control object distance constitutes occupancy in the area of interest.
 - Passive sonar receives acoustic information from the environment.
- Camera:
 - Provides visual confirmation concerning the occupancy of an area of interest.
 - Adequate information processing power required to interpret copious amounts of data gathered by the system.

- Electromagnetic Detection:

- Ultra-wideband coded oscillating RF signals are sent out of a processor unit via 'transmit' cables. When coupled with 'receive' cables an electromagnetic detection 'near field' is generated surrounding the cable length. Interference due to occupancy causes perturbations in the near field resulting in reduction of the oscillation amplitude. Detection of amplitude reduction constitutes occupancy.

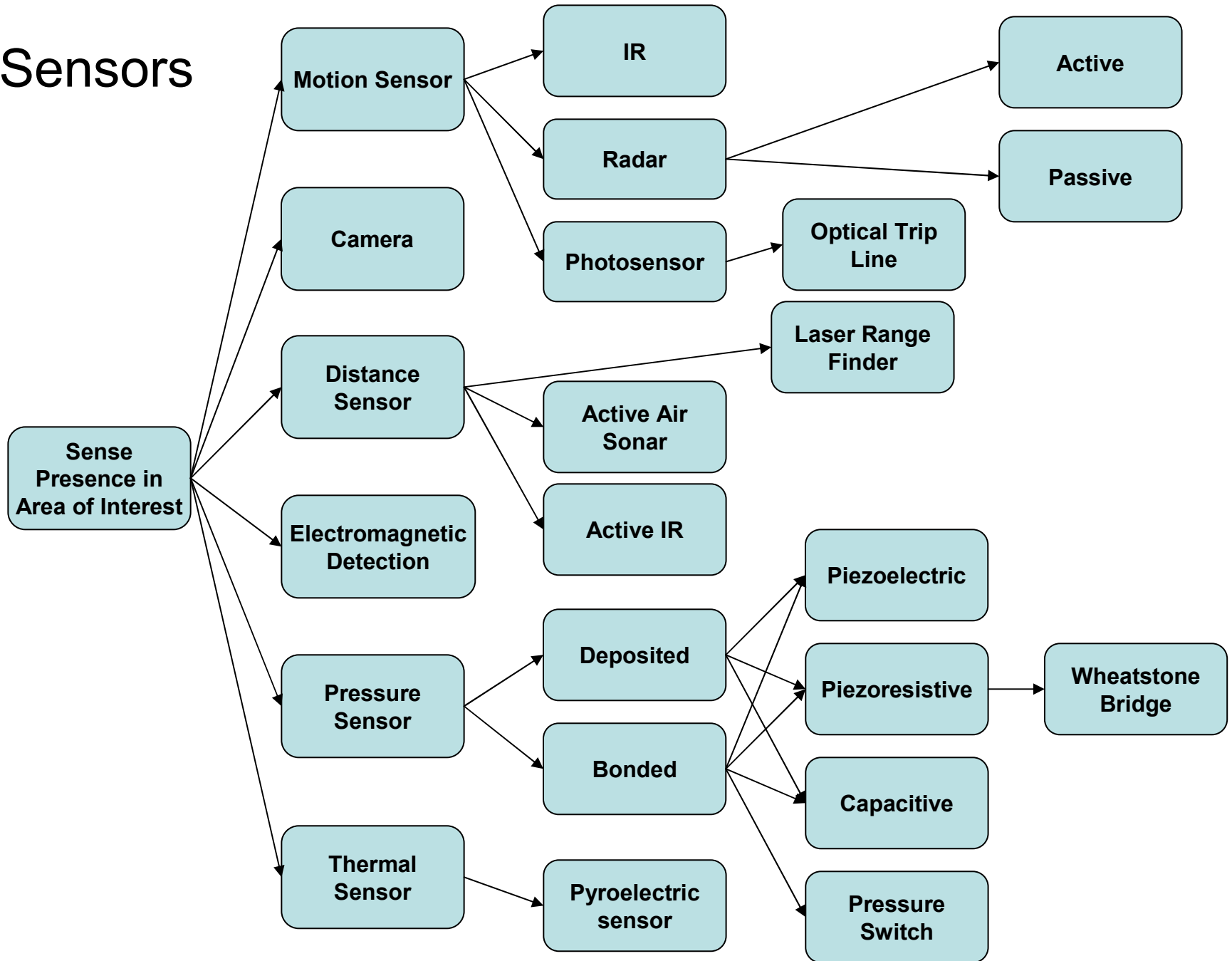
- Pressure Sensor:

- Pressure sensor devices detect stress variations in a controlled environment due to the weight of an individual in or near an area of interest.

- Passive IR:

- Also known as Thermal IR.
- Detects the black-body radiation emitted from living organisms within its range of operation. The black-body radiation is a function of the organisms body heat.
- The detection of black-body radiation generates a change in device output voltage. Voltage change is monitored by other systems to prompt occupancy recognition.

Sensors



Information Processors

- Combination - Microcontroller, FPGA, & Transceiver:
 - Similar to using just a microcontroller except now use an FPGA channel to collect and analyze the data from the sensor and then use a microcontroller to transmit the data using a radio. An example of such a system can be found at <http://www.patentstorm.us/patents/5718234-description.html> where a FPGA channel and a microcontroller were used to transmit patients' data wirelessly.
- Microcontroller & attached Transceiver
 - Instead of using a pre-built sensor node, attempt to build one to suite the needs of the occupancy sensor system using a simple microcontroller and a transceiver. Below is an example of a PIC microcontroller used with an EEPROM and a transceiver to act as a basic radio controller. The picture is from www.byonics.com/piccon/.
- FPGA:
 - An FPGA is a field programmable gate array device containing programmable logic blocks that can be programmed to perform just about any function. In this case one or multiple FPGA devices could be used to process the sensor data and send the data to a connected transceiver.

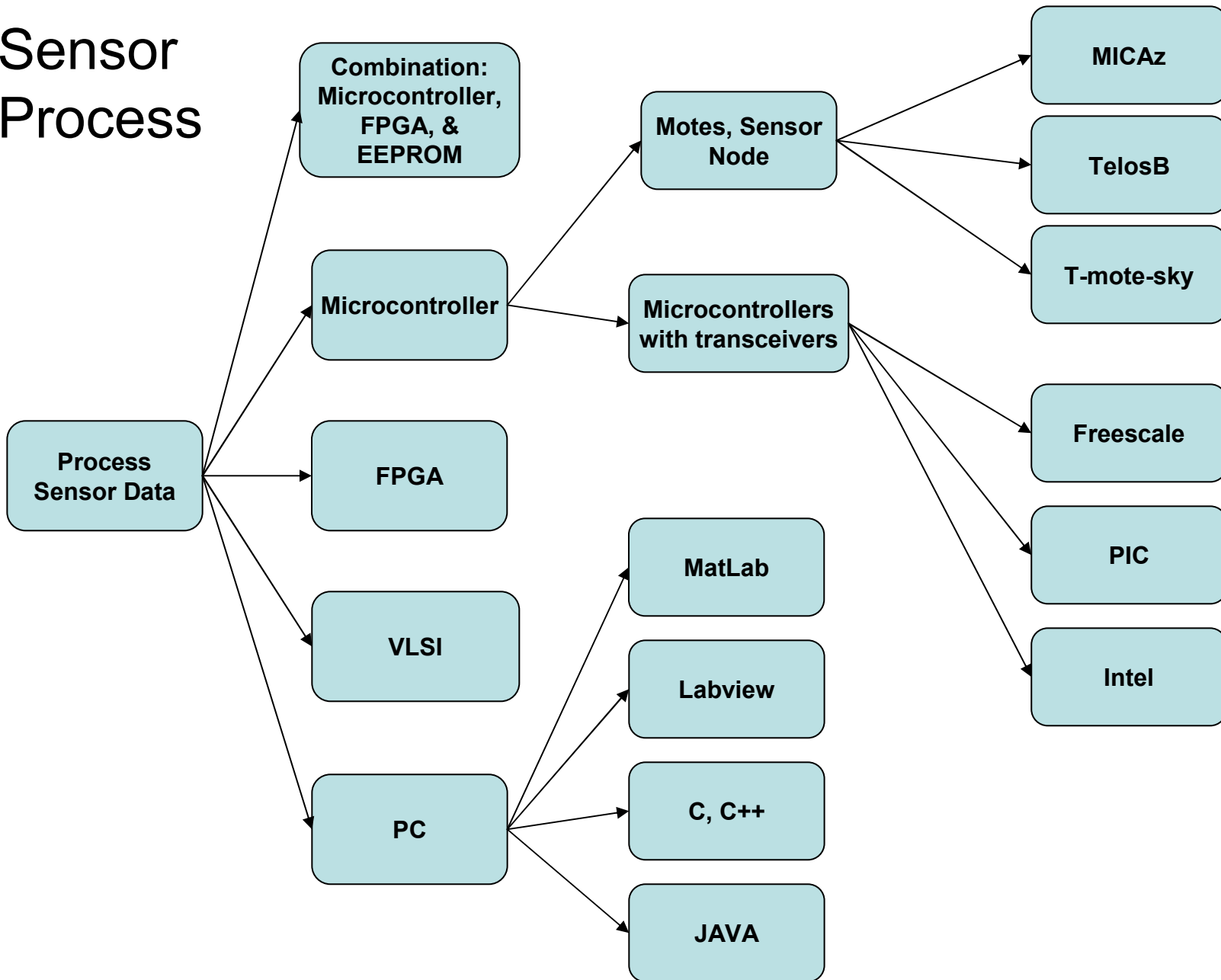
- VLSI:

- Using VLSI a chip can be made to perform the specific needed functions for processing data for the occupancy sensor. Generally this would be performed in the final product only and not a prototype.

- PC:

- The sensors can be hooked up to a simple breadboard and then connected to a PC or Laptop using either USB or a serial port. A microcontroller may still be needed to transmit the data to the PC, but the PC will contain the necessary programs and hardware to process the sensor data. Note, a program may need to be built using C, Matlab, or Labview.

Sensor Process



Concept Combination Table

Sensor System	Solution Base	End Processor
Motion	Microcontroller	Motes
Distance	PC	VLSI
Thermal		Programming Language
Pressure		FPGA
Camera		Stand alone Microcontroller
Electromagnetic Detector		

Concept Variations

	Area Detection Method	Sensor System	End Processor
A	Motion & Distance	IR (thermal) Active Sonar (distance)	T-mote-sky
B	Distance	Active IR	TelosB
C	Electromagnetic Detector	PC	Labview
D	Pressure & Thermal	Piezoresistive (pressure) IR (Thermal)	PIC
E	Camera	PC	Java
F	Thermal	IR	T-mote-sky

Concept Screening Matrix

	Concept Variations					
Selection Criteria	A	B	C	D	E	F
Cost	1	1	0	3	0	1
Availability	3	3	0	2	0	3
Programmability	2	2	3	0	3	2
Ease of Use	2	2	0	0	1	2
Physical Appeal	1	2	1	2	0	3
Versatility	1	2	1	0	0	3
Compatibility w/ existing networks	2	2	3	1	3	2
Accuracy	3	3	2	2	3	2
Verification	3	1	2	2	3	0
Durability	2	1	3	2	0	2
Net	20	19	15	14	13	20
Rank	1	3	4	5	6	2
Continue	yes	yes	no	no	no	yes

Final Occupancy Sensor System Concepts

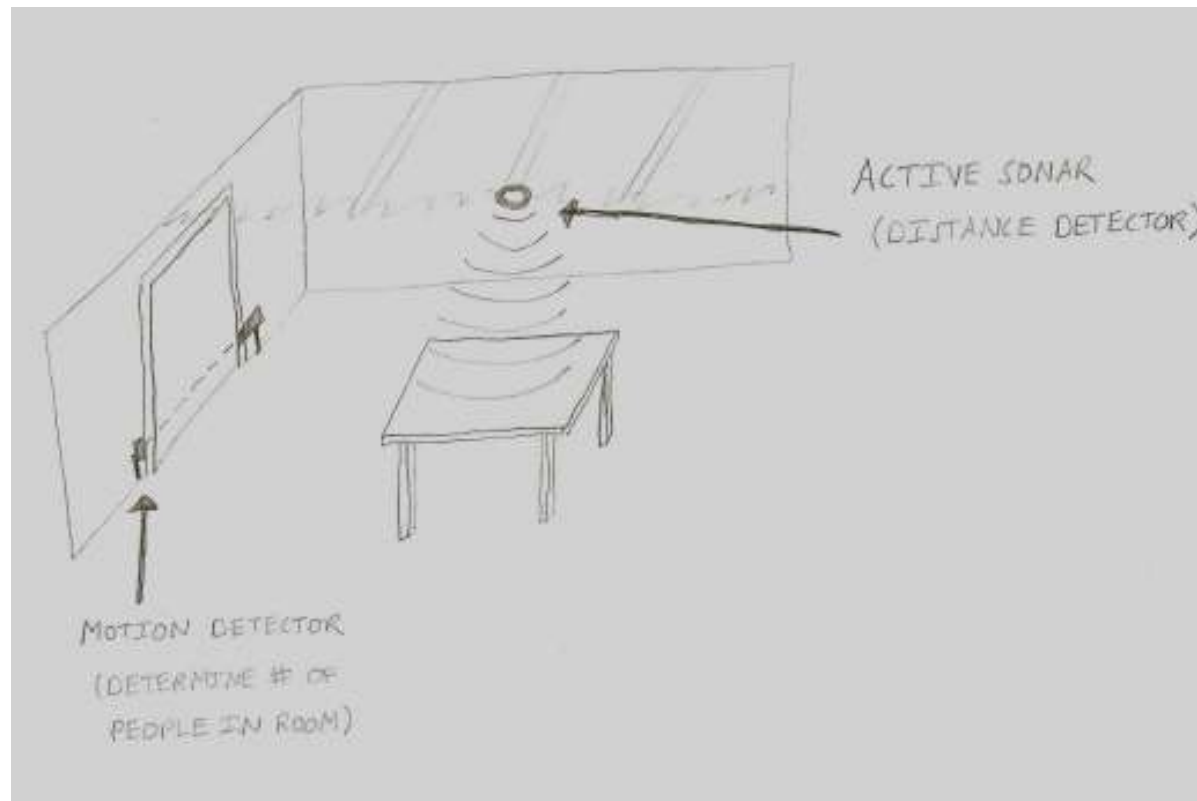
Concept Changes:

1. The use of a pressure sensor system to detect presence in an area of interest was not pursued for a number of reasons. This sensor system seemed to have a lot of advantages due to its simplicity and accuracy, however low versatility, high cost, and inability to verify results have led us in a different direction. In order to use a pressure sensor system piezoresistors would have to be implanted under the flooring or in the chairs individuals will sit in. These sensors must then be wired to the mote system in order to effectively relay data. Unfortunately, the cost of implementing this system is much too high and time consuming for a customer who would like to purchase the system.
2. The use of ultrasonic sensors was considered a good method of determining distance an object at the beginning of the project, but new sensor configurations that were developed which led to an increased interest in these technologies. Originally we believe the sensors would be required to remain in a static location; however our research determined that the sensor could easily be attached to much more versatile platforms.
3. Distance IR systems are an excellent way to recognize the presence of an individual in an area of interest. However, through our research we believe that these systems can not successfully complete a majority of the needs statements collected from potential consumers. Therefore, this detection device has been reduced to a second method of pursuit.
4. Research proved that EM detection systems are incredibly effective in satisfying most customer needs. However, the complexity of the device along with cost considerations has eliminated the pursuit of this approach. The EM detection system may be a good technology to pursue for an effective occupancy detection system, but only with a large increase in funding and time for research and implementation.

The concept changes above have led to the following final product concepts.

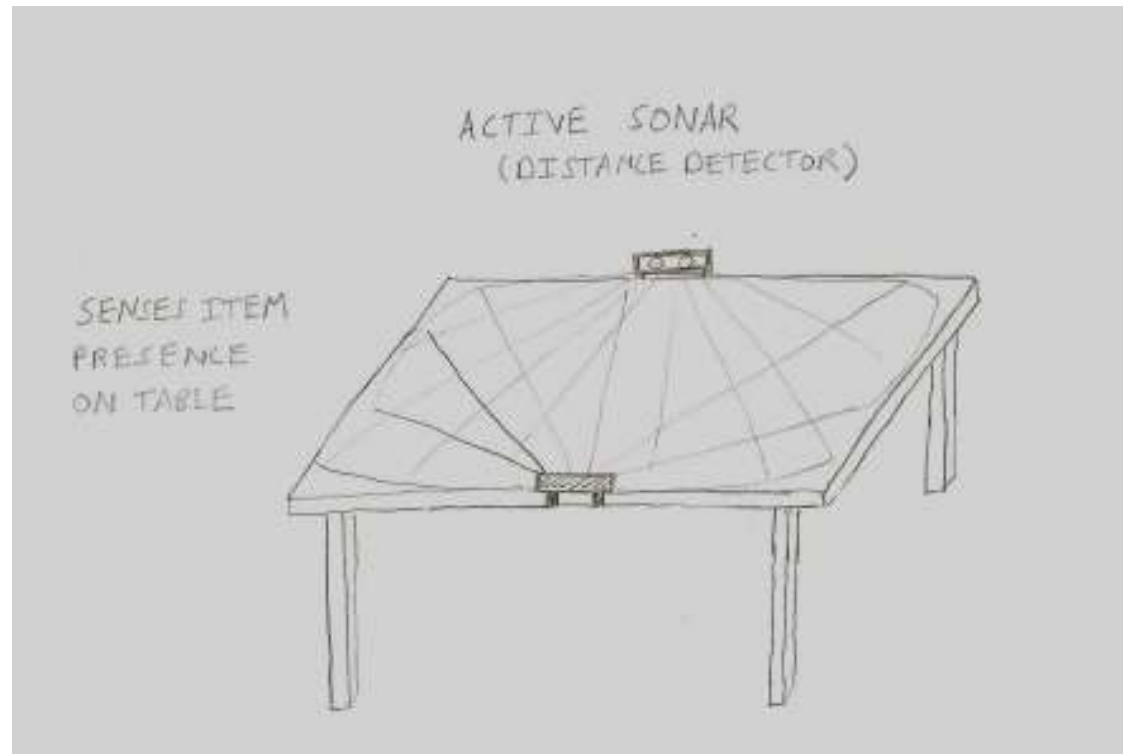
A. Motion and Distance

Use motion to detect a person coming into and out of an area. This allows the sensor system to keep count of how many people are in the area. A distance sensor is used to keep track of how much of the area is being used. The original idea was to have the distance sensor placed directly where the objects would be placed and to have the motion detector around the given area. However, this system would work best in a closed space such as a study or conference room, so the concept was adjusted to have the motion detector near the entry point of the occupancy area and the distance detector on the ceiling or nearby wall.



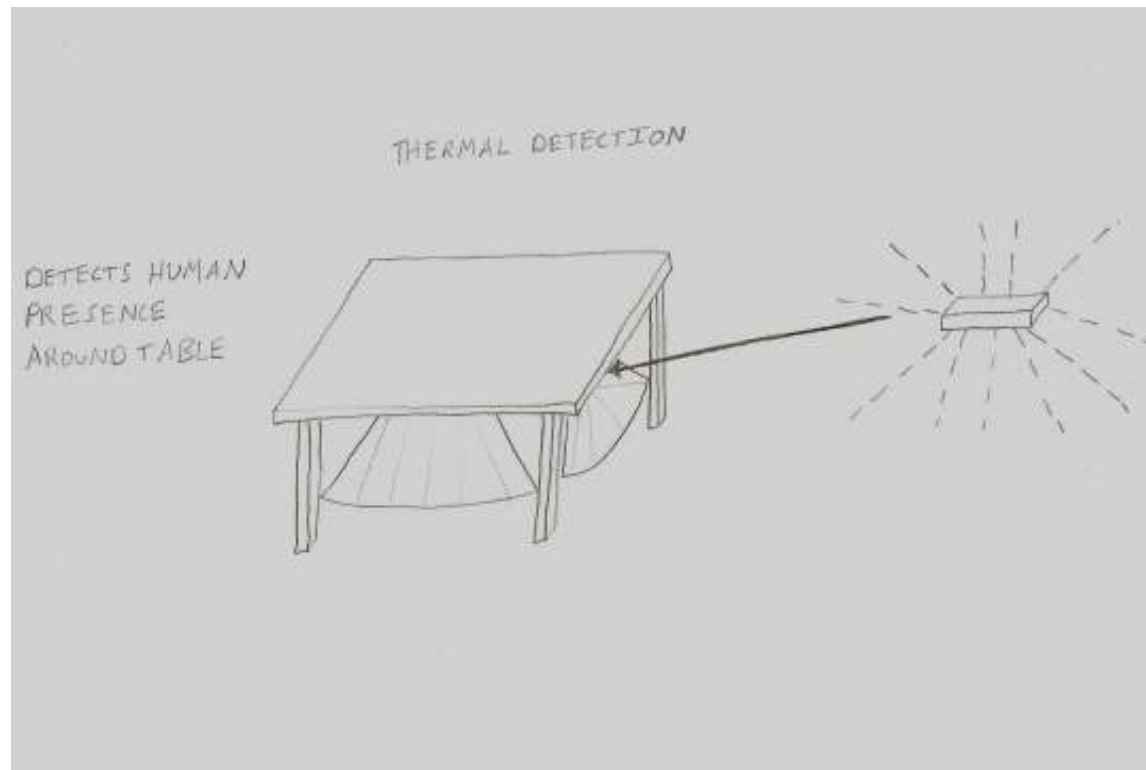
B. Distance:

Using a combination of distance sensors, the occupancy sensor system can sense a person's presence in a given area by sensing a change in distance sensed by any given sensor. The original idea was to have the distance sensors placed along an area, such as along the edge of the table to check if a person was sitting at the table. However, this did not address people leaving things at a table, or if the space was being used but the person was not in the area. Therefore, the concept was changed to address only the occupancy of objects in an area. See image below.



C. Thermal:

Using thermal sensors near a person's presence in an occupancy area, the sensor system can detect a person's presence in the area by sensing body heat. The original idea was to place these thermal sensors along the edge of the area, such as the edge of a room or the edge of a table. However, this would probably get in the way of normal activity and may be susceptible to damage. Therefore, the concept was changed to address this issue by placing the thermal sensors out of the way of normal activity, such as on the ceiling or underneath a table. See image below.



Patent Reviews

Patent Number: 7123139

Patent Title: Wireless Integrated Occupancy Sensor

Abstract: An occupancy sensor is provided for determining whether a room is occupied. The occupancy sensor integrates a battery-powered PIR motion detector and a battery-powered Hall Effect switch, each of which communicates wirelessly with a controller, in a single housing.

Claims Summary:

1. An occupancy sensor contained in a single housing for detecting the occupancy of a room with an access door.
2. A battery-powered passive infrared motion detector for producing a motion detected status message.
3. A battery-powered Hall Effect switch for producing a door open or door closed status message.
4. The unit wirelessly transmits a low battery status message when batteries below 20 percent capacity.
5. A housing with tamper switch and ability to send a tamper detected status message.
6. The motion detector and the Hall Effect switch communicate wirelessly with a controller and are both contained in a single housing.

Effects on Design:

The reviewed patent/system is similar to the Motion & Distance concept solution. The sensors for our project are not incorporated into the housing that contains the microcontroller and wireless transceiver, so that aspect does not pose a difficulty. However, the low battery status message and the use of a PIR motion detector to determine if a room is occupied are similar to our concept design. The Hall Effect switch for determining whether a door is open or closed would probably not conflict with our design choices.

Patent Number: 6587049

Patent Title: Occupant Status Monitor

Abstract: A system using passive infrared technology to determine whether a person is present in a space by analyzing the thermal situation. A detector mounted on the wall or ceiling collects the thermal data. A microprocessor in a desk top control module or a personal computer determines occupant status (normal or emergency) from the data and instructs a wall-mounted indicator to activate occupant status signals.

Claims Summary:

1. A detector disposed to sense a plurality of parameters of thermal energy in and relative to a given space and transmit this data to a processor.
2. A processor to receive data transmitted by the detector, compare that data with a predetermined data set representative of attributes of one of a person and of the space, and to transmit a plurality of instructions.
3. An occupant status monitor wherein the detector is at least one passive infrared receptor.
4. An occupant status monitor wherein the processor is a microcomputer housed in a stand-alone control module.
5. An occupant status monitor wherein the processor is a personal computer.

Effects on Design:

This system is similar in some aspects to the Thermal concept solution. The fact that this product uses a thermal sensor to detect the presence of an individual and then uses a microprocessor to analyze the sensor data and transmit status signals is significantly similar to our design concept. However, the fact that this design is used to determine the actual status of the individual and not just if they are in the room helps to make it different from our design.

Patent Number: 7245991

Patent Title: Distributed Architecture Irrigation Controller

Abstract: The system consists of a primary processor connected to multiple station modules. Each station module controls a valve and has its own microcontroller. The processor executes a stored watering program to control/instruct the station modules. Messages are generated and bi-directionally sent and received between the main processor and modules. Each message contains an identification field with an instruction that describes a meaning of the message. The processor and the micro-controllers each interpret the messages received and determine a course of action.

Claims Summary:

1. Each module contains a microcontroller that can process multiple sensor inputs.
2. The main processor and the microcontrollers in the modules communicate over a bus network using bi-directional messages. All units involved are capable of generating messages and performing pre-determined actions based on the messages they receive.
3. The messages used to communicate over the network consist of an identification field and an instruction field that can be interpreted by the processors.

Effects on Design:

This product is similar to our overall design of a distributed system of modules that process sensor inputs and communicate with a central controller. The bi-directional communications aspect is similar to our design, but we plan to create our own network protocol to differentiate the product from other systems that communicate in similar manners. Overall, this design is similar only in its overall layout, as our design will use wireless communications and the modules will be different from this system.

Patent Number: 6909921

Patent Title: Occupancy Sensor and Method for Home Automation System

Abstract: This system is comprised of a room occupancy sensor, a home automation system and a method for automatic control of devices throughout a home. The occupancy sensor system consists of entry/exit sensors for detecting movement through doorways that separate rooms in the home, room motion sensors for detecting room occupancy, spot sensors to detect occupancy of specific locations within the rooms, and house status sensors to detect the status of certain parameters of the home. A central controller communicates with the sensors and controlled objects over a communications network. Sensors and controlled objects can be added to the system in a 'plug and play' manner, and are monitored by using a system of states for each room.

Claims Summary:

1. The spot occupancy sensors are adjusted based on the feedback from the room occupancy detector.
2. Each occupancy sensor is redundantly checked by other occupancy sensors, all of which use a base algorithm to determine if a set of sensor readings matches a pre-determined profile of motion and room occupancy.
3. The method of using entry/exit sensors to detect motion between rooms, room motion sensors to detect occupancy within a room, and spot sensors to pinpoint locations within an area.
4. The interface of using the home automation system to gather information from the occupancy sensor network and automatically control devices in the home.
5. The method used to analyze sensor input and make automatic control decisions based on a pre-determined set of options.

Effects on Design:

This design uses a plurality of sensors to determine occupancy. This could affect our design choices, as one of our designs uses a similar system of multiple sensors to determine occupancy and for redundancy. However, our system will not be used to automatically control a set of household devices.

Patent Number: 6970751

Patent Title: Method and apparatus for providing distributed scene programming of a home automation and control system

Abstract: A method and apparatus for providing a simple user interface for programming scenes and multi-way groups in a home automation and control system. Each device participating in the home automation and control system is equipped with control logic for providing the simple programming interface. Through the control logic, each device maintains its status in a system-wide programming mode and retains knowledge of its inclusion or exclusion in the current scene or multi-way group being programmed. Broadcast messages are used to maintain the integrity of the system programming mode. Each device knows when a scene or multi-way group being programmed and is automatically captured and incorporated once the new scene or multi-way group has been started.

Claims Summary:

1. Each device has a plurality of states that are entered as the result of messages sent from other members of the scene or multi-way group or as the result of actuation from a sensor input.
2. The method for placing a device into a said state based on input gained from other devices in the same scene or multi-way group as the device.
3. The ability for a device to automatically maintain the knowledge of what scene or multi-way group it is part of and the ability to notify other devices in the same collection of its membership.

Effects on Design:

The key claim of this system is the ability of the devices to automatically enter or exit groups based on programming messages sent throughout the system and sensor inputs. This concept is similar to our overall system scheme in that the final display aspect of our system will know about all of the active components and be able to display that information. Our system design does not rely on each device maintaining its state based on the states of all other related devices, which differentiates our solution from this one.

Concept Testing Interview

1. Do you frequently encounter areas that you believe are occupied because there are objects left on the table?
2. Do you frequently leave your own possessions in an area that you are working in? If yes, for how long?
3. How long do you believe an object that has been left on a table should be left undisturbed before you consider sitting at the table with the object?
4. Are you interested in a system solution that will inform you that there are objects on a table, but no one is currently sitting at the table?
5. Do you have any concerns about placing this physical object in front of you in an area that may possibly reduce your total workspace? This physical object would likely have small dimensions.
6. Where would you prefer to have the object placed that would interfere least with your work?
7. What physical object size do you believe will negatively impact the efficiency of your work or be a cause of annoyance to you?
8. Are there any other locations within your workspace that you believe would interfere with your work?
9. What do you believe is a reasonable cost per table to determine if the table is in use? What price is more reasonable: \$100, \$200, \$500, \$1000? As a reference do you believe \$5000 is a reasonable price to install the system on M-level?
10. Based on our discussion how likely do you believe it is for a company or institution that has a need for this system to purchase our product within the next year?

Interview Purchasing Results

Interviewee:	1	2	3	4	5	6	7
Definitely not		X					
Probably not						X	
Might/might not	X		X				
Probably				X			X
Definitely					X		

N = number of U.S. universities = 4,140

A = 0.5 %

F_{def} = 10%

F_{prob} = 20%

P = 0.4(0.1) + 0.2(0.2) = 4.8%

$$Q = PNA = (4140)(0.05)(.048) = 10$$

N – Our product can be marketed to thousands of companies and organizations, but we have limited this costing analysis to universities in the United States. College students must manage their time extremely well in order to successfully complete their work. The occupancy sensor system was developed partially as a tool to help eliminate undue stress placed on college students.

A – Within the first year of production A is the approximate number of universities expected to become aware of the sensor system.

P – The total number universities aware of the sensor system that will actually purchase the system within one year of operation.

Q – The total number of sensor systems we can expect to sell to universities across the U.S.

Costing

Equipment	#	Price	Total
Motes	2	\$100 - \$200	\$200 - \$400
IR	3	\$15 - \$40	\$45 - \$120
Sonar	3	30 - \$60	\$90 - \$180
			\$350 - \$600

For every sensor system sold we can expect to produce between 100 and 1000 sensor nodes per system. These approximations are functions of the size of the university and the number of students attending the university.

*Note, we already have two motes. Just need to buy sensors.

Final Concept

- A combination sensor scheme
 - Thermal IR & Sonar
 - The combination of sensors may be aggregated in one box or assembled as part of a multi-unit design
- Sensor Node
 - Mote: comprised of a microcontroller with radio
 - Used to analyze sensor data and transmit relative information

Diagram: Aggregate Model

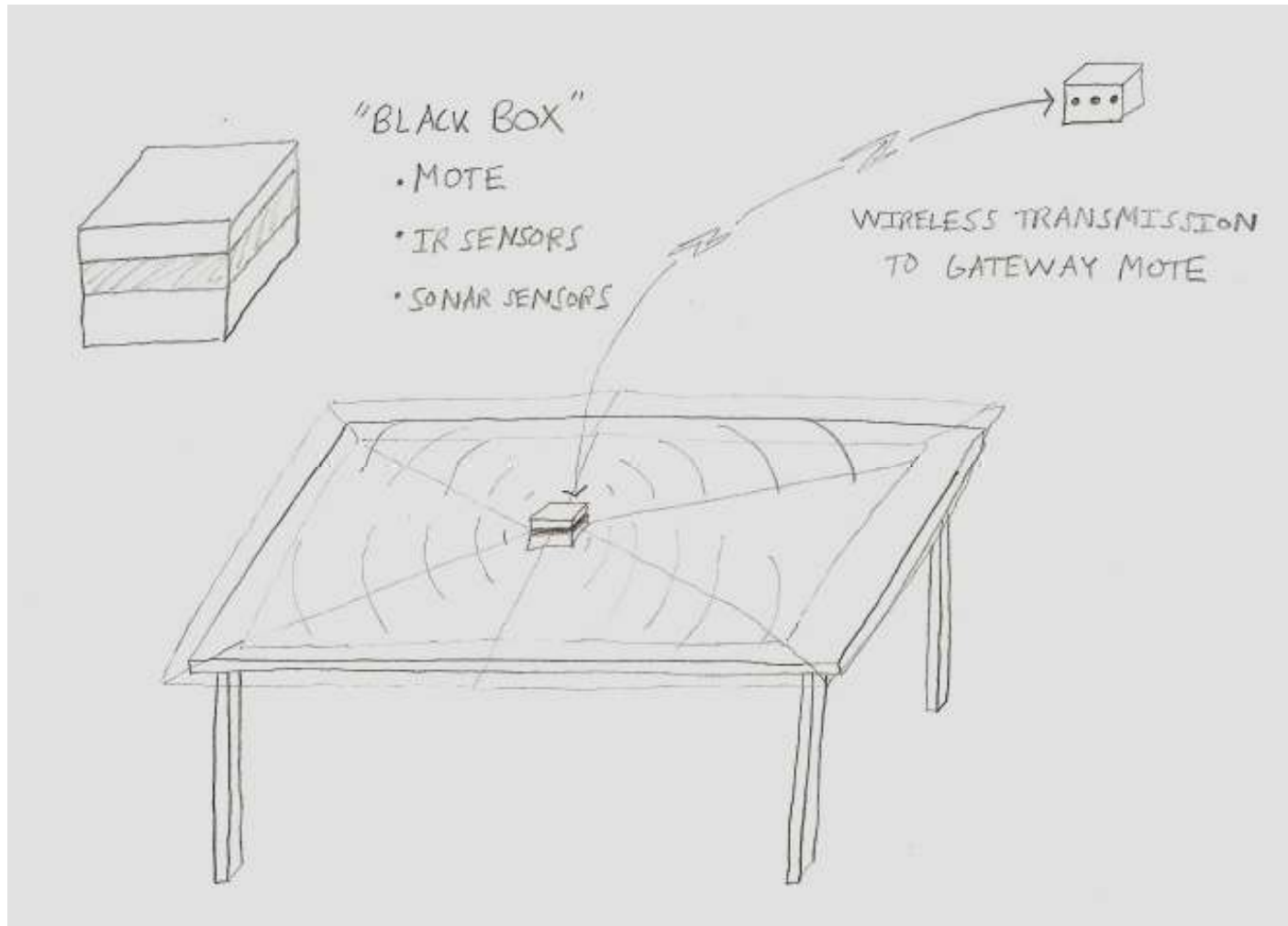
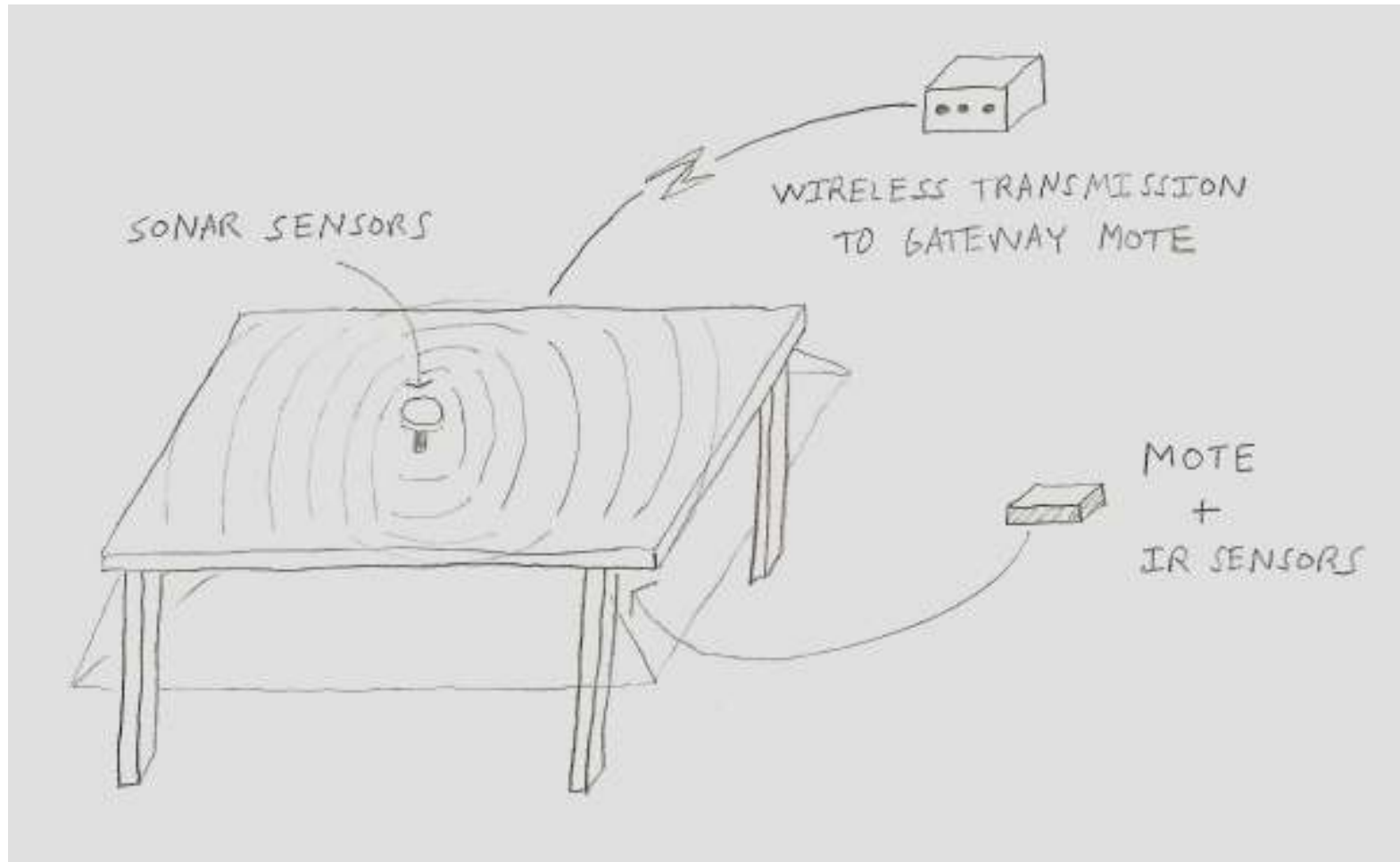
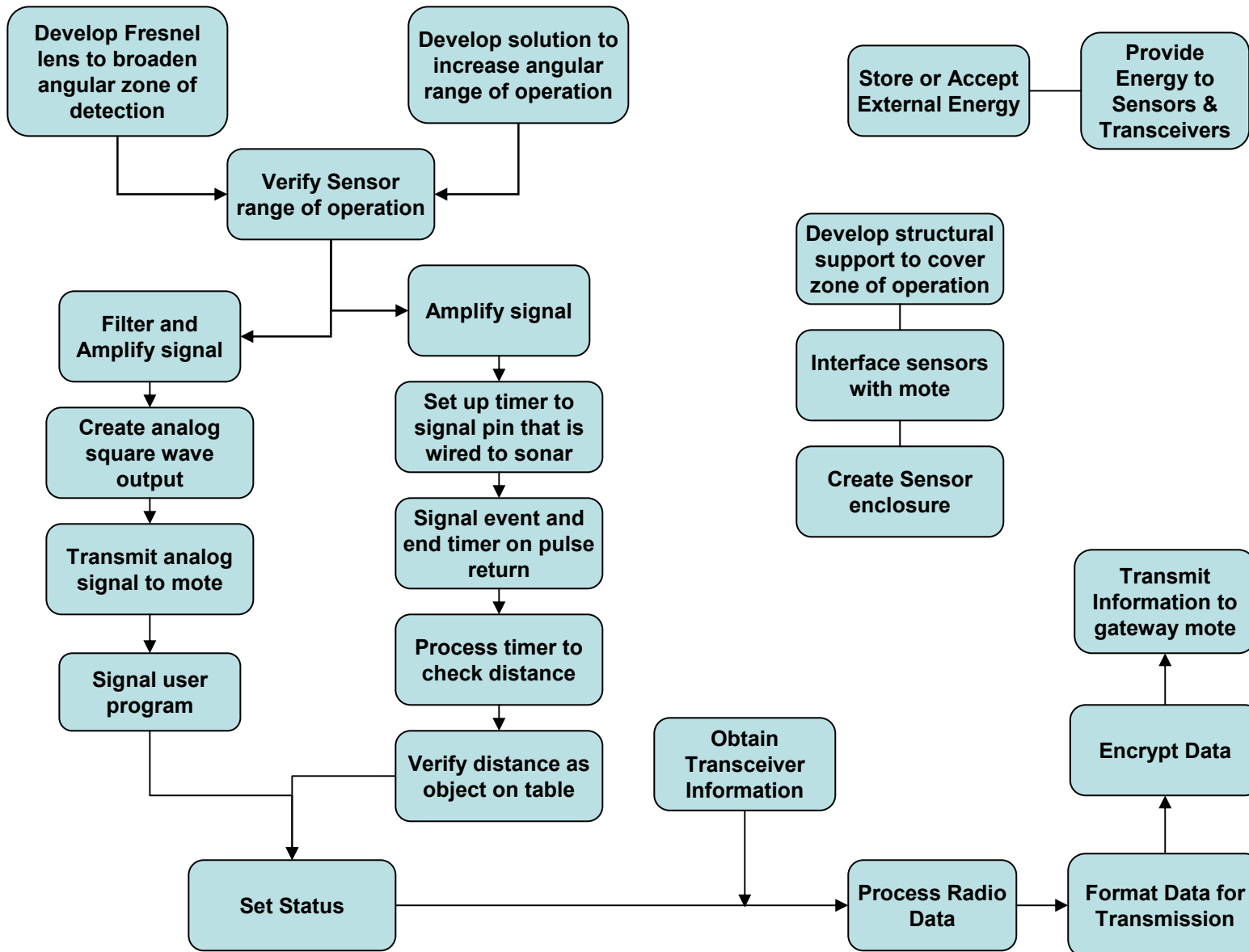


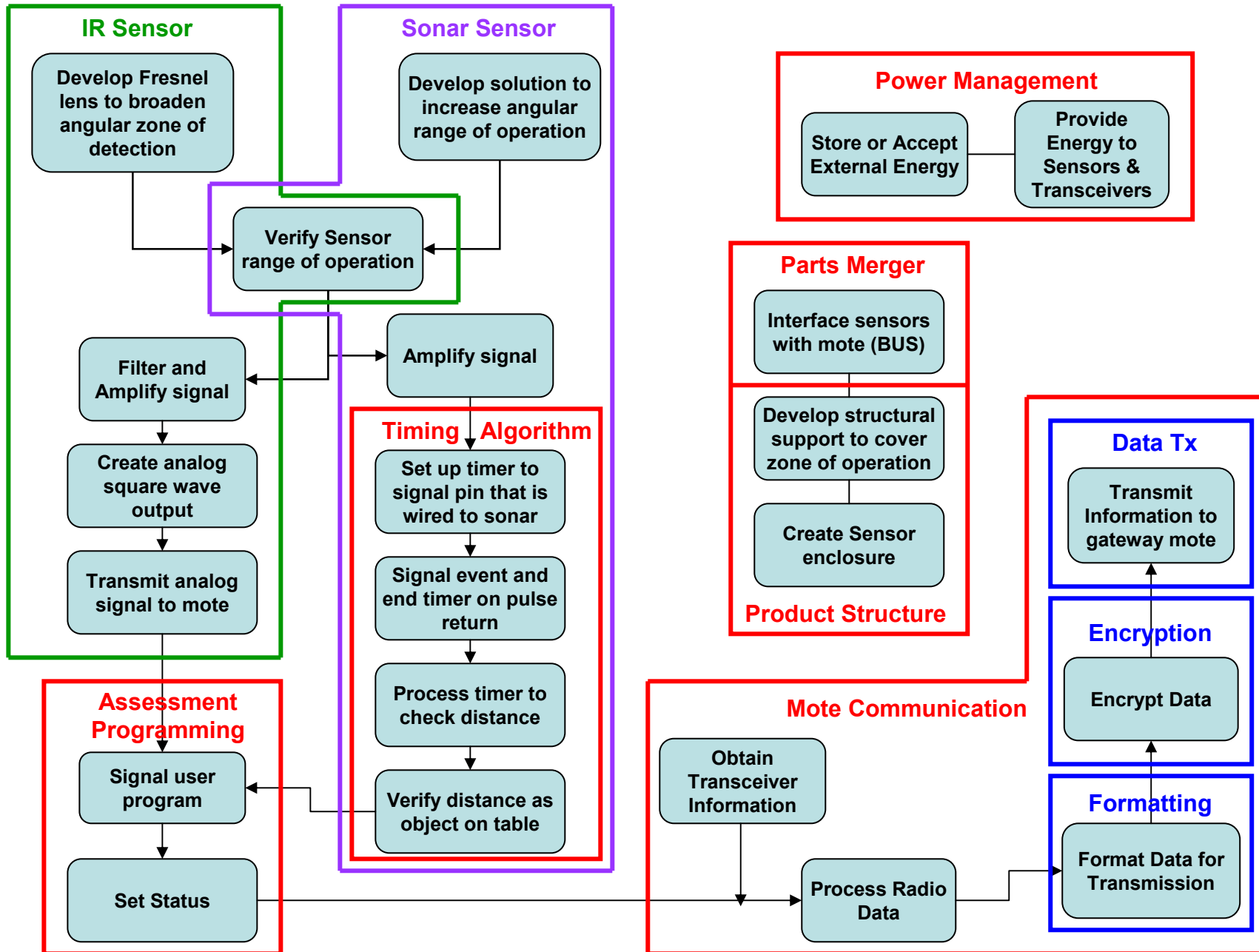
Diagram: Multi-unit Model



Product Architecture



System Chunks



- **IR Sensor:**

Processes and circuits that are required to efficiently detect thermal radiation and transmit useful information to the occupancy assessment program.

- **Sonar Sensor:**

Processes and circuits that are required to efficiently detect objects present on the surface of the work table and transmit the information to the occupancy assessment program

- **Timing Algorithm:**

- This algorithm is a necessary step to create a timed sonar pulse. Timing is necessary to determine the distance an object is from the sonar sensor. Objects located within a specified distance will send a signal to the assessment program.

- **Assessment Programming**

The assessment programming block is a combination of hardware data and software programming that will determine the occupancy of an area of interest.

- **Mote Communication:**

Effective mote communication is necessary to transmit occupancy information to a gateway for remote access.

- **Formatting:**

- Create data message using software

- **Encryption:**

- Mocked process that is necessary to ensure data integrity and security

- **Data Transmission:**

- Data must be transmitted carrying a message to other motes within the occupancy system.

- **Parts Merger**

All sensors and circuits must be effectively wired to provide accurate data for information transmission and system operation.

- **Product Structure:**

A secure structure must be developed to incorporate all hardware components to provide protection from the environment without limiting operational range.

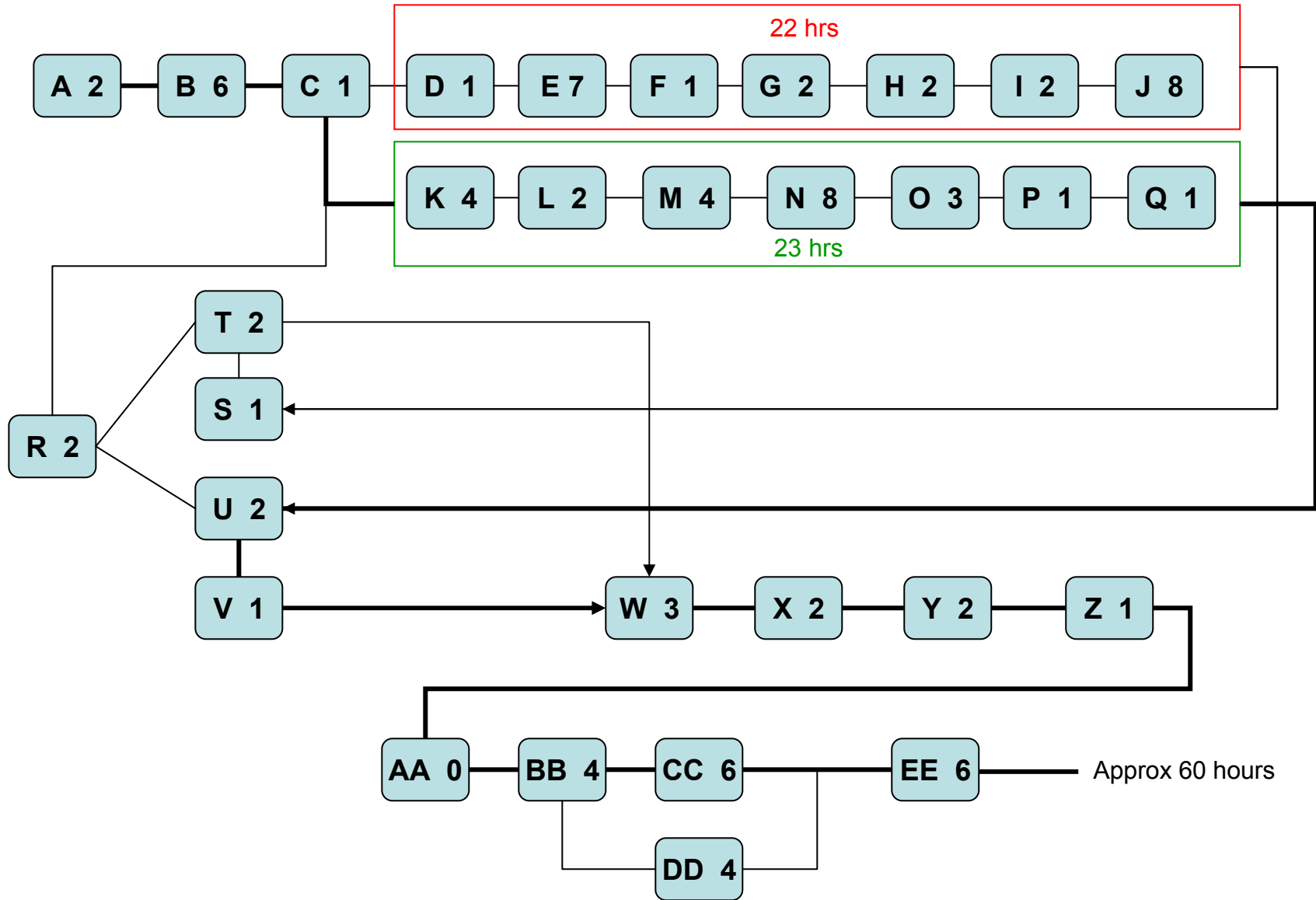
- **Power Management:**

Develop efficient method to properly supply all hardware components with adequate power without overloading circuits.

Process Steps

A	Determine Sensor and Mote power specs	2
B	Develop Power Management circuitry	6
C	Ground and power mote and sensors	1
D	Test IR sensor range	1
E	Broaden IR angular sensor range	6
F	Retest IR sensor range	1
G	Filter IR Signal	2
H	Amplify IR signal	2
I	Create square wave analog signal	2
J	Interface IR sensor with mote	8
K	Develop circuit to test sonar operational output under various operating scenarios	4
L	Amplify sonar signal	2
M	Develop timing algorithm for sonar operation	4
N	Interface sonar sensor with mote	8
O	Test sonar sensor using timing algorithm	3
P	Filter sonar signal that is not received within specified time interval	1
Q	Verify sonar sensor results under various test scenarios	1
R	Create top level program for occupancy conditions	2
S	Create software interface with IR sensor to signal occupancy program	2
T	Test occupancy using IR sensor	1
U	Create software interface with sonar sensor to signal occupancy program	2
V	Test occupancy using sonar sensor	1
W	Test occupancy for combination sonar and IR system	3
X	Process radio data	2
Y	Format radio data	1
Z	Program mote communication	2
AA	Encrypt data (mocked) will not be completed	0
BB	Transmit information to gateway mote	4
CC	Create PC level program to gather gateway mote data	6
DD	Create PC level program for display	4
EE	Test occupancy program	6

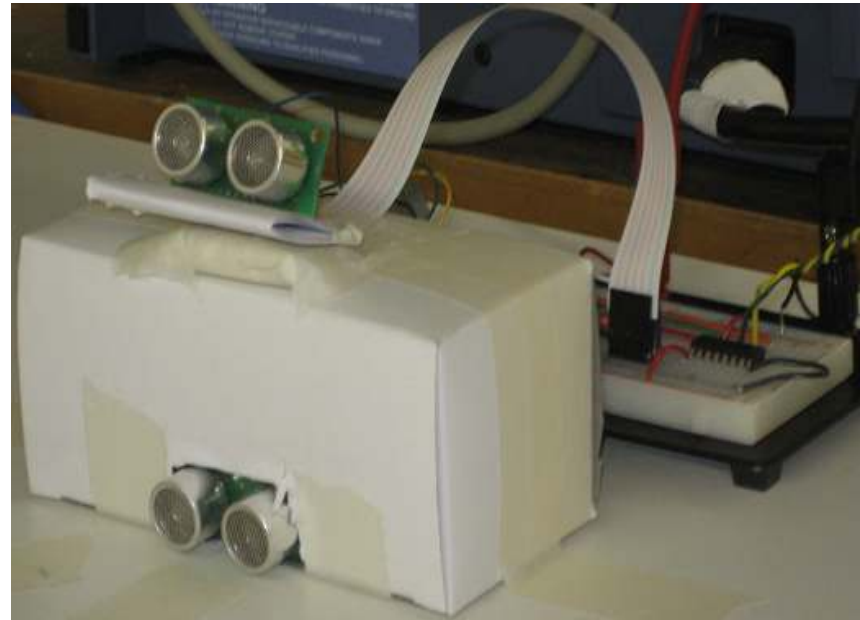
Pert Chart



Prototype

The working prototype of the Advanced Occupancy Sensor demonstrates the functionality of the core technology of the system.

- Two active air sonar sensors controlled by a timing algorithm programmed within a microcontroller detect the presence of people or objects within the area of interest. One sensor is aimed at the torso of an individual for person detection while a second sensor, positioned horizontally, detects objects placed on the table.
- Sensor range extends approximately 3 feet and can detect anything within 45°.
- Unfortunately, due to programming difficulty and time constraints the IR thermometer planned for person detection was abandoned until next semester.
- Sensor results are continuously updated and stored within a PIC.



- A Tmote-sky wireless sensor module connected to the sensor circuit examines the sensor values stored within the PIC and wirelessly communicates the information to a detached gateway mote.
- The remotely located gateway mote is connected to a PC that is programmed to interpret the mote data and output the state of the area of interest. The PC will determine whether the system is:

- A. Occupied by Person
- B. Occupied by Object
- C. Unoccupied



- Wireless Communication

```

shane@money-tos: /opt/tinyos-2.x/apps/os_1/SerialReceive — ...
shane@money-tos: /opt/tinyos-2.x/apps/os_1/SerialReceive$ python runprogram.py
Flushing the serial port..
OCCUPIED BY PERSON
  
```

```

shane@money-tos: /opt/tinyos-2.x/apps/os_1/SerialReceive — ...
shane@money-tos: /opt/tinyos-2.x/apps/os_1/SerialReceive$ python runprogram.py
Flushing the serial port..
OCCUPIED BY PERSON
UNOCCUPIED
  
```

- State Changes: *First detects a person. Then detects nothing. Finally detects an object in the vicinity.*

```

shane@money-tos: /opt/tinyos-2.x/apps/os_1/SerialReceive — ...
shane@money-tos: /opt/tinyos-2.x/apps/os_1/SerialReceive$ python runprogram.py
Flushing the serial port..
OCCUPIED BY PERSON
UNOCCUPIED
OCCUPIED BY OBJECT
  
```

Product Specifications

- Sensors
 - Active Air Sonar: Devantech SRF04
- Mote
 - Tmote-Sky
- Microcontroller
 - PIC16F887

Appendix

Interview concerning potential occupancy sensor system

Interviewee: Edison Leung
Interviewer: Shane Woolwine
Date: October 6th, 2007
Type of User: Typical User

Question/Prompt	Customer Statement	Interpreted Need
How would you like this displayed?	I want to be able to track where all people are in the library	The system can display information about everyone who is in an area.
	I would like to see exactly who is where, like dots on a map.	The system can display occupancy data show exactly where people are in a space.
	I would like to be able to tell the system what my name is, where I am in case I want to be found by my friends.	The system has the ability for users to input information about themselves
Appearance	Whatever equipment is necessary should be small and out of the way	The equipment will not distract people.

Interviewee: John
Interviewer: Shane Woolwine
Date: October 5th, 2007
Type of User: Lead User

Question/Prompt	Customer Statement	Interpreted Need
How would you like this displayed?	<p>I would like to be able to access the information online</p> <p>I would like to know where people are sitting specifically. I.E. chairs used in the library</p>	<p>The system has a webpage that displays occupancy data</p> <p>The system checks chair</p>
	I would like to not have to go to the library to check if it is full	<p>The system has a webpage that displays occupancy data</p> <p>The system can reveal partial occupancy for its given area</p>
	I would like table information to be displayed in a quadrant format	<p>The system can only display occupancy data as binary format. No pictures will be used.</p>
Are you worried about invasion of privacy?	Yes, I would like the data to be displayed in a true/false manner. No other description needed.	The system uses some electronic sensor
	I would not mind an infrared sensor to gather this information	
Cost	I think it would be best to combine a series of sensor nodes to one access point in order to save cost	One piece of equipment has the ability to check more than one occupant area.
Robustness / Accuracy	I would like to see more than one type of sensor used so that it would be less likely to fail	Multiple sensors are used to increase accuracy
	I am also worried about people leaving to go to the bathroom. It should check more than once over a set period of time before deciding inoccupancy	The software for this system is aware of many tricky occupant situations
Power Management	I would like a system where power is used as little as possible.	The systems software is written to use a clever power saving scheme.
Appearance	I like the idea of something in sight so that we know that we are being sensed	The system is placed near a door or at the top of a table.

Interviewee: Mike Liang
Interviewer: Shane Woolwine
Date: October 5th, 2007
Type of User: Lead User

Question/Prompt	Customer Statement	Interpreted Need
How would you like this displayed?	I want a display for each table along with the chairs around it. It should be able to tell me if there are any empty chairs in the area.	The system can display empty chairs around a table.
How do you envision an occupancy sensor system to work?	I do not want cameras to be used. I like the idea of passive infrared sensors.	No cameras are used in this system.
	Some sort of combination sensor mechanism should be used.	More than one type of sensor is used.
Cost	A cheap sensor node should be used. Preferably one readily available	The system is built using readily available and cheap sensor nodes.
Power Management	I would like to have the option of both having it powered by battery and by ac.	The equipment can be plugged in or can operate on battery power.
	I want the software to contain a good algorithm for power saving.	A power saving software scheme is used.

Interviewee: Sunyia Hussain
Interviewer: Shane Woolwine
Date: October 6th, 2007
Type of User: Typical User

Question/Prompt	Customer Statement	Interpreted Need
How would you like this displayed?	I want a system that can tell me which computers, tables, and cubicles are free.	The system is versatile in location of implementation
	I want it to display number of occupancy as long a visual aid for me to see where rooms and computers are full.	The system can display numerical as well as visual data.
	I should be able to view a webpage with this information off campus	The system can put the information on a webpage.
	I just want to see if a particular space is free. I don't care how many people are in a room.	The system displays only relevant open space data.
Appearance	I don't want any equipment to distract me.	The equipment will not distract people.

Interviewee: Alan Lam
Interviewer: Shane Woolwine
Date: October 6th, 2007
Type of User: Typical User

Question/Prompt	Customer Statement	Interpreted Need
How would you like this displayed?	I would like to be able to access the information online	The system has a webpage that displays occupancy data
	I am only concerend with study rooms and computers	The system is versitile in location of implentation.
	I would like to know how many people are in a given area	The system can display a numerical value for number of people in an area.
Appearance	Whatever equipment is used should be unseen	The equipment is small and can be placed out of sight.
	It should not get in the way of me studying	The equipment is not distracting.
	It should not make any sounds	The equipment is not distracting.

Interviewee: Herb Geary
Interviewer: Mitch Williams
Date: October 6th, 2007
Type of User: Typical User (Business Owner)

Question/Prompt	Customer Statement	Interpreted Need
Information Display	I'd like to be able to access this information from my computer or PDA, such as in a webpage.	A website interface is available to display gathered information.
Possible applications	It would be nice to know which bathrooms and restaurants are crowded, or not, in a mall.	The system is adaptable to multiple locations and configurations.
Privacy Concerns	Is this thing going to be a 'Big Brother' type of system?	The system is sensitive of user privacy issues.
Maintenance/Repair	What if a sensor breaks? How will I know to fix or replace it?	The system notifies users of maintenance.
Privacy Concern	Can people hack the system or monitor/intercept its signals?	The transmissions of the system are secure.

Interviewee: Rachel Geary
Interviewer: Mitch Williams
Date: October 7th, 2007
Type of User: Typical User (College Student)

Question/Prompt	Customer Statement	Interpreted Need
Information Display	It should be easy for an average non-technical person to understand and use.	The system is user-friendly.
Possible applications	People switch tables in restaurants all the time. It would be nice to know if that happened and what table is now occupied/unoccupied.	The system monitors multi-seat locations.
Privacy Concerns	If the data is used to make changes to the environment or monitor someone's behavior without them knowing, then it is an issue.	The system is sensitive of user privacy issues.
Maintenance/Repair	I don't want to have to babysit one of these things.	The system is highly automated.
Privacy Concern	What if someone just grabs the sensor off the wall/chair/whatever? Then the system is compromised.	The sensors are designed to be compatible with the environment they are used in.

Interviewee: Jacquelyn Brenner
Interviewer: Adam Winter
Date: October 7th, 2007
Type of User: Typical User

Question/Prompt	Customer Statement	Interpreted Need
Possible applications	<p>Coworkers never know whether a conference room is occupied or not. I get really annoyed when people knock on the door and interrupt my meeting when they are trying to locate a room of their own.</p>	<p>The system provides real time occupancy information that can be downloaded from remote locations.</p>
Need prioritization	<p>I want a system like this at the mall for dressing rooms because the systems used today doesn't work well.</p> <p>This system could be used for a lot of different areas in a school system like the gym, library, or hallways. The administration would be able to monitor if people are in hallways or rooms they shouldn't be in or students could find out if rooms/machines are in use.</p> <p>Movie theatres could use this system to find out if people are sneaking into movies that they did not pay for.</p> <p>It would be really cool to see exactly how many people are in a room.</p>	<p>The system correlates occupancy information with alternate mediums.</p> <p>The sensor resolution accurately determines the number of occupants in an area of interest.</p>
Information gathering	<p>A security system could really benefit with this system because they would be able to determine exactly where an intruder is.</p> <p>It would be convenient if it were mounted on the wall so you don't need to worry about someone tripping on it or it getting in someone's way.</p>	<p>The system can display occupancy data show exactly where people are in a space.</p> <p>The sensors are designed to be compatible with the environment they are used in.</p>

Current systems: detrimental effects	Time is wasted, there are many annoyances, and possibly even fights between employees. You have to remember "time is money". Currently, you have to schedule a conference room, but that system doesn't work very well.	The system improves time and facility management.
Price	I think about \$200 would be as much as someone should pay for the sensors. An entire database would depend on a company's need and budget.	The system is priced affordably.
Sensor Range	The sensors should be able to detect people in a room of average size. You can always add extra sensors to get correct information.	The systems is expandable and extensible.
Durability	Make sure it is contained so that noone can mess with the guts of the system	The system is tamper proof.
Range of application	I can only imagine using this in a contained area not outdoors. However, amusement parks, stadiums, and parking lots could benefit from the system.	The system can be configured to work outdoors.

Interviewee: Peter Harvey
Interviewer: Adam Winter
Date: October 7th, 2007
Type of User: Typical User

Question/Prompt	Customer Statement	Interpreted Need
Possible applications	<p>You can use the system to examine your office environment to see how effectively work space is being used. It also increases efficiency, communication around the workplace, and eliminates interruptions.</p> <p>If you are on vacation or at work you could check the security of your home.</p> <p>The system has many applications if you don't limit it to just the detection of people. You could also use it to for storage systems to determine space available.</p>	<p>The system provides real time occupancy information that can be downloaded from remote locations.</p> <p>The system is used to detect object occupancy and is not limited to people.</p>
Need prioritization	<p>The detection of the number of people will eliminate a lot of confusion. Example, if a janitor is in a room cleaning it it is not really occupied, but noone would know this a very general system.</p> <p>Detecting the number of people can also show how much usage a room really gets.</p>	<p>The sensor resolution accurately determines the number of occupants in an area of interest.</p> <p>The system correlates occupancy information with alternate mediums.</p>
Information gathering	<p>The environment is obviously a busy place because you wouldn't need this system if it weren't. In a busy place people move around a lot to the system needs to know if a space is actually occupied or just someone passing throught the area.</p> <p>What happens if the room is rearranged?</p> <p>Put it by the door where it could count the number of people in a room.</p>	<p>The sensors are designed to be compatible with the environemnt they are used in.</p>

Privacy Concern	Yes and no. You are in a public place and there is no information that can be used in malice against you. You don't know the name of the person sitting at the area of interest. An audio system would make me feel uncomfortable, but if you advertise that there are cameras in the area they might be okay.	The system is sensitive of user privacy issues.
Current systems: detrimental effects	There is a lot of wasted time. This cuts down on effective communication.	The system improves time and facility management.
Sensor Range	Individual seat detection would be optimal.	The sensor resolution accurately determines the number of occupants in an area of interest.
Durability	It needs to be able to withstand people constantly sitting on a pressure sensor.	The system is resistant to environmental strains.

Product Decomposition Explanation

Inputs

Energy:

Energy is supplied as in input in the form of either AC or DC power.

Data Control:

The occupancy sensor system requires a data control input to control the data flow, analysis and computation within the system.

Sensors:

For the occupancy sensor system a sensor input is needed to sense to the occupant's presence in a giving area.

Radio:

Since the system will be wireless, communication needs to be maintained within the system and the display. This will be done through some sort of radio. Therefore, each individual component within the larger system will need to be able to handle a radio communication input.

Sub-problems

Store or Accept Energy:

Addressing the issue of deciding whether to supply energy to the system or storing it for later use when energy may not be available.

Provide Energy to Sensors & Transceivers:

This addresses the ability to provide the necessary power to all the different components within the system.

***Process Sensor Data:**

The ability to process sensor data poses a very complex problem addressing the ability of the data control to accurately interpret the sensor data regarding occupancy information.

Process Radio Data:

Radio data coming into the data control requires a complex solution regarding reading the data input and analyzing the corresponding data.

Format Data for Transmission:

Before transmitting new data it must be formatted in a standardized message format for the entire occupancy system.

Encryption of Data:

To increase security of the information sent wirelessly regarding occupancy information it must first be encrypted. This will help resist possible attacks against the system.

***Sense Presence in Area of Interest:**

This is quite possibly the most complex problem with the current occupancy system model. A sensor system must be developed to address the issue accurately sensing occupancy information in the area of interest for the particular sensor.

Obtain Transceiver Information:

Receive data from the radio and send the data to the data control in a way that the data control may then begin to process the information.

Outputs**Transceiver Information Output:**

The output message sent through radio regarding either newly created occupancy information or a relay of past occupancy information.

Key**Dotted Line:**

The dotted line shows that the radio input for one part of the system may be an output for another and vice versa. Essentially, the radio input is some other components output.

Dashed Line:

Corresponds to possibly not constant input. For example, a part of the system may not actually have any sensor data to deal with, but just relays radio information.

Concept Variation Explanations

- A. Motion and Distance
 - Use motion to detect a person coming into and out of an area. This allows the sensor system to keep count of how many people are in the area. A distance sensor is used to keep track of how much of the area is being used.
- B. Distance:
 - Using a combination of distance sensors, the occupancy sensor system can sense a person's presence in a given area by sensing a change in distance sensed by any given sensor.
- C. Electromagnetic Detector
 - Using an Electromagnetic Detector, a field is generated that is then broken by the change of the EMF by a large object or person breaking that field. This is used to detect number of people in a given area.
- D. Pressure and Thermal
 - A combination technique employing both a pressure and a thermal sensor. A pressure sensor can sense objects or people in a given area and the thermal sensor can be used to verify a person's presence.
- E. Camera
 - A camera employed to actually record and send image data regarding the occupancy area. This can then be sent to a PC where an image analysis program can decide whether the space is free or not.
- F. Thermal
 - Using thermal sensors around the edge of an occupancy area, the sensor system can detect a person's presence in the area.

Costing and Final Product Interview

Interviewee: Lindsey Giel

*Note: open with the fact that we have developed a solution to our occupancy question

1. Do you frequently encounter areas that you believe are occupied because there are objects left on the table?
Yes pretty often.
2. Do you frequently leave your own possessions in an area that you are working in? If yes, for how long?
No never.
3. How long do you believe an object that has been left on a table should be left undisturbed before you consider sitting at the table with the object?
15 minutes.
4. Are you interested in a system solution that will inform you that there are objects on a table, but no one is currently sitting at the table?
Yes. This would not limit your detection capabilities.

It is important to inform you that the solution to this problem requires the development of a physical object that must be placed in the vicinity of the area of interest in question.

1. Do you have any concerns about placing this physical object in front of you in an area that may possibly reduce your total workspace? This physical object would likely have small dimensions.
It wouldn't really bother me.
2. Where would you prefer to have the object placed that would interfere least with your work?
Center of the table or above the table would be good.
3. What physical object size do you believe will negatively impact the efficiency of your work or be a cause of annoyance to you?
Make it 4" x 8" maximum dimensions. No more than 2" thick.
4. Are there any other locations within your workspace that you believe would interfere with your work?
I need to be able to comfortably cross my legs.
5. What do you believe is a reasonable cost per table to determine if the table is in use? What price is more reasonable: \$100, \$200, \$500, \$1000? As a reference do you believe \$5000 is a reasonable price to install the system on M-level?
I wouldn't pay more than \$200 per unit.
6. Based on our discussion how likely do you believe it is for a company or institution that has a need for this system to purchase our product within the next year?
I wouldn't personally buy the system because there is not need. A company that has the money may buy it though. This could help reduce interruptions in meetings and save the company money.

Interviewee: Ryan Johnstin

*Note: open with the fact that we have developed a solution to our occupancy question

1. Do you frequently encounter areas that you believe are occupied because there are objects left on the table?

Yes all the time.

2. Do you frequently leave your own possessions in an area that you are working in? If yes, for how long?

Yes all the time, probably no more than half an hour.

3. How long do you believe an object that has been left on a table should be left undisturbed before you consider sitting at the table with the object?

An hour.

4. Are you interested in a system solution that will inform you that there are objects on a table, but no one is currently sitting at the table?

Yes because I would then be able to interpret those areas as being occupied. I would not have to waste my time looking for that table to discover that the user was just temporarily not at the table.

It is important to inform you that the solution to this problem requires the development of a physical object that must be placed in the vicinity of the area of interest in question.

1. Do you have any concerns about placing this physical object in front of you in an area that may possibly reduce your total workspace? This physical object would likely have small dimensions.

No as long as it was small and out of the way.

2. Where would you prefer to have the object placed that would interfere least with your work?

It would be best for me if it was anywhere greater than arms length away, preferably at the edge or center of the table.

3. What physical object size do you believe will negatively impact the efficiency of your work or be a cause of annoyance to you?

It should be no larger than a 8x11 sheet of paper.

4. Are there any other locations within your workspace that you believe would interfere with your work?

I don't allow it to touch my legs.

5. What do you believe is a reasonable cost per table to determine if the table is in use? What price is more reasonable: \$100, \$200, \$500, \$1000? As a reference do you believe \$5000 is a reasonable price to install the system on M-level?

\$100 or less. I would say \$5000 sounds about right, but maybe a little on the higher end.

6. Based on our discussion how likely do you believe it is for a company or institution that has a need for this system to purchase our product within the next year?

It would depend on the overhead of the organization trying to buy the system. If the company believes it can benefit from the system by increasing efficiency in the workplace I would say there is a very high probability that they would buy the system. However, if no revenue is generated from the system there is little chance of buying it.

Interviewee: Sage Farrar

*Note: open with the fact that we have developed a solution to our occupancy question

1. Do you frequently encounter areas that you believe are occupied because there are objects left on the table?
Yes it can be very frustrating.
2. Do you frequently leave your own possessions in an area that you are working in? If yes, for how long?
Yes for the most an hour but I always have people watch my stuff.
3. How long do you believe an object that has been left on a table should be left undisturbed before you consider sitting at the table with the object?
It depends on what it is. A textbook I would say 20 minutes, but I would never sit at a table with personal possessions on it.
4. Are you interested in a system solution that will inform you that there are objects on a table, but no one is currently sitting at the table?
Sure, but if it wasn't an option it wouldn't be a problem.

It is important to inform you that the solution to this problem requires the development of a physical object that must be placed in the vicinity of the area of interest in question.

1. Do you have any concerns about placing this physical object in front of you in an area that may possibly reduce your total workspace? This physical object would likely have small dimensions.
No I don't think so.
2. Where would you prefer to have the object placed that would interfere least with your work?
Place it dead in the center of the table or at the edge or at the edge.
3. What physical object size do you believe will negatively impact the efficiency of your work or be a cause of annoyance to you?
3" x 3". Keep it less than one centimeter thick.
4. Are there any other locations within your workspace that you believe would interfere with your work?
Make sure I can still cross my legs without hitting the device.
5. What do you believe is a reasonable cost per table to determine if the table is in use? What price is more reasonable: \$100, \$200, \$500, \$1000? As a reference do you believe \$5000 is a reasonable price to install the system on M-level?
\$5000 for one floor is too much. I think something like \$10,000 for the whole library would be a good system. \$50 per unit would be a good price.
6. Based on our discussion how likely do you believe it is for a company or institution that has a need for this system to purchase our product within the next year?
I don't see many places buying this product because they could just find areas the old fashioned way. They could just go check an area to see if it is occupied.

Interviewee: Zach Rosswog

*Note: open with the fact that we have developed a solution to our occupancy question

1. Do you frequently encounter areas that you believe are occupied because there are objects left on the table?

Yes I do. If there is stuff at a table I'm not sitting there.

2. Do you frequently leave your own possessions in an area that you are working in? If yes, for how long?

No I don't.

3. How long do you believe an object that has been left on a table should be left undisturbed before you consider sitting at the table with the object?

Ten minutes.

4. Are you interested in a system solution that will inform you that there are objects on a table, but no one is currently sitting at the table?

Yes that's a good system improvement.

It is important to inform you that the solution to this problem requires the development of a physical object that must be placed in the vicinity of the area of interest in question.

1. Do you have any concerns about placing this physical object in front of you in an area that may possibly reduce your total workspace? This physical object would likely have small dimensions.

It could potentially bother me. I don't want it to dictate where I have to put my stuff.

2. Where would you prefer to have the object placed that would interfere least with your work?

Put it in the center of the table.

3. What physical object size do you believe will negatively impact the efficiency of your work or be a cause of annoyance to you?

4" x 12". Keep it less than two inches thick.

4. Are there any other locations within your workspace that you believe would interfere with your work?

Not that I can think of.

5. What do you believe is a reasonable cost per table to determine if the table is in use? What price is more reasonable: \$100, \$200, \$500, \$1000? As a reference do you believe \$5000 is a reasonable price to install the system on M-level?

\$100 would be a reasonable price, but I wouldn't pay more than \$200 per unit. I don't think it is worth it at that price.

6. Based on our discussion how likely do you believe it is for a company or institution that has a need for this system to purchase our product within the next year?

Well Hopkins can just raise our tuition again and make us pay for it. That would make it real easy for them to buy a new system.

Interviewee: Alex Hsaie

*Note: open with the fact that we have developed a solution to our occupancy question

1. Do you frequently encounter areas that you believe are occupied because there are objects left on the table?
Yes I see it quite often.
2. Do you frequently leave your own possessions in an area that you are working in? If yes, for how long?
Yes all the time. I usually have someone watch it.
3. How long do you believe an object that has been left on a table should be left undisturbed before you consider sitting at the table with the object?
If no one is there and the book has been there for a while I would sit there. I would sit down right away.
4. Are you interested in a system solution that will inform you that there are objects on a table, but no one is currently sitting at the table?
Yes it brings in a little of my own judgment into the system.

It is important to inform you that the solution to this problem requires the development of a physical object that must be placed in the vicinity of the area of interest in question.

1. Do you have any concerns about placing this physical object in front of you in an area that may possibly reduce your total workspace? This physical object would likely have small dimensions.
I am totally fine with that, especially if you understand why the object is there.
2. Where would you prefer to have the object placed that would interfere least with your work?
Put it in the center of the table out of my immediate work area.
3. What physical object size do you believe will negatively impact the efficiency of your work or be a cause of annoyance to you?
I would like it about the size of a cell phone.
4. Are there any other locations within your workspace that you believe would interfere with your work?
Having it on the edge would bother me a little.
5. What do you believe is a reasonable cost per table to determine if the table is in use? What price is more reasonable: \$100, \$200, \$500, \$1000? As a reference do you believe \$5000 is a reasonable price to install the system on M-level?
Around \$500 would be reasonable, but pushing the price limit.
6. Based on our discussion how likely do you believe it is for a company or institution that has a need for this system to purchase our product within the next year?
A company just needs to see a return on investment to buy the system. Any company that can really increase their productivity by buying the system should do so. A new model probably won't sell very well, but once the system is developed it could become pretty popular.

Interviewee: Jennifer Hou

*Note: open with the fact that we have developed a solution to our occupancy question

1. Do you frequently encounter areas that you believe are occupied because there are objects left on the table?
If there are things at a table, I assume that someone is there so the space is available. However, if it looks like only one person is at the table, I will try to sit there.
2. Do you frequently leave your own possessions in an area that you are working in? If yes, for how long?
Yes, to print something out, to find a book, or to go use a computer.
3. How long do you believe an object that has been left on a table should be left undisturbed before you consider sitting at the table with the object?
I don't really think about it. I usually just sit there right away.
4. Are you interested in a system solution that will inform you that there are objects on a table, but no one is currently sitting at the table?
To be able to find out if things on a table are associated with people or just things left behind I believe would be very useful.

It is important to inform you that the solution to this problem requires the development of a physical object that must be placed in the vicinity of the area of interest in question.

1. Do you have any concerns about placing this physical object in front of you in an area that may possibly reduce your total workspace? This physical object would likely have small dimensions.
No, this would not bother me at all.
2. Where would you prefer to have the object placed that would interfere least with your work?
It would be best to put it in the center if possible, along the edges would be very difficult because people need to write.
3. What physical object size do you believe will negatively impact the efficiency of your work or be a cause of annoyance to you?
As long as it does not blink or make noise, I wouldn't mind it at all.
4. Are there any other locations within your workspace that you believe would interfere with your work?
The edge would be a bother.
5. What do you believe is a reasonable cost per table to determine if the table is in use? What price is more reasonable: \$100, \$200, \$500, \$1000? As a reference do you believe \$5000 is a reasonable price to install the system on M-level?
Just on the tables. \$200 - \$300 would be best because this is not really a new technology, just different.
6. Based on our discussion how likely do you believe it is for a company or institution that has a need for this system to purchase our product within the next year?
I would definitely suggest buying this system solution to any organization that needs additional structure to increase its efficiency. If the resources are available many companies may invest in this product.

Interviewee: Steve Iannelli

*Note: open with the fact that we have developed a solution to our occupancy question

1. Do you frequently encounter areas that you believe are occupied because there are objects left on the table?
Yes single books – left & forgot sometimes, but backpack equals occupied
2. Do you frequently leave your own possessions in an area that you are working in? If yes, for how long?
Yes, everything backpack, jacket, books, laptop. About 15 minutes.
3. How long do you believe an object that has been left on a table should be left undisturbed before you consider sitting at the table with the object?
15 minutes.
4. Are you interested in a system solution that will inform you that there are objects on a table, but no one is currently sitting at the table?
Yes, I consider the table occupied if there are objects on it. This would help me to find a table more quickly.

It is important to inform you that the solution to this problem requires the development of a physical object that must be placed in the vicinity of the area of interest in question.

1. Do you have any concerns about placing this physical object in front of you in an area that may possibly reduce your total workspace? This physical object would likely have small dimensions.
No not really.
2. Where would you prefer to have the object placed that would interfere least with your work?
**Center of table would be unacceptable; stuff might get put on top of it.
End of table, possibly raised, would be ok.**
3. What physical object size do you believe will negatively impact the efficiency of your work or be a cause of annoyance to you?
Size of a novel would be alright, size of laptop would be too large.
4. Are there any other locations within your workspace that you believe would interfere with your work?
Don't put it on table where it could get in the way of books, laptops, etc.
5. What do you believe is a reasonable cost per table to determine if the table is in use? What price is more reasonable: \$100, \$200, \$500, \$1000? As a reference do you believe \$5000 is a reasonable price to install the system on M-level?
**Per table \$150
\$5000 for M-level sounds reasonable**
6. Based on our discussion how likely do you believe it is for a company or institution that has a need for this system to purchase our product within the next year?
I would say that companies would probably not buy the system. It seems like more of a luxury item to me rather than a business necessity. The system does not accomplish enough to justify a large investment.

