

iNODE for iDOCENT

iNODE for iDOCENT (indoor Digital Orientation Communication and Enabling Navigational Technology)

Design Proposal
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Executive Summary

iDOCENT is a phone application created to assist navigation throughout buildings on Michigan State University's campus. The software application is designed primarily for visually impaired individuals, as it vocally speaks turn by turn directions to the cell phone user. iDOCENT uses existing Wi-Fi access points to receive the device's signal strength for localization purposes.

The iNODE for iDOCENT will be designed to supplement existing access points to increase system accuracy or expand the application's usage to buildings without Wi-Fi networks. The iNODE will be of less cost than implementing more router access points on the engineering network and will be portable to allow strategic placement for achieving the best system accuracy results. The unit will consist of a Wi-Fi chip module, microprocessor, power supply, battery source, and transceiver.

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Introduction

The Global Position System (GPS) is widely used as a means for navigation assistance in outdoor applications around the earth. Today, GPS is commonly integrated into many mobile devices including smartphones, making navigation assistance applications very common and portable. Universities around the country have begun taking advantage of this technology and portability to create applications for navigation assistance throughout campuses for mobile users. However, GPS is unreliable when it comes to indoor navigation because satellite signal transmissions are blocked.

The RCPD (Research Center for People with Disabilities) on the campus of Michigan State University (MSU) and our sponsor contact there, Stephen Blosser, proposed a design project to overcome this unreliability. The MSU spring ECE 480 team completed a design by creating the iDOCENT phone application solution by using Wi-Fi triangulation as a means for indoor navigation assistance. The phone application gathers the location of available Wi-Fi access points and assigns a factor based on the signal strength received by the phone from the specific access points, and performs a triangulation algorithm.

The customer's overall objective is to create a system that will make indoor navigation more feasible for people with disabilities such as the blind. The main problems with the previous iDOCENT project was the inability of the application to work in areas where a Wi-Fi network was not available, or where there may be a Wi-Fi network but not enough access points and the inconsistency of accuracy depending on the amount of access points available. Designing a way to extend the functions of the iDOCENT application to the previously described areas and creating a more consistently accurate system is very important to the system development.

The iNODE for iDOCENT will be supplemental hardware that will work in conjunction with the phone application. The purpose is to place the iNODE in a desired building to increase the accuracy of iDOCENT or allow iDOCENT to be used in areas without a Wi-Fi network. The sponsor given specifications for the iNODE are the use of RF signals for communication with the application and to increase the accuracy consistency of the overall system to always be within ten feet.

Background

Global Positioning System (GPS) is a modern day solution to paper maps, allowing a user to access their current location and find routes to their destinations. GPS is based on satellites in space that send out information about time and location to mobile devices receivers. This is a proven system that the United States government provides; however, it comes with its drawbacks. As stated in the introduction, trying to access GPS signals indoors can present a problem due to building walls attenuating these signals. This has led to research into other areas that will allow for indoor location.

Solving this GPS reliability problem has led to several different design alternatives that are based upon the main RF signals smartphones have available to their applications. The main tools available that we considered viable options for our hardware solution were the cellular network, Bluetooth connectivity, Wi-Fi, or a combination of these solutions.

Bluetooth is a technology that is common and readily available for use in smartphone applications, allowing two or more devices to be paired together by a password or passcode. This was originally considered to be a viable design solution; however some key drawbacks led to further research into other technologies. The range for Bluetooth transmission was the first major concern addressed. This range is typically only 20 to 30 meters and would call for the implementation of multiple modules in a given area, which would lead to a rise in cost. Another con against Bluetooth, as stated previously, is that a connection is necessary in order to pair with other Bluetooth capable devices. This could create complications for users who are possibly visually impaired or who may not have the technical knowledge needed. The system would also require the ability of multiple users to connect and use the system at the same time. Bluetooth hardware modules typically do not allow multiple connections simultaneously transmitting and receiving data, and if they do it would not allow the amount of connections potentially needed with many users using the iDOCENT application. Lastly, Bluetooth hardware modules do not offer a default method for calculating signal strength, which for our project is a main component to be sent to our server for triangulation of a cellular device.

The cellular network, specifically the 3G signal was the next possible design solution the team researched. This RF signal is implemented on most new and upcoming phones but it is not a free service and requires purchasing a data package. Cell phone companies are currently moving to data packages that have a set limit on usage. Ultimately, iDOCENT could be used often by the visually impaired and could potentially cause high data usage rates as it loads maps in real time as the user moves. The team wants iDOCENT to be able to be used often with no extra cost to the user. Other drawbacks that we have found in researching 3G signal is that signal strength in certain areas is not always reliable in buildings around campuses or in basements of buildings. The Engineering Building at Michigan State University is a good example of this.

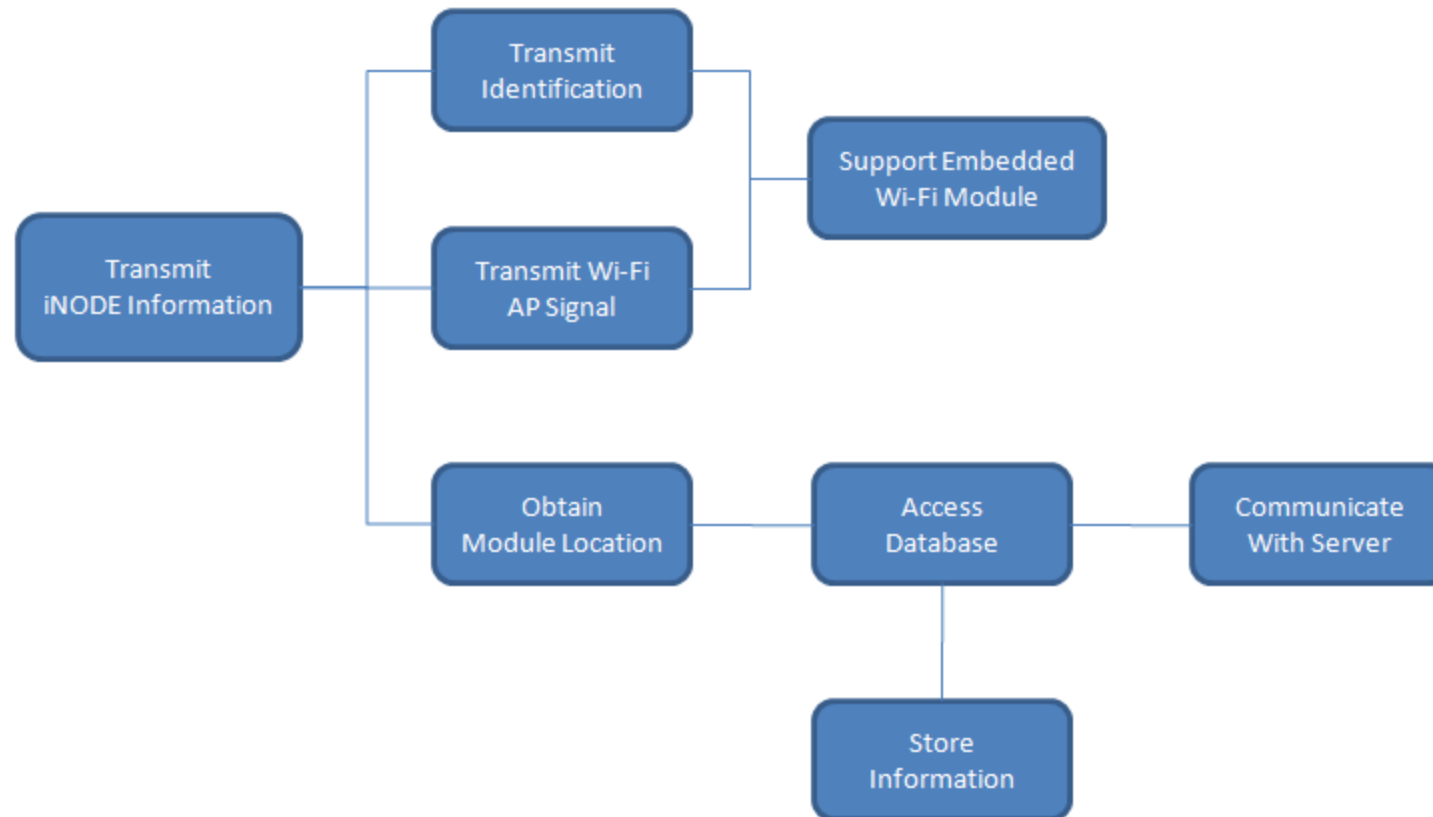
Wi-Fi is another RF signal that could possibly be used as a solution for our iNODE and was the RF signal chosen by the previous team. Virtually all smartphones today are Wi-Fi capable, and users often prefer it to their 3G data plans because of faster data rates in certain areas and the 3G data limits discussed previously. Wi-Fi networks are also very common and available in buildings, especially on college campuses, to allow for indoor navigation. A strong advantage to using Wi-Fi is that it incorporates signal strength packages into its transmission to other Wi-Fi compatible devices and will allow us to easily access this information. An area of concern, however, with Wi-Fi is a possibility of causing a disruption in the transmitted bandwidth and slowing down upload and download speeds for other devices on that network.

After considering these different routes we have found that Wi-Fi triangulation is the most practical and easiest to implement into our project. It is readily available and is also already used by the previous group's project which we are expanding upon. Since we have decided upon Wi-Fi, we considered improving our device by including a combination of either Bluetooth or 3G with Wi-Fi, but this will bring in a complexity to our project which is not necessary, increase the cost of our devices to where we are no longer seriously competing with Wi-Fi access points, and will also bring in each respected technologies drawbacks.

Objectives and Design Specification

We will be following a set of objectives to enhance the design from the previous iDOCENT's location algorithm. As Phase 2.1, we will be working close with last semester project and enhance the algorithm by including a hardware design to create more access points in areas of the Engineering Building at Michigan State University that might not have strong enough signal strength as well as areas that do not have any signal strength. Some of these areas might include bathrooms and stairwells, which caused problems in moving from one floor to the next. These simulated access points, iNODE, will need to be uniform to other access points in the Engineering Building to be easy uploaded to the previous database for iDOCENT app and will also need to be able to transmit a basic service set identification, BSSID, that is unique to each iNODE to be able to be identified by the test phone to be sent to our server. This module will need to be cost effective in order to make this a better solution to just buying more access points and will need to be fed from lithium batteries to keep these modules portable and able to be free of power outlets. An area of concern as well as an objective is to make sure our module does not interfere with the existing Engineering Building, EGR Wi-Fi, and not slow down upload and download speeds used by other computers, devices, and users throughout the building. Our overall design should work seamlessly with the previous design project's iDOCENT app and should make for a better and smoother display of turn by turn navigation throughout the Engineering Building. The overall design specification is to make a system that will navigate a person inside a building within 10 feet of accuracy.

Fast Diagram

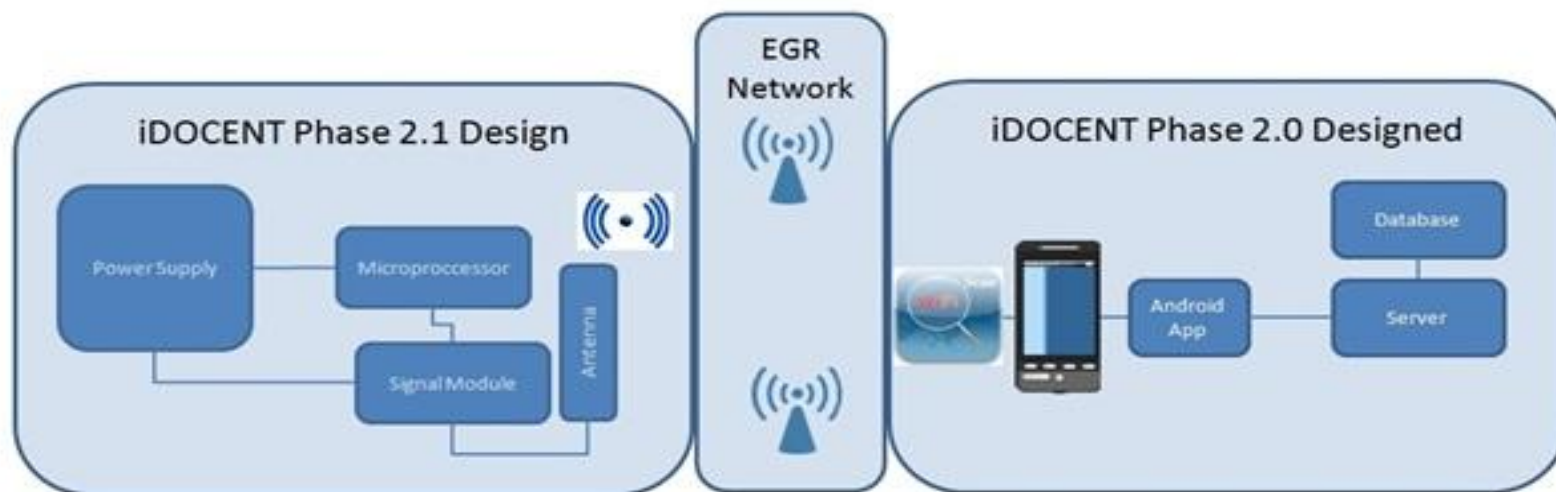
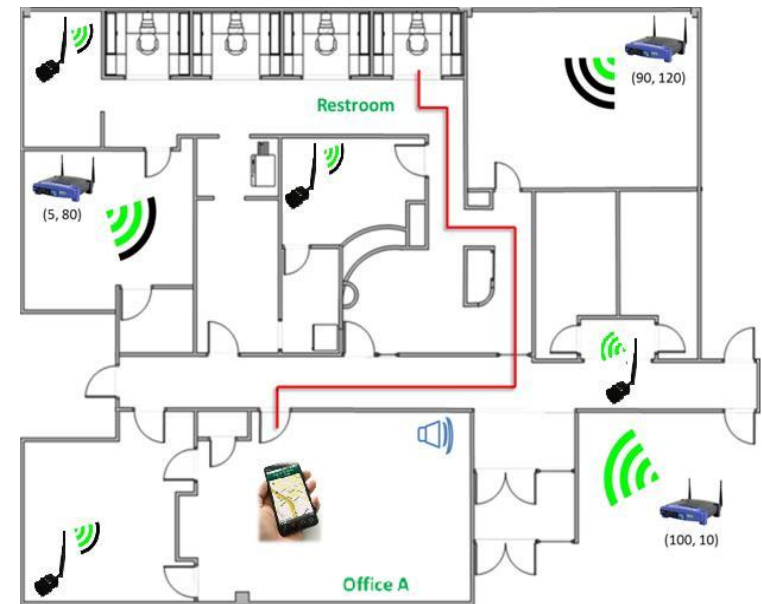


The ultimate goal of the iNODE hardware solution is to transmit the relevant Wi-Fi signals and location information to the iDOCENT application. As the diagram is read from the left to the right, the question “How” is asked for each step. To transmit the relevant iNODE information, the hardware must transmit its identification and Wi-Fi signal. This is accomplished by supporting the Wi-Fi module with a power supply and microprocessor. The server must transmit the module location and transmitting power. This is accomplished by accessing a data base with the relevant stored information stored on a server.

Conceptual Design Description

The conceptual design illustrates the iNODE working in conjunction with the iDOCENT application created by the spring semester ECE 480 team. The diagram to the right shows the layout of a building with typical Wi-Fi access points and portable modules representing our iNODE module. The smart phone in Office A and the accompanying red line is representing the user receiving a path based on signal strengths

The diagram directly below illustrates the hardware overview of the the iDOCENT application. The signal module block represents the Wi-Fi communication chip module being controlled and supported by a micro-processor. The power supply will provide the microprocessor and signal module with power via portable battery supply. The antenna acts as the transceiver to communicate with the smartphone. The iDOCENT Phase 1.0 block represents the previous teams project contributions that currently work with EGR Wi-Fi access points shown in the EGR Network block.



Ranking of Conceptual Designs

Research was gathered on a variety of different RF signals for the best available hardware solution to the iDOCENT application as discussed in the background section. Each design approached was ranked over several different criteria, with each specific criterion given a rank to represent its importance in the decision process. The total criteria score for a specific design solution was calculated by multiplying the rank for the weight of the criteria importance by the rank given for the specific design on that criterion. Each design solution final rank is the sum of all their total criteria score. The ranking system used was based on a one to five scale with one being the best rank, and five being the worst. Therefore, the design solution with the lowest score was decided as the best solution for the iDOCENT hardware solution.

Decision Matrix

Criteria	Criteria Importance	Bluetooth Module Design	Wi-Fi Module Design	3G Module Design	Combination of Wi-Fi + Bluetooth or 3G
Available Tools	4	2	2	1	4
Range of Signal	2	4	2	1	3
Ease of Implementing with Application	3	4	1	4	3
Reliability of Signal	1	2	2	5	2
Ease of Use	1	4	2	1	4
Overall Cost	1	2	1	3	4
Previous Knowledge	3	3	2	4	4
Grand Total		45	26	39	53

Criteria Rank Legend	
1	Best
2	Good
3	OK
4	Not Good
5	Worst

The Wi-Fi Module Design was considered the best solution because of its low rankings on the most important criteria, with the combination option being the worst as seen by the diagram.

Proposed Design Solution

From our Ranking of Design it is clear that using the Wifi network will prove to be the best implementation. Our goal is to use the iDOCENT cell phone application created by the spring ECE 480 Design team and develop a system to work with the application to improve its means of operation. Our proposed design solution is aimed to increase the accuracy and real time tracking from the previous semester's project with our prototype iNODE. The iNODE will be a small battery powered module that will be added on top of an existing Wifi network. These modules will not transport internet like a Wifi access point, but will communicate on the same Wifi operating frequency band. We will add the iNODE in areas of a building that have poor Wifi to increase the accuracy. This will also increase the resolution of the cell phone's application to display a more accurate tracking of the individual on the iDOCENT virtual map. To achieve these goals, the project will require the implementation of a hardware device to supplement an existing Wifi network, as well as modifications to the iDOCENT cell phone application.

The iNODE will be the hardware portion of the design solution. We will design the iNODE to be battery powered which will allow for required placement of the device to achieve maximum accuracy. We will design the power supply to run off of lithium ion batteries which will maximize the lifetime of the batteries so they do not need to be changed constantly.

The next portion that will need to be considered for design will be a microprocessor. Since the design team is familiar with the PIC microcontroller as well as its low power and cheap cost we have chosen to use a microprocessor from Microchip. The microprocessor will be needed to maintain the proper protocol layering for the certified IEEE Wifi 802.11 Wifi band. The PIC will also contain the proper data that we will transmit to the cell phone. Microchip has many electronic solutions and because of their reliability of their product we have also chosen to pair the PIC microcontroller with a Wifi module for the transmitter.

As stated before we will choose to purchase the MRF24WB0MB for the Wifi module. The Wifi module will act as a transmitter for the certified Wifi operating band. This module will have radio frequency components that are optimized to talk at 2.4GHz. The Wifi module was chosen because of its convenient capabilities to work with the PIC microcontroller as well as the option for an external antenna and printed circuit board antenna. This Wifi module will need to be low power, and also have an antenna mount for that is the unit that will transmit our BSSID and to the cell phone. The module will have a previously set MAC address which is the component used for identification by the iDOCENT cell phone application. The PIC microcontroller and Wifi module will need to be developed on a Microchip development board for the prototype design. This development board will be used to download the proper protocol layering that will be placed on the PIC microcontroller as well as placing the Wifi module in the proper mode of operation. We will choose to have the Wifi module in the access point mode, but

the module will not transmit any data. This may reduce the overall throughput of the established Wifi network, but this should be minimal due to the lack of data being transmitted.

Finally we will choose to use the printed circuit board antenna to transmit out signal as well as supplementing the antenna with an external antenna. The purpose of this is to increase the systems signal strength for indoor navigation. The convenience of the MRF24WB0MB is that the data sheet contains a list of antenna manufacturers that have previously developed solutions for this device. The antennas are properly matched for their impedance characteristics and will significantly supplement the transmitter.

The other portion of our solution will consist of software updates. The previous team had implemented a server that contained a database of all the Wifi access points inside the Engineering Building at Michigan State University. The server was taken down when the previous team had finished their project. We will need to develop a new server that will implement the locations of all the existing Wifi routers inside the engineering building as well as the iNODE information. The locations of the modules are mapped in a specific coordinate system that the previous team developed, which our modules will need to be added to the coordinate mapping system and loaded to the database. The server will also be updated to allow for more features for navigation. Currently the iDOCENT application does a decent job at locating an individual, but it lacks in the aspect of directing an individual to a requested room.

We will also need to modify the cell phone application to recognize our Wifi modules. There are three modes of operation for a Wifi router. We will need to enable to cellphone application to search for our module which will not be transmitting any internet, just a BSSID (MAC address) across the Wifi network. The cell phone application will also need to be updated to send the received iNODE information across its service network back to our server for proper triangulation. We will also need to update the digital map that the iDOCENT application displays for the user to implement our iNODE's for location purposes.

Risk Analysis

The risks assessed are based on the critical path shown in the GANT chart located in the project management plan. The plan lays out the tasks involved in creating a supplemental hardware solution to the iDOCENT application. This includes but is not limited to software development, hardware designing, and product testing. The analysis of risk was assessed on the three key concerns below.

Risk Assessment

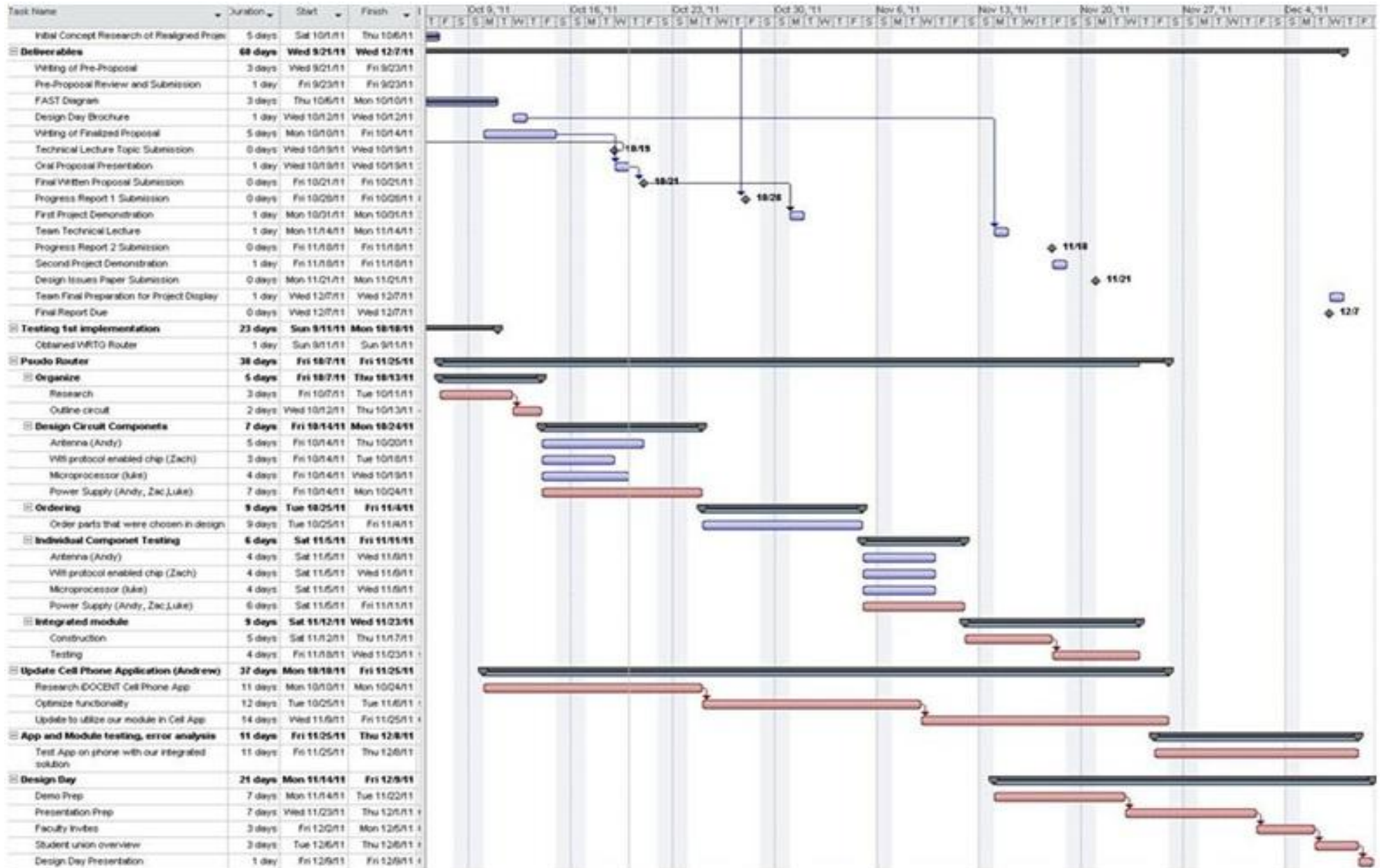
Risk Assessment			
Task at Risk	Description	Number	Color
iNode's will have sufficient power and will be able to be portable	Minor, Low Likelihood	4	Green
Wi-Fi algorithm will be able to be aided by implementation of iNodes	Serious, Likely	12	Yellow
Ability to design iNode technology and still be cost effective (cheaper than manufactured Access Points)	Serious, Low Likelihood	8	Yellow

Risk Analysis Matrix

Risk Analysis						
Likelihood	Near Certainty	5	10	15	20	25
	Highly Likely	4	8	12	16	20
	Likely	3	6	9	12	15
	Low Likelihood	2	4	6	8	10
	Extremely Improbable	1	2	3	4	5
		Minimal	Minor	Major	Serious	Catastrophic
Impact						

Risk Value Legend		
Low	< 5	Green
Medium	> 5 & < 15	Yellow
High	> 15	Red

Project Management



Summary of Project:

Our project requires both the implementation of a hardware device to supplement an existing Wifi network, as well as modifications to the iDOCENT application that was created by the spring ECE 480 design team. The hardware portion (iNODE) will be designed to increase accuracy of localization as well as increase floor distinction. The software portion of our design will be an effort to optimize the previous iDOCENT cell phone application as well as modify it to recognize our iNODE.

Summary of Methodology:

Our general approach will be to further research the growing field of indoor navigation as we make progress into design. Due to multiple risk factors such as a wide variation of signal power with interference from both physical and non-physical objects, as well as other factors stated in the Proposed Design Solutions section, we have narrowed our design implementation to one design. This implementation will consist of a hardware design solution as well as a software design solution. The design team will consist of four student engineers:

- Andy Dutton: team manager
- Andrew White: presentation and lab coordinator
- Luke Heide: document preparation
- Zach Menard: web master

The proposal will be updated as needed throughout the project, and will be available on the team's individual website.

Work Breakdown Structure and Estimates:

We will first discuss a high level overview of what the iNODE will consist of, as well as software updates necessary for the project.

The goal of the iNODE will be to supplement the existing Wifi network in the Engineering Building at Michigan State University to increase the accuracy of the iDOCENT cell phone application. The main objective of this concept of design is to create a cost effective solution to issues that resulted with the initial phase of the project, as well as come up with a module that could be deployed in a building without Wifi to allow the iDOCENT application to effectively navigate people around a building. Because the previous implementation of the iDOCENT application works with Wifi routers, our current goal is to make a system that will be cheaper than purchasing an off the shelf Wifi router. The other goal of this solution is to allow it to be easily deployed inside a building with no existing Wifi network.

To meet that objective, we will create a Wifi module that will not transmit data to the end user as well as have no need to speak with a Wifi router. This will be done by having the phone talk to the module, gather its id. And signal strength and send that information over the 3G or 4G network that the phone used back to the server which will implement the triangulation method for location.

To do this we will need our implemented hardware to have a standalone power supply. This is because our system will not transmit any data over the Wifi band like a typical router would, so we can minimize some location issues by creating a battery powered module. Secondly we will need a module that will allow for proper protocol layering across the Wifi band. This Wifi module will need to be low power, and also have an antenna mount for that is the unit that will transmit our BSSID and to the cell phone. Many of Wifi module manufacturers have either printed circuit board antennas, or a mini coaxial cable jack for an external antenna. Our antenna will have an antenna where the impedance is properly matched to the circuitry of the Wifi module. And finally we will need a microprocessor to drive the Wifi module. With these four units in mind for the hardware design solution, we will need to keep power consumption at a minimum as well as cost to try to undercut the cheapest reliable Wifi router. Currently we are looking at a number of Wifi modules because this is our critical component. The Wifi module is going to be the most expensive piece of our design, as well as the most difficult to implement. The modules on the market are roughly 20mm X 30mm with a ball grid soldering mount. This causes a problem because we do not have the capabilities of ball grid soldering at this facility, and would cost extra to have a company to create a printed circuit board to solder and mount our device to. We are currently looking into the Microchip MRF24WB0MB for multiple reasons. The Microchip MRF24WB0MB is noted for its low power consumption, as well as a list of manufacturers for proper impedance matched antennas. They also have a daughter board unit that has the Microchip MRF24WB0MB mounted with pins that will fit easily into a bread board unit for easy testing purposes. That unit along with the development tools to get the proper protocol layering uploaded into the module is a bit pricey. Although expensive, research has shown that the Microchip MRF24WB0MB with matched antennas offers the highest range for Wifi connectivity for inside a building. The design of the hardware solution will be achieved by two members of the group:

Andy Dutton:

Andy will be in charge of ordering all hardware for the proposed solution. Andy will be in charge designing the power supply and the Wifi module. The power supply will be designed to power the circuit at a steady 3.3 volts from lithium ion batteries. Along with the power supply, Andy will be responsible for the ordering of the Wifi module, and loading it with the proper protocol layering.

Zachary Menard:

Zachary will be in charge of the microcontroller and the antenna for adequate transmission of the modules BSSID. Zachary will be in charge of the proper programming for the microprocessor's communication to the Wifi module. This effort will be shared between both Andy and Zachary to ensure proper communication between microprocessor and Wifi module. Zach will also be in charge of choosing and testing the antennas for the most consistent results for signal strength.

The other portion of our solution will consist of software updates. The previous team had implemented a server that contained a database of all the Wifi access points inside the Engineering Building at Michigan State University. The server was taken down when the previous team had finished their project. We will need to develop a new server that will implement the locations of all the existing Wifi routers inside the engineering building. The locations of the modules are mapped in a specific coordinate system that the previous team developed, which our modules will need to be added to the coordinate mapping system and loaded to the database. We will also need to modify the cellphone application to recognize our Wifi modules. There are three modes of operation for a Wifi router. We will need to enable the cellphone application to search for our module which will not be transmitting any internet, just a BSSID across the Wifi network. The Cellphone application will also need to be updated to send the received iNODE information across its service network back to our server for proper triangulation. We will also need to update the digital map that the iDOCENT application displays for the user to implement our iNODE's for location purposes. The software implementation will consist of two student engineers:

Luke Heide:

Luke will be in charge of the software updates that will be for the server of iDOCENT. The server database will need to be updated to add our iNODE into the database. The server is necessary for the iDOCENT application; therefore we will need to get the server up and running before we can modify the iDOCENT application. The database will also need to be updated for the most accurate best path, as the students from last year said their navigation tools were not working the best.

Andrew White:

Andrew will be in charge of modifying the android phone application. The cell phone application will need to be updated to both see and transport our iNODE's information for location purposes. Currently the Application surveys for possible access points, during this surveying it should recognize the iNODE as a Wifi device, but not an access point. We will need to extract the BSSID and the signal strength, and have that data sent over to the server database for triangulation purposes. Andres will also be in charge of modifying the user interface to make it more creative and friendly.

The iNODE hardware will be built in sections. The iNODE will need to be individually tested for their integrity of the system. The building and individual testing will be done by the person responsible for their technical task. We will implement multiple stages of testing to ensure the integrity of our individual components. During the preliminary stage, each person will be working on their technical roles and performing individual testing. From here we will integrate the hardware components together and spend time testing the integrated system. The integrated iNODE module will need to be completed before the software team can finish their software updates and test the system. Therefore the critical design component for successful completion will rely on a quick turn over for the hardware design. Once both the hardware design and software modifications are completed we will spend time testing the finished design solution. This process will be done as a team, with the point of contact for each sub-component will be the person delegated by their technical tasks.

From here we hope to pilot this experiment in the Engineering Building on campus. If this is not available to us, we will attempt to pilot this experiment with a dummy network in an open building. This implementation would harm the budget of the program for it will require the purchasing of multiple routers and a server to create our own network. The development of the hardware will be done in the ECE 480 lab.

Budget

The budget for this project was pre-defined. The course provides a 500 dollar budget per team. Our system should be a low cost solution that would be cheaper in production than what one would expect to pay for a Wifi router. If the Wifi router can be made cheaper, then we would just add a Wifi router into the network. Our goal is to ultimately undercut the cost of a Wifi access point. The implementation will consist of creating a prototype. This prototype will be significantly more expensive than a production model. We intend to use the Microchip MRF24WB0MB along with a PIC microprocessor. The initial costs will need to be built on a development module. That development module will be the most expensive portion of the iNODE development. After this the next most expensive piece will be the Wifi module. The

expenses are due to the prototyping of this module. Once a prototype is created, the production model would be significantly cheaper. Below is a table of our projected budget.

Budget

Row Labels	iDOCENT Costs		
	Sum of Quantity	Sum of Cost	Sum of Total Cost
iNODE Hardware	14	\$32.47	\$69.42
Smartphone for testing	2	0	0
Antenna*	2	5.45	10.90
Wifi Module*	2	23.74	47.48
PIC Microprocessor*	2	2.16	4.32
Lithium Ion Batteries*	6	1.12	6.72
iNODE Development **	2	\$189.98	\$189.98
Microchip Explorer 16	1	129.99	129.99
PIC tail daughter board	1	59.99	59.99
iDOCENT Software	3	0	0
Smartphone app	1	0	0
Website Domain	1	0	0
Server Update	1	0	0
Presentation	2	\$34.79	\$34.79
Mobile App Presentation Poster	1	\$14.79	\$14.79
Poster Supplies	1	\$20	\$20
Grand Total	21	\$257.24	\$294.19

Financial Analysis

Description	Amount
Available Funds	\$500.00
Enterprise Costs	-\$294.19
Extra for Error	\$205.81

*Individual costs are more expensive for prototype model. These supplies are offered at a discount for large quantity ordering, which will reduce the overall cost of the product.

** The Microchip Explorer Development board and PIC tail daughter board would be a one-time purchase and would only be necessary for the prototype model. The production model would not include these pieces.

References

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