NAVIGATING USING WIRELESS ACCESS POINTS

(NUWAP)

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(NUWAP)

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ABSTRACT

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Wireless Geographic Logging Engine (WiGLE), the best known organization for tracking Wireless Local Area Networks (WLAN) reports 91,813,202 unique Wi-Fi access points in their system worldwide. WLANs are very common in urban areas, yet the uses of them are underutilized for navigation. Assisted Global Positioning Systems (A-GPS) is the most common use for WLAN in navigation in order to decrease the time needed to find the user's current location. To further utilize WLAN, wireless positioning systems on mobile computing devices can be created which only utilize WLAN. To fulfill the need for indoor navigation, we propose Navigation Using Wireless Access Points (NUWAP), a system which only utilizes WLAN that would be used where Global Positioning Systems (GPS) perform poorly. Such areas would include shopping centers, hospitals, schools, conference centers, and sport stadiums. In order to make wireless positioning systems, such as NUWAP, more common place research focusing on algorithms using pre-existing WLAN in the fields of access point plotting and navigation methods are studied. Using NUWAP, experiments were conducted to discover how router range and router density affect the chances that a path will be found. The results from these experiments show that wireless access points selection is not as important when the density of access point is large. From this research, a set of algorithms was created to help future local wireless navigation systems guide their users towards their destination.

ACKNOWLEDGEMENTS

Thanks are extended to Dr. Mina S. Guirguis for his time, patience, and guidance. Without his insight, key concepts of this work would have not been realized.

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TABLE OF CONTENTS

LIST OF FIGURES

CHAPTER I

INDOOR NAVIGATION

Introduction to Indoor Navigation

Figure 1. Example of the Data in WiGLE's Database. This image is of all the wireless access points in a region of downtown Austin. Image provided by WiGLE.net.

The use of Global Positioning System (GPS) is wide spread and many users have a hard time navigating the world without it. Unfortunately, GPS does not work indoors due to buildings blocking line of sight with the satellites, which are used as reference points for navigation. Indoor navigation systems must find reference points to locate and navigate users other than satellites. Some reference points which can be used instead of satellites for indoor navigation are Radio-Frequency Identification (RFID), Bluetooth, and Wireless Local Area Network (WLAN).

Indoor Navigation Methods

RFID works with both RF transmitters and RF receivers that communicate data between one another. Data is stored on the transmitters, and then the data is read by the receivers. To use this communication for navigation, the transmitters hold the information about a room and passageway between rooms; then the receivers must read this information and find a path using this data. The main problem with this method is that transmitters must be added and all the users of the system must have an expensive receiver (Hiu, Darabi, Banerjee, and Jing 2007).

Bluetooth works with both Bluetooth receivers and Bluetooth transmitters similar to other wireless communicating protocols which abide by the IEEE 802.15. To use this type of communication for navigation, Bluetooth transmitters must be placed around rooms and passageways to inform the system of the physical layout of the area. The main problems with this type of method are that transmitters must be added much like the RFID method. The other problem is that the signals of the transmitters are relatively short range compared to WLANs, meaning more Bluetooth access points must be used (Vasalya, and Agrawal 2012).

WLAN works with both wireless receivers and wireless transmitters, which use the wireless communication protocol, IEEE 802.11. This protocol also allows users to connect to a network. To extend this type of communication for navigation, a system must relate wireless transmitters to physical layouts of an area. No extra infrastructure must be added due to the prevalence of wireless transmitters in indoor environments where such systems would be implemented. A main problem with this system is that the range of effective use for networking is so large, that not enough wireless transmitters could be in an area for effective navigation (Hiu, Darabi, Banerjee, and Jing 2007). However, with the push for “small cell” access points, which have a shorter range, this issue could be easily resolved. The increasing use of “small cell” access points can be tied to decreasing interference between access points (Androne, and Palade 2012).

From these other methods, we selected WLAN for our system to use for navigation. This method meets the necessary feature for navigation. Each wireless access point has its own unique basic service set identification (BSSID), which is the access point's hardware media access controller (MAC) address. Thus, it is possible to distinguish one access point from another. By doing this, we can use each point as a digital landmark to guide a user from their current location to the location of their choosing.

WLAN navigation would be beneficial in areas where GPS would be insufficient to guide users to their destination. Such areas are complicated public venues or dense urban areas where GPS is not specific enough, such as inside buildings. Research into indoor wireless navigation has been conducted, focusing on adding additional infrastructure into these buildings for navigation. In this research area, systems have been designed to work by adding infrastructure such as Bluetooth access points and communication hubs which allow communication between wireless access points and Bluetooth access points (Agrawal, and Vasalya 2012). This type of system does work; however, it would be beneficial to try to minimize the amount of extra infrastructure added to these network systems. So to accomplish this goal, NUWAP's research is going to focus on algorithmic and data structural ways to accomplish wireless navigation. With Wi-Fi technology, indoor navigation algorithms have proven accuracy to two meters with 90% success (Hiu, Darabi, Banerjee, and Jing 2007). These algorithms must deal with the poor accuracy of Wireless Access Points due to the receivers picking up different signal strengths from obstacles and other receivers' interference with navigation (Wang, Jia, Lee, and Li 2003). This research is sectioned into topics focusing on NUWAP's overview, data structures, algorithms, and resource constraints for this wireless point navigation system.

CHAPTER II

NUWAP

NUWAP Overview

NUWAP is a wireless access point navigational system that needs two aspects in order to work: data collection and data processing. Each part of the system could benefit from the other. For example, if the processing is fast and accurate more people would be inclined to use the system and may allow their paths to be tracked. This means that more data could be input to the system making it better. This specific system is developed and tested using Java, yet the ideas, data structures, and algorithms can be implemented on any framework. Most of the computing could be done on an external server and the information can be sent to the client, which can be any device using a modern mobile operating system. The reason why mobile devices would be preferred to be used as clients is because people are more likely to carry these devices and they are capable of many wireless connections such as cellular data, Bluetooth, GPS and Wi-Fi. This system is not made to replace or make GPS obsolete, but instead it is designed to enhance A-GPS systems.

Data Collecting

The first part of NUWAP will be dealing with access point plotting. For the data collection, the optimal solution is to make it either social media based or as a game to encourage users to input locations and allow tracking of their movements via the system. Fun Theory is the idea of making mundane or non-exciting activities simple and fun. By applying this theory, incentives are given to people making them want to collect data. People can win points for accomplishing different tasks. Some of these tasks include finding handicap accessible paths, finding new rooms, or finding new routes. With this information the navigation part of the application can give routes that only use stairs or routes which are handicap accessible. With the system collection being fun, the number of people collecting data should increase, which in turn will increase the number of access points in the system's database. Another way of collecting data would be to use an external organization's database, such as the Google system or WiGLE.net. The NUWAP system could link Google calendar's events to the current location of the user. By doing this the access points around the event's location link to that area. By using Google calendar's events and the user's current location, NUWAP could be non-invasive to the user and still expand the system's database. By doing this NUWAP increases its database which would in turn increase the system's accuracy for its users. Once the data of the access points and the area landmarks are collected the system then must associate wireless access points to landmarks. When the data is in a form which is usable for NUWAP, this part of the system is complete. NUWAP's data processing only needs to run if the system collects new data in an area.

Navigation

The second part of NUWAP will be dealing with the actual navigation. The navigation section will use the plotting information in order to provide paths for the user. The system uses its database of known landmarks and wireless access points to create a path for the user. This path can be used to guide a user by relative directions. With the system's database, it makes a subset of relevant locational data between the user's desired destination and the user's current location. Once this subset is created, the system can select nodes from the landmark subset and then from the wireless access point subset until the user's current location is found. With this data, relationships between landmarks and wireless access points are drawn which creates a tree data structure. The program then finds the user's current location, which is an end leaf node and climbs down the tree saving the path it takes until the user's desired location is found.

CHAPTER III

NUWAP'S DATA STRUCTURES

Data Structures

In computer science, data structures are virtual structures which allow data to be grouped in a uniformed way so that one can write algorithms to access the data within them. The NUWAP system uses the basic data structures known as arrays to store the system's data. An array is a data structure that contains continuous memory slots for similar data. Unlike standard arrays, the NUWAP's arrays are resizable, making them dynamic. In certain languages, programmers are allowed to create data structures which are configurable to the data needs of the programmer within one unique data structure.

Figure 2. Example of the Router Data Structure. Shows a visual representation of the router indexed data structure.

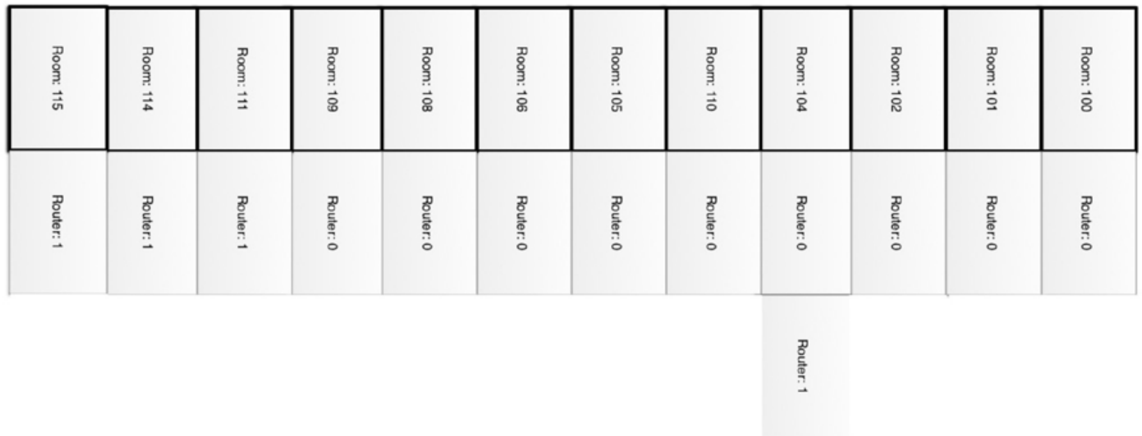

Figure 3. Example of the Room Data Structure. Shows a visual representation of the room indexed data structure.

<u>Router Data Structure</u>

By making unique data structures which bundle different kinds of data, the NUWAP's data structures contain information pertaining to access points and data about the rooms around them. Each block in the array represents an access point node, which are distinguished by their BSSID. By doing this, there should only be one entry in the array for each access point in an area. Each block contains the BSSID, approximate signal range, and a dynamic array which contains the rooms around it. Different access points in the array can have overlapping entries about rooms. This overlap in information allows NUWAP to graph out the physical layout of a map in relation to access points in the area.

<u>Room Data Structure</u>

However, the system also must relate rooms to access points from the data in the router data structure. Due to this, a similar data structure to the router data structure is used. This new data structure contains the room name, and dynamic arrays which hold access points around it. Using these two structures together, NUWAP creates an easier to access and faster to compute data representation of the area. By making two arrays that are redundant, it takes up more spatial memory resources; however these redundancies are necessary to boost NUWAP's performance.

By utilizing these two data structures, NUWAP completes its task of finding paths for its users. These data structures are designed to be accessed with a great deal of speed by consuming spatial memory resources. The increase in spatial memory resources can be minimized by creating separate zones for these data structures so that NUWAP does not need to load information that is irrelevant to the current user's request.

CHAPTER IV

ALGORITHMS

Navigating Algorithm

An algorithm is simply a structured way of doing something. A common example of an algorithm is the steps required to make a peanut butter and jelly sandwich. This example is the essence of an algorithm.

In NUWAP's primary path calculating algorithm, the key information needed from the user is the end destination; the other information is taken care of by other parts of NUWAP. Once the navigation function starts, it uses the end destination and finds its way to the user's current location. The decisions of which wireless access points should be followed starts at the end location until the user's current location is found. Each time a new wireless access point or location is added, the decisions of the next action grows. This structure created by the decisions of the system makes a tree. NUWAP utilizes recursion and tree data structures as the algorithm searches the two arrays to find a path for the user. First the algorithm starts creating the tree with the access points' array and then goes to the rooms' array, alternating between the two structures in order to create the tree. Recursion is a tool in which one takes a large task then breaks it up into small simple tasks that can be finished many times in order to complete the large task.
Due to this, recursion is a powerful tool. However, it takes a toll on the hardware of the system, because the process is very memory intensive due to having to save all the other paths in order to backtrack. Because of the resource needs of this kind of operation, it

could be a poor choice to conduct calculations on a mobile device that has limited sources of computing power and memory. So this algorithm could be used on a server and then the route information could be sent to the user once the server is done calculating.

Currently, NUWAP only uses wireless access points. However, NUWAP's code is written in such an abstract way that other kinds of communication protocols such as cellular towers and Bluetooth hubs could be added to increase the accuracy of the system.

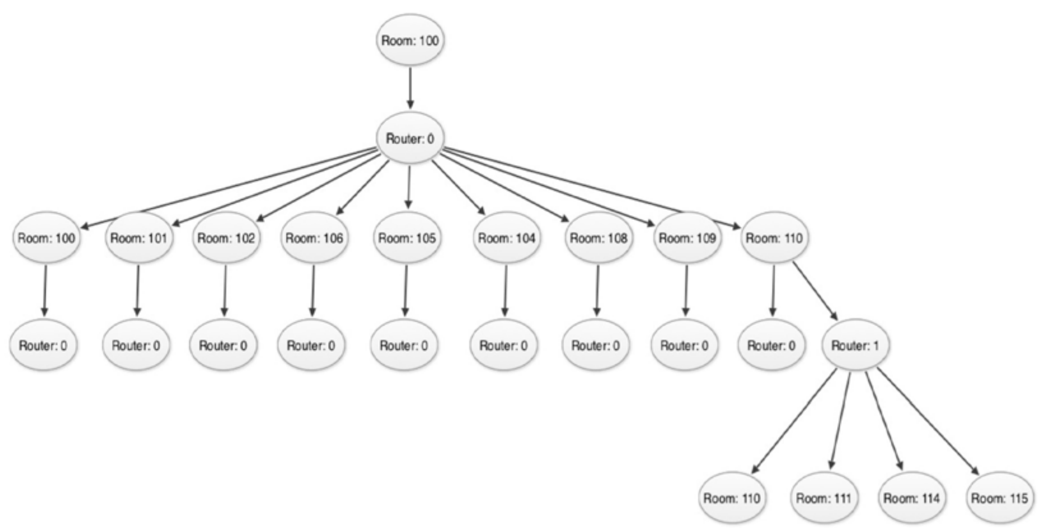

Figure 4. Example of NUWAP's navigation tree. Shows an example of the possible path decisions, which are created as the NUWAP algorithm works. This structure is also known as a tree.

CHAPTER V

SYSTEM CONSIDERATIONS

Resource Constraints

With the use of data redundancy and recursion, NUWAP's use of memory has the potential of becoming large when processing large sets of data. Due to the possibility of large amounts of information sets, NUWAP could be run from a server where the resources are not as limited. Currently the algorithm is non-threaded (not having the ability to seem like it is doing multiple things at once), which is not optimal. To increase performance, one of the first ideal revisions in the code is to make it threaded, so it has the ability to multitask. NUWAP can easily become multithreaded, but by doing this it would create an even larger strain on the system on which it runs. As the data set increases, NUWAP's calculations grow in time to be completed. It would be beneficial for it to be done externally on a server and then have the information sent to the client, instead of calculating on the client.

Security Concerns

The security of both the user and the wireless access points are important to this project. The safety of the wireless access points are protected by not directly allowing the user to know the location of the device while navigating the user to their desired destination. This application only needs to see that an access point is emitting a signal. The application does not need to connect to any access point. This way the application can use all signals in a given area without risking the security of the user or gaining illegal entry to the access point. The navigational part of the application should have no need to track the user and the user identity does not need to be known. Tracking of the user can be turned off. This feature is for privacy of the client. All data that is collected should be done so anonymously. The only reason why this system would need to link the data and the user would be in the case of it being a game. The specific user would need to be tracked in order for the application to award appropriate in-game points.

CHAPTER VI

SIMULATIONS

Experiments

Figure 5. Example of the Area Layout for the Research's Experiments. This figure is a very simple test layout for the conducted experiments.

In order to find the optimal map landscape for NUWAP, experiments have been done to find out what roles node density and node signal range play in the effectiveness of the navigational algorithm in these scenarios. The experiments consisted of an ideal simulated square floor map with no obstacles allowing all rooms to access their adjacent rooms. The signal range of wireless access points were simulated by discrete range values of how many rooms a specific access point can reach. Since the signal ranges were simulated, each access point could reach a signal range which is beyond any real access point's capability. To ensure that the system actually created a useable path for a person, limits were placed on paths so one wireless access point could not be the path for all rooms. If a router could see all rooms the accuracy of the system would be poor, and the system would think the user's current location is the destination. The density experiment works by placing a fixed amount of routers on a map based on the layout's placement rules, the range of all the routers are the same and are fixed for all the tests. The sign range experiment works by placing access points with a fixed signal range on a map based on the layout's rules, the number of access points stay the same for each test. After setting up both the test environment and the limits on acceptable correct paths, experiments were run using different layouts of maps to study the layout in relation to node density and node signal range. The kinds of layouts used in these experiments were random placement of node, linear fixed direction placement, and linear bi-direction placement. The random layout was created from thirty randomly generated access point locations for each trial in the two experiments. The linear bi-directional layout, which is pictured in Figure 6, was created from three columns which place nodes alternating from the top left side and the bottom left side of the simulated map. The linear fixed direction placement layout which can be seem in Figure 7, was created from three columns of access points starting from the top left side of the simulated map. The linear bi-directional and linear fixed direction layouts may look like the same set up, but they are different due to the router placement at each step of setting up the layouts. The linear bi-directional layout places routers alternating between the top and bottom of the map. By doing this the first router which is router 0, is place in room 102, then the second router which is router 1, is placed in room 192. The linear fixed direction layout places routers only from one side of the map. By doing this the first router which is router 0, is place in room 102, then the second router which is router 1, is placed in room 105. These processes continue until all thirty routers are placed.

Room: 100	Room: 101	Room: 102 Router: 0 Range: 3	Room: 103	Room: 104	Room: 105 Router: 2 Range: 3	Room: 106	Room: 107	Room: 108 Router: 4 Range: 3	Room: 109
Room: 110	Room: 111	Room: 112 Router: 6 Range: 3	Room: 113	Room: 114	Room: 115 Router: 8 Range: 3	Room: 116	Room: 117	Room: 118 Router: 10 Range: 3	Room: 119
Room: 120	Room: 121	Room: 122 Router: 12 Range: 3	Room: 123	Room: 124	Room: 125 Router: 14 Range: 3	Room: 126	Room: 127	Room: 128 Router: 16 Range: 3	Room: 129
Room: 130	Room: 131	Room: 132 Router: 18 Range: 3	Room: 133	Room: 134	Room: 135 Router: 20 Range: 3	Room: 136	Room: 137	Room: 138 Router: 22 Range: 3	Room: 139
Room: 140	Room: 141	Room: 142 Router: 24 Range: 3	Room: 143	Room: 144	Room: 145 Router: 26 Range: 3	Room: 146	Room: 147	Room: 148 Router: 28 Range: 3	Room: 149
Room: 150	Room: 151	Room: 152 Router: 25 Range: 3	Room: 153	Room: 154	Room: 155 Router: 27 Range: 3	Room: 156	Room: 157	Room: 158 Router: 29 Range: 3	Room: 159
Room: 160	Room: 161	Room: 162 Router: 19 Range: 3	Room: 163	Room: 164	Room: 165 Router: 21 Range: 3	Room: 166	Room: 167	Room: 168 Router: 23 Range: 3	Room: 169
Room: 170	Room: 171	Room: 172 Router: 13 Range: 3	Room: 173	Room: 174	Room: 175 Router: 15 Range: 3	Room: 176	Room: 177	Room: 178 Router: 17 Range: 3	Room: 179
Room: 180	Room: 181	Room: 182 Router: 7 Range: 3	Room: 183	Room: 184	Room: 185 Router: 9 Range: 3	Room: 186	Room: 187	Room: 188 Router: 11 Range: 3	Room: 189
Room: 190	Room: 191	Room: 192 Router: 1 Range: 3	Room: 193	Room: 194	Room: 195 Router: 3 Range: 3	Room: 196	Room: 197	Room: 198 Router: 5 Range: 3	Room: 199

Figure 6. Example of the Linear Bi-Directional Layout. This figure is to help visualize the differences between the linear bi-directional and linear fixed direction layouts.

Room: 100	Room: 101	Room: 102 Router: 0 Range: 3	Room: 103	Room: 104	Room: 105 Router: 1 Range: 3	Room: 106	Room: 107	Room: 108 Router: 2 Range: 3	Room: 109
Room: 110	Room: 111	Room: 112 Router: 3 Range: 3	Room: 113	Room: 114	Room: 115 Router: 4 Range: 3	Room: 116	Room: 117	Room: 118 Router: 5 Range: 3	Room: 119
Room: 120	Room: 121	Room: 122 Router: 6 Range: 3	Room: 123	Room: 124	Room: 125 Router: 7 Range: 3	Room: 126	Room: 127	Room: 128 Router: 8 Range: 3	Room: 129
Room: 130	Room: 131	Room: 132 Router: 9 Range: 3	Room: 133	Room: 134	Room: 135 Router: 10 Range: 3	Room: 136	Room: 137	Room: 138 Router: 11 Range: 3	Room: 139
Room: 140	Room: 141	Room: 142 Router: 12 Range: 3	Room: 143	Room: 144	Room: 145 Router: 13 Range: 3	Room: 146	Room: 147	Room: 148 Router: 14 Range: 3	Room: 149
Room: 150	Room: 151	Room: 152 Router: 15 Range: 3	Room: 153	Room: 154	Room: 155 Router: 16 Range: 3	Room: 156	Room: 157	Room: 158 Router: 17 Range: 3	Room: 159
Room: 160	Room: 161	Room: 162 Router: 18 Range: 3	Room: 163	Room: 164	Room: 165 Router: 19 Range: 3	Room: 166	Room: 167	Room: 168 Router: 20 Range: 3	Room: 169
Room: 170	Room: 171	Room: 172 Router: 21 Range: 3	Room: 173	Room: 174	Room: 175 Router: 22 Range: 3	Room: 176	Room: 177	Room: 178 Router: 23 Range: 3	Room: 179
Room: 180	Room: 181	Room: 182 Router: 24 Range: 3	Room: 183	Room: 184	Room: 185 Router: 25 Range: 3	Room: 186	Room: 187	Room: 188 Router: 26 Range: 3	Room: 189
Room: 190	Room: 191	Room: 192 Router: 27 Range: 3	Room: 193	Room: 194	Room: 195 Router: 28 Range: 3	Room: 196	Room: 197	Room: 198 Router: 29 Range: 3	Room: 199

Figure 7. Example of the Linear Fixed Directional Layout. This figure is to help visualize the differences between the two linear layouts.

Range Results

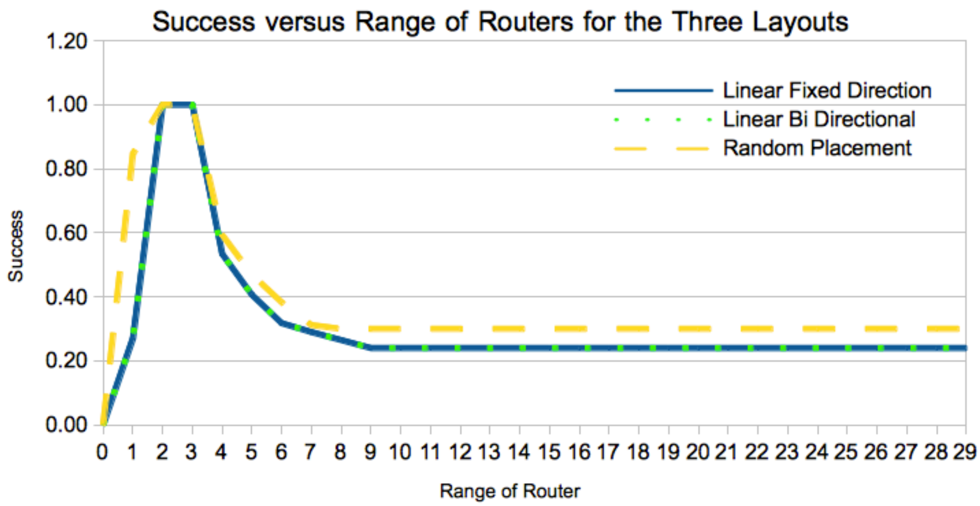

Figure 8. Example of the Increasing Range Graph. This figure shows the results for the range experiment with the three different kinds of layouts, each with a fixed number of rooms.

The router range experiment which is displayed in Figure 8 shows that the range of an access point has negative effects below and above certain thresholds. If the range of the access point is too small more routers would be needed to make the system functional, this is not a negative for NUWAP, because the more routers in a system the more accurate this system becomes. More routers in an area may seem costly or likely to cause inference between users wanting to connect to the internet. This is not the case, there is a push for "small cell" access points which are cheaper, consume less power and have a shorter range than traditional "macro cell" access points. With the utility of "small cell" providing better internet connectivity in urban environments, the use of these networks is expected to grow in those areas (Androne, and Palade 2012). With more access points in an area, systems like NUWAP become more accurate. Long signal range has similar negative effects as short signal range, the system would figure it need less access points. With less access points the accuracy of NUWAP becomes poor due to the lack of routers to guide the user. The wider router range issue can be seen as interference between routers claiming to be by a room, which in fact they are not near. This issue can be seen starting at the router range of 4 in Figure 8. The access points at this section of the graph show the system failing to provide correct results further from the user's location. Since the NUWAP can provide correct paths for destinations close to the user, the success in this section does not go to zero.

<u>Density Results</u>

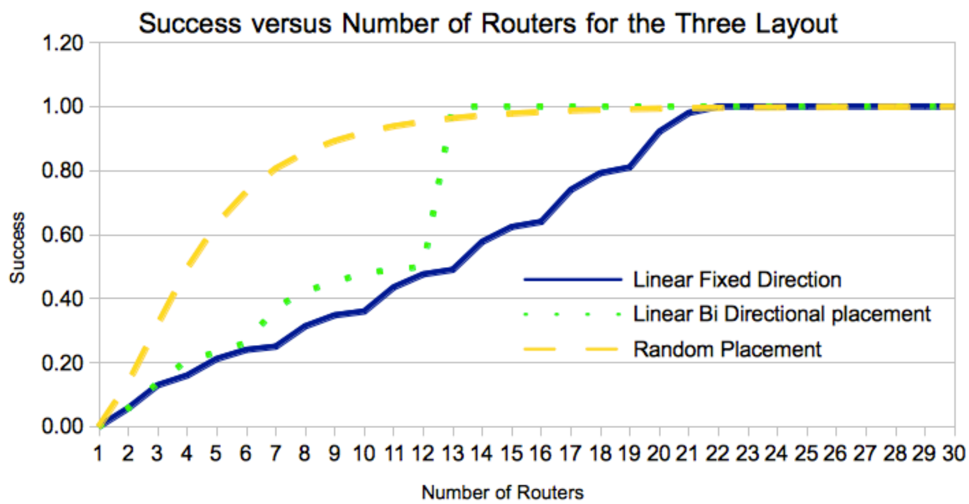

Figure 9. Example of the Increasing Density of Router's Graph. This figure shows the results for the density experiment with the three different kinds of layouts, each with a fixed range.

The node density experiment which is pictured in Figure 9 shows random placement to increase the success rate of navigation the fastest between 0 and 7 routers. This trend does not continue and the random placement layout slows between 7 and 30 routers. Due to this the linear fixed direction and linear bi-direction eventually have higher plot points before the end of the experiment. The linear bi-direction layout's results have a large spike in success because the routers from each side begin to merge, linking both sides of the map. This large spike on the linear bi-direction layout's results can be seen between 11 and 12 routers in Figure 9. The random placement had a fast growth because the map was empty; almost any placement increased the plot's success. When more access points are on the map, each additional random access point will be less likely to increase the success rate. The bi-direction plots increase faster than linear fixed direction throughout the experiment. This shows that placement affects the number of access points needed to allow maximum coverage of this system on a map. The randomly placed access points with increasing router range shows that the range of three rooms provides the best chance of finding a path in an area. With the results from all three of the layouts in the node density experiment the best strategy for placing nodes is to spread the nodes out. By doing this each access point is likely to cover ground that no other access point covers, which increases success of the system.

CHAPTER VII

CONCLUSION

Summary

Through our research and work performed for NUWAP, future wireless point navigation systems can draw upon the data structures, algorithms and resource constraints from this work to make their own systems better and more robust. Indoor navigation is nearing an exciting turning point. Wireless access points are already prevalent in urban areas giving internet access to our wireless devices. Systems can draw upon this untapped navigation resource to give people even easier navigation in these urban environments. In the future, applications such as NUWAP will guide their users down to a single room and be on many people’s phones making indoor navigation just as easy as using GPS. To follow this project, please visit https://github.com/onebitknightly/NUWAP.

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