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# WSN implementation for indoor Service Mobile Robot

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**Abstract**

The trend that has been focused on in this thesis is how to integrate the WSN to assist the robot purposes. Three major issues are implemented: determining the location of the robot, path planning to the target, as well as environmental monitoring and control. The location of the robot depends on WSN by using trilateration algorithm based on RSSI, and the path planning has been selected path between the robot location and target location, besides that, the implemented has been monitored and controlled the environment. The wireless communication was established to exchange the information between the robot and the Base Station (PC) in indoor localization.In addition, the estimated start location for the robot was affected on path planning determined for the robot. When path planning sends the path as courses to the robot, the accuracy of the digital compass effects on the direction of the robot.In addition the digital compass is affected by electronic fields of the environment.

**Keyword: M**obile robot, WSN, trilateration, RSSI, A* path planning.

## 1. INTRODUCTION

Wireless Sensor Network (WSN) applications are worldwide and have many applications for the service of humanity. Within these applications some are used in Robotics where it's applied in two ways: The first trend is integrating the WSN to help in robot applications, and the second trendis to apply the robot for the WSN purposes.Each device is denoted as a 'node'. Each node is equipped with a sensing device, a wireless radio, and a microprocessor and has different functions in a network where some nodes might be used for sensing, but somewhat collecting the sensor data or used for routing and other are used as actuator or locaters. [1]

A robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools or specific devices through variable programmed motions for performance of variety tasks [2].

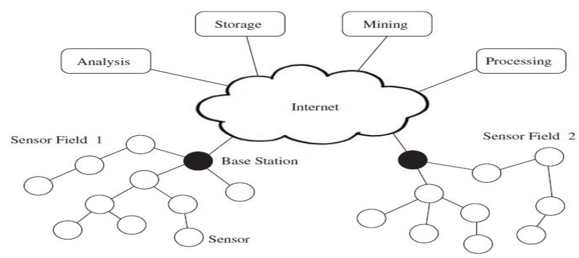
WSN can supports solving the robotics field problems such as Path planning, localization, sensing, and multiple robot coordination, since the main application for WSN with Robotics is a navigation system because the service robot should move without any accident, and to make the robot reach its goal [3].The Trilateration method, is one method has been used in this research to find the location of robot in map with range based scheme by calculated distance from measuring the RSSI values between each localized node and the robot [5]

The path planning problem may be considered as an optimization problem. It concerns finding the path from start location to target location. The path planning problem for mobile robots can be classified mainly into two divisions; global path planning and local path planning.

In global path planning, the environment surrounding the robot is known and the path which avoids the obstacle is selected. In the local path planning, the environment surrounding the robot is unknown, and sensors are used to detect the obstacles and avoid collision .There are many algorithms which can be used to find the best path to the goal, such as Depth-First, Breadth-First, and Heuristic searches such as A* and Best-First .[6]

## 2. ROBOTIC LOCALIZATION AND PATH PLANNING USING WSNS

Wireless Sensor Networks can be implemented to aid in solving problems that exist in the field of robotics. A wireless sensor has not only a sensing component, but also communication, storage capabilities, and on-board processing as shown in figure (1). With these enhancements, a sensor node is often not only responsible for data collection, but also for in-network correlation, analysis, and fusion of its sensor data with a data from other sensor nodes.




Figuer(1) wireless sensor network architecture [4]

Path planning, localization, sensing, and multiple robot coordination are a few examples of areas in which WSNs can provide many solutions. One of these solutions is using path planning method by examines the use of RSSI measurements to guide the robot around an indoor environment. Nodes are distributed around a room, each sending separate radio frequencies which the robot estimates its distance in relation to the node. The nodes direct the robot to its destination by guiding the robot based on its perceived distance to each node or its location within the network, rather than navigating based on its perceived location in the room. [4, 7]

Other path planning algorithms also exist, but with the purpose of guiding a robot through a network while avoiding collisions with nodes and other obstacles within the network. *In addition to that, there are several methods of mobile localization* within a sensor network involve using RSSI measurements and nodes with known locations. Some methods use a robot utilizing a modified Simultaneous Localization and Mapping (SLAM) algorithm to localize itself within the environment. Particle filters are also sometimes used for localizing robots equipped with sensor nodes.Another common method for triangulation without RSSI is by measuring ultrasonic.

## 3.ROBOT LOCALIZATION BY TRILATERATION AND RSSI

Locate the robot within a specific environment and limited (indoor environment) is one of the most important problems in the world of robotics, and how to solve this problem with support of the WSN was done in this thesis by applying a trilateration algorithm where at least 3 nodes were installed that are pre known place then the distance is calculated between the robot and every node by accounted RSSI ,as it's known, the received signal strength hasan inverse-square relationshipwith the distanceas shown in the following expression in equation (1):[8]

$$P_r \propto \frac{1}{d^2} \quad (1)$$

Where $P_r$ is the received power at distance d from the transmitter. This expression clearlystates that the distance could be found by comparing the difference between transmission power and received power, or it is called "path loss".In practical measurement, the increment of paths loss due to increment of distance may bedifferent when it is in different environments. This leads to environmental characterization using path loss exponent (η) as described in equation (2):

$$P_r = \frac{P_{r(d0)}}{(d/d_0)^n} \quad (2)$$

Where$P_r$is the received power at (d) and $P_{(d0)}$ is the received power measured at distance $d_0$. Generally, $d_0$ is fixed as a constant$d_0$ = 1 m. Path loss exponent (n)in the expression is one of the most important parameters for environmental characterization because of multi-path fading and indoor shadowing[15].

For each enclosedarea of indoor environment, a pair of these parameters (n, $P_{r(d0)}$) are used to represent the conditions of the area. After $P_{(d0)}$ is obtained, the receiver is moved to other locations to measure path loss exponent (n) using the following equation (3):

$$n = \frac{P_{r(di)} - P_{r(d0)}}{10 \times \log_{10}(d/d_0)} \quad (3)$$

Where $P_{r(d)}$ is the received power measured at a distance d from the transmitter, which is expressed in dBm.
But the value of n can be determined from the measured data by minimizing total error as in equation (4):

$$n = \frac{\sum_{i=1}^{m}[p_{r(di)} - p_{r(d0)}}{\sum_{i=1}^{m}[10 \times \log_{10}(\frac{d}{d_0})]} \quad (4)$$

After the two main environmental parameters nand $P_r(d_0)$ are obtained. Thus, the distance between transmitters and receivers can be estimatedusing the following expression as in equation (5):

$$d = d_0 * 10^{\left(\frac{P_{r(d0)} - P_{r(d)}}{10\,n}\right)} \quad (5)$$

After calculatingthe distances between the robot and each node then calculating the values of its whereabouts, depending on the trilateration algorithm.

For the indoor location system 2D trilateration is used to find location of robot, which will be on an XY plane. One can visualize this by looking at figure (2), where the star dot in the center has an unknown location. The star dot will represent the location of the robot that is being searched for. The reference nodes, also known as the locater nodes, are labeled A, B, and C, the distances between the reference nodes and the robot are labeled $d_a$, $d_b$ and $d_c$. The intersection between all three nodes is the location of the robot.

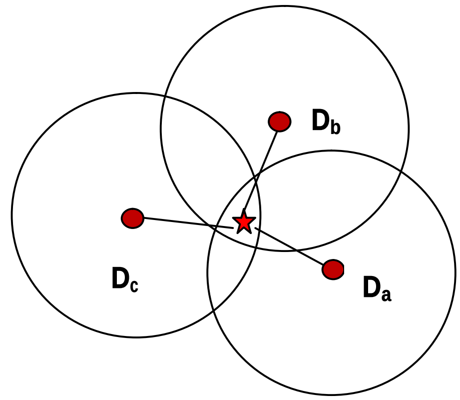



Figure (2) Trilateration technique

The signal strength can be converted into distance as explained previously, by given us the three known distances which are needed for trilateration.Once the distance is calculated, trilateration will be used to find the position of the robot. The way 2D trilateration works is shown below. In the following equations Xi and Yi represent the position of Ai (nodes), where i=1, 2, 3…

$$d_a^2 = (x - x_a)^2 + (y - y_a)^2 = x^2 - 2x.x_a + x_a^2 + y^2 - 2y.y_a + y_a^2 \quad (6)$$

$$d_b^2 = (x - x_b)^2 + (y - y_b)^2 = x^2 - 2x.x_b + x_b^2 + y^2 - 2y.y_b + y_b^2 \quad (7)$$

$$d_c^2 = (x - x_c)^2 + (y - y_c)^2 = x^2 - 2x.x_c + x_c^2 + y^2 - 2y.y_c + y_c^2 \quad (8)$$

To simplify this system of quadratic equations, equation (7) will be substituted into equations (6) and (8), which will leave two linear equations:

$$d_b^2 - d_a^2 = 2x(x_a - x_b) + x_b^2 - x_a^2 + 2y(y_a - y_b) + y_b^2 - y_a^2 \quad (9)$$

$$d_b^2 - d_c^2 = 2x(x_c - x_b) + x_b^2 - x_c^2 + 2y(y_c - y_b) + y_b^2 - y_c^2 \quad (10)$$

Rearranging the equation (9) and (10) to produce new equation and newvariable as follows:

$$2x(x_a - x_b) + 2y(y_a - y_b) = (d_b^2 - d_a^2) - (x_b^2 - x_a^2) - (y_b^2 - y_a^2)$$

$$2x(x_c - x_b) + 2y(y_c - y_b) = (d_b^2 - d_c^2) - (x_b^2 - x_c^2) - (y_b^2 - y_c^2)$$

$$x(x_a - x_b) + y(y_a - y_b) = \frac{(d_b^2 - d_a^2) - (x_b^2 - x_a^2) - (y_b^2 - y_a^2)}{2} = v_b \quad (11)$$

$$x(x_c - x_b) + y(y_c - y_b) = \frac{(d_b^2 - d_c^2) - (x_b^2 - x_c^2) - (y_b^2 - y_c^2)}{2} = v_a \quad (12)$$

Resolving equations(11) and (12) to gain the intersection point 'x' and 'y' of these two equations as the following equation for 'y' value and equation for 'x' value respectively [9]

$$y = \frac{v_b(x_c-x_b)-v_a(x_a-x_b)}{(y_a-y_b)(x_c-x_b)-(y_c-y_b)(x_a-x_b)} \quad (13)$$

$$x = \frac{v_a-y(y_c-y_b)}{(x_c-x_b)} \quad (14)$$

The time of flight between ultrasonic transmissions between the nodes are used to calculate the location of the robot and its pose or direction with respect to the position of the receiver nodes. [7]

## 4. ROBOT PATH PLANNING

Path-planning finds the shorterand more optimal path between two locations. Any path that hasminimumcost such as amount of turning and shorter distanceor whatever a specific requirements it's be the optimal path[10, 11]. One of the algorithms of path planning (A* algorithm) has been used in this research.

A star (A*) algorithm is one of the best known path planning algorithm, This algorithm uses a combination of heuristic searching and searching based on finding the shortest path. A* algorithm is defined as the best-first algorithm, because each cell in the configuration space is evaluated by thevalue:

$$F(n) = g(n) + h(n) \quad (15)$$

To accomplish the A* implementation two lists must be created: "open list" which is the list of cells that are actively considered as candidates for next step, and"closed list"which is the list of nodes that have already evaluated and aren't considered again. In the beginning, add the starting cellin the closed list and look at all the cells adjacent to the starting cell, and add the walkable cells to the open list while ignoring cells that aren't walkable. In addition must assign a "parent" to each cell,Figure (3)shows the open list whichis outlined in green squares, and the parent cell is noted by gray arrows (point A its "parent cell") [6, 12, 13, 14].

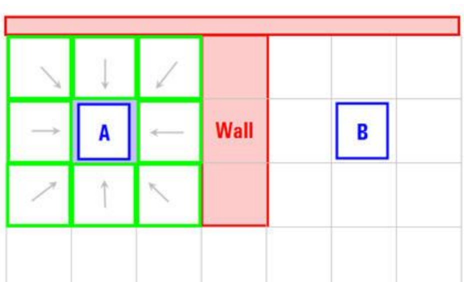



Figure (3)the open list and parent cell in A* algorithm

The path is generated by repeatedly going through the open list and choosing the cell with the lowest F (n) score, g (n) is the movement cost to move from the starting point to the given cell using the path generated to get there,h (n) can be estimated in three heuristic functions:

**A. Manhattan Distance:**

$$h(n) = D * (|n.h - goal.x| + n.y - goal.y|) \quad (16)$$

Where D represents the cost of moving one cell to one of its neighbors, it allows to be moved in four directions only (North, South, East and West).

**B. Diagonal Distance:**

$$h(n) = D * \max(|n.h - goal.x| + |n.y - goal.y|) (17)$$

It allows us to move in 8 directions

**C. Euclidean Distance:**

$$h(n) = D * \sqrt{((n.h - goal.x)^2 + (n.y - goal.y)^2)} (18)$$

In Figure (4) could see the results of the scoring of the first round of cells.

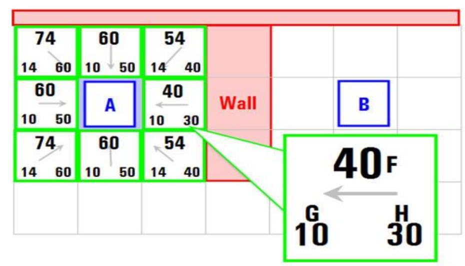



Figure (4) the scoring of F (n), G (n) and H (n)

Next, the lowest f (n) score cell ischosen from the open list and is moved it to the closed list. All of the adjacent cells that are walkable should be added to the open list. Continue to repeat this process until the target cell addedto the closed list. The map would be like Figure (5).

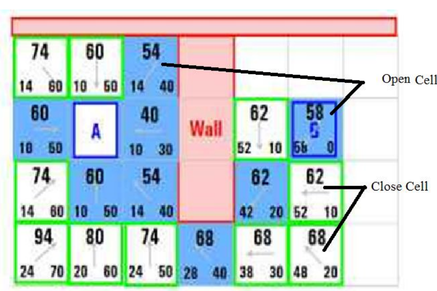



Figure (5) open and close cells calculated by A* algorithm

At the end to determine the path, start from the target cell, and work backwards moving from one cell to its parent, this will finally take back to the starting cell. It should be like the Figure (6). This path is the least cost path from the starting cell (A) to the target cell (B).

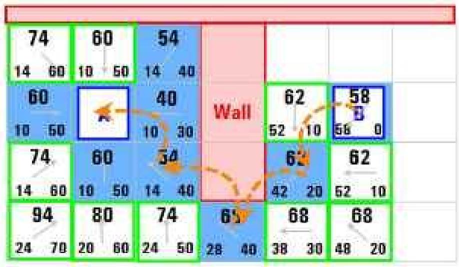



Figure (6) path determined by A* algorithm

## 5. System Design

Robotics is a worldwide interest, it's important in the service of humanity in many applications of various fields. One of most applications in the robotics is the integration with the WSN. The most important application of integrated robot with the WSN is how the robot can determine its location inside the environment with the aid of the WSN and how identifying the path towards the goal with obstacles avoidance, as well as gathering information and applying control for specific task.

The proposal design has consists of three main parts which are robot location, path planning, and service monitoring and control. Figure (7) show illustration of proposal work.

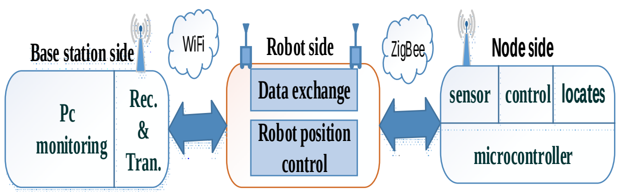



Figure (7)Main block diagram for architecture system

### 5.1 Hardware design

The robot (Rover 5) combined with Arduino Mega as a main microcontroller with each motors driver, encoders, compass, ultrasonic, Wi-Fi shield and XBee module. Figure (8) shows the components areconnected together in the

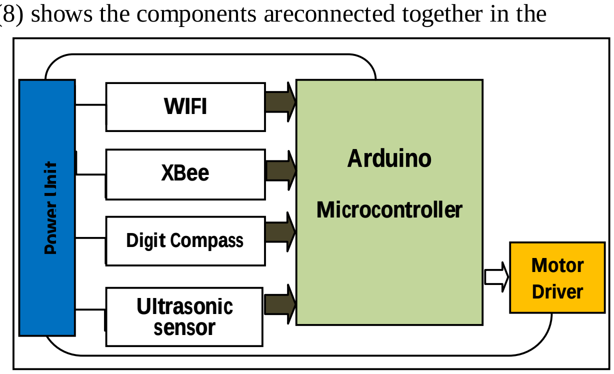



Figure (8) Block diagram of robot components

### 5.2 Procedure of Communication

The Important partis the selection of appropriate equipment to implement the system, where the main part contains a mobile robot which contains achassiswith a microcontroller,an Encoderto measure the motion or position, digital compass to determine the direction of the robot , ultrasonic sensor to avoid obstacles as well as communication modules to provide communication between the robot and the nods (XBee module with its shield to provide ZigBee network) andbetween the robot and the Base Station (PC) (Wi-Fi Shield provides Wi-Fi network ).

The main keys in the mobile robot implementation:

- ➢ In initial MR power the MR establishes the communication with the nods by ZigBee network and with BS by Wi-Fi network.
- ➢ According to the command sent from BS (read sensors or actuator task) the MR must know its location and the goal location(which be the one of the Nodes location) and move toward the goal and run the command (the calculation of localizationis doing in the BS).
- ➢ In the first moment the robot sends (RSSI command) to the nods (ZigBee) and transmits answer data from nodes to BS (Wi-Fi) where it calculates the path planning for MR.
- ➢ BS sends the path as courses (heading, steps) to MR (Wi-Fi), the robot moves according to the courses until it reachesits goal.
- ➢ MR sends a command (read or relay ON/OFF) to the node and the node sends a replay after it runs the command (ZigBee).
- ➢ MR sends
- ➢ node's data (feedback for control task or sensors data for read task) to BS to display in monitor (Wi-Fi).

### 5.3 Procedure of collecting sensors' data

The function of sensor and actor nodes are to collect data from the environment and perform appropriate actions based on this collected data, for that each node has 4 major components:sensor part, processor (Arduino Uno), communication module (Xbee module and its shield) and control part which is represented by a relay for switch ON\OFF task.Figure (9) represents the block diagram of Sensors and actors node

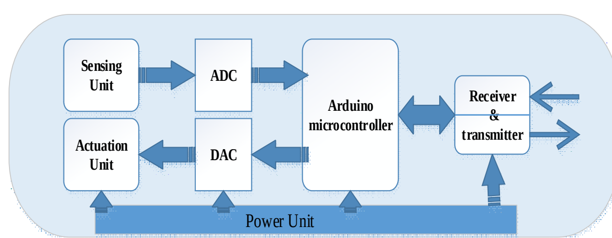



Figure (9) Sensor and Actuatornodeblock diagram

## 6. Nodes Hardware Integration

Each node containsthese devices:

- ➢ The Arduino Uno board used for sensor readers, actuator, and locater nodes. Is represented as a processor part.
- ➢ IS Shied, is a Multi-channel relay/switch shield. It includes 2 channels of relay with internal power supply. Itprovides controlling of voltage from low to high.
- ➢ Xbee module to provide ZigBee communication protocol with robot.

- Sensor devices: light and temperature sensors.

Each node is represented as an End Device ZigBee network and isconnected with MRvia ZigBee network. There are three nodes to satisfy localization algorithm requirements and all nodes send their RSSI value when the MR requeststhem but when each node receives a specific command only the concerned node sends its data.Figure (10) shows the procedure of the nodes.

There are three main purposes for each node:

- Tosatisfy localization algorithm requirements (as node locates) by providing RSSI value (when received data packet hasa command 1).
- To monitor the environment by providing sensor data (one node for temperature sensor and another for lighting intensity(when received data packet has a command 2).
- To control a task in the environment by applying an actuator, one node to actuate fan and another to actuate light as a case study (when received data packet has acommand 3 for ON and 4 for OFF).

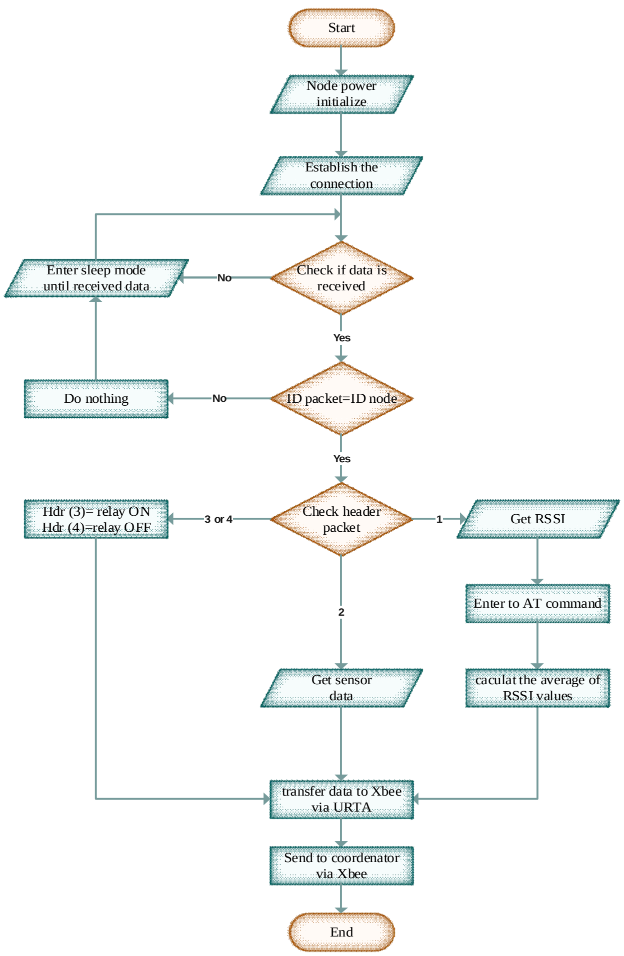



Figure (10) Nodeprocedure flow chart

## 7. Base Station (BS) side

BS (a Personal Computer) representsthe mind for the robot and a monitor interface with the user.In BS all calculations of localization and path planning algorithms are done using MATLAB program and to calculate the location of the MR according to location parameter values ($RSSI_i$ ,n , $d_0$), in addition tocalculating path planning based on A* algorithm according to start location (robot location) and goal location (one nodes location) and sending path courses to MR. In another hand MATLAB is used to display the data and send commands of read sensors or control tasks.

## 8. Robot localization implementation:

The MR was Located with supportedWSNby applying a trilateration algorithm. A pair of the parameters (n, $P_{r(d0)}$) where n is path loss and $P_{r(d0)}$is the received power signal at the distance of 1 meter wascalculated experimentally,

For the indoor location system 2D trilateration is used to locatethe robot, which will be on an XY plane.Figure (11) shows the flow chart of the proposed procedure for MR location algorithm.

Practically proposed procedure of algorithm:

1. Fix the location of the nodes in the map using MATLAB program in addition to the (n, $P_0$) values.
2. When locate button in MATLAB GUIis clicked the order of location is sent to the robot via Wi-Fi.
3. After the robot receives the location command, the robot sends a beacon signal to the nodesin order via ZigBee network to inquire about the existence and it measures the RSSI values.
4. When the node receives the RSSI order, it filter the RSSI values (taking average for several values) then sends the average value of RSSI to the robot.
5. The robot passes the RSSI values to the BS to calculate the distances and the robot's (x,y) location in the MATLAB using equation (14) and (15).
6. The robot's (x,y) location acts as a start point in the map to start the path planning part.

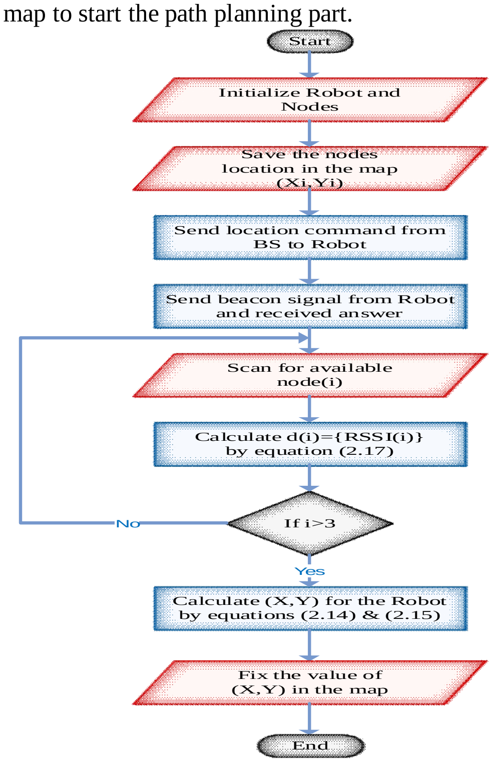



Figure (11) proposed procedure of MR localization algorithm

### 9. General Data Packet transmission for BS and Nodes via Coordinator

The communication paths of data packets are shown in Figure (12),where the start path (i) is used to send orders from BS to theMR. For example in the location state the location order is sent from path (i), Forcommunication path (2i),themobile robot broadcasts a message to all reference nodes (N1, N2, N3). Reference nodes were awakened up and sent back to the robot with (3i). The robot then collects the data packets with its IDs and RSSI values from all reference nodes and then forwards it to the BS through path (4i) to estimate the location coordinates of the robot, and the data display and monitoring in BS.

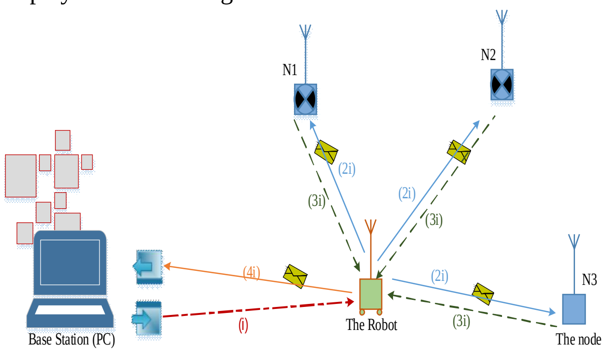



Figure (12) Data packet transmission

### 10. Robot path planning implementation:

Path planning in robots depends on the environment: static or dynamic, known or unknown etc. Global path planning using A* algorithm is investigated in this work. After calculating a robot's location and fixing the coordinates in the map and fixing goal coordinates as shown in figure (13) A* algorithm is applied to determine the path from start to goal location while avoiding static obstacles.

When path planning iscalculated, the MATLAB program sends the required positions as courses have angles and steps (course [heading, steps]) that are required to reach the goal for example as [ course (200,250) ].

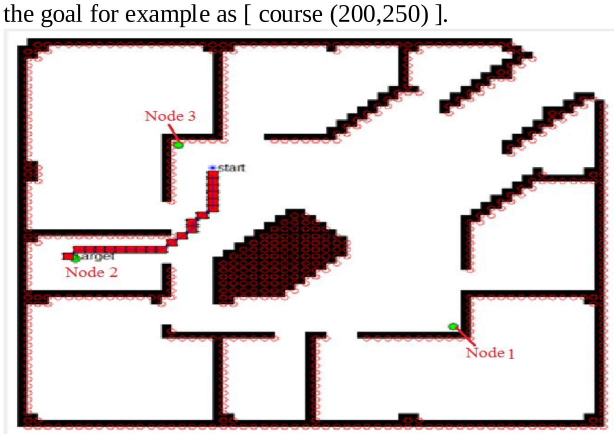



Figure (13)started and goal location with path planning calculated in BS

### 11. System Implementation and Results

There are three phases presented the implementation of proposed system design. The first phase locates the MR based on RSSI of three nodes and examines the robot's localization accuracy. In the second phase, the robot path planning in an environment movesfrom start location(was found at first phase)to the desired destination. The third phase includes tasks for monitoring environment and actuator.

To initialize the proposed system, first,an environmental characterization should becalculated thatlocalization algorithm requires$P_0$ (received signal power at distance of 1 meter) and n (path loss exponent)to be specified for that, the RSSI values are collected from reference nodes at various distances andusing these RSSI values to findsuitableparametersof $P_0$and n. Throughout the experimentation suitablefound to be (46dBm).

In an indoor environment, the power signal strength is not linear as the distance is linearly increasedbecause of indoor shadowing and multi-path fading effectsRSSI signals, for that theyarefluctuating over time and distance. Therefore,it is hard to achievinghigh accuracyin distance and location.So the average for RSSI values are taken to reduce the error and increase the accuracy of the distance and location.

Using Eq. (5) determining distance depends on theRSSI which is shown in table (1):

Table (1) determined distance based on RSSI

| RSSI value (dBm) | Actual distance (m) | Calculated distance d (m) | errors |
|---|---|---|---|
| 51 | 2 | 1.715 | 0.255 |
| 56 | 3 | 2.458 | 0.469 |
| 61 | 4 | 3.854 | -0.026 |
| 60 | 5 | 4.614 | 0.153 |
| 66 | 6 | 6.404 | -0.404 |
| 73 | 7 | 8.378 | -1.377 |

### 12. Practical Location tasking

Location determined tasks were experimented atthe ground floor of the Collegeof Information Engineering with 18×18 square meters of area, the node coordinates fixed at : **A**(5.5,5.5), **B**(5.5,14), **C**(14,14).

The localization method started by clicking on the "locate" button in the designed GUI, when clicking on this button the location is detected, then theorder is sent from the BS to the robot via Wi-Fi networkthen the robot send an order to nodes to give the RSSI values viaZigBee network, next the robot sends back these values into the BS to calculate the distance between the robot and the nodes then findsX and Y values of the robot position.

The efficiency of the mobile robot localization tested by tack more one at various places with an average of 50 packet of RSSI values as shown in the results in table (3).Thetime taken to calculate the location is approximately (4-5) minutes.Figures (15) show some cases of the robot location

Table (3) results of robot localization

| cases | Actual location (MR) (m) | | Measuredlocation (m) | | Error (meter) |
|---|---|---|---|---|---|
| | X | Y | X | Y | |
| C1 | 9 | 14 | 9.86 | 13.55 | 0.97 |
| C2 | 5 | 9 | 5.98 | 7.96 | 1.42 |
| C3 | 10 | 5 | 11.12 | 5.32 | 1.16 |
| C4 | 9 | 8 | 8.50 | 7.85 | 0.52 |
| C5 | 14 | 11 | 13.62 | 12.54 | 1.58 |
| C6 | 15 | 8 | 15.27 | 7.11 | 1.03 |
| C7 | 7 | 2 | 8.95 | 1.47 | 1.97 |

But for some cases the error can be marginally big such as 4-5 meter. This happens when people are present in the environment and this cause huge errors when applying path planning at estimated starting location. In addition, in some cases the error is small but also causes huge interruption in path planning when the estimationis inside the wall or in another neighbor room.

13. **Path planning tasking**

The second part of integrated WSN with robotswhich relates to determining the path of the robot from the starting point until it arrives tothe target point where the actuator nodes areconsidered target points, the path planning is determined through A * algorithm that was applied in MATLAB program and sentthe path as courses that contain the number of steps that the MR must be driven,in addition to the direction.

The area is divided into a grid with block 0.3 * 0.3 mwhere the block size is smaller which means the error decreasesbecause at each block the courses were calculated by A* algorithmand at each course the robot checks its direction using a digital compass andcorrects it's direction according to the direction that it received in the courses. Figure (14) shows the closed celles as calculated by A* algorithm which represent the static obstacles.

Path planning test is implemented on the robot in information engineering college of Al-Nahrain University.

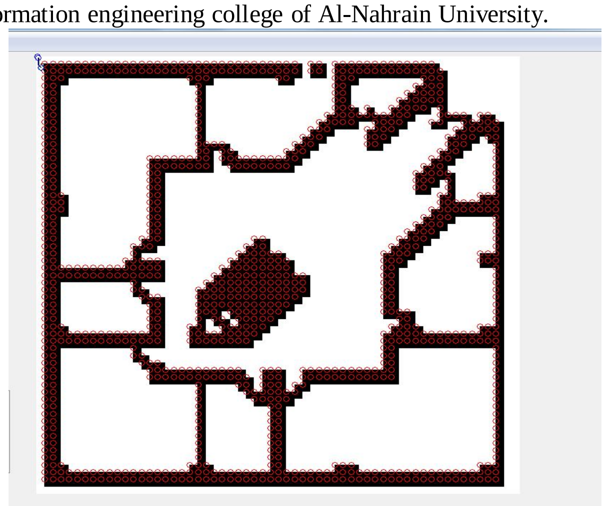


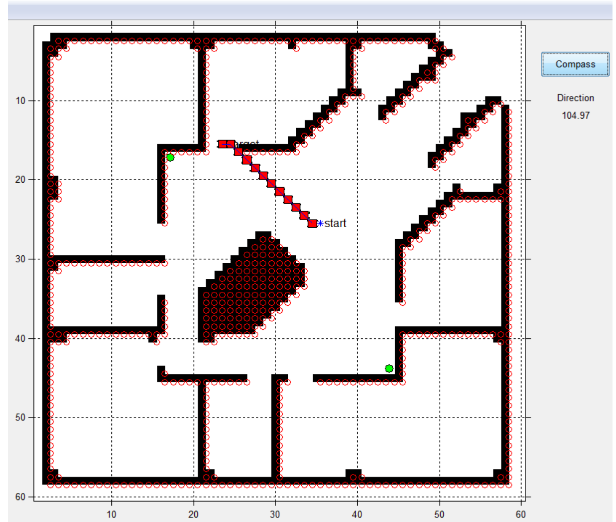
Figure (14) the closed cellswhich calculated by A* algorithm

The table (4) shows the results of robot path planning that illustrates the start location and target location with the error that accrues when the robot reaches the target location. This error appears again because the electronic compass do not always work with good resolution. For the purposes of an experiment the start location of the robot is entered manually and to avoid the errors that are caused by robot localization accuracy.

an error that occurred because of the accuracy of thedigitalcompass and affected by magnetic fields that were generated by electronic devices.

Table (4) shows the results of robot path planning

| Path No. | Start location (x, y) | goal location (x, y) | Distance (m) | No. of courses | Missing Distance (m) |
|---|---|---|---|---|---|
| 1 | (2, 1) | (3.8, 3.5) | 3 | 7 | 0.3 |
| 2 | (12, 8) | (12, 12) | 4 | 13 | 0.4 |
| 3 | (10.5, 7.5) | (7, 4.5) | 3.9 | 12 | 0.7 |
| 4 | (6, 10) | (7, 4.5) | 5.5 | 18 | 1 |




The figure (15) MR calculated path for case (3) from result

14. **Monitoring and actuator experiments**

The third part in WSN applications with the robotics is using the robot to monitor the environment and act a certain task for the environment. The mobile robot is considered as a movement coordinator that combines information from other nodes and sends this information to the BS or it makes acertain task via ZigBee wireless network.

After the robot is near to the target node there are two tasks that the robot can apply: one for reading sensor and second for actuator. For reading sensor, there are temperature sensor (node 1) and light sensor (node 2) and when determining "read" button of Node 1 the robot sends read order to node 1 to read temperature sensor and send back the temperature data to BS to be displayed for the user. Same scenario when selecting "read" button for Node 2 but for light density sensor.

The second task for actuator test which used (ON/OFF) operating for fun and light as a case study. When determining "relay on 1" button of Node 1 the robot send operating command to node 1 to operate the fun (ON) or operate (OFF), the same scenario when selected "relay on 2" button of Node 2 but for lamp.

## 5. CONCLUSIONS

During the implementation of proposed system, a number of conclusions and the following are the most important ones:

•It has been found that the mobile robot successfully finds its location depending on RSSI measurements from 3 nodes with error 1-3 meter, this error showing challenging difficulty to depend on a single algorithm to accurately determining location with

•Path planning algorithm could be used to minimize energy consumption and to depend on the WSN network as a location sensor rather than using Doppler radar or other sophisticated location sensors.

•It has been proven that the mobile robot can be used as a mobile coordinator and collect information from other nodes, in addition it could make specific controls for the environment.

•It has been proventhat can establish heterogeneous network successfully with the mobile robot by establishing ZigBee network between the robot and the nodes and Wi-Fi network between the robot and BS.

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