IMPLEMENTATION OF A REFINERY INSPECTION ROBOT BY USING WI-FI BASED COMMUNICATION AND LOCALIZATION

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Abstract— Oil and gas refineries can be a dangerous environment for human life because of extreme heat, toxic gasses, and unexpected catastrophic failures. A mobile robotic platform is developed to augment on how human operators interact with these environments. This paper focuses on the use of WiFi module for communicating and localizing the robot. Algorithms are developed and tested to minimize the total number of WiFi access points (APs) needed to cover an environment for the localization of robot. The throughput requirements are consideration and it is ensured that every location in the region can be reach by at least k APs. Whenever multiple WiFi APs are close together, there is a potential for interference. A graph-coloring heuristic is used to determine the channel allocation of AP. WiFi fingerprinting based localization is also developed. All the algorithms are implemented and tested in real world scenarios.

Keywords— WIFI Access Points, Localization, Channel Allocation.

I. INTRODUCTION

Oil and gas refineries present challenging environments in which to work can cause health and safety hazards to human life. For instance, in oil and gas industries, during maintenance, inspection, or repair of facilities in a refinery, the workers(humans) may be exposed to extreme high temperatures (+50 C) for an extended period of time, to toxic gasses including methane, Sulfur Dioxide (SO_2) , Nitrogen Oxides (NO_x),Silica (Silicon Dust/Franking Sand**)** and H_2S, and to unexpected catastrophic failures. One way of removing human exposure from these types of situations is to instrument an oil refinery with a wireless sensor network [1], which would attach a wireless sensor on every gauge and valve. Unfortunately, this approach will be expensive and labor-intensive. Without maintenance wireless sensors are failure prone. Hence, maintenance of the network and reliability of the data to be collected from the network are extremely challenging. We, therefore, choose a different approach that aims to augment how the human operators interface with the physical world. A mobile robotic platform is analogous to a physical human, it can move through an environment autonomously while sensing its surroundings with an array of sensors. Further constraints are applied while introducing physical systems into an oil and gas environment. All the devices deployed must meet the specified standards set by the industry. A detailed explanation of these standards applied to a mobile robot is given in [2].

In our interdisciplinary project we aim to automate oil and gas processes using a mobile robot. A mobile robot capable of both tele-operation and autonomous control. The robot is capable of path planning, tracking, avoiding obstacle and auto inspection. Communication between robot and the control station occurs over WiFi. For more details on the design of the system, interested readers may refer to our paper [3].

Fig. 1. A refinery inspection mobile robot.

The robot is equipped with sensors for monitoring parameters such as increase in temperature, leakage of a harmful gas and for detecting the level of humidity.

Methods had been proposed for the design of an autonomous robot for refineries but the use of wifi communication and localization was not done [2], [4].

In this paper, we focus on use of WiFi ,while using a mobile robotic platform in an oil refinery. Specifically, we have considered the two problems: WiFi communication and localization. Firstly, while the robot is mobile and autonomous, an operator must be able to communicate with it so as to receive sensor data collected from the refinery as well as send it various commands that manipulate the robot or the arm, request specific information, or directs it to move in a certain way. most of refineries lack a wireless network infrastructure. Therefore, the WiFi access points (APs) must be strategically placed throughout an environment to minimize the number of AP's required to achieve full coverage needed for communication. Secondly for a robotic system to work autonomously, it must have an accurate understanding of its own location. Generally an oil refinery often is comprised of tall structures made of steel, so GPS may not always be available. WiFi localization becomes essential here. It complements localization methods using other sensors which are built in a robotic system.

II. RELATED WORK

In this section we discuss work done in providing wireless communication in an oil refinery. Previous work [1] has proposed the use of wireless sensor networks (WSNs) for remote monitoring to detect leaks of harmful by-products of oil refineries. WSNs are capable of being equipped with an array of sensors; the major limitation of WSNs is battery life as well as their failure prone nature. A robotic mobile platform is developed [4], [2] to provide reliable and secure two-way wireless communication at a lower cost and less maintenance than a WSN. In [4], localization is performed through Simultaneous Localization and Mapping (SLAM). In [2], localization is performed through inertial navigation system (INS) and infrared sensor (IR) with reflective tapes to characterize specific shaped objects. There Communication was established through WiFi to operator control station and through Bluetooth to a nearby handheld device. While both systems had used WiFi for communication and localization, none of them had provided details.

III. WIFI COMMUNICATION

Two kinds of data are communicated between the robot and the control station. The Control information has been given the highest priority as it informs the robot how to act accordingly and react, i.e.: if it is direct movement commands through tele-operation or more usual commands such as informing the robot of a new destination for inspection.
Generally an oil refinery does not have WiFi infrastructure available; here we need to determine the minimum number of WiFi APs needed and where to be deployed so that the entire region is covered. When multiple APs are located close to each other, need is to determine how different channels could be used by each AP to avoid interference. The following subsections describe the algorithms used to solve these issues.

A. AP Placement (localization)

While placing APs in an given environment, the throughput that would supports both control information and sensor information must be maintained so that communication at every location is ensured. For this every time the robot should be in communication range of at least one AP.This is called as single coverage.
Therefore, the single-coverage WiFi AP placement issue is for determining the minimum number of APs and their locations so that each and every location in the environment can reach at least one AP for a given region and throughput needs specified by the application.
The algorithm considers every location during each iteration by mapping the coverage of the APs already chosen and for the the propagation of the new AP. The signal of the new AP is propagated till it reaches the cut-off distance or an object-node is encountered. The best AP for that particular iteration is then chosen as the one which would provides the minimum average distance between all uncovered nodes. That AP is thus added to the list of best APs. Once all nodes had been covered, the list of best AP locations is found.

B. Channel Allocation

To ensure that every time the robot collects information from different parts of refinery, it is under the communication coverage due to APs,a approach of k-coverage can be implemented. In k-coverage for better reliability and localization APs are placed in such a way that at a time the robot will be under the communication coverage provided by at least k- APs.
But if more APs are deployed the may be issues of interference. So, to avoid that the allocation of channels for each AP is crucial.

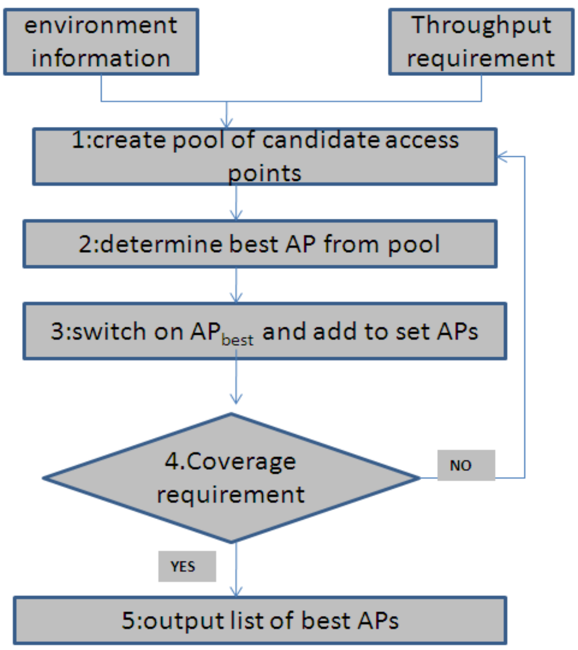

Fig. 2. Algorithm flow of access point placement

IV.BLOCK DIAGRAM OF ROBOT SECTION

i.POWER SUPPLY- IC LM7805 is used for providing a constant power of +5V.
ii.LM35-this is temperature sensor. It has 3 pins .pin 1 is for power and 2 is grouned.pin 3 is for taking the output.

iii.MQ-2-this the for detecting the leakage of gases. The mesh is made up of indium tin oxide. The sensitivity can be varied by means of a potentiometer. It has got3pins.pin 1 for supply, pin 2is grounded and pin 3 is for taking the output .The safety levels are used as the reference voltage levels. If due to the leakage the output voltage is more than the reference voltage then commands for sounding been is made by the microcontroller.
iv.HSM-20-it the humidity sensor it has got two pins .pin 1for supply of 5v and pin 2 gives the comparator output. In the comparator the reference level is assumed to be allowable humidity level without compromising on safety of the plant.
v. RASPBERRY PI-the is the controlling section. The device gives commands to the robot and a display comment based upon the measured parameters levels and accordingly sounds different kinds of beep.
vi. MOTOR DRIVERS-the drivers have the codes for making the robot to follow a specific straight path ,to avoid obstacles ,to make turns etc. is responsible for the moment of robot. If the robot has to make a right turn then the right front wheel has to move to a degree. Similarly for the left rotation.
Vii. WIFI-wireless fidelity is used as the communication module. So that the information is transmitted by robot, sensors and the control section

V.WORKING OF THE ROBOT

The robot control unit is built around ARM 11 device, by using a RASPBERRY PI. The robot is equipped with sensors to sense rise in temperature, sense the leakage of a harmful gases and for detecting the humidity levels. The control unit records the data given by various sensors and give commands to the robot for further inspection. Whenever temperature is more than the safety level preprogrammed at microcontroller, microcontroller will decode a beep alarms through controller once the measured humidity value is more than that of safety level preprogrammed at microcontroller; it decodes different type of beep alarms. Similarly when gas concentration crosses the level of safety, microcontroller decodes siren alarms. Different sensors values are displayed in the LCD of refinery workers section. In the control station the information is received by WIFI and the status of the sensors is monitored with the laptops and required action is performed by sending signals to Microcontroller.

CONCLUSIONS

For a robot to autonomously navigate in an Oil and gas refinery, it must be able to communicate with the control room and also be able to localize itself. In this work we have define the kinds of communication required to deploy an autonomous robot. We have studied Wi-Fi signal propagation characteristics and applied the findings to determine WiFi AP placement. We have also assign channels to interfering APs.
The robot makes use of different sensors to monitor the various parameters so that the safety is maintained.

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