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IoT based remote railway signaling system

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ABSTRACT

Cancellation and delay of trains is a very common problem that the Railways faces during heavy fog in winters especially in Northern Regions of India. One of the key reasons for the delay is the inability of the engine drivers to see the light signals from a faraway distance. The solution aims to provide a feasible way to overcome this problem by implementing an IoT based remote railway signaling system which is highly reliable, cost efficient, scalable, and robust for practical Indian conditions. The system is divided into three phases. In the first phase, wireless transmitters (NRF modules) are installed in the signal posts along with corresponding receivers in the train engines. Therefore, when the signal turns red or green, the wireless transmitter will send the signal to the train on that track approaching towards the signal. The train will receive the signal and a red or green bulb will be switched on in the engine control dashboard inside the driver's cabin itself. The driver will thus know that the status of the signal ahead without depending on the visibility of distant light signals. The second phase couples the signal posts with a GPRS module (SIM900A) to provide internet connectivity and a connection to the AWS cloud through an IoT technology stack. This will allow Railways to set up centralized control rooms and control the signals in real time remotely. The third phase is a proposal to increase the efficiency of the system by connecting multiple signal posts to one GPRS gateway module through an ad-hoc network through LoRa technology. This phase is just a proposal for future work. The system aims to be designed to suit Indian conditions. Hence it has been made cost efficient by using only minimal components while being easy to use and scalable so that it can be implemented on a national level.

Keywords— *IoT, Railway Signaling System*

1. INTRODUCTION

Designing and implement an IoT based remote railway signaling system which is highly reliable, very cost efficient, scalable, and robust for practical Indian conditions. Indian Railways is one of the largest employers in the world. It also serves as one of the key contributors to the GDP of India directly and indirectly. It is the fourth largest railway network in the world comprising of 119,630 Km. of total track. Indian Railways carries about 8.107 billion passengers annually i.e. more than 22 million passengers a day and 1.101 billion tons of freight annually. Such a large system also requires the use of most sophisticated systems being operated in the most extreme conditions with a guarantee of high reliability and optimal costs. But the concept of Internet of Things (IoT) is still an untouched territory in the stack of technologies being used by the Railways. Although IoT has demonstrated itself of being a very potentially beneficial addition to the Railways, it is yet to be applied on a large scale mainly due to conflict of interests, priorities and cost constraints. Also, Railways has been very pessimistic on estimating the return on investment (ROI) on upgrading the system.

2. LITERATURE REVIEW

Cancellation and delay of trains is a very common problem that the Railways faces during heavy fog in winters especially in Northern Regions of India. One of the key reasons for the delay is the inability of the engine drivers to see the light signals from a faraway distance. With Railways looking forward to innovations to solve this major problem and its intention to invest in upgrading the system, there is a clear feasible opportunity to develop a scalable system which the railways can widely use to solve the problem. The system needs to be designed in a way such that the up-gradation process can be used in the future improvisations. With the advent of cheaper electronics, highly reliable wireless technology, and widely available & well tested IoT stacks, it is possible to develop a viable solution and apply it for widespread mass application in the Railways. We have developed a system keeping these points in view to solve this problem.

3. BASIC CONCEPT AND BLOCK DIAGRAM

The solution aims to provide a feasible way to overcome the problem of poor visibility of signal by providing an alternative such that the driver can get the signal status inside his cabin dashboard itself. The solution can be divided into three phases as discussed below:

Phase-1

In the first phase of design, the solution works by installing small wireless transmitters along with the light signal posts. The wireless transmitters can be easily coupled with the train lights

in a way that when the red-light glows, a 'red' status is broadcasted by the transmitter and similarly when the green light glows, a 'green' status is broadcasted by the transmitter. The train engines are installed with corresponding receiver systems. Therefore, the status of the signal (green or red) is always being broadcasted by a wireless transmitter to any near-by approaching train. The train will receive the wireless signal at a suitable distance from the signal posts beforehand itself and the corresponding red or green bulb will be switched on in the engine control dashboard inside the driver's cabin. The driver will thus know the status of the signal ahead take required measures if needed. The driver does not have to look for the signal outside as he will get the status inside his cabin itself. The system, thus, reduces dependency of the driver on visibility of distant light signals which might not be visible in foggy winters as he can view the status of signal inside his cabin itself. The system can be installed over the same signal post along with the on which lights are installed. The power requirements of the system can also be very easily met in this way, freeing the system from any battery dependencies. The proposed idea is simple, cheap and can stop delay of trains due to fog by an enormous scale. Moreover, the system also adds an additional layer of safety to the system in cases where lights fail or get damaged.

Figure 1: Traditional Setup in normal condition

Figure 2: Traditional Setup in fog (Signal post is not visible to the driver)

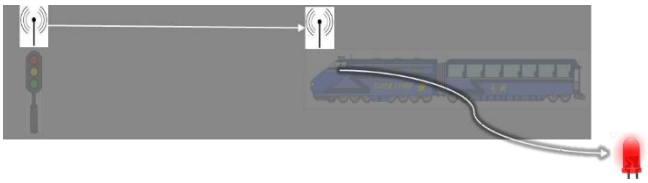


Figure 3: Proposed Setup where Transmitter sends signal to receiver in engine and corresponding light glows inside driver's cabin itself

Phase-2

The second phase builds itself on the first phase and is a step towards automatizing the signal post controlling system through the advent of IoT technology stack. In the second phase, the light signal posts are additionally installed with GPRS module. The signal post can now easily connect to the internet and communicate with a server on cloud. The server will be coupled with a database that stores the data about the signal posts and their current real time status. The signal posts will be in real time synchronization with the database and its status. Since the system is completely connected to the internet, the signals can now be easily controlled remotely from any location by authorized personnel with the correct credentials. This allows Railways to set up centralized control rooms rather than distributed ones that could help reduce costs. Also, since the system is controlled wirelessly through GPRS, costs for maintenance of wired signal connections would nullify.

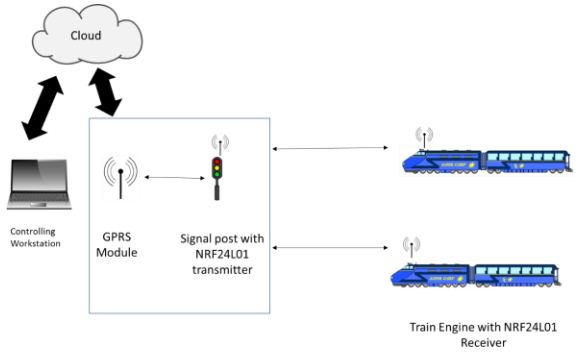


Figure 4: Schematic Diagram with Phase II implementation

Phase-3

The phase III of the project is a proposal for increasing the efficiency of phase II. The cost for maintaining a GPRS connection with the required QoS for each signal post can be very high. Moreover, since the signal post has to only send a few bits of data through the connection, bandwidth will always be under consumed. To overcome this problem, one GPRS connection can be used to serve multiple signal posts. This can be done by connecting the signal posts to each other by an ad-hoc network in a tree topology with its root node connected to the server through internet. This root node will act as a concentrator/gateway node for all the other nodes. LORA, a long range reliable transceiver is proposed for use in this case for communication between concentrator and the signal post. It can be used to set up ad-hoc networks up to a radius of 30 kilo meters and can serve thousands of nodes at a time. Since LoRa gateways are not available in open market in surplus, it was not possible for the group to implement this phase due to lack of resources.

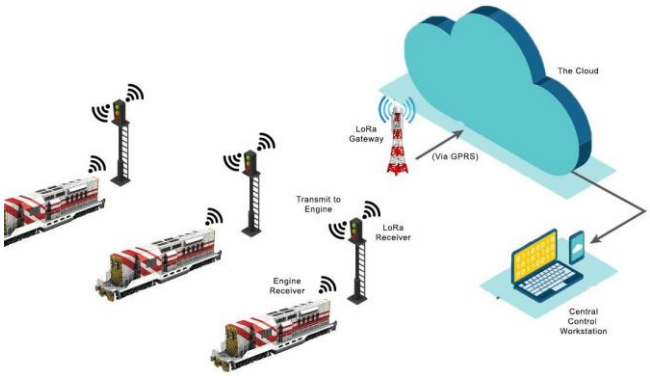


Figure 5: Schematic Model of Proposed System with Phase III implementation

4. TECHNICAL SPECIFICATION AND DESIGN APPROACH

Various hardware was tried and tested for meeting the requirements of the project. They were evaluated on the basis of performance, cost, reliability and suitability. The following hardware modules were chosen for the final project.

4.1 Arduino Uno

The UNO board is the first in the series of USB Arduino boards which is easy to work with and best board to start with electronics and coding. It is very robust micro controller with 14 digital I/O pins, 6 analog inputs and 16 MHz quartz crystal. It has everything needed to support a micro controller, just needed to plug USB cable. The Arduino board is used for connecting and controlling all the other peripherals of the system. It is setup in the signal post as well as the train engine. Arduino interfaces with GPRS module, radio transmitter and the traditional light system on the signal post side. On the receiver side, it controls the radio receiver and the lights on the dashboard.

4.2 Arduino Mega

The Arduino MEGA 2560 is specially designed for projects with more complexity. It has 54 digital I/O pins and 16 analog input pins which helps us building more complex projects. It has everything needed to support the micro controller, only thing needed is to connect it to computer with a USB provided and a power source. The Arduino Mega can be interchangeably used with Arduino Uno when more pins are required for connecting additional peripherals and add-ons to the system.

4.3 NRF24L01+

The nRF24L01+ module is an ultra-low power (ULP) RF transceiver module for the ISM (Industrial, Scientific and Medical) band using the 2.4GHz frequency. It is marketed by Nordic Semiconductors. With very low power requirement, advanced power management, and a 1.9 to 3.6V supply range, the nRF24L01+ has been widely applied in academic and industrial projects.

4.4 SIM900A

SIM900A is a module that has been used in the project to connect to the internet. It uses internal TCP/IP stack to connect with internet via GPRS. It works on two frequencies i.e. 900/1800 MHz. It is controlled by AT commands to connect and perform various operations.

4.5 DRF1278F

DRF1278F is a part of family of cheap RF front-end transceiver module using the SX1278 module from Semtech. It keeps the advantages of the original module from Semtech but simplifies the circuit design. The high sensitivity of LoRa modulation and high-power output make the module suitable for long range, low data rate applications.

4.6 LoRa Module

LoRa stands for Long Range Radio. It is a wireless communication technology mainly aimed for M2M communication and IoT networks. LoRa uses a two-way wireless spread spectrum data modulation approach that has been developed & trademarked by a US electronics firm named Semtech. LoRa is proprietary. It tends to use a simple CSS (Chirp Spread Spectrum) pulsed FM "sweeping frequency" modulation rather than more widely used DSSS (Direct Sequence Spread Spectrum) or FHSS (Frequency Hopping Spread Spectrum). Claimed ranges are typically 10 times that of regular UHF wireless data systems.

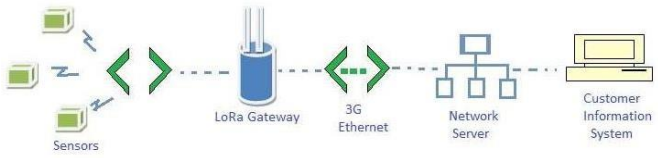
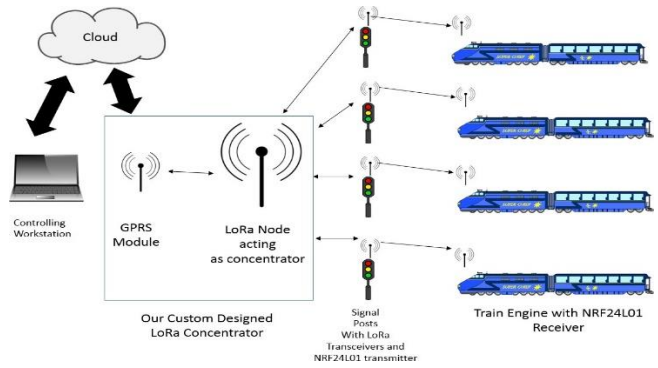


Figure 6: Basic architecture of LoRa network



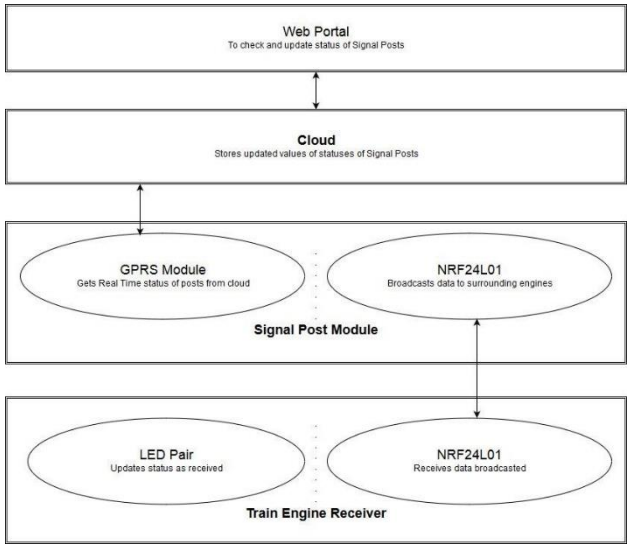


Figure 7: System Architecture with Phase III

The data flow graph for the system with Phase II implementation is as follows:

4.7 Software Specifications

(a) Web portal: The web portal consists of a web application with an interface to search and control the status of signal posts across the system. A user can login to the system with the correct User ID and password. Different users can be given access to control only certain signals as per the requirement.

(b) Cloud: The cloud consists of the database and server to host the web application. The project uses Amazon Web Services (AWS) cloud for the implementation purposes. It also serves the requests by different signal posts about their real time status.

(c) GPRS Module: The GPRS module sends an HTTP request to the server with the signal post ID. It gets the HTTP response with the status as a result. The GPRS module then forwards this data to the NRF module through the Arduino.

(d) NRF transmitter Module: The NRF module receives the status from the GPRS module and starts broadcasting it to the surroundings. The data flow graph for the system with Phase III implementation is as follows.

4.8 Circuit Diagrams

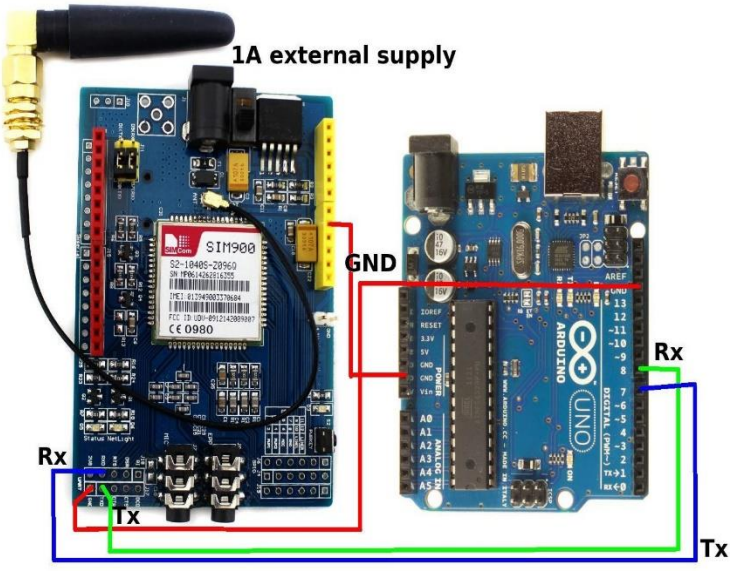


Figure 8: Circuit connection of SIM900A with Arduino

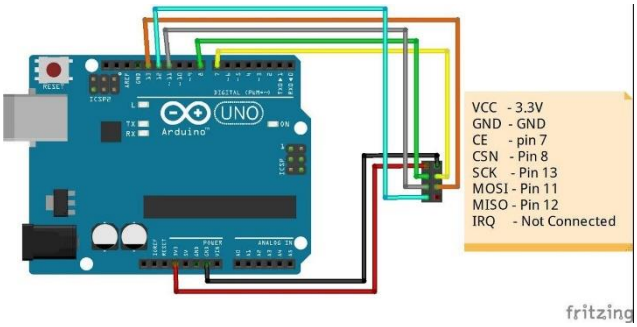
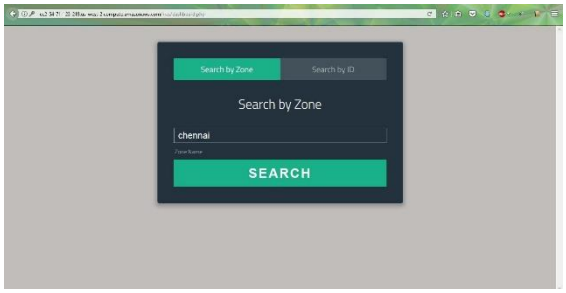
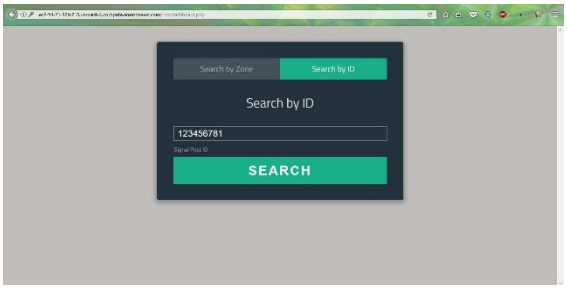
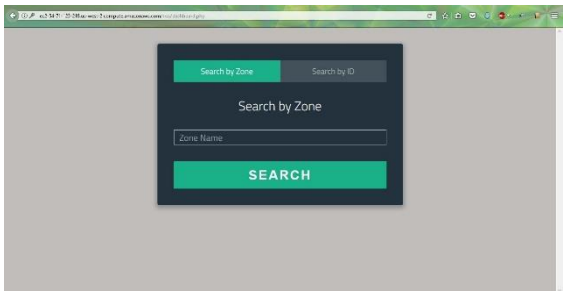


Figure 9: Circuit connection of Arduino and NRF module







5. PROJECT WEBSITE DEMONSTRATION

(a) The user enters the credentials as username and password.
(b) The user is redirected to a dashboard where the user can search for signal posts by either a region or a directly by signal post ID.
(c) The user can then enter the name of the region.
(d) Or the user can enter the name of the signal post ID.
(e) If the user is searching for signal posts by ID, the signal post along with the current status is listed.
(f) The user can toggle the button to change the status of the signal.
(g) If the user searches for signals by ID, all the signals will be listed along with their current statuses. The user can similarly toggle the buttons to change their status.

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