ADAPTIVE WIRELESS SENSOR NETWORKS FOR CONDITION MONITORING IN RAILWAY

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Abstract: The main contribution of this paper is to propose a prototype design of hardware and software architecture for a railway condition monitoring system. In the range of recent years, sensing technologies has expanded widely, whereas sensor devices have become cheaper. This led to rapid expansion in condition monitoring of systems, structures, vehicles, and machinery that are using sensors. Wireless sensor networks can now be used for monitoring the railway infrastructure such as bridges, rail tracks, track beds, and many track equipment along with vehicle health monitoring such as chassis, bogies, wheels and wagons. The wireless sensors network technology for monitoring in the railway industry is used for analyzing systems, structures, vehicles, and machinery. Main focus is on practical engineering solutions, identification of sensor configurations and network topologies.

Index Terms: Asset management, condition monitoring, decision support systems, event detection, maintenance engineering, preventive maintenance, railway engineering, wireless sensor networks (WSNs).

I. INTRODUCTION

Experts estimate that the railway industry will receive US$300 billion worth of global investment for development, upgrading, and expansion over the five years from 2009. Ollier noted that effective management of rail infrastructure will be vital to this development, upgrading, and expansion, particularly if coupled with a move to intelligent infrastructure. A key part of the management will be condition monitoring. Condition monitoring detects and identifies deterioration in structures and infrastructure before the deterioration causes a failure or prevents rail operations. In simple condition monitoring, sensors monitor the condition of a structure or machinery. If the sensor readings reach a predetermined limit or fault condition, then an alarm is activated. However, this simplistic approach may lead to a large number of false alarms and missed failures. It only provides local analysis but does not take advantage of the superior capabilities when the sensors are networked and their data processed collectively. Integrated data processing allows an overall picture of an asset's condition to be achieved and overall condition trends to be determined.

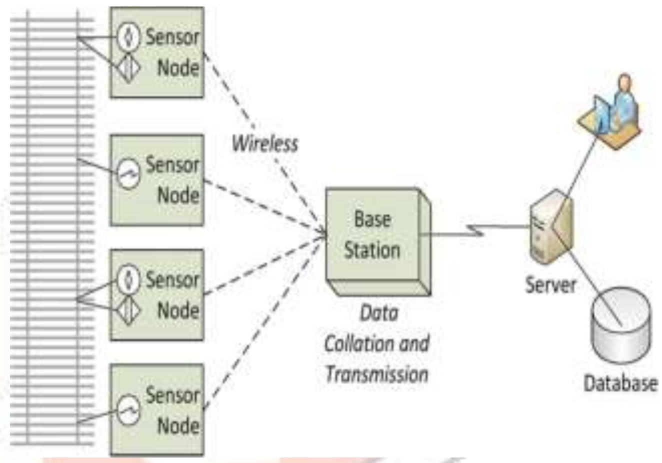

Fig.1. Figure shows a typical WSN setup for railway condition monitoring.

Sensor devices are mounted on boards attached to the object being monitored; examples include track, bridges, or train mechanics. One or more sensors are mounted on a sensor board (node). The sensor nodes communicate with the base station using a wireless transmission protocol; examples include Bluetooth and Wi-Fi. The base station collates data and transmits it to the control center server possibly through satellite or GPRS. There are variations on this setup. In some systems, the sensor nodes may communicate directly with the server rather than via the base station. In other systems, the user accesses the data directly via the base station.

In recent years, networking technologies such as wireless communication and mobile ad hocnetworking coupled with the technology to integrate devices have rapidly developed. The new technologies allow vast numbers of distributed sensors to be networked to constantly monitor machines, systems, and environments. Wireless sensor networks (WSNs) are wireless networks of spatially distributed and autonomous devices. They use sensors to cooperatively monitor infrastructure, structures, and machinery. A typical WSN for railway applications is shown in Fig. 1. Each sensor node generally has a radio transceiver, a small microcontroller, and an energy source, usually a battery. WSNs and data analytics allow the railways to turn data into intelligence. They provide decision support through continuous real-time data capture and analysis to identify faults. The data from distributed systems such as sensor networks are constantly monitored using classification prediction or anomaly detection to determine the current and future status of the distributed network. Lopez-Higuera et al. developed a staircase of structural health monitoring, where the higher the level, the higher the complexity and functionality. The simplest Level 1 systems detect the presence of damage without locating it, whereas Level 2 provides location information. A Level 3 system is able to grade the degree of damage and a Level 4 system can estimate the consequences of the damage and remaining service life. Finally, a Level 5 system will comprise complex hardware, custom algorithms and software to allow the diagnosis and/or the prognosis and even to recommend the solution to a problem.

WSN monitoring provides continuous and near real-time data acquisition and autonomous data acquisition (no supervision is required); increased frequency of monitoring compared with manual inspection; improved data accessibility, data management, and data use compared with non-networked systems as all data can be collected and processed centrally; the ability to combine data from a wide variety of sensors; intelligent analysis of data to "predict and prevent" events using intelligent algorithms; the ability to turn data into information about the status of important structures, infrastructure and machinery; and, a global data view that allows trending information to be determined where degradation is happening slowly over a relatively long period of time.

II. BLOCK DIAGRAM AND MODULES DESCRIPTION

2.1 Block Diagram

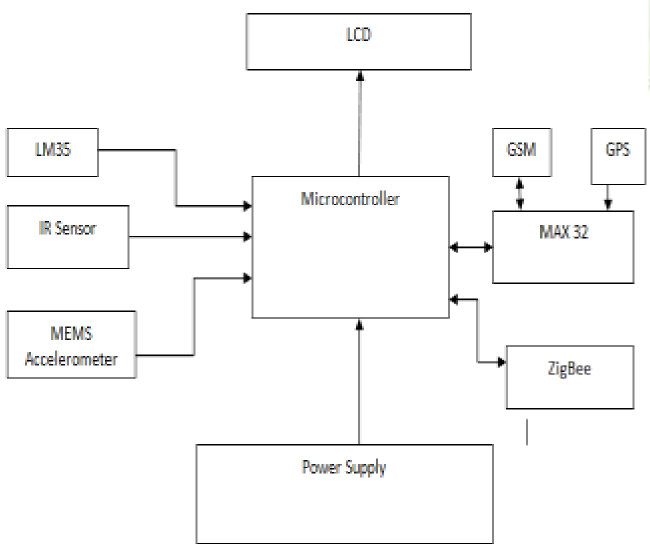

Fig.2. Block Diagram

Brief Description: The Hardware architecture includes a comprehensive set of sensors and power for condtion monitoring in Railway industry.The sensors used are lm35 , IR sensor and MEMS accelerometer sense the conditions of train .if any change in given conditions occur then senors activate the micro controller then microcontroller will communicate with the zigbee and GSM modules in order to send information to near by station are for long distances.Through GPS location will be traced.

2.2 Hardware Requirements

1. Regulated Power Supply
2. Microcontroller (ARM7)
3. Liquid Crystal Display (LCD)
4. Zigbee Module
5. MEMS Accelerometer
6. GSM, GPS Modules, etc.

1. Regulated Power Supply

The power supplies are designed to convert high voltage AC mains electricity to a suitable low voltage supply for electronic circuits and other devices. A power supply can by broken down into a series of blocks, each of which performs a particular function. A DC power supply which maintains the output voltage constant irrespective of AC mains fluctuations or load variations is known as "Regulated DC Power Supply". The 5V regulated power supply system as shown below:

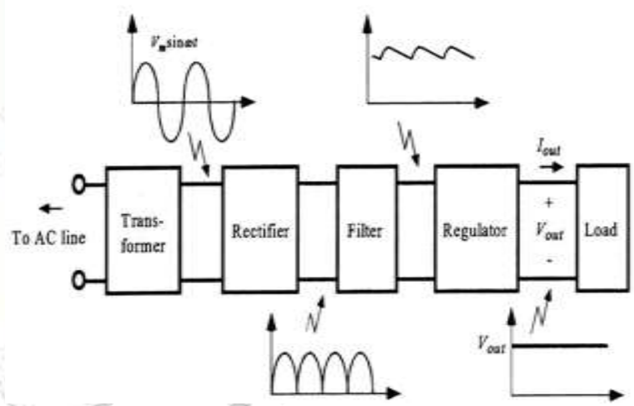

Fig.3. Components of a typical linear power supply

2. ARM LPC2148 Microcontroller

The LPC2148 microcontroller is based on a 32/16 bit ARM7TDMI-S CPU with real-time emulation and embedded trace support, that combines the microcontroller with embedded high speed flash memory ranging from 32 kB to 512 kB. A 128-bit wide memory interface and unique accelerator architecture enable 32-bit code execution at the maximum clock rate. For critical code size applications, the alternative 16-bit Thumb mode reduces code by more than 30 % with minimal performance penalty.

Due to their tiny size and low power consumption, LPC21418 is ideal for applications where miniaturization is a key requirement, such as access control and point-of-sale. A blend of serial communications interfaces ranging from a USB 2.0 Full Speed device, multiple UARTS, SPI, SSP to I2Cs and on-chip SRAM of 8 kB up to 40 kB, make these devices very well suited for communication gateways and protocol converters, soft modems, voice recognition and low end imaging, providing both large buffer size and high processing power. Various 32-bit timers, single or dual 10-bit ADC(s), 10-bit DAC, PWM channels and 45 fast GPIO lines with up to nine edge or level sensitive external interrupt pins make these microcontrollers particularly suitable for industrial control and medical applications.

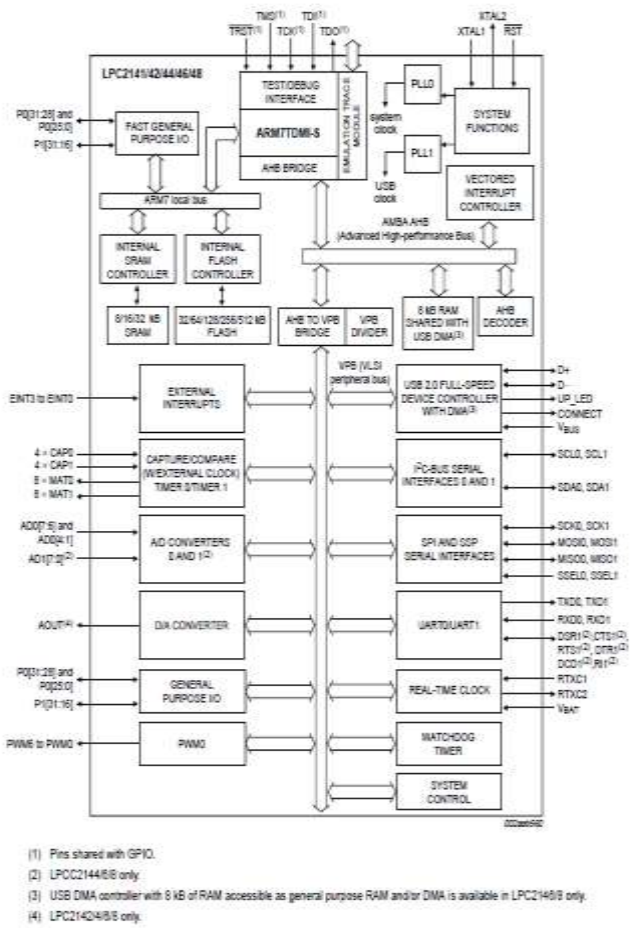

Fig.4. Block diagram of ARM LPC2148

Features:

- 16/32-bit ARM7TDMI-S microcontroller in a tiny LQFP64 package.
- 8 to 40 kB of on-chip static RAM and 32 to 512 kB of on-chip flash program memory.128-bit wide interface/accelerator enables high speed 60 MHz operation.
- In-System/In-Application Programming (ISP/IAP) via on-chip boot-loader software. Single flash sector or full chip erase in 400 ms and programming of 256 bytes in 1 ms.
- Embedded ICE RT and Embedded Trace interfaces offer real-time debugging with the on-chip Real Monitor software and high speed tracing of instruction execution.
- USB 2.0 Full Speed Compliant Device Controller with 2 kB of endpoint RAM. In addition, the LPC2146/8 provide 8 kB of on-chip RAM accessible to USB by DMA.
- One or two (LPC2141/2 vs. LPC2144/6/8) 10-bit A/D converters provide a total of 6/14 analog inputs, with conversion times as low as 2.44 µs per channel.
- Single 10-bit D/A converter provide variable analog output.
- Two 32-bit timers/external event counters (with four capture and four compare channels each), PWM unit (six outputs) and watchdog.
- Low power real-time clock with independent power and dedicated 32 kHz clock input.
- Multiple serial interfaces including two UARTs (16C550), two Fast I2C-bus (400 Kbit/s), SPI and SSP with buffering and variable data length capabilities.

Architectural Overview:

The LPC2148 consists of an ARM7TDMI-S CPU with emulation support, the ARM7 Local Bus for interface to on-chip memory controllers, the AMBA Advanced High-performance Bus (AHB) for interface to the interrupt controller, and the VLSI Peripheral Bus (VPB, a compatible superset of ARM’s AMBA Advanced Peripheral Bus) for connection to on-chip peripheral functions. The LPC2148 configures the ARM7TDMI-S processor in little-endian byte order. AHB peripherals are allocated a 2 megabyte range of addresses at the very top of the 4 gigabyte ARM memory space. Each AHB peripheral is allocated a 16 kB address space within the AHB address space. LPC2148 peripheral functions (other than the interrupt controller) are connected to the VPB bus. The AHB to VPB bridge interfaces the VPB bus to the AHB bus. VPB peripherals are also allocated a 2 megabyte range of addresses, beginning at the 3.5 gigabyte address point. Each VPB peripheral is allocated a 16 kB address space within the VPB address space. The connection of on-chip peripherals to device pins is controlled by a Pin Connect Block. This must be configured by software to fit specific application requirements for the use of peripheral functions and pins.

3. Liquid Crystal Display (LCD)

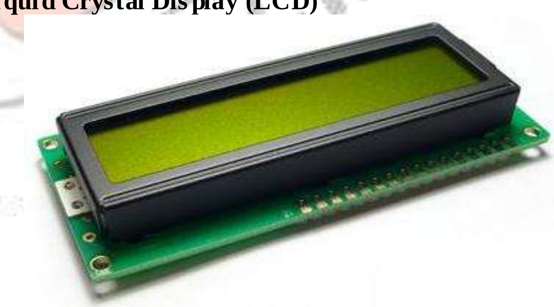

Fig.5. Liquid Crystal Display

Liquid crystal displays (LCD s) have materials which combine the properties of both liquids and crystals. Rather than having a melting point, they have a temperature range within which the molecules are almost as mobile as they would be in a liquid, but are grouped together in an ordered form similar to a crystal. An LCD consists of two glass panels, with the liquid crystal material sand witched in between them. The inner surface of the glass plates are coated with transparent electrodes which define the character, symbols or patterns to be displayed polymeric layers are present in between the electrodes and the liquid crystal, which makes the liquid crystal molecules to maintain a defined orientation angle. One each polarizeris pasted outside the two glass panels. These polarizers would rotate the light rays passing through them to a definite angle, in a particular direction. When the LCD is in the off state, light rays are rotated by the two polarizers and the liquid crystal, such that the light rays come out of the LCD without any orientation, and hence the LCD appears transparent. When sufficient voltage is applied to the electrodes, the liquid crystal molecules would be aligned in a specific direction. The light rays passing through the LCD would be rotated by the polarizers, which would result in activating / highlighting the desired characters. The LCD's are lightweight with only a few millimeters thickness. Since the LCD's consume less power, they are compatible with low power electronic circuits, and can be powered for long durations.

The LCD s won't generate light and so light is needed to read the display. By using backlighting, reading is possible in the dark. The LCD's have long life and a wide operating temperature range. Changing the display size or the layout size is relatively simple which makes the LCD's more customer friendly. The LCD s used exclusively in watches, calculators and measuring instruments is the simple seven-segment displays, having a limited amount of numeric data. The recent advances in technology have resulted in better legibility, more information displaying capability and a wider temperature range. These have resulted in the LCD s being extensively used in telecommunications and entertainment electronics. The LCD s has even started replacing the cathode ray tubes (CRTs) used for the display of text and graphics, and also in small TV applications.

4. Zigbee Module

The explosion in wireless technology has seen the emergence of many standards, especially in the industrial, scientific and medical (ISM) radio band. There have been a multitude of proprietary protocols for control applications, which bottlenecked interfacing. Need for a widely accepted standard for communication between sensors in low data rate wireless networks was felt. As an answer to this dilemma, many companies forged an alliance to create a standard which would be accepted worldwide. It was this Zigbee Alliance that created **Zigbee**. Bluetooth and Wi-Fi should not be confused with Zibgee. Both Bluetooth and Wi-Fi have been developed for communication of large amount of data with complex structure like the media files, software etc. Zigbee on the other hand has been developed looking into the needs of communication of data with simple structure like the data from the sensors.

Fig.6. Zigbee Module.

Zigbee is a low power spin off of WiFi. It is a specification for small, low power radios based on IEEE 802.15.4 – 2003 Wireless Personal Area Networks standard. The specification was accepted and ratified by the Zigbee alliance in December 2004. Zigbee Alliance is a group of more than 300 companies including industry majors like Philips, Mitsubishi Electric, Epson, Atmel, Texas Instruments etc. which are committed towards developing and promoting this standard. The alliance is responsible for publishing and maintaining the ZIgbee specification and has updated it time and again after making it public for the first time in 2005. Most of the recent devices conform to the Zigbee 2007 specifications has two feature sets– Zigbee and Zigbee Pro. The manufacturers which are members of the Alliance provide software, hardware and reference designs to anyone who wants to build applications using Zigbee.

5. MEMS Accelerometer

Microelectromechanical systems (MEMS) are small integrated devices or systems that combine electrical and mechanical components. They range in size from the submicrometer (or sub micron) level to the millimeter level, and there can be any number, from a few to millions, in a particular system. MEMS extend the fabrication techniques developed for the integrated circuit industry to add mechanical elements such as beams, gears, diaphragms, and springs to devices. Examples of MEMS device applications include inkjet-printer cartridges, accelerometers, miniature robots, microengines, locks, inertial sensors, micro transmissions, micromirrors, micro actuators, optical scanners, fluid pumps, transducers, and chemical, pressure and flow sensors. New applications are emerging as the existing technology is applied to the miniaturization and integration of conventional devices. These systems can sense, control, and activate mechanical processes on the micro scale, and function individually or in arrays to generate effects on the macro scale. The micro fabrication technology enables fabrication of large arrays of devices, which individually perform simple tasks, but in combination can accomplish complicated functions. MEMS are not about any one application or device, nor are they defined by a single fabrication process or limited to a few materials. They are a fabrication approach that conveys the advantages of miniaturization, multiple components, and microelectronics to the design and construction of integrated electromechanical systems. MEMS are not only about miniaturization of mechanical systems; they are also a new paradigm for designing mechanical devices and systems. The MEMS industry has an estimated $10 billion market, and with a projected 10-20% annual growth rate, it is estimated to have a $34 billion market in 2002 [1]. Because of the significant impact that MEMS can have on the commercial and defense markets, industry and the federal government have both taken a special interest in their development.

6. GSM Module

This is a GSM/GPRS-compatible Quad-band cell phone, which works on a frequency of 850/900/1800/1900MHz and which can be used not only to access the Internet, but also for oral communication (provided that it is connected to a microphone and a small loud speaker) and for SMSs. Externally, it looks like a big package (0.94 inches' x 0.94 inches' x 0.12 inches) with L-shaped contacts on four sides so that they can be soldered both on the side and at the bottom. Internally, the module is managed by an AMR926EJ-S processor, which controls phone communication, data communication (through an integrated TCP/IP stack), and (through an UART and a TTL serial interface) the communication with the circuit interfaced with the cell phone itself. The processor is also in charge of a SIM card (3 or 1,8 V) which needs to be attached to the outer wall of the module. In addition, the GSM900 device integrates an analog interface, an A/D converter, an RTC, an SPI bus, an I²C, and a PWM module. The radio section is GSM phase 2/2+ compatible and is either class 4 (2 W) at 850/ 900 MHz or class 1 (1 W) at 1800/1900MHz.

Fig.7.GSM SIM900 Module

The TTL serial interface is in charge not only of communicating all the data relative to the SMS already received and those that come in during TCP/IP sessions in GPRS (the data-rate is determined by GPRS class 10: max. 85,6 kbps), but also of receiving the circuit commands (in our case, coming from the PIC governing the remote control) that can be either AT-standard or AT-enhanced SIM Com type. The module is supplied with continuous energy (between 3.4 and 4.5 V) and absorbs a maximum of 0.8 A during transmission.

7. GPS Modem

GPS receivers use a constellation of satellites and ground stations to compute position and time almost anywhere on earth.

Fig.8. GPS Modem

Notice the moving point on the globe and the number of visible satellites. At any given time, there are at least 24 active satellites orbiting over 12,000 miles above earth. The positions of the satellites are constructed in a way that the sky above your location will always contain at most 12 satellites. The primary purpose of the 12 visible satellites is to *transmit* information back to earth over radio frequency (ranging from 1.1 to 1.5 GHz). With this information and some math, a ground based *receiver* or GPS module can calculate its position and time.

8. Temperature Sensors (LM35)

The LM35 series are precision integrated-circuit temperature sensors, whose output voltage is linearly proportional to the Celsius (Centigrade) temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient centigrade scaling. The LM35 does not require any external calibration or trimming to provide typical accuracies of ±1/4°C at room temperature and ±3/4°C over a full -55 to +150°C temperature range. Low cost is assured by trimming and calibration at the wafer level. The LM35's low output impedance, linear output, and precise inherent calibration make interfacing to readout or control circuitry especially easy. It can be used with single power supplies, or with plus and minus supplies. As it draws only 60 µA from its supply, it has very low self-heating, less than 0.1°C in still air. The LM35 is rated to operate over a -55° to +150°C temperature range, while the LM35C is rated for a -40° to +110°C range (-10° with improved accuracy). The LM35 series is available packaged plastic TO-92 transistor package. The LM35D is also available in an 8-lead surface mount small outline package and a plastic TO-220 package.

Features:

1. Calibrated directly in ° Celsius (Centigrade)
2. Linear + 10.0 mV/°C scale factor
3. 0.5°C accuracy guarantee able (at +25°C)
4. Rated for full -55° to +150°C range
5. Suitable for remote applications
6. Low cost due to wafer-level trimming
7. Operates from 4 to 30 volts
8. Less than 60 µA current drain
9. Low self-heating, 0.08°C in still air
10. Nonlinearity only ±1/4°C typical

8.3 (IR) Infrared Technology

Technically known as "infrared radiation", infrared light is part of the electromagnetic spectrum located just below the red portion of normal visible light – the opposite end to ultraviolet. Although invisible, infrared follows the same principles as regular light and can be reflected or pass through transparent objects, such as glass. Infrared remote controls use this invisible light as a form of communications between themselves and home theater equipment, all of which have infrared receivers positioned on the front. Essentially, each time you press a button on a remote, a small infrared diode at the front of the remote beams out pulses of light at high speed to all of your equipment. When the equipment recognizes the signal as its own, it responds to the command. But much like a flashlight, infrared light can be focused or diffused, weak or strong. The type and number of emitters can affect the possible angles and range your remote control can be used from. Better remotes can be used up to thirty feet away and from almost any angle, while poorer remotes must be aimed carefully at the device being controlled. The light our eyes see is but a small part of a broad spectrum of electromagnetic radiation. On the immediate high energy side of the visible spectrum lies the ultraviolet, and on the low energy side is the infrared. The portion of the infrared region most useful for analysis of organic compounds is not immediately adjacent to the visible spectrum, but is that having a wavelength range from 2,500 to 16,000 nm, with a corresponding frequency range from $1.9*10^{13}$ to $1.2*10^{14}$ Hz.(From http://hyperphysics. phy-astr.gsu.edu/hbase/ems3.html : the frequency of infrared ranges from 0.003 - 4 x 10^{14} Hz or about 300 gigahertz to 400 terahertz.).

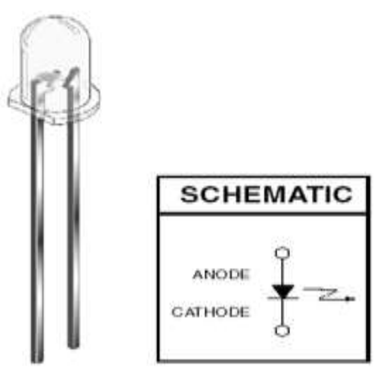

Fig.9. IR Sensor

III. RESULTS

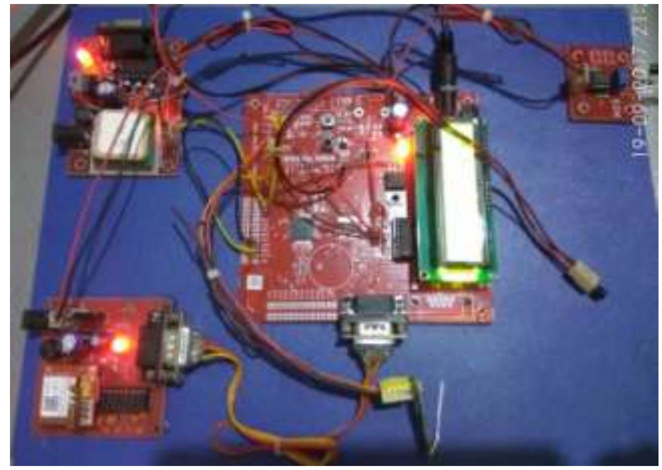

Fig.8

Fig.9

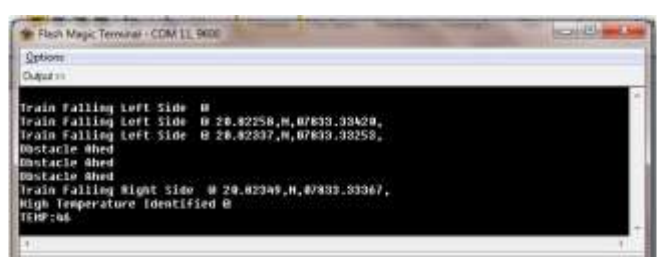

Fig.10

IV. CONCLUSION AND FUTURE SCOPE

Conclusion: Accidents are the major causes for traumatic injuries. Wireless sensor network which continuously monitors the railway track through the sensors and detect any abnormality in the track. The sensor nodes are equipped with sensors that can sense the vibration in the railway track due a coming train. The geographical positioning sensors are placed on the trains. These sensors send the train‟s geographic location. Until recently, railway inspection has been visually performed, but this only examines objects superficially and intermittently, and the analysis needs to be interpreted by an expert, who can be subjective. Sensors are objective and can provide data from the entire object (including internally) to allow the whole object‟s health to be fully assessed and to analyze its durability and remaining life time. A broad range of sensors are used in railway monitoring to provide an extensive range of data and allow monitoring of different structures, vehicles and machinery. The main challenge for WSNs in railway applications is determining the best measurement technologies to use. The WSN must be reliable and accurate to enable effective condition monitoring in harsh and inaccessible environments but must also be cost effective. It must be possible to translate the sensor data from the WSN into relevant and clear information to enable decision support in the railway infrastructure maintenance lifecycle. The paper divides railway condition monitoring into fixed monitoring for immobile infrastructures such as bridges, tunnels, tracks and associated equipment, and movable monitoring for vehicles and their mechanics. Fixed monitoring uses sensors to monitor vibrations, stresses and sound waves passed through structures (acoustics) caused by passing trains (short term monitoring) and also changes in stresses, pressures and sound waves passed through structures over the longer term (long-term monitoring). One of the key issues for fixed monitoring is network topology. The topology is constrained by the requirements of the monitoring and by the physical environment. Sensor nodes can be arranged in either an ad hoc or a preplanned configuration. Determining the optimum node placement is a complex task and often requires a tradeoff. The network configuration can be optimized against a number of different constraints. A network may minimize relay nodes, may need to ensure a minimum level of service (include a certain level of redundancy), minimize energy usage to preserve battery life, or may need to ensure accessibility of the nodes. The communication mechanisms, for example, Bluetooth, Wi-Fi, GSM, or satellite also need to be evaluated to ensure coverage and reliability and the routing protocol to ensure data is successfully transmitted from sensor node to base station to control center. Another issue is powering the sensors as fixed monitoring often requires placing sensor nodes in inaccessible locations, for example, in tunnels, on bridge trusses, or in rail track beds. Many sensors use batteries but replacing batteries in inaccessible locations may not be possible. Authors have considered ambient energy harvesting such as converting vibrations caused by passing trains into energy or using solar power. These energy harvesters may be accompanied with energy storage such as capacitors. Authors have also reduced sensor energy usage using event detection where a single cheap sensor detects approaching trains and wakes a larger sensor network to commence taking measurements of a bridge structure.

Future Scope: By adding GPRS to this design we can continuously maintain the database

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