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A survey of railway condition monitoring by ZIGBEE wireless sensor nodes

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Abstract— This paper has been proposed to survey of Railway condition monitoring by using Zigbee wireless sensor nodes.Many wireless protocols used for conditioning and monitoring in the railway.A track-borne energy transducer is a smart device for harvesting energy of trains or rail transportation systems. In this paper, the authors extend this application through introducing a self-powered ZigBee wireless sensor node. The proposed hardware prototype consists of a ZigBee coordinator trail road-side and a series of sensors (Accelerometer, temperature sensor, humidity sensor, and infrared detector) connected to a ZigBee end device at rail-side. The ZigBee end device is powered by the magnetic levitation energy harvester and communicated wirelessly with the ZigBee coordinator. The magnetic levitation oscillator is selected due to its broad-band response characteristics. The results indicate a peak–peak output voltage of 2.3 V under the condition that the vehicle travels over the rail-born device at the speed of 105 km/h.

Index Terms—Energy harvesting, Internet of Things, magnetic levitation, railway condition monitoring, wireless sensor networks, ZigBee.

I. INTRODUCTION

Rail transport, as a means of conveyance of passenger and cargo, plays an important role in our daily life. The building of rail infrastructure has experienced a sustainable growth in the past decade, especially in some developing countries. However, in remote area it is difficult to ensure power supply of rail-side monitoring equipment because wired power supply is not available for railways deployed in these locations . If we use wireless power supply such as batteries ,it is also a big challenge for the maintenance and replacement of batteries in remote or inaccessible locations .It is therefore necessary to develop a new energy strategy. Actually, Germany has already engaged in covering more than one-third of its annual twelve billion kilowatt-hour energy requirement for the railway network with renewable sources by 2020 . The saved energy is capable of powering wireless sensor networks (WSNs), which can be used for monitoring the railway infrastructure such as bridges, turnout, rail tracks, cuttings and tunnels, and track beds . This motivates the authors in this paper to develop a self-powered wireless sensor network for railway condition monitoring. This technology contributes to resolving the power supply problems of rail-side monitoring devices and benefits the development of Internet of Things (IOT) in the area of intelligent transportation. The rail side sensors are connected to the ZigBee end device and powered by the track-borne energy harvester. The data can bet transmitted to the ZigBee coordinator and be accessed through webpage on the internet with cloud computing technology.

II.RELATED WORKS

There have been a lot of work done on Railway condition monitoring. The possibility of establishing a self powered wireless sensor network by integrating the techniques of ZigBee stack protocol and energy harvesting .

2.1 "Wireless Sensor Networks for Condition Monitoring in the Railway Industry: A Survey",[1]

This paper has reviewed the range of WSNs used for condition monitoring in the railway industry. The emphasis is on the practical engineering solutions, principally which sensors devices are used and what they are used for; and, identification of sensor node configurations and network topologies. Until recently, railway inspection has been visually performed but this only examines objects superficially and transmits the data from the movable nodes to a static node when the static node is in range, or the movable nodes form a network with a base station within the network which transmits the data over a suitable mechanism, such as satellite or GSM. This paper focuses on the sensor technology used to generate condition monitoring data to enable practical condition monitoring systems. These data must be managed and turned into useful information to generate useful information. Condition monitoring systems must store large quantities of data to build models for analysis. The data must be validated first to ensure that they are correct and error-free (sensor faults, noise, null values, communication errors, etc.). This process may even be performed in the sensor node's microcontroller; thus, only valid data are transmitted thus minimizing the transmission load. These data can then be processed in a number of different ways to generate information. Once data are collated, they can be analyzed using robust algorithms to identify faults in near real time. Algorithms need to be robust as WSN data is noisy, can be intermittent, may contain errors, has many interdependencies and the data volume is very high. The WSN data can also be stored and analyzed over longer time periods to identify long term progressive faults such as a slowly developing crack. Some systems incorporate contextual data that describe the ambient conditions, which will affect the object monitored. These contextual data can be built into models to improve the coverage and accuracy of the model and to help provide explanation of condition monitoring decisions.

2.2 "Harvesting energy from the vibration of a passing train using a single-degree-of-freedom oscillator",[2]

In this paper, the energy harvested from the track-side vibration induced by the passage of a train is studied, as a specific practical application of time-limited excitation, where there is only significant vibration input for the duration of the train passage. Such energy could be used to power or recharge batteries of rail-side equipment, such as wireless sensors for monitoring railway track health and temperature, warning light systems etc. Such applications are of particular importance in remote areas, where there is a lack of electrical infrastructure. A related area is the harvesting of energy from train suspensions but this is considered to be a more classic case of harvesting energy from steady-state vibration and is well-covered in the literature. Some research work in the area of scavenging energy from trains has recently focused on the design of specific harvesting devices from the technological and electro-mechanical point of view. For instance, an electromagnetic mechanism converting pulse-like linear vibration into regulated rotational motion was presented in a wide-band piezoelectric harvester was designed to generate power in various frequency regions; a piezoelectric generator installed under the sleeper, was used to scavenge energy from vertical vibrations of the track a device mounted on rail- ties (sleepers) was used to converted the vertical displacement of the rail into electrical energy through mechanical amplification and rectification a comparison between an inductive coil device driven by the vertical rail displacement, and a piezoelectric device driven by the longitudinal strain produced by rail bending was presented in . Several other power harvesting devices capable of scavenging power from the vertical deflection of railroad track are discussed in and simulations on the maximum power potential for different prototypes along with their optimal number and location are presented . However, in all work cited above, no insight is given regarding the fundamental theory of vibration energy harvesting from time-limited excitation, which is the basis for the development of physical prototypes and devices. The aim of this paper is thus to present a fundamental investigation on the maximum available energy that could be potentially harvested from a passing train using a linear single-degree-of-freedom oscillator. Using an acceleration time history of vertical vibration measured on a sleeper during the passage of an Inter-city 125 train in the United Kingdom, passing at a speed of about 195 km/h, the optimum mechanical parameters of a linear energy harvesting device are determined. Since the operational frequency range of the harvester is below 35 Hz, the dynamics of the railway track are ignored. This would not be the case, however, when the train passes over a bridge, for example, where bridge dynamics.

2.3 "High-Altitude Wind Energy for Sustainable Marine Transportation",[3]

This paper investigates the use of a controlled tethered wing, or kite, for naval transportation. Linked to a boat by light composite-fiber lines, the kite is able to fly between 200 and600 m above the sea and to generate high traction forces. A mechatronic system named Kite Steering Unit (KSU) that is installed on the boat controls the kite and converts the line speed and force into electricity. Different from previous works, the boat is also equipped with electric propellers so that naval propulsion can be achieved both directly, i.e., through the towing forces exerted by the lines, and indirectly, i.e., through the electricity generated by the KSU that is fed to the electric propellers via a battery pack. The optimal system operating conditions that maximize the boat speed for the given wind characteristics are computed. Then, a model predictive controller is designed, and numerical simulations with a realistic model are carried out to assess the performance of the control system against the optimal operating conditions. The results indicate that, with this system, a completely green naval transportation system can be obtained, regardless of the wind direction.

2.4 "Challenges Toward Wireless communications for High-Speed Railway", [4]

High-speed railway (HSR) brings convenience to peoples' lives and is generally considered as one of the most sustainable developments for ground transportation. One of the important parts of HSR construction is the signaling system ,which is also called the "operation control system," where wireless communications play a key role in the transmission of train control data We discuss in detail the main differences in scientific research for wireless communications between the HSR operation scenarios and the conventional public land mobile scenarios. The latest research progress in wireless channel modeling in viaducts, cuttings, and tunnels scenarios are discussed. The characteristics of non stationary channel and the line-of-sight (LOS) sparse and LOS multiple-input–multiple-output channels, which are the typical channels in HSR scenarios, are analyzed. Some novel concepts such as composite transportation and key challenging techniques such as train-to-train communication, vacuum maglev train techniques, the security for HSR, and the fifth-generation wireless communications related techniques for future HSR development for safer, more comfortable, and more secure HSR operation are also discussed.

2.5 "A User-Customizable Urban Traffic Information Collection Method Based on Wireless Sensor Networks", [5]

Traffic monitoring can efficiently promote urban planning and encourage better use of public transport. Efficient traffic information collection is one important part of traffic monitoring systems. Based on a technique using wireless sensor networks (WSNs), this paper provides a flexible framework for regional traffic information collection in accordance with user request. This framework serves as a basis for future research in designing and implementing traffic monitoring applications. A two-layer network architecture is established for traffic information acquisition in the context of a WSN environment. In addition ,a user customizable data-centric routing scheme is proposed for traffic information delivery, in which multiple routing-related information is considered for decision-making to meet different user requirements. Simulations have shown good performance of the proposed routing scheme compared with other traditional routing schemes on a real-world urban traffic network.

2.6 "Green Energy and Content-Aware Data Transmissions in Maritime Wireless Communication Networks", [6]

This paper proposed ,the advances of wireless technologies, maritime wireless communication network is emerging as one of the important information transmission systems. Generally ,the transmissions in maritime wireless networks can be classified into two types: terrestrial and satellite communication .By utilizing the legacy analog high-frequency/medium-frequency and very high frequency radios, long-range/medium-range or short-range ship-to-shore and ship-to-ship communications near port water can be enabled, respectively. However, such transmissions are not able to provide high rate services. With satellite communications, i.e., Fleet Broadband, the transmission can achieve a high data rate of up to 432 kb/s, but launching satellites into orbits leads to prohibitive service fees. Compared with land-based wireless communication, the maritime wireless networks suffer the much higher costs for devices deployment, energy consumption, and maintenance of maritime wireless networks. Therefore, it is essential to develop a novel cost effective wideband maritime communication network by innovative communication technologies from land to sea. Green energy refers to eco friendly and sustainable energy sources, e.g., wind, solar, and modern biomass. Among a variety of green energy sources, wind power rapidly grows at the rate of 30% annually, which achieved 198 GW all over the world in 2010. Solar power is another popular green energy source, and cumulative global photovoltaic installations surpassed 40 GW at the end of 2010 . Moreover, with the development of green energy technology, crystalline silicon devices can approach the theoretical limiting efficiency of 29%.Motivated by the relative high performance-cost ratio, solar and wind power are two of the most common energy sources that have been extensively used to power wireless networks, particularly the network infrastructure. For instance, the Green WiFi initiative has developed a low-cost solar-powered standardized WiFi solution for providing Internet access to developing areas. The wind-powered wireless mesh networks are also applied for emergency network deployment after disasters .The advances of green wireless networks have provided an alternative energy for maritime wireless networks, which can significantly decrease the cost of maritime wireless networks establishment and maintenance. For instance, due to the long coastline, some info stations may be constructed on the island or other remote areas, and thus, it might be prohibitive and inconvenient to use cable to connect electricity grid and access to the island for maintenance. By using green energy, the infestations can be easily constructed, and less maintenance is required, which can significantly reduce the cost.

2.7 "Commercial Applications of Wireless Sensor Networks Using ZigBee", [7]

This paper focused on commercial applications of wireless sensor networks by using of ZigBee .Now a days wireless networks sensors are active with help of ZigBee. The recent release of standards in the field, such as IEEE802.15.4 and ZigBee, brought the technology out of research labs and stimulated the development of numerous commercial products. Moving from early research in military applications, sensor networks now are widely deployed in diverse applications including home automation, building automation, and utility metering. Although many early sensor networks used proprietary routing algorithms and RF technology, most recent products use standards-based networking and RF solutions. A key enabling standard for much of the commercial activity in the wireless sensor network area is the IEEE 802.15.4 standard. This PHY and MAC (media access control) layer standard defined a 250kb/s direct sequence spread spectrum (DSSS) radio operating in the2.4GHz unlicensed band with lower bit-rate alternatives in the 868 MHz and 900 MHz bands. This standard now enjoys extensive silicon support, primarily in the 2.4GHz band. On top of this PHY and MAC layer standard, several proprietary and standards-based sensor network systems emerged. The one with the most vendor and end-product support is the ZigBee standard. This article presents a survey of the most active application areas that use ZigBee and the trends that drive them, focusing on systems that are commercially available. The ZigBee standard has evolved since its original release in 2004. Several years of field trials and product development experience were rolled into a new revision of the standard set, to be ratified in early 2007, known as ZigBee Pro. This article highlights some of the field learning that went into the standard and what has changed in the specification to address field lessons and commercial feedback. Much of what makes possible more commercial applications is the emergence of a more complete ecosystem around the standard. Major enabling trends in this ecosystem also are examined. Finally, new areas of activity in the standards body are highlighted. The majority of applications currently deployed using the ZigBee standard fall into three application areas are home automation and monitoring, building automation, and utility meter reading and control.

2.8 "A Comparative Study of Wireless Protocols: Bluetooth, UWB, ZigBee, and Wi-Fi",[8]

Bluetooth (over IEEE 802.15.1), ultra-wideband(UWB, over IEEE 802.15.3), ZigBee (over IEEE 802.15.4), and Wi-Fi (over IEEE 802.11) are four protocol standards for short range wireless communications with low power consumption. From an application point of view, Bluetooth is intended for a cordless mouse, keyboard, and hands-free headset, UWB is oriented to high-bandwidth multimedia links, ZigBee is designed for reliable wirelessly networked monitoring and control networks, while Wi-Fi is directed at computer-to-computer connections as an extension or substitution of cabled networks. In this paper, we provide a study of these popular wireless communication standards, evaluating their main features and behaviors in terms of various metrics, including the transmission time, data coding efficiency, complexity, and power consumption. It is believed that the comparison presented in this paper would benefit application engineers in selecting an appropriate protocol. Index Terms- Wireless protocols, Bluetooth, ultra-wideband This paper analyzed the Bluetooth, UWB, ZigBee, andWi-Fi protocols, which corresponds to the IEEE 802.15.1,802.15.3, 802.15.4, and 802.11a/b/g standards, respectively. The IEEE defines only the PHY and MAC layers in its standards. For each protocol, separate alliances of companies worked to develop specifications covering the network, security and application profile layers so that the commercial potential of the standards could be realized.

2.9 "A Novel Radiator for a 2.4 GHz Wireless Unit to Monitor Rail Stress and Strain",[9]

A novel mobile antenna structure is presented to relay stress and strain data on railroad tracks. The antenna structure is a unique design employing dual probe-fed radiating cavities integrated with a Zigbee IEEE 802.15.4 wireless transceiver. This structure is mounted against the rail web and has a compact design to ensure survivability. A dielectric filler is employed inside each radiating cavity to minimize cavity width and protect the integrity of the mobile antenna structure. Measurements are given for a fabricated prototype to verify simulated performance characteristics .A dielectric filler was also used in both cavities to reduce cavity width while also preventing outside debris from compromising its integrity. Key to the final design was the location, orientation, and size of each radiating aperture relative to the rail. The dual cavity design provided a gain of 3 dBi along the directions (parallel to the rail) used for communication with the train mounted interrogator units. Range tests were performed on a fabricated prototype antenna structure, verifying simulated performance characteristics by establishing a valid communication link at a distance up to 91 m for a 100 mW train mounted interrogator and a 1 mW transceiver integrated into the RSM. The measured gain and input impedance were also in good agreement with simulations.

2.10 "Electromagnetic Energy Harvesting from Train Induced Railway Track Vibrations",[10]

An electromagnetic energy harvester is designed to harness the vibrational power from railroad track deflections due to passing trains. Whereas typical existing vibration energy harvester technologies are built for low power applications of Milliwatts range, the proposed harvester will be designed for higher power applications for major track-side equipment such as warning signals, switches, and health monitoring sensors, which typically require a power supply of10 Watts or more. To achieve this goal, we implement a new patent pending motion conversion mechanism which converts irregular pulse-like bidirectional linear vibration into regulated unidirectional rotational motion. Features of the motion mechanism include bidirectional to unidirectional conversion and flywheel speed regulation, with advantages of improved reliability, efficiency, and quality of output power. It also allows production of DC power directly from bidirectional vibration without electronic diodes. Preliminary harvester prototype testing results illustrate the features and benefits of the proposed motion mechanism, showing reduction of continual system loading, regulation of generator speed, and capability for continuous DC power generation.

III.METHODS AND ANALYSIS

Main challenges faced by railway engineers for railway track monitoring are: 1) power supply problem of rail-side equipment. Wired monitoring devices depend on the grid infrastructure, which needs huge investments; whereas the wireless ones require batteries which can only work for a certain time period. The railway track is very long, cross remote or natural region, rendering the replacement of batteries impossible. 2) money-consuming to deploy the railway monitoring system. It costs much to deploy traditional monitoring equipment. Thanks to the rapid development of semiconductor manufacturing process and large scale integrated circuit, Micro Electromechanical Systems (MEMs)-based sensor technique offers a low cost, low power, and integrated approach to structural healthy monitoring of railway track. ZigBee as low power consumption, low cost, limited data rate, and high reliable and secure communication protocol has well suited for the application of wireless sensor networks for railway condition monitoring. The objective of this paper is to solve the power supply problem of rail-side ZigBee devices and build up a self powered railway monitoring prototype with ZigBee protocol stack and magnetic levitation energy harvester. Compared with the WSN system powered by solar energy ,the proposed solution is independent on the weather condition and can be used for both the railway transit in tunnel and the urban rail transit. Compared with the other vibration based energy harvesting solution, the proposed one is capable of energy harvesting at wide frequency range with small displacement amplitude, which fits the requirement of the vibration characteristics of the railway track.

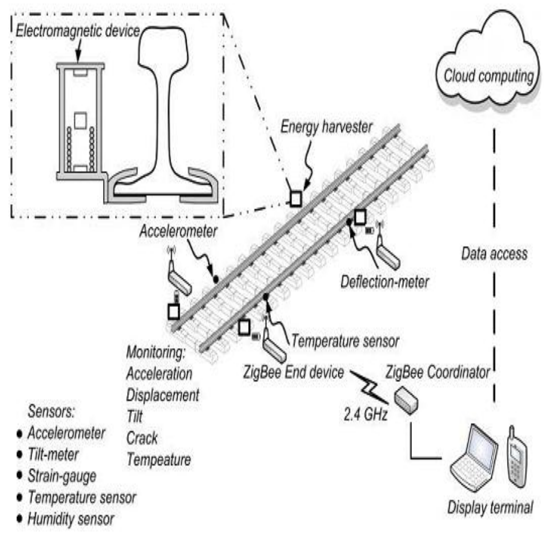

Fig: 3.1Railway condition monitoring by ZigBee wireless sensor

The proposed hardware prototype consists of a ZigBee coordinator at road-side and a series of sensor(Accelerometer, temperature sensor, humidity sensor, and infrared detector)connected to a ZigBee end device at rail-side. The ZigBee end device is powered by the magnetic levitation energy harvester and communicated wirelessly with the ZigBee coordinator. The hardware prototype is shown in Figure 3.2

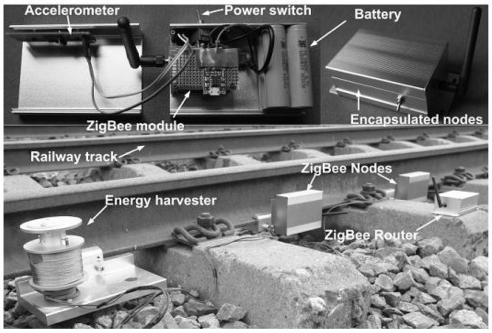

Fig: 3.2 Encapsulated sensor node prototype developed by SWJTU

IV.CONCLUSION

Three types of track-borne electromagnetic device were compared. The rail vibration velocity had the direct correlations with the generated voltage of electromagnetic devices. The signals are nearly same in amplitude profile and opposite in phase. system locates away and no longer scales linearly. We could engage manually such nonlinearities through adjusting then on-linear parameter β and damping ratio of the magnetic. It should be noted that the proposed energy harvester can generate enough power for ZigBee end device when the vehicle passes; in case of no vehicle passing through, there is no wheel set/track interaction energy for enabling the system. Therefore, an energy storage circuit with batteries and supplementary power source (e.g. wind turbine) are necessary for round-the-clock and long-term monitoring. The energy harvester can charge the batteries (either by under-track wind turbine or by electromagnetic devices) and extend the applications. At a distance above20 m, the communication between the ZigBee end device and coordinator became unstable Unlike the wireless monitoring application in the Bridge and elevated highway, whose mounting height of nodes is very large; the track-borne ZigBee nodes are connected to the rail foot and the railway track is quite close to the ground foundation, so the effects of RSSI in relation to mounting eight should also be considered. Requirement of a feasible railway condition monitoring system includes: 1) Reduced maintenance; 2) Save cost;3) Constructability: the ease and efficiency with which the monitoring system can be mounted; and 4) Maintenance strategy: relied on the prediction of failure rather than maintenance based on a regular schedule.

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