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Wildlife Conservation and Rail Track Monitoring using Wireless Sensor Networks

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Abstract—In this paper we put forward an approach, first of its kind, to collectively address conservation of elephants by preventing their death being overrun by trains and monitoring the integrity of the rail track. It utilizes a unique method for deterring the elephants using infrasonic sound from crossing the rail track. For obtaining this output the sensing devices are placed in proximity areas of the rail track using a novel passive node mobility mechanism. These devices act as an input to the actual sensing nodes, that would emit the infrasonic sound. Utilizing a novel two - cycle communication and sensing check the integrity of the rail track is evaluated and the result is informed to the regional base station (RBS). The proposed approach offers a promising solution to the two issues, subject to field evaluation and validation.

Keywords—wireless sensor networks, railway accidents, railway safety, animals,

I. INTRODUCTION

Wireless sensor networks (WSNs) are composed of miniature micro electro mechanical systems (MEMS) capable of sensing various physical parameters. WSNs are energy constrained due to limited availability of battery resources on the sensor nodes. Their applications span across areas such as: industrial monitoring, defence - border intrusion, structural monitoring, environment and habitat monitoring [1], [2]. Use of WSNs for environment and habitat monitoring applications offer the opportunity to monitor natural and man made events such as volcanic eruptions, forest fires and landslides. Remote deployment of WSNs provide crucial insight about environmental and habitat events that would be otherwise be infeasible. Due to the inaccessibility and inhabitable conditions prevalent for humans. Wildlife monitoring is a sub category within this area. Wildlife monitoring gains significance considering the depleting forest and increasing number of species on the verge of extinction. Wildlife monitoring serves in direction of protecting and conserving the animals by recording the various activities of a given species and other parameters concerning the species. Similarly, deployment of WSNs within structures such as bridges, dams, roads and buildings enables effective monitoring of these structures to minimize maintenance - repair cost and preventing loss of life and property that could result due to structural damage [1], [3], [4]. Wildlife monitoring and structural monitoring are primarily non - linked research areas. Accordingly, they have been addressed on an individual basis with a fair amount of suitable mechanisms being put forward in the literature. In this paper we are addressing a concern that has a component of structural monitoring - railway track and wildlife conservation - elephants. We refer to

the wildlife aspect as wildlife conservation and not as wildlife monitoring to stress on the point that implementation of the approach achieves wildlife conservation of the elephants in an unequivocal manner. To the best of the authors' knowledge this is the first work that addresses these two specific, and non - related issues. The structure of the remaining paper is as follows: we discuss the related work on wildlife monitoring - conservation and structural monitoring in Section II. The proposed approach is detailed in section III, and we present the possible future work and conclusions related to this work in section IV.

II. RELATED WORK

Wildlife monitoring using WSNs to study the activity patterns of badgers in dense woodland environment based on micro climatic conditions has been put forward in [2]. Surveying of white tail deer to determine its conservation status using a delay tolerant sensor network has been stated in [5]. Authors in [6], propose a method for localization of elephants based on an acoustic sensor network. The motivation for determining the location of the elephant - Asian elephant (*Elephas maximus*) is to assist in minimizing elephant - human conflict resulting due to damage to crops and other human habitation. A method wherein based on the vibrations of the passing trains,utilizing rich extracted feature sets, the deployed sensor nodes can identify the train type *i.e.* slow, fast, passenger, goods, and determine faulty wheels has been presented in [4]. Using trains as data mules to relay information about railway infrastructure from locations/areas where this is no direct access to Internet has been put forward in [7]. In India a considerable length of the railway network passes through reserved forests. Many of these forests areas are home to the Asian elephant. There have been many elephant deaths overrun by trains in the recent times in India [8]. India regrettably also faces a left wing extremist movement in some of the states, with the people in the movement referred as maoists - naxalites. Naxalites at times take an awful step of removing a section of the rail track, in dense forest areas to register their protest. This has resulted in loss of life and property in some cases when their activity has gone unnoticed. The proposed approach is therefore directed to address the two broad issues, specifically in the Indian context. Some of the vocalizations of elephants, rumble, are within the infrasonic range, *i.e.* less than 20 Hz, the minimum human audible range. The elephants can communicate long distances through infrasonic sounds [6], [9]. The audible range of the elephants is 16 Hz - 12 kHz. These facts have been utilized in the proposed approach.

III. PROPOSED APPROACH

It comprises of certain entities that collectively form the the system to achieve the set out objectives. The entities include: deployment and collection agent, passive sensing nodes (PSNs), active sensing nodes (ASNs), Regional Base Station(RBS) and maintenance - repair.

A. Deploying and Collection Agent

Trains operating on the given section would spray the PSNs on the two sides of the railway track as shown in Fig. 2a. using dispensing tubes on the rail engine. The operational structure of the PSNs have been described in the following sub section. The angle at which the various tubes work would be such that they ensure a uniformity of deployment in the region adjoining the railway track. This could be fine tuned based on detailed experimentation. The spraying of the PSNs could be done by any rail engine pulling a train, passing through the designated area. PSNs would be, subsequently, later on collected by passing trains. The collected PSNs would be examined for operation worthiness, and redeployed again with the afore-stated process. Collection of the PSNs would only be carried out by goods train as they have a sanctioned low running speed compared with passenger trains. The PSNs would have an external casing of iron. This would protect the internal circuit from damage, and enable remote collection of PSNs using a unique method utilizing electromagnetic principle. An electromagnetic board would be fixed on both sides of the brake van / guard coach at the rear of the train as shown in Fig. 2b. That shows the electromagnetic board in both positions folded and unfolded. The board would have a maximum width of upto 2135 mm from the centre of the track, *i.e.*, a maximum of 1335 mm (width of the track 1600 mm) [10]. On passage of current the electromagnetic board would attract the PSNs. On retrieving to the folded position and removal of current source, PSNs would collect in a bag placed under the folding position. A time interval of at least 12 hours between the dispersal and collection rounds would be maintained, considering their operation limits. In addition, collection of PSNs would prevent their accumulation in the deployed area and minimize environmental damage. With the aforesaid approach of deploying the PSNs by dispensing tubes and collection by electromagnetic board, deploying and collection agent - the train has provided a new form of passive mobility for sensor nodes. As the operational utility of deployed PSNs is dependent on how and where they are deployed by the agent. This approach highlights that point that using passive mobility mechanisms utility of sensor nodes can be exploited in many unconventional ways in comparison with the active mobility mechanisms.

B. Passive Sensing Nodes

As evident from the name, PSNs are not suppose to perform any active sensing, they are suppose to assist the ASNs in the overall system operation. The PSNs would be sprayed by the passing trains as stated in the aforesaid section. The PSNs would comprise of a pressure based piezoelectric sensor, a button cell as supplemental power, a sound emitter and a timer IC. The complete unit would be enclosed in casing to provide rigidity and collection using electromagnetic board stated earlier. The casing would have an irregular shape to resemble the other lying pebbles, else elephants could avoid



Fig. 1. Passive sensing nodes (some encircled), red arrows - the maximum possible width of electromagnetic board

stepping on them as shown in Fig.1, the base photograph has been taken from [11].

C. Active Sensing Nodes

The ASNs would assist the PSNs in deterring the elephants from approaching close to the railway line. The ASNs collectively would also ensure the integrity of the railway track. The ASNs would comprise apart from a radio transceiver circuit, an ultrasonic emitter and / or receiver, piezoelectric crystal for energy harvesting through vibrations, acoustic sensor and an infrasonic sound emitter. The ASNs would be placed firmly with the rail at a level to stay clear of the rail wheel. As the ASNs would be subjected to tremendous vibrations the whole unit would be packed in a firm casing that would ensure the safety of the circuitry but would not hinder in energy harvesting utilizing the vibrations. The ASNs would have a communication radius of 12 m.

1) *Wildlife Conservation:* Once the elephant steps on a PSN the sound emitter would beep for a prefixed time as set by the timer. The sound emitter used would emit the sound in frequency range greater than 12 kHz and less than 20 kHz. This range is non audible to elephants but audible to humans. The sound beeps emitted by the PSNs would be picked up by the acoustic sensor in ASNs. That would be activated every minute to sense any possible beeps from PSNs. The ASNs would emit a sound in the infrasonic range, preferably at the precise frequency used by elephants to give out distress calls. The piezoelectric crystal for energy harvesting unit would also serve as a vibration sensor to determine an approaching train. The ASN would accordingly only emit infrasonic sound if a train is approaching. It is expected that based on the output from the crystal the ASN would be able to ascertain an approaching train as early as possible (as far as possible). The elephant(s) would be deterred this way from crossing the railway track by the infrasonic sound from the ASN(s).

2) *Track Monitoring:* The ASNs would collectively ensure that the railway track is intact and there is no possible threat to railway traffic. This has been shown in Fig. 3. The railway tracks in India are usually considered to be either in the form of short welded rail (SWR) or a long welded rail (LWR). The SWR has a length of 36 m composed of three 13 m sections while the LWR would be minimum 250 m long [12]. We consider here SWR for demonstrating our approach as shown in Fig.3. A block section composed of five such SWRs is

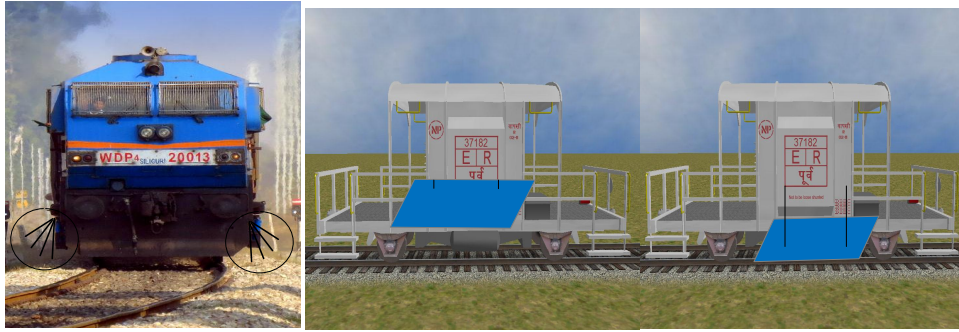


Fig. 2. a) Sensing device dispensing tubes b) Electromagnetic board on brake-van folded and unfolded

considered. We refer a block section here as a unit of SWRs terminating at either one or both sides with a signal. We refer it as the RBS, it would be the converging point of two sections. The size of a section (composed of SWRs sections) has to be upper bound since in the event of a malfunction by ASNs there could be a very long stretch unattended, also the amount of processing and validating time required would increase with the length of the section. We anticipate that a block section of 10 SWR sections would be the maximum feasible, *i.e.*, 360 m of rail track without a RBS. On both the rails six ASNs would be placed securely. The ASNs would have an address of the form 3AR that would refer ASN number 3 on the 'A' SWR section on the 'R' right rail. The initial nodes would be provided the address and placed on rail edges, other ASNs would register their address based on positions of the initial nodes. The ASNs would be placed 6 m apart from each other thereby equally covering the SWR length. A criss-cross pattern of placement between the two rows collectively is obtained, based on the placement of the extreme edge ASNs in reference to the adjoining section. The criss cross pattern formed by the ASNs collective is utilized in the two cycle check on the rail tracks as in the following sub-section.

D. Communication and Sensing Cycles

There would be two communication and sensing cycles - odd and even for monitoring the rail tracks, alternating between each other following the pre decided duty cycle periods. ASN1 and ASN6 on both the rails would have a ultrasonic emitter and receiver other nodes would only have an ultrasonic receiver. In the odd communication cycle the ASN1 in left most SWR section emits an ultrasonic wave. Ultrasonic receiver in ASN3 would detect the wave and send a message addressed for ASN5 on the same rail (5AR) that it has successfully received the ultrasonic wave from ASN1 emitter. ASN5 would also have an ultrasonic receiver and should detect the ultrasonic wave. The ASN5 on successfully receiving ASN3 message and the wave reception would communicate with ASN1 on the left rail track about successful check of right rail. ASN1 would initiate a communication in the reverse direction with ASN3 and ASN5. This communication would circulate back to the ASN1-L with the message hopped by ASN3-R and ASN5-R on the opposite rail as shown in the Fig 4a. If the ASN1-L on the left track does not receive the initial communication from ASN5 on right track based on ultrasonic waves it would still trigger the reverse message communication at a stipulated time. If it hears back from the other nodes on a message

hop then it would still inform the ASN1 on the adjoining section to proceed, alternatively it will issue an alert message to adjoining ASN1 that an even cycle has been initiated in is SWR section. ASN1-L would inform ASN6-R to emit the ultrasonic wave. As this would be a non scheduled even cycle the last leg of the cycle ASN2-L would inform ASN1-L. If this message is successful then ASN1-L section 2 would be informed that the tracks are OK. Faulty ASNs on the odd cycle would be examined and corrected by the railway men on duty. This has been described in the sub-section on maintenance and repair. Alternatively, a warning message would be send across straight to the RBS in a multi hop manner, this message would override all active cycles. On successful completion of the odd communication and sensing cycle the RBS would initiate the even cycle in the reverse direction as shown in Fig. 4b. The two cycles will occur every 15 minutes in the day and every 10 minutes at night, with such duty cycling the ASNs would conserve sufficient energy. That could be utilized to power the acoustic sensor and implied infrasonic emissions. Such a duty cycle based system is not impacted by the multihop delay that would occur between the ASNs, as in the current application a hard real time operation is not required, and the intention is to detect any abnormality in the system well in advance by regular monitoring. This is realistic approach considering the running speed of trains atleast 40-70 km/hr and accordingly the braking distance requirement. ASNs would be time synchronised to ensure the required communication and sensing cycles are met as per schedule. Every 2 hours the ASNs would involve in a clock drift correction. The system can afford a clock drift for up to 2 hours considering the non requirement of a hard real time deadline and the clock drift accumulation rate of 4 ms between nodes in 100 seconds [13].

E. Regional Base Station

As stated earlier the communication and sensing cycles would initiate and terminate at the RBS. RBS would be an interface device between the ASNs and the railway signalling equipment. The railway signalling equipment would display a permission for train to go or stop based on information received from RBS.

F. Maintenance and Repair

As the ASNs would be subjected to strong vibrations there is a slight likelihood of malfunctioning and damage to an ASN unit. The railway tracks are physically examined by railway

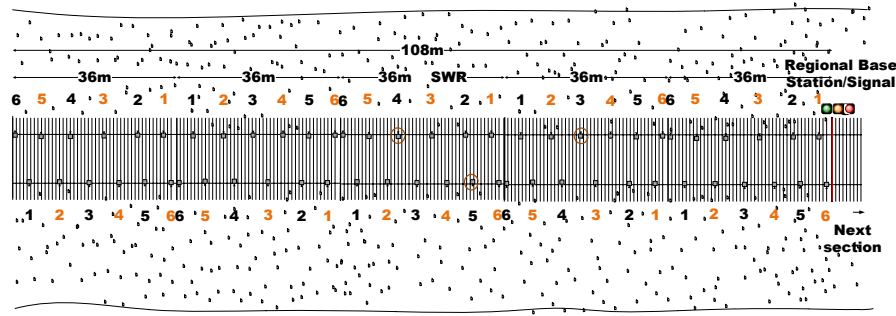


Fig. 3. Active sensing nodes (encircled), passive sensing nodes, RBS at section limit

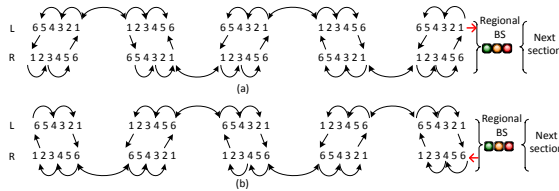


Fig. 4. Communication and sensing cycles a) odd b) even. Red arrows - termination or initiation at RBS

men in shifts round the clock. The railway men would be provided with a mobile device basically a mobile base station (BS) that could communicate with the ASNs. In a single section any of the nodes hearing the mobile BS could report about possible fault nodes based on the lapses if any in the communication and sensing cycles described earlier. Railway men would carry additional ASN units that could replace an existing ASN if required. The newly affixed ASN would acquire its address based on correspondence with immediate neighbours. The railway men would also examine the PSNs and deploy additional PSNs in an area where needed, and also collect PSNs that are lying beyond the maximum permissible length of operation from the railway length *i.e.* 1335 mm.

IV. CONCLUSIONS

In this paper we have proposed an approach that addresses conservation of elephants by preventing them from being overrun by trains, along-with monitoring the integrity of the rail track. The proposed approach offers a mechanism for addressing the issues at hand with minimal human involvement and avoidance of any additional expensive infrastructure. This paper also proposes a new system for deploying and collecting sensor nodes. The implied passive mobility offered to the nodes by the train, functioning as a deploying and collection agent has been proposed for the first time. This passive mobility mechanism for nodes justifies that there are many other possible ways for moving sensor nodes other than active mobility mechanisms. There are many aspects of this proposed approach that require a field based feasibility evaluation and thereby this paper presents an opportunity for extensive experimentation. Especially regarding the dispersal and collection of PSNs, particular infrasonic sound frequency at which elephants show maximum deterrence and operation

of ultrasonic wave between ASNs.

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