Electric Fence Intrusion Alert System (eleAlert)

Abstract—We present the design and implementation of an intrusion detection and alerting mechanism (eleAlert) for fences separating wildlife habitats and human settlements. Our objective is to improve the effectiveness of electric fences as a solution to the prevailing human-elephant conflict (HEC) in many parts of the world.

eleAlert uses a network of sensors to detect and locate damages instantly, and alert communities under threat via the mobile communications network.

Keywords—Human-Elephant Conflict, Intrusion Detection, Early Warning, energy efficient communication protocol

I. INTRODUCTION

The Asian elephant is one of the most endangered mega herbivores in the world. The biggest threats to its survival are habitat loss and conflict with humans over crop raiding [1, 2].

As the largest terrestrial vertebrate in Asia, and a CITES Appendix I listed species, conserving the Asian elephant is a globally important conservation objective [3].

The greatest conflict is caused by socio-economic factors such as population growth and economic development which have not given due consideration to the ecological needs of the elephant. Bangladesh, India, Kenya, Sumatra and Sri Lanka are among the countries hardest hit by the HEC.

In 1996, twelve elephants had been poisoned in Riau province in Sumatra. In May 2002, 17 elephants had been poisoned in North Sumatra [5]. In Kerala, 704 elephants have been killed since 2003, which translates into an annual average of 100 elephants [6].

In the Dry Zone of Sri Lanka, 70% of the wild elephant populations live outside the wildlife protected areas, sharing land with rural people. From 1992 - 2010, 1045 people were killed by elephants and 2,792 elephants were killed by farmers and from 2004 to 2007 a total of 3,103 homes were destroyed by elephants. The damages caused by elephants to crops in the area has been estimated to cost Rs. 1,100 million (US$10 million) annually [7].

Reconciling the conservation of the Asian elephant with human interests has to be given the highest priority [4]. To achieve such a level of co-existence innovative and cost effective strategies using effective technologies are needed.

Electric fences are a common means used worldwide to control the movement of animals especially elephants. Over 1000km has been erected in Sri Lanka with over 300 km being erected in 2009.

However, elephants are able to damage fences by ingenious means, enabling them to walk over it. Delays in locating and repairing damages puts the bordering villages into great risk.

The main objectives undertaken in this research is to device a technique for:

- detection and location of electric fence intrusions independently of fence construction type and manufacturer
- provision of early warning to threatened communities and prompt information to fence maintenance crews

II. FAULT AND INTRUSION DETECTION IN FENCES

Numerous perimeter intrusion detection systems such as [8, 9] have been researched and/or are available commercially. These are intended for securing locations such as airports and military bases and are not suited technically and economically for protecting wildlife fences extending over tens or hundreds of kilometers where severe energy constraints and harsh environmental conditions exist.

Electric fences reported in [10] are accompanied by proprietary tools to detect faults. The information available indicates that only the direction of the fault is found with these tools, and manual methods are resorted to locate it.

The technique reported in [11] locates each fault using manual voltage and current measurements along the fence, following the direction displayed on the fault finder. Most reported fault finding techniques use similar principles.

The alarm system in [12] consists of a number of detectors, each having a unique identifier. When the segment is broken, the detector transmits the identifier by means of an integrated antenna.

III. OVERVIEW OF ELEALERT

An intrusion detection system for electric fences should:

- detect and locate breaches to the fence,
- consume very low energy
- be repaired and maintained by persons with little technical know-how, with locally available material.
- be monitored remotely
- operate in areas with poor connectivity
be scalable to be installed along long lengths of electric fencing.

The system architecture shown in Figure 1 consists of a Remote Transmitting Unit (RTU), Bridges separating the fence into segments and a number of Location Identification Tags (LITs) within each segment. The RTU is the gateway between the system and the mobile network. The devices are connected by a pair of thin copper wires, which perform multiple functions of intrusion detection, power distribution and communication.

When an intrusion occurs, it is detected and communicated by the RTU to a central access station and to designated persons. A novel physical layer protocol which conserves energy and simplifies the hardware design of the components has been adopted for communication. The central access station which runs a web server, can be used to view the status of the fence over the Internet.

The RTU is also capable of remotely switching on and off the fence energizer when repairing an intrusion.

An intrusion detection system for 12 km length of fence may be implemented with one RTU, 12 bridges (at a maximum spacing of 1 km) and up to 15 LITs per segment between bridges. The segment length and the number of LITs per segment are flexible in order to trade off accuracy with cost. Only the RTU needs to be installed in a location with mobile network connectivity. Since only SMS is used, even a relatively weak signal strength is sufficient.

IV. SYSTEM DESIGN

A. Intrusion Detection and Location

The intrusion detection mechanism is shown in Figure 2. The steps in the detection process are as follows:

1. Each bridge powers its side A LITs.
2. A break of wires at LITs 3 and 4 in segment S3.
3. This wakes up B3.
4. B3 powers S3 and polls S3 LITs.
5. B3 finds the intruded location.
6. B3 issues an alert packet to side A
7. The packet is received by B2.
8. B2 passes the packet to its side A
9. B1 does the same as B2
10. RTU receives the packet.
11. RTU disseminates SMS messages.

B. Communication

Conventional communication means such as radio, infrared or laser are not usable due to cost and power constraints. Therefore communication is achieved by the same pair of wires used to detect and power the LITs. A novel physical layer protocol is developed to achieve this with minimum hardware components. This has made it possible to make the LITs small in size, simple and low cost.

Table 1 lists the packet types used for communication within the system. Each packet is a combination of 3-bit header field and a 5-bit address/data field.

The header field indicates the operation to be done. The address field is the address of the LIT/Bridge to which the packet is directed to, or generated from.

A simple repetition of packets twice is used for error protection. Non-matching packets are discarded.
C. Achieving energy efficiency

The RTU is powered with a set of small solar panels and a backup battery. Bridges are powered with three AA type batteries. LITs in a segment are powered by the bridge allocated to that segment. The entire system is kept in sleep mode when idling to achieve long battery life.

The LITs/bridges are woken up by a packet in the line. For this, each packet is preceded by a 50us wakeup pulse. The data packet follows after a 4ms delay in order to provide time for the LITs/bridges to stabilize. As soon as a LIT/bridge processes a packet it goes back to the sleep mode with extremely low power consumption.

D. Cost reduction

The cost of the LITs had to be minimised as they are to be replaced if damaged in an elephant intrusion. Therefore a small 8-pin microcontroller (Tiny25) with very few additional components had to be used to develop the LIT.

E. Administration, testing and maintenance

The repair work is done by reconnecting the broken wires. Since the network is several kilometers long, on site verification of the system after a repair was necessary.

The system automatically detects this repair and informs the repair people via SMS. In bridges a simple interface with a simple LED menu is provided to test the LITs after installation and repair.

The RTU carries out tests of the entire system at predetermined intervals and informs the results to a designated mobile number as a SMS report. This contains the battery levels of the bridges and information of malfunctioning LITs if any.

<table>
<thead>
<tr>
<th>Packet Type</th>
<th>Purpose</th>
</tr>
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<tbody>
<tr>
<td>ALARM</td>
<td>Informs the RTU of an intrusion by a Bridge</td>
</tr>
<tr>
<td>ACK</td>
<td>Acknowledgement from RTU/Bridge/LIT</td>
</tr>
<tr>
<td>CHECK</td>
<td>To inform completion of a repair</td>
</tr>
<tr>
<td>ASSADR</td>
<td>To change the Address of a LIT</td>
</tr>
<tr>
<td>TEST</td>
<td>To command bridges to test its LITs</td>
</tr>
<tr>
<td></td>
<td>To request Test report.</td>
</tr>
<tr>
<td></td>
<td>To send test report.</td>
</tr>
<tr>
<td>FNCOFF</td>
<td>Request to switch off the fence energizer</td>
</tr>
<tr>
<td>FNCON</td>
<td>Request to switch on the fence energizer</td>
</tr>
<tr>
<td>BATL</td>
<td>Request/send battery level of a bridge</td>
</tr>
</tbody>
</table>

Thus, continuous remote monitoring of the system is facilitated. Also a manager of the system can send and SMS to the RTU and request a test report at any time, for example after a repair.

The server is used to communicate with the RTU via SMS messages for administrative and monitoring tasks.

V. IMPLEMENTATION AND TESTING

The system has been implemented and tested in elephant habitats demarcated by electric fences. Figure 3 shows the eleAlert components that have been developed. Figure 4 shows the components in the pilot installations.

Results of pilot tests were used to improve particularly the power efficiency of the system. It is estimated that the battery life of the Bridges will be approximately 6 months, and that the RTU can operate for over 5 consecutive days without solar power. The sensing and communication mechanisms were also improved following the field trials.

![RTU and Bridges](image1)

B1….B4: Bridges
S1……S4: Segments
L1…..L15: LITs

Figure 2. Step-by-step illustration of the detection mechanism
VI. CONCLUSION
The novelties of eleAlert lie in the sensing and communications mechanisms and the ability to monitor fences remotely. The main objectives of the system have been proven through pilot trials.
While using state-of-the-art electronic, sensing and communication technologies, simplicity has been a major consideration in the development of eleAlert.
Since the system is independent of the electric fence it can be effectively used to enhance the protection provided by fences already installed as well as new ones.

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REFERENCES

(a) RTU
(b) Bridge
(c) LIT

Figure 3. eleAlert Components
Figure 4. Photographs from Pilot Installation. Clockwise from top left: RTU, LIT, Bridge, Community Support.