A System to Provide Early Warning of Human and Vehicle Intruder Activity

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ABSTRACT

Sandia National Laboratories developed and installed a prototype Virtual Presence and Extended Defenses (VPED) system to provide early warning of human and vehicle intruder activity. The purpose of a VPED system is to extend the intrusion detection capabilities of an existing security system (particularly in remote or difficult-to-monitor areas) in order to achieve early warning of adversary actions. The VPED system provides a complementary approach to traditional perimeter security systems by extending and augmenting the existing system's performance and increasing the overall probability of detection (P_D) for certain adversary paths, while minimizing nuisance and false alarms. Thus, the VPED system is intended to improve the probability of system effectiveness (P_E) by increasing detection for specific adversary approaches beyond the existing fence. Sandia has deployed this system in a densely wooded location and has been testing its performance for 12 months and the system continues to generate data. This paper details the VPED system architecture and features and discusses how the system performed.

INTRODUCTION

Today's security challenges require facilities to detect adversaries as soon as possible, and as far away from the protected area boundary as possible. Traditional security systems employ fences, clear zones, sensors, and cameras to detect adversaries at the perimeter. However, response personnel need reliable information as early as possible in the event of an attack.

Virtual Presence and Extended Defense (VPED) systems can augment fixed-site security by enabling response forces to have earlier warning of adversary attacks and surveillance than provided by current systems.

VPED allows facilities to place sensors and assessment capabilities beyond a site perimeter to detect adversaries, typically in rugged or wooded areas that cannot use standard physical protection systems. VPED is designed to detect personnel and small vehicles along avenues of approach or in assembly areas. The VPED system includes sensor nodes that support various sensor transducers and cluster nodes that provide video assessment capability as well as software that provides substantial nuisance alarm reduction. Both sensor and cluster nodes use RF links to send data to a command center. Sensor nodes use internal batteries and can operate for an estimated eight years. Cluster nodes are powered by solar panels and provide both day and night assessment and sensor fusion capabilities. VPED has low power needs.

SYSTEM OVERVIEW

Flexibility was a principal design guideline for the VPED system (Figure 1). The combination of sensors, fusion algorithms, multi-layer architecture, and user interfaces allows the developers to tailor VPED deployment to various situations.

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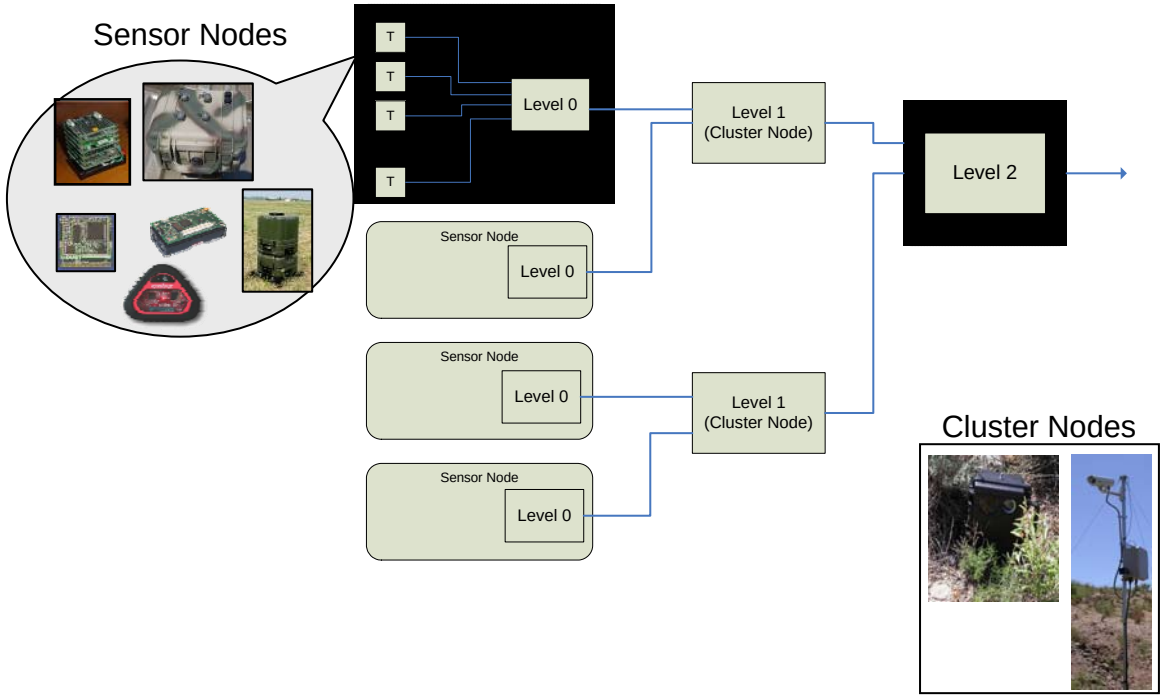

Figure 1. VPED System Architecture

Deployed in varying field environments, VPED systems were tailored to meet specific challenges. Each VPED system consists of ***sensor nodes*** (that support various types of sensors) and ***cluster nodes*** (that gather sensor data and provide video assessment capabilities). One of the most notable features of these systems is that sensors can be located almost anywhere, included wooded areas (Figure 2), a mountain ravine, or along a paved road. Sensors communicate via radio frequency links to cluster nodes that send data to a Command Center or to standalone systems in the field. VPED operators can alert responders immediately, allowing evaluation of the situation before adversaries reach the perimeter.

Figure 2. Example of a wooded area where a VPED system was deployed

VPED uses a variety of technologies to detect intruders:

- Intelligent sensor algorithms attempt to classify detections as persons, vehicles, or “other.”
- To avoid high nuisance alarm rates, sensor-fusion algorithms combine multiple sensor input to differentiate between human intruders and environmental factors.

- Operators can use captured images from area cameras to determine the cause of an alarm without dispatching patrols.

Figure 3. Cluster nodes gather data from sensor nodes and use cameras to survey the area

USER INTERFACE

The VPED system can be deployed with a stand-alone interface for responders operating without a command and control system. The VPED user interface is web-browser-based and can be deployed almost anywhere on a user's network. For users with a command and control system, the VPED is designed to work with other display systems through standard network interfaces such as XML. VPED can be quickly customized to work with most modern, network-based command and control systems.

Optimal performance of VPED systems is achieved when sensor and assessment systems are tuned to maximize their performance in the local terrain. VPED tuning times are currently a few hours to a few days during initial system installation and require a period of monitoring and adjustment. Thus, VPED is optimized for permanent installations rather than mobile or tactical applications. Optimal performance of VPED systems is achieved when sensor and assessment systems are tuned to maximize their performance in the local terrain. After installation, VPED sensor, fusion, and cluster node parameters can be modified remotely, allowing operators to adjust gain settings or algorithm settings without field maintenance.

Power
VPED has low power needs for both the sensors and cluster nodes, and alleviates the need for traditional power supplies. Sensor nodes are self-powered by internal batteries that can work for up to eight years, which makes VPED systems ideal for remote locations. In addition, cluster nodes are designed to be low power and can operate on solar panels.

Reducing Nuisance Alarms
VPED uses four technologies to reduce the nuisance alarm rate (NAR):

- Intelligent sensor algorithms that attempt to classify detections as persons, vehicles, or other.
- Sensor fusion that combines multiple sensors together to provide accurate detection
- Video assessment to allow operators to determine the cause of a detection without having to dispatch patrols.
- A user interface that can be operated effectively under high sensor alarm rates.

SENSING
To detect intrusions, VPED uses the Sandia Compact Sensor Node (SCSN) and advanced sensor nodes. The primary technology for each of these sensor nodes is a geophone. Geophones detect low-frequency acoustic energy coupled through the ground and, to a lesser extent, through the air. In addition, both sensor nodes have the ability to interface to any sensor that provides a binary signal. The SCSN can connect directly to the transducers that comprise the Mini-Intrusion Detection System (MIDS). This capability allows external MIDS break-wire, passive infrared (PIR), beam-break, or magnetic transducers to be connected to the SCSN. For these external binary sensors, the SCSN formats a message upon receipt of the binary signal and sends that message up the VPED network to the next higher network layer. The algorithm looks for strength of the energy that caused the event and the frequency of the signal, and then tries to identify whether or not the energy source is a vehicle. Animals and other environmental conditions can affect the sensors, which the algorithms consider in the adjudication process.

Figure 4. A VPED sensor node with an inconspicuous, ground-mounted antenna gathers data from a variety of sensors and processes information for the cluster node

CLUSTER NODE
Sensors produce detection events. These events are transmitted via radio frequency (RF) to a cluster node, which performs three functions:

1. ***A communications bridge*** to connect short-range sensor communications to longer-range radios.
2. ***A sequencer*** that manages sensor events and video capability to allow tagging of events with snapshot video. This capability is used only if cameras are used.
3. ***Local fusion of sensors*** that allows fusion to be distributed throughout the system.

COMMAND NODE

Sensor events, either fused or unfused, are sent from any cluster nodes to a single command node. The command node is a central data manager for all incoming VPED information. Global or area-specific sensor fusion can also be implemented on the command node. The command node collects, translates, and forwards event information to the designated user interfaces.

SENSOR FUSION

One of the most critical tasks the VPED system must perform is the fusion of sensor event information to reduce nuisance alarms. Individual sensors can be expected to have a nuisance alarm rate (NAR) from a few per day to tens per hour, depending on the environmental factors of the site. Our fusion algorithms have been developed to combine sensor inputs from multiple sensors to remove unimportant environmental events while maintaining an acceptable probability of detection. Sandia has developed several sensor fusion algorithms that can account for lightning strikes, that can filter out random events, and that can track intruders directionally.

Other features common to all fusion algorithms:

1. Algorithms can be added or modified “on the fly.” This feature allows installers to tune system performance without restarting the software.
2. All sensor events are assigned relative weights for weighing the relative importance of “hits” by different types of sensors. This general concept can be used to optimize fusion algorithm performance based on the sensor’s function or abilities.
3. Fusion algorithms can be chained. Thus, a time-gated algorithm can be used as the input to a tracking algorithm.
4. The fusion software can run at several node levels in the system, or “anywhere and everywhere.” This ability to run in multiple locations is critical as the system becomes larger. The fusion ability is distributed, which prevents system slowdowns or single points of failure. Installers can take advantage of all computer resources.

SYSTEM SUMMARY

The VPED System has operated for over a year with 440,000 hours on the Sandia Compact Sensor Nodes (SCSN's) with no failures. The Talon hardware has had both a hardware and software refresh in the last year, with no failures. Cameras and cluster nodes continue to operate, despite adverse environmental conditions and Sandia performed software updates in the last year. The command node is still operational and will be upgraded to the latest operating system later this summer. Radio systems have been upgraded and new software was loaded in the last year. The system has proved to be robust, sustainable, and amenable to hardware and software updates with no system failures. The probabilities of detection for both vehicles and walkers exceed the Department of Energy standard requirements. The development team continues to improve the algorithms and enhance the system’s technical readiness level.