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BORDER GUARDS SYSTEMS USING HYBRID WIRELESS SENSOR NETWORKS

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ABSTRACT

Early days, the conventional border guards systems suffer from intensive human involvement. Recently, unmanned border guards systems employ high-tech devices such as unmanned aerial vehicles, unattended ground sensors and surveillance towers equipped with camera sensors. However, any single technique encounters that cannot be solved the problems such as high false alarm rate and line of sight constraints. There lacks a logical system that coordinates various technologies to improve the system accuracy. In this paper, we discuss the concept of hybrid wireless sensor network architecture for border guards systems, is introduced. It utilizes the most advanced sensor network technologies including the wireless multimedia sensor networks and the wireless underground sensor networks.

KEYWORDS

Border guards, Wireless sensor networks, Multimedia sensor networks, Underground sensor networks.

1. INTRODUCTION

Border guards systems have recently gained interest to address the concerns about national security. The major challenge in protecting long stretches of borders is the need for intensive human involvement in guarding the premises. Conventional border guards system consists of security checkpoints and border troops. The security checkpoints are set up on the international roads where all vehicle traffic is stopped to detect and apprehend illegal aliens, drugs and other illegal activity. Each border troop watches and controls a specific section of the border. The troops guard the border according to predetermined route and time interval. Under the conventional border guards system even modest sized areas require extensive human resources if manual guarding is considered alone.

To monitor the border in real-time with high accuracy and minimize the need for human support, multiple surveillance technologies which complement each other are required. To address the challenges still faced by the existing surveillance techniques, we introduce Border Guards System, a new border guard's system framework based on hybrid wire-less sensor networks which can accurately detect and track the border intrusion with minimum human involvements. Border Guards System utilizes the most advanced sensor network technologies, including wireless multimedia sensor networks (WMSNs) and wireless underground sensor networks (WUSNs).

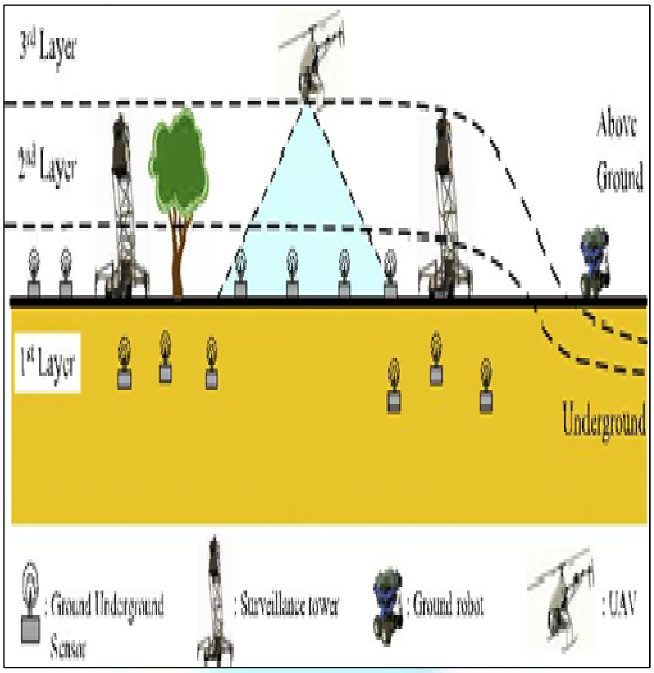
The hybrid WSN consists of three types of sensor nodes:

1. Multimedia sensor nodes that are equipped with video cameras or night vision scopes and deployed on the surveillance towers,
2. Scalar sensor nodes that are equipped with vibration/seismic sensor and deployed on the ground or buried underground, and
3. Mobile sensor nodes that roam throughout the border on the surface or in air. These three types of sensor nodes while the potential benefits of Border Guards System are significant, several research challenges need to be addressed be-fore a practical realization. In this paper, a framework to deploy and operate Border Guards System for border guards is de-scribed. Based on this framework, research challenges and open research issues are discussed.

2. SYSTEM ARCHITECTURE OF BORDER GUARDS SYSTEM

Current WSNs for border guards are based on a flat, homogeneous architecture in which every sensor has the same physical capabilities and can only interact with neighboring sensors .Such a structure results in several shortcomings in border guards such as limited cover-age and high false alarm rate that require additional human intervention. Instead, we consider a hierarchical WSN architecture with heterogeneous sensor nodes as shown in Figure1. In this architecture, three different types of sensors are used in three different layers of the hierarchy.

FIGURE 1: NETWORK ARCHITECTURE OF THE HYBRID WIRELESS SENSOR NETWORKS FOR BORDER GUARDS



As shown in Figure1, the system architecture of Border Guards System has three layers. The unattended ground sensors and the underground sensors constitute the lower layer of the architecture, which provide higher granularity for monitoring. At the second layer, multimedia sensors improve the accuracy of the system through visual information. Finally, mobile ground robots and unmanned aerial vehicles constitute the higher layer that provides additional coverage and flexibility. Advanced WSN Devices are:

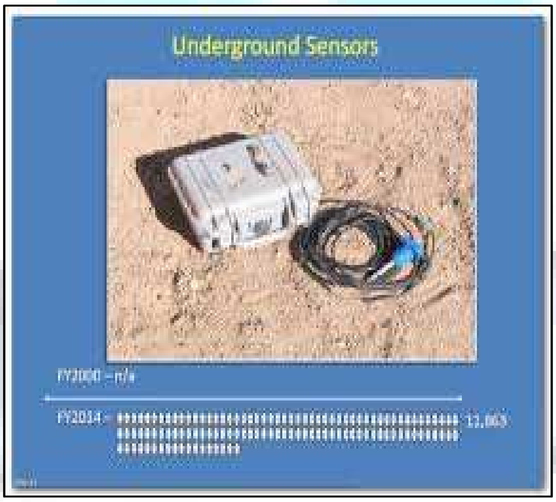
1. Ground Sensors and Underground Sensors,
2. Mobile/Stationary Surveillance Towers,
3. Unmanned Aerial Vehicles (UAV's).

2.1. GROUND SENSORS AND UNDERGROUND SENSORS

The ground sensors and the underground sensors in the lower layer are resource-constrained, low-power scalar sensors, which perform simple tasks such as taking seismic/vibration measurements and sending the information to data sink or processing hub. In Figure 2, the underground sensors can either communicate with the ground sensors or other underground sensors.

Due to the complex underground channel characteristics, new physical layer propagation techniques are needed to realize the communications, such as underground electromagnetic wave techniques or magnetic induction waveguides Different from the camera sensors in the surveillance towers or UAVs, the ground/underground sensors can detect non-line-of-sight intruders. However, as discussed in the introduction, based on the limited information acquired by ground/underground sensors, it is difficult to distinguish actual intrusion alarms from false positives. Consequently, the false alarm rate of the ground/ underground sensors is considerably high.

FIGURE 2: UNDERGROUND SENSORS



2.2. MOBILE/STATIONARY SURVEILLANCE TOWERS

As shown In Figure 3, Mobile or stationary surveillance towers can host very powerful and reliable multimedia sensors, i.e., radars, cameras, and sensors, which constitute the second layer of the hierarchy. The multimedia sensors are resource-rich, high-power devices with higher processing ability and larger communication range. As a result, these components are also used as local processing hubs. The multimedia sensors are responsible for more complex tasks such as collecting the sensing reports from the ground/underground sensors, detecting possible intrusion according to the sensing reports as well as the local image/video information.

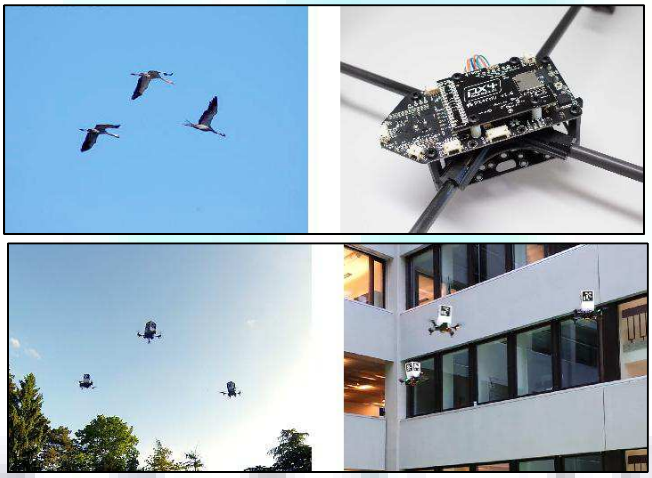
As a result, the false alarm rate of the ground/underground sensors can be significantly reduced. After the surveillance towers con-firm intrusion detection, they report the detection results to the remote administrator, and inform the mobile sensors the position of the intrusion for target tracking. Furthermore, the measurements and image/ video information are stored for future use. There may also existing cooperation between imaging sensors to detect intrusions collaboratively. In this case, correlation-based camera selection schemes and data compression frameworks are required to reduce the redundancy among correlated cameras.

FIGURE 3: MOBILE STATIONARY/SURVEILLANCE TOWERS

2.3. UNMANNED AERIAL VEHICLES (UAVs)

In addition to the stationary components, unmanned aerial vehicles (UAVs) and robots provide additional capabilities at the third layer. As shown in figure 4, UAVs have recently been used for several applications including environmental surveillance and infrastructure maintenance Drones and Remotely Piloted Vehicles(RPVs) are two types of UAVs. Drones are configured for autonomous flight with a pre-determined course and schedule. RPVs are remotely controlled by ground operators. In addition to mobility, UAVs can also be equipped with on board sensors and camera systems to provide additional coverage in an on-demand basis. Furthermore, UAVs can track intruders based on information from stationary sensors and help the border guard's agents catch intruders.

FIGURE 4: UNMANNED ARIAL VEHICLE (UAV)



Due to cost and coverage considerations, the number of sensors in the first layer is much larger than that at the higher layers. Accordingly, the network is divided into several clusters. The ground/underground sensors form several clusters, where the multimedia sensors also act as cluster heads. Similarly, multiple multimedia sensors coordinate with each other to form higher layer clusters that are maintained by mobile nodes. The higher layer information from the multimedia sensors is used at the mobile nodes that are dispatched to locations of intrusion for target tracking.

3. BORDER GUARDS TECHNIQUES

Border guards have extensively been based on human involvement. However, the relative cost for the increasing number of personnel as well as the diminishing accuracy through human-only surveillance has required the involvement of high-tech devices in border guards. Among these, Unmanned Aerial Vehicles (UAVs) for aerial surveillance have recently been used to automatically detect and track illegal border crossing. Due to the large coverage and high mobility of the UAVs, the intensive human involvement in low-level surveillance activities can be reduced. This allows valuable human resources to be allocated to decision management activities based on information from these devices. However, similar to the conventional border guards systems, UAVs alone cannot cover the whole border at any time. There may exist times when certain sections of the border are not being monitored. Moreover, the UAVs have significantly higher costs and accident rates than those of manned aircrafts and require large human footprint to control their activities.

In addition, inclement weather conditions can also impinge on the surveillance capability of UAVs. To complement the UAV activities, recently Fiber Optic Sensors (FOSs) are introduced. Seismic sensors are equipped with FOSs so that they can measure pressure waves in the earth caused by intruders.

However, FOS communication depends on a single wire along the border. As a consequence, any single point-of-failure can affect very long distances. Due to the harsh environmental conditions along a border, wired sensor systems are not robust. Moreover, deployment costs of wired sensors surpass existing costs in long borders limiting their practical application.

Compared to the wired sensors, Unattended Ground Sensors (UGSs) provide higher system robust-ness. UGSs have been intensively used for military Intelligence Surveillance and Reconnaissance (ISR) applications. UGSs can detect vibration/seismic activity or magnetic anomaly, which indicate that people or

vehicles are crossing the border. Moreover, UGSs can pick up moving heavy vehicles (such as tanks) from a distance of 500 m and walking humans from 50 m. However, the information provided by the UGSs can be limited and inaccurate. There-fore, based on the limited information acquired by current ground sensors, it is difficult to distinguish actual intrusion alarms from false positives, i.e., nuisance warnings caused by environment elements (insects, weather, animals, etc.).
According to the US department of homeland security, 90% of the alerts are caused by animals or environment impacts instead of illegal immigrants and these results in a significant amount of wasted time for the deployment of agents to check on the provided information. In addition, it has been reported that the existing sensors are of-ten damaged by insects or moisture and hence, are not robust to external impacts.
While scalar sensors such as vibration sensors are important to detect an intrusion, these sensors provide limited information to classify the intruder. To this end, surveillance towers equipped with video monitors and night vision scopes provide high accuracy in human detection and keep false alarms to a minimum. The monitoring range is also much larger than the ground sensors. These systems, however, typically require human interaction to determine the type of intrusion. Moreover, the video monitors require the target within the line of sight. If the monitoring area consists of obstacles such as rocks, brushwood, or trees, the miss rate increases.
The existing techniques for border guards, which include surveillance towers, ground sensors, or unmanned aerial vehicles, are deployed completely aboveground. In certain areas, aboveground components are vulnerable to the effects of the environment, vehicles or large animals. Visible devices may also be easily found, damaged, or avoided by intruders. For instance, for a system with surveillance towers, the intruders will look for areas and times not properly covered by adjacent towers. In addition to these major challenges, the existing solutions for border guards systems lack a coherent system that coordinate various technologies to improve the system accuracy.

4. ADVANTAGES
Compared with the existing border guards techniques provide the following advantages:
- The multimedia sensors provide accurate detection as well as large detection range;
- The ground sensors provide additional information that cannot be detected by the multimedia sensors, e.g. in cases here the intruder is hidden behind an obstacle that cannot be detected by the imaging sensor;
- The underground sensors guarantee the proper system functionalities here aboveground visible devices are not preferred for act of hiding purposes;
- Mobile sensors provide intrusion tracking capability to track the intruders after they have been detected;
- It detect the intrusion and report the results to a remote administrator;

5. DEPLOYMENT OF BORDER
GUARDS SYSTEM
In border guard's applications, the established monitoring network should cover a significantly large monitoring area. However, the sensing radius of a single sensor node is normally limited. Thus, a large number of sensor nodes are expected to fulfill the coverage requirement. Moreover, different types of sensor nodes (e.g., underground, ground, camera and mobile sensors) provide different coverage capabilities. The deployment of border guards system such as
- Deployment of ground/underground sensors,
- Deployment of surveillance towers,
- Deployment of UAVs.

6. OPERATION FRAMEWORK
The operation framework is described to realize the basic functionalities of border system. Since the hybrid WSN consists of three types of sensing information are generally complementary to each other. The multimedia sensors provide still image or video information of the border area but the intruder behind any obstacles cannot be detected. The ground sensors can sense the ground vibration as well as the magnetic anomaly caused by the intrusion. The underground sensors can also sense the vibration of the ground but the attribute of the sensing measurements are different from those acquired by the ground sensors. The false alarm rate of underground sensors is also high. Hence, these heterogeneous set of information should be to improve the decision accuracy and minimize the Miss Rate and false alarm rate.
The operation framework of border guards system used to detect the intrusion detection by using detection algorithm. It has consists of the following three parts:
1. Cooperative intrusion detection,
2. Intrusion tracking,
3. Detection-oriented communication.

6.1. COOPERATIVE INTRUSION DETECTION
In Border system, by the cooperation between the ground/underground sensors and the multimedia sensors on the surveillance towers, the false alarm rate can be low while the miss rate can be also kept at a low level. Although the camera sensors have high detection accuracy, the images and videos collected by the cameras still require human involvement. To reduce the human involvement, two methods could be utilized.
- Centralized Object Detection: In this method, cameras take image of the suspicious areas detected by ground/underground sensors, perform image compression locally, and send the compresses data to remote processing center equipped with high computation capacities, where pattern recognition algorithm are performed to automatically detect intrusion based on the received images. Therefore, image data can be divided into priority levels that correspond to those of the resolution. In this way, all image data with the least level of resolution are sent intact, while others can be transmitted partially on demand.
- Distributed Object Detection: In this method, camera sensors collaboratively perform object detection and recognition without involving the remote processing center. Since exchanging images among cameras consume considerable energy and spectrum, light-weight and distributed detection schemes are preferred. Different from conventional cameras, address event image sensors selectively extract and output only a handful of features of interest from the visual scene such as location, motion, direction of motion and lighting. These features form a symbolic representation of the visual scene that is much easier to process on resource camera nodes.

6.2. INTRUSION TRACKING
After an intrusion is detected by the unattended ground/underground sensors and confirmed by the multimedia sensors on the surveillance towers, at least one UAV or ground robot is dispatched to track the intruder so that the border system troops can effectively catch and control the intruder.
In first, the location of the intrusion is reported to the nearest UAV or ground robot through the surveillance towers in a multi hop. Then the surveillance towers continue to monitor the movement of the intruder. Those surveillance towers report the direction and velocity of the Intruder to the dispatched UAV or robot. After receiving the updated information of the intruder, the UAV or robot can adjust its moving direction to track the intruder. The UAV or robot is expected to reach the intruder before the intruder gets out of the monitoring area of the surveillance tower.

6.3. DETECTION-ORIENTED COMMUNICATION
To the facility of timely and accurate object detection, efficient and effective communication protocols are required to support two types of transmissions:
- Sensor-camera transmission
- Camera-remote center transmission

6.3.1. SENSOR CAMERA TRANSMISSION
Sensor camera transmission is based on many to many communication paradigms since multiple events can be detected simultaneously by ground/underground sensors, and these events have to be reported to the corresponding camera towers whose field of views covers the locations of the detected events. The

conventional many too many communication schemes aim to reduce the energy consumption or network congestion when multiple sources send packets to multiple sinks. More specifically the many to many communication problem is modeled as the multi network design problem with an objective to minimize the number of links that constitute source sink paths. This leads to increased network lifetime and reduced contention on the wireless medium. In this scheme, a gird structure is established after the sensor deployment. Then, a cluster head is randomly selected from the sensors within each grid and this cluster head represents the whole grid to receive the updated information regarding the sink mobility.

In contrast to the conventional many to many communication schemes, the sinks in the border system architecture are also camera towers which have limited coverage. This means that ground sensors need to send alarms to the specific towers that cover their location. These approaches significantly reduce the amount of data relayed to the towers and save the spectrum resources.

6.3.2. CAMERA REMOTE CENTER TRANSMISSION

Both centralized and distributed object detection schemes require timely and reliable data/image transmissions from camera towers to the remote control center. To facilitate distributed detection scheme, the scalar data, i.e., the local detection/recognition results are required to be forward to remote control center. Since the camera towers form a one-dimensional chain, this leads to a linear network topology.

Under such topology, the communication protocols are favorable since they are specifically designed for linear networks that deal with scalar data. However, to support the centralized detection scheme, all captured images have to be forwarded to the remote control center.

Example algorithm is shows how to automatically detect and track a face using feature points.

```
oldPoints = points;
while ~isDone(videoFileReader)
videoFrame = step(videoFileReader);
[points, isFound] = step(pointTracker, videoFrame);
visiblePoints = points(isFound, :);
oldInliers = oldPoints(isFound, :);
if size(visiblePoints, 1) >= 2
[xform, oldInliers, visiblePoints] = estimateGeometricTransform(...
oldInliers, visiblePoints, 'similarity', 'MaxDistance', 4);
bboxPoints = transformPointsForward(xform, bboxPoints);
bboxPolygon = reshape(bboxPoints', 1, []);
videoFrame = insertShape(videoFrame, 'Polygon', bboxPolygon, ...'LineWidth', 2);
% Display tracked points
videoFrame = insertMarker(videoFrame, visiblePoints, '+', ...
'Color', 'white');
% Reset the points
oldPoints = visiblePoints;
setPoints(pointTracker, oldPoints);
end
step(videoPlayer, videoFrame);
end
% Clean up
release(videoFileReader);
release(videoPlayer);
release(pointTracker);
```

7. CONCLUSION

In this paper, introduce Border Guards system, a hybrid wireless sensor network architecture for border guards to reduce the intensive human involvement and to improve the detection accuracy of current border guards systems.

Border guards system is coherent system that coordinates various technologies, including unmanned aerial vehicles, unattended ground/underground sensors, and surveillance towers equipped with camera sensors.

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