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INTRUSION SHIP DETECTION USING WIRELESS SENSOR NETWORKS

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ABSTRACT

A Wireless Sensor Network (WSN) has been emerging in the last decade as a powerful tool for connecting physical and digital world. WSN has been used in many applications such as habitat monitoring, building monitoring, smart grid and pipeline monitoring. In addition, few researchers have been experimenting with WSN in many mission-critical applications such as military applications. An innovative solution for intrusion detection system in sea is being presented. Intrusion detection on the sea is a critical surveillance of problem for harbor Protection, border security, and the protection of commercial facilities, such as oil platforms and fisheries. Equipped with the three axis accelerometer sensors, we deploy an experimental Wireless Sensor Network (WSN) on the sea surface to detect ships. Using the signal processing techniques and cooperative signal processing, we can detect any passing ships by distinguishing the ship-generated waves from the ocean waves.

KEYWORDS

intrusion detection, wireless sensor networks, border protection, target monitoring, signal processing.

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1. INTRODUCTION

The traditional methods of detecting ships entail the use of radars or satellites which are very expensive compared to other. Besides the high cost, satellite images are easily affected by the cloud cover, and it is difficult to detect small boats or ships on the sea with marine radar due to the noise or clutter generated by the un even sea surface.

Hence, we go for the new system. Terrestrial intrusion detection with Wireless Sensor Networks, deploy magnetometers, thermal sensors, and acoustic sensors is monitored areas to detect the presence of intruders. Though such networks are work well on the land, it is challenging to deploy these sensors on the sea surface for ship detection. The main challenge is that when sensors are deployed on the sea surface, they cannot static and get tossed by ocean waves.

A v-shaped wake and its resulting waves are generated by a ship passing through the water. We proposed a system of ship detection by taking an advantage of the characteristics of ship-generated waves with WSNs. To detect ships three-axis accelerometer sensors is used with the iMote2 on buoys on the sea surface. Using signal processing, we observed that ocean waves and ship-generated waves have been different energy spectrums.

We designed three-tier intrusion detection for system to detect intruding vessels. In this System, we propose to make use of spatial and temporal correlations of an intrusion to increase detection reliability. This is the first detailed, systematic experimental study of ship intrusion detection with WSNs.

FIG. 1: WAKE WAVES GENERATED BY BOAT

2. ASPECTS OF WAVES

A Wave is disturbance or oscillation (of a physical quantity), that travels through matter or space, accompanied by a transfer of energy.

Wave motion transfers energy from one point to another, often with no permanent displacement of the particles of the medium-that is, with little or no associated mass transport.

They consist, instead, of oscillations or vibrations around almost fixed locations. Waves are described by a wave equation which sets out how the disturbance proceeds over time.

The mathematical form of this equation varies depending on the type of wave.

3. TYPES OF WAVES

There are two types of waves.

1) Mechanical waves
2) Electromagnetic waves

The Mechanical waves propagate through a medium, and the substance of this medium is formed. The deformation reverses itself owing to restoring forces resulting from its deformation. For example, sound waves propagate via air molecules colliding with their neighbors.

When air molecules collide, they also bounce away from each other. This keeps the molecules from continuing to travel in the direction of the wave.

The electromagnetic waves do not require a medium. Instead, they consist of periodic oscillations of electrical and magnetic fields generated by charged particles, and therefore travel through a vacuum.

These types of waves vary in wavelength, and include radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation-rays, and gamma rays.

4. WAVE GENERATION

Wave is generated by forces that disturb a body of water. They can result from a wide range of force-the gravitational.

Out in the ocean, as the wind blows across a smooth water surface, air molecules push against the water.

This friction between the air and water pushes up tiny ridges or ripples on the ocean surface. When waves are being generated by strong winds in a storm, the sea surface generally looks very chaotic, with lots of short, steep waves of varying heights.

Ocean waves often have quite a different aspect, forming long, rolling peaks of uniform shape. For this reason, physical oceanographers differentiate between two types of surface waves:

Seas and swells. Seas refer to short-period waves that are still being created by winds or area very close to the area in which they were generated.

Seas are short-crested and irregular, and their surface appears much more disturbed than for swells. Swells refer to waves that have moved out of the generating area, far from the influence of the winds that made them.

Wave energy is dissipated as waves travel, and short-period wave components lose their energy more readily than long-period components.

As a consequence of these processes, swells from longer, smoother, more uniform waves than seas.

5. MEASUREMENT OF WAVES

When a ship moves across a surface of water, it can be generating waves which comprise divergent and transverse waves.

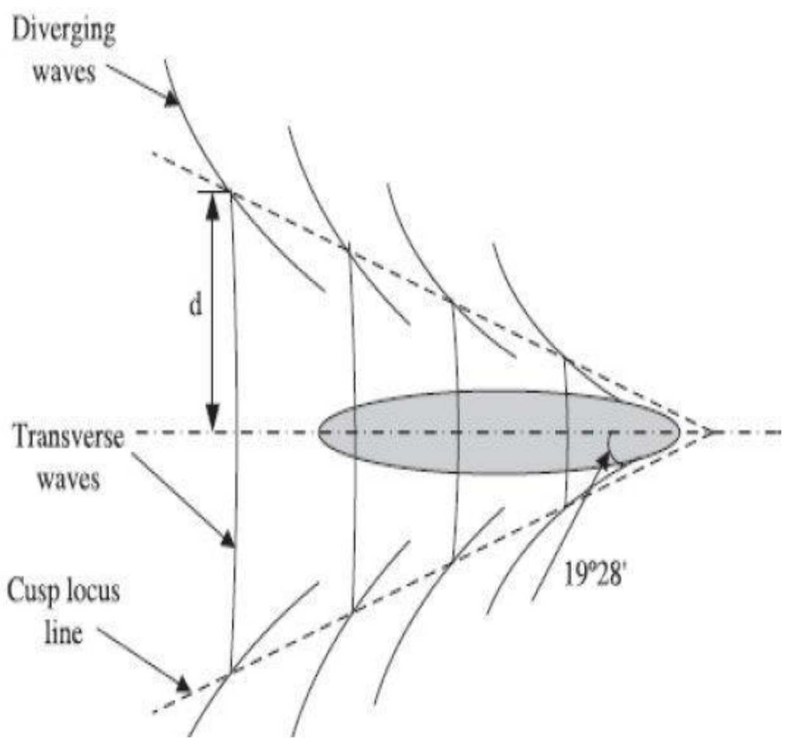
The old method of measuring ship-generated waves is to measure the pressure fluctuations at some elevation points in the water column, then transform the pressure into the wave height.

However, this method requires an expensive equipment. It is difficult to deploy the devices underwater.

Touse an accelerometers to measure the actual surface movement of ship-generated waves.

When the accelerometer is used in an ocean environment, then buoy and the accelerometer undergo a generally oscillatory, sinusoidal-like vertical acceleration due to wave action.

FIG. 2: SHIP GENERATED WAVE MODEL

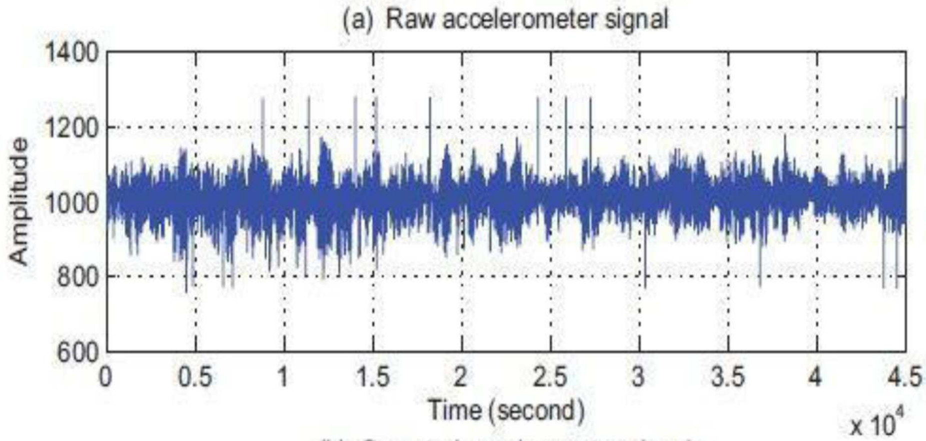


In order to distinguish between ship-generated waves and ocean waves, we can use Short Time Fourier Transform to process the measured signals.

With 2,048 point sample STFT, we observe that the ship-generated waves a normal ocean waves have a different energy spectrum.

Its Spectrum has a high, single waste away concentration around a characteristic period around 1 Hz. On the tendency, the spectrum of the ocean waves combined with the ship waves.

FIG. 4: (a) RAW ACCELEROMETER SIGNAL



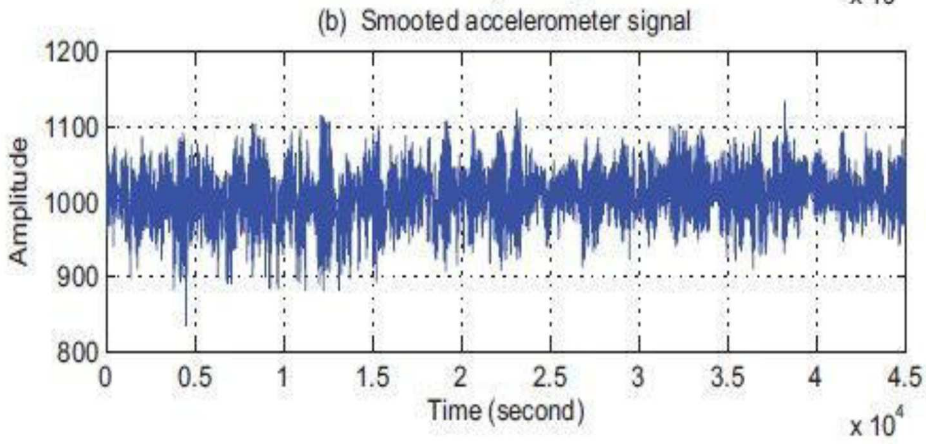
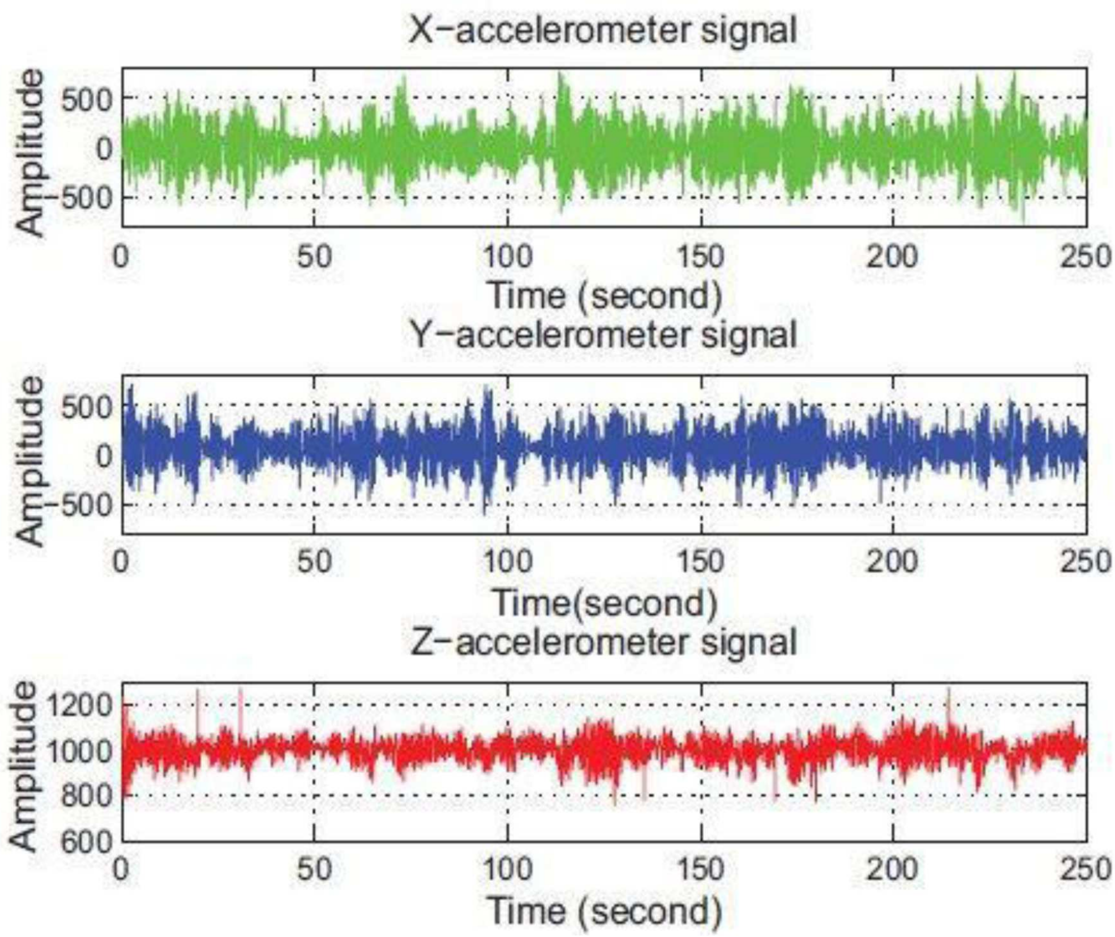


FIG. 4: (b) SMOOTHED ACCELEROMETER SIGNAL



6. SYSTEM DESIGN FOR SHIP INTRUSION DETECTION

In this section, we first present the architecture of the distributed intrusion detection system, and then discuss the three-tier intrusion system in detail.

6.1. ARCHITECTURE OF INTRUSION DETECTION SYSTEM

A reliable intrusion detection system involves node level detection, cluster-level classification, and sink-level classification.

The node-level detection involves the sampling event and extracting features. Once a node can detect a target, it is better that only the extracted features are transmitted to the local head node or a sink for further signal processing and classification, due to the energy constraints of the sensor node and the limitations of the communication bandwidth.

A Cluster-level classification deals with more complicated tasks, such as Collaborative Signal Processing or regional data fusion.

The clusters are formed according to the geographical locations of nodes or the migrations of the external "event" after the network is deployment.

In each and every cluster, local head node takes charge of the data fusion or other coordination tasks within the cluster. Sink-level detection involves the processing type data sent from local head nodes, and the final decision will be reported to the external used via satellite or other means.

To cause a real long-term intrusion detection surveillance system, some power management should be used. To avoid this need for expensive periodic battery changes, the nodes may need expensive solar panel or other perpetual-powering solutions.

Some middleware services should be considered, such as the location of nodes, time synchronization, and routing infrastructure.

6.2. NODE-LEVEL DETECTION

At node level detection, the task for a single node is to detect when a ship waves generated by a near by passing ship.

So, in order to do that, the individual node periodically samples.

The event and processes the sample data to extract features and then event and processes the sampled data to extract features for node level detection.

FIG. 5: ANCHORED NODE DEPLOYMENT

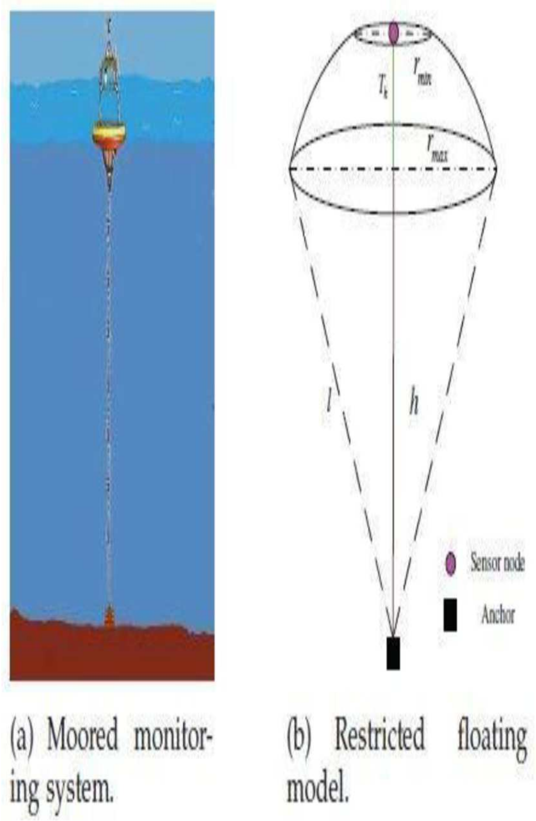
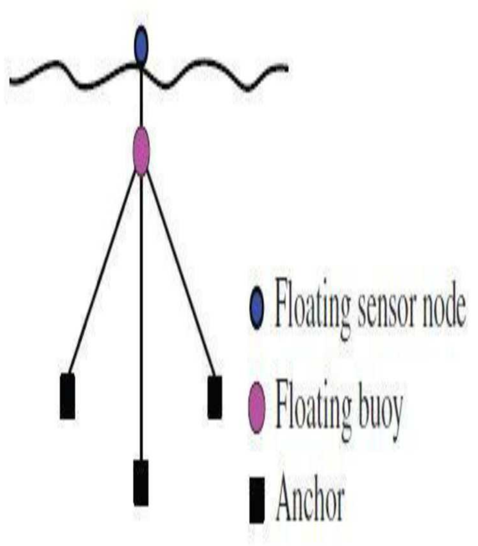


FIG. 6: NODE DEPLOYMENT WITH THREE ANCHORS



6.3. CLUSTER-LEVEL DETECTION

When a ship travels through the sensor networks, the waves are generated by the passing ship disturb the sensor areas A1; A2; A3 in sequential manner. These areas have been spatial and temporal correlations.

By making use of these correlations, we can improve the reliability of the detection system. In order to monitor the entire deployed area are temporary clusters are combined with static clusters.

The static clusters are formed according to the geographical location of the nodes, and then temporary clusters are formed on demand when a node's alarm is trigger. Since the nodes positions are fixed, they know where their neighbors are located in system.

When a node discovers a ship intrusion, it is initiating a temporary cluster, informs its neighboring nodes and automatically becomes the temporary cluster head. If more than one nodes are detects a ship intrusion before it receives detection signals from other nodes, it sends out their average detection energy, thus the node with the higher detection energy becomes the cluster head.

If the nodes within the cluster also find the intrusion, they report findings to the temporary cluster head. If the cluster head has not received any report within a certain period of time, it will be cancel the temporary cluster because its positive finding maybe a false alarm.

6.4. SINK-LEVEL DETECTION

Processes the data sent from local head nodes and the final decision will be reported to the external user via satellites or other means.

The multi-target detection monitors several intrusion targets at the same time indifferent geographical areas over large distances.

It increases the reliability of the intrusion detection with reduced false alarms with respect to special and temporal correlations of detection.

The self organizing localization algorithm which enhances the sensor nodes to be location-aware is deployed in the proposed system.

7. PROPOSED SYSTEM

The process of finding accurate location of sensor node is called as localization. The issue of energy efficiency and efficient data transmission is critical due to limited battery power and then limited storage capacity of sensors.

The Spatial correlation is more doubtful due to higher distance among sensors and long propagation delays.

PROPOSED ALGORITHM

Adaptive self-organizing localization algorithm is used to develop in proposed system. It can be able to operate under modes of parameters such as:

Temperature: Ranges 23to26 degrees centigrade within 33 meters.

Distance: Node's deployment distance D is within 40 meters.

The proposed localization techniques use only the distance estimation between the reference Nodes (RN) and Ordinary Nodes (Or N).

RNs can be able to detect their position by means of GPS to find the accurate location of OrNs. OrNs are those nodes which can execute without any centralized control to make randomly deployed WSN to be location-aware.

In order to perform a collaborative sensing tasks the sensor nodes must estimate their position by means of a distributed positioning algorithm. Average Error (AE) is calculated to weight the efficiency of proposed algorithm,

$$AE = \frac{\sum_{i=1}^{500} \sqrt{((x_i - x_i^*)^2 + (y_i - y_i^*)^2 + (z_i - z_i^*)^2)}}{500}$$

Where (xi, yi) is a real sensor position and (xi*, yi*) is estimated localization.

7.1. NETWORK MODEL AND NODE LEVEL DETECTION

An undirected graph G (V, E) where the set of vertices V represent the mobile nodes in the network and are presents set of edges in the graph, which can be represents the physical or logical links between the mobile nodes.

Sensor nodes are placed at a same level of task. Two nodes are communicating directly with each other are connected by an edge in the graph. Let N denote a network of m mobile nodes, N1, N2...Nm and let denote a collections of n data items d1; d2;... ; Dn distributed in the network. For each pair of mobile nodes and Nj, let tij denote the delay of transmitting data items of unit-size between these two nodes.

The experimental system is with 30 nodes deployed in such a way that five nodes in a row and a total number of six rows is kept. The node deployment distance D is 25 m.

A ship travels along with one side of the deployed area with three different speed levels and with each speed the test runs some defined rounds.

The Node-level detection Sample the event and extract those features. Once the node detects a target the extracted features are transmitted to the local head node or a sink for further signal processing and classification due to the energy constraints of the sensor node and the limitations of the communication between bandwidth.

Sample the signal value at time t is ai, then the total number of sampling points in time period T is u.

The moving average and the standard deviation is defined as

$$m_T' = \beta_1 \times m_T + m_{\Delta t} \times (1 - \beta_1),$$

$$d_T' = \beta_2 \times d_T + d_{\Delta t} \times (1 - \beta_2),$$

The anomaly frequency is defined as

$$a_f = \frac{NA_{\Delta t}}{N_{\Delta t}}$$

7.2. CLUSTER-LEVEL DETECTION AND SINK-LEV EL DETECTION

If more than one node detects a ship intrusion before it receives a detection signals from other nodes, the nodes contend to become the temporary cluster head. To simplify the process, when the nodes are trying to set themselves up as cluster heads, they could also send out their average detection energy thus the node with the higher detection energy becomes the cluster head. If the nodes within the cluster also find the intrusion then they report the findings to the temporary cluster head.

If the cluster head has not received any report within a certain period of time, it will be cancelling the temporary cluster because it's positive finding maybe a false alarm.

However, if it receives enough positive reports in a timely fashion it will be process the received data using the spatial and temporal correlations of the ship waves. We define time correlations in row i.

Because the cluster head knows the positions of each node, we arrange all the reports according to their position and reporting time. If the number of ordered reports is N,

$$C_{rt(i)} = \frac{N}{n},$$

The group's time correlations Nt

$$C_{Nt} = \pi C_{rt(i)}$$

CNe describes the cluster's energy correlation of coefficient C measures the spatial and temporal correlations in a cluster and is defined as

$$C = C_{Nt} \times C_{Ne} ,$$

Estimate the speed of the intruding ship using the equation,

$$V = \frac{D \sin(\alpha - 70^{\circ})}{(t_4 - t_3) \sin \varnothing},$$

7.3. SINK-LEVEL ESTIMATION

The intruding ship will keep moving it will be eventually move away from the monitored area. When it raises the false alarm when several clusters are affected and disappears.

It processes the data sent from local head nodes and the final decision will be reported to the external user via satellites or other means. To distinguish between the friend and foe ships add ID to friendly ships.

When such ships come the system will not sound intrusion alarms. Then it increases the reliability of the intrusion detection with reduced false alarms with respect to spatial and temporal correlations of detection.

7.4. NODE LOCATION ESTIMATION

The proposed localization technique uses only the distance estimation between the reference Nodes and Ordinary Nodes.

RNs are able to detect their position by means of GPS to find the accurate location of Ordinary Nodes. Ordinary Nodes are nodes which execute without any centralized control to make randomly deployed WSN to be location-aware.

In order to Performa collaborative sensing tasks the sensor nodes must estimate their position by means of a distributed positioning algorithm.

Average Error (AE) calculated to weigh the efficiency of proposed algorithm using the formula 1.

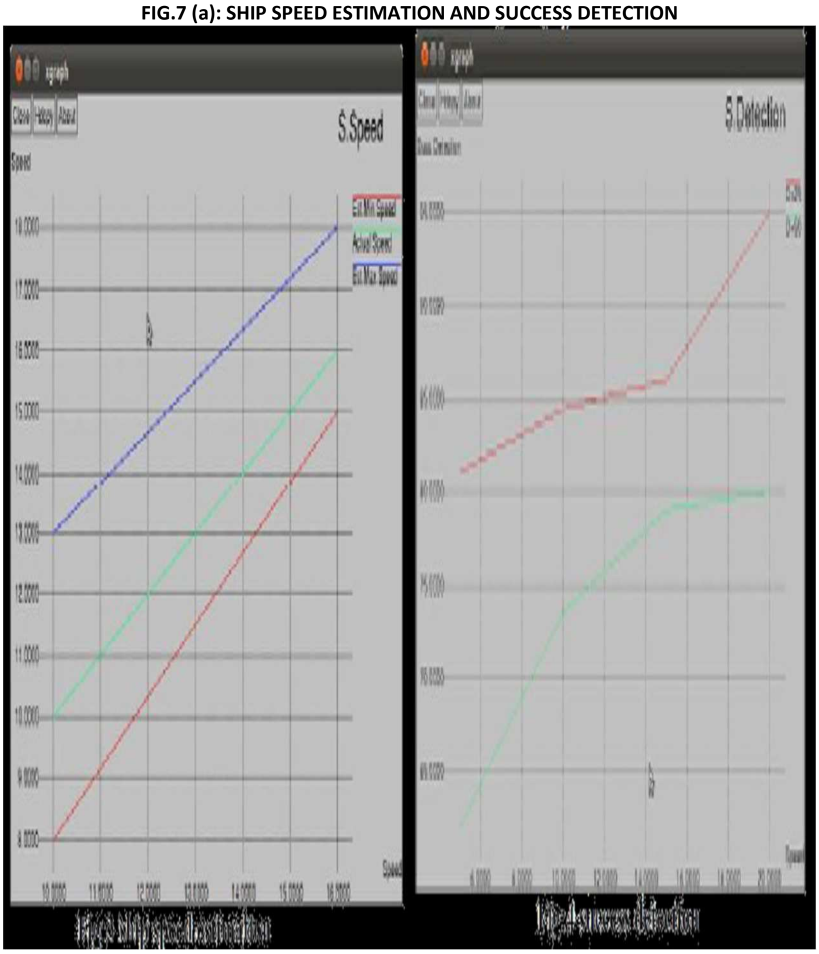
8. ANALYSIS OF PROPOSED SYSTEM

In order to improve the energy consumption in efficient way, localization algorithm is proposed.

Its consistency caused due to erroneous depth which is calculated using pressure sensors and find the average error in calculated node location.

It autonomously performs the assigned task without human intention. The block diagram describes the overall methodology of the proposed system,

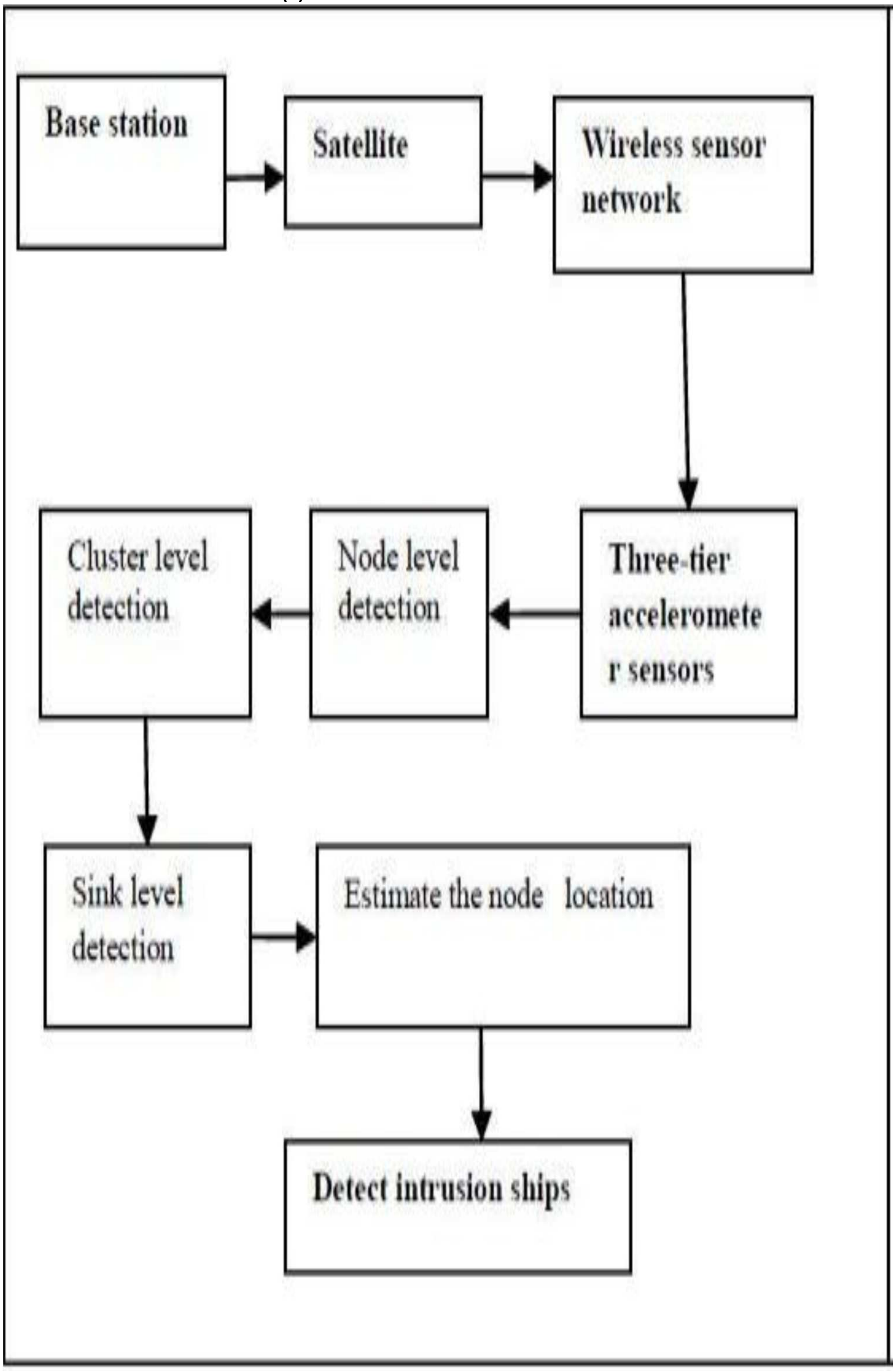
FIG.7 (a): SHIP SPEED ESTIMATION AND SUCCESS DETECTION



The above graph shows the ship speed estimation and success detection in accordance with the intruder ship.

The minimum and maximum and the average speed that the ship could attain, any ship that exceeds the ratio calculated is considered to be an intruder ship.

FIG. 7 (b): BLOCK DIAGRAM OF THE PROPOSED WORK



The below block diagram describes the working methodology of the proposed system. Using the three-tier accelerometer sensor to detect the intrusion ship. We introduced four algorithms namely node level, cluster level, sink level and node location detection to detect the intrusion ship more efficiently and accurately.

9. CONCLUSION

The developed architecture enables the system to conduct efficient information of processing including detection and classification in a large-scale WSN.

This architecture naturally distributes sensing and computation tasks at different levels of the system so that the sensor network can support high-quality of sensing and reliable classification without involving special high-power nodes.

With evaluation data collected from field tests in physical environments, the evaluation demonstrates excellent performance on the detection rate, classification result, attribute (velocity) computation accuracy and the timely information delivery.

Then the developed approach is further extended in future in many ways. Propagation of ship waves over large distances is not concentrated in the existing system. Real sensor network system drops buoys from a plane rather than the grid environment have to be analyzed. The main limitation of our schemes is that it requires a relatively dense network, especially to detect a high detection ratio with the small boats because of the high noise on the sea.

The power management in sink level detection is another methodology to improve the performance of the detection system in efficient way. On the other hand, seek solutions for supporting online intrusion detection system.

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