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IFAA ANALYSIS: AN INTELLIGENT FRAMEWORK AWARE ALGORITHM TO DETERMINE SHORTEST ROUTE TO BOUNDARY OF AREA UNDER ATTACK IN MILITARY SURVEILLANCE AND RECONNAISSANCE WSN AND ANALYSIS

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ABSTRACT

Wireless sensor networks (WSNs) have proven effective in military applications of surveillance and reconnaissance. Sensors capable of detecting pressure, temperature, movement and presence of specific chemicals are deployed in such applications. Traditionally, sensor data is collected and transferred to a centralized high-capacity node or control station. Analysis of data is carried out at such centralized facilities. Information or intelligence gathered from sensor data after analysis is later used to generate control and management commands that are relayed back to sensor nodes. The situation is analogous to an actual wartime scenario where soldiers who are on the field are equivalent to the sensors. Soldiers observe and sense the situation and communicate their observations to the decision maker who is stationed in the control tent. On gathering field information, the decision maker analyses the data and arrives at his decision which is again communicated to the soldiers on the field. Soldiers as well as sensors are not placed illogically or randomly but intentionally and strategically. Observations made on the field ultimately affect how the soldiers or sensors continue to function. Intelligence gained on the field ultimately gets used on the field itself. Our attempt is to observe, analyze and apply intelligence on the field itself. This work proposes an intelligent algorithm that is aware of the sensor network topology, analyses sensor data within the network and uses the network framework to arrive at usable intelligence. Locally generated intelligence avoids communication to and from the command/control and adds value to military surveillance and reconnaissance applications of WSN. Intelligent sensor management allows us to use just the necessary number of sensors while saving resources on otherwise redundant expenditure. In the present work we have designed and applied a dynamic shortest route to the boundary of the area under attack. We have compared the results of simulation experiments incorporating the proposed algorithm against a control experiment without the algorithm.

Keywords: *WSN, Surveillance, Shortest route, Intelligent framework, Framework awareness*

1. INTRODUCTION

Wireless sensor networks (WSNs) are described as a collection of specialized units capable of sensing and communicating observations equipped with an appropriate communication infrastructure. They are designed and developed either for monitoring or recording different phenomenon or circumstances in differing terrain. Temperature, air pressure, atmospheric humidity, wind direction and velocity, light intensity, mechanical vibrations sound intensity, power-line voltage, physiological functions, and pollution levels are some of the most regularly monitored characteristics utilizing a sensor networks. Because a sensor network can connect the physical and logical realms, it is one of its most important strengths. It can do this by gathering information from the physical world and transmitting it to sophisticated logical devices that can process it to generate intelligence. Because of this specific strength, it is possible that the collection of data for military and civilian purposes will need less human interaction or interference if we use technology to its full potential. Such an application saves precious lives too. Figure 1 depicts a military surveillance situation in a visual form.

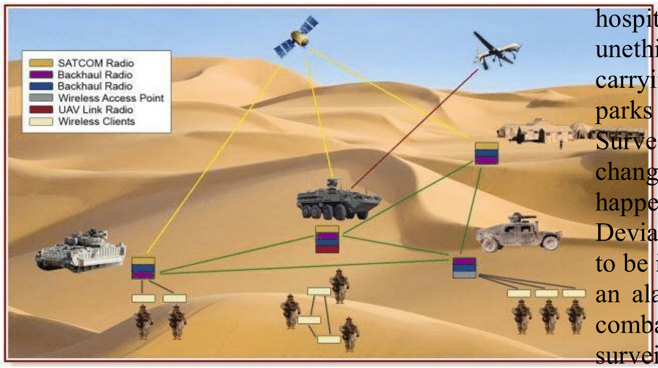


Fig.1.Military surveillance scenario

Military personnel managing surveillance must keep a vigil on the nation's borders, where adversaries may infiltrate, and an assault could be launched against own troops. The area under surveillance might either be a vast land mass or a large body of water. As a result of the topography, a comprehensive examination of the monitoring area's geography is required. Managing such surveillance manually is a herculean task. Applying a WSN in place of a human team is a wise alternative. A wireless client can then be deployed, which is an individual that uses a wireless network's services. At the location of surveillance, there are multiple equipment like armored, and patrolling vehicles equipped with radar (both terrestrial and aerial). If the boundary of area under surveillance is bordered by an ocean, then ships, boats, and water vehicles are required to monitor the oceanic zones, which are under the command and control of naval troops. Advanced prevalent technologies include SATCOM Radio, Backhaul Radio, Wireless Access Point, and UAV Link Radio allow them to communicate with the local and central control units. Sensors of different type namely acoustic, vibration, seismic, and motion sensors are used extensively in such applications. Among the duties of military surveillance systems are monitoring the borders, monitoring friendly troops, monitoring the reconnaissance of opposing forces, equipment, and ammunition, target tracking, and the evaluation of combat damage caused by nuclear, biological, and chemical attacks.

Surveillance is defined as the ceaseless task of monitoring activities of a system with its constituent entities in order to validate compliance with set norms of eventless behavior [1]. The set norms of behavior are in fact location defined. They are prone to vary based on society and moral code. As an example, restrictions on smoking in hospitals, schools or at fuel stations are both unethical and physically dangerous. Ban on carrying weapons in to theatres, public areas like parks and schools are government enforced laws. Surveillance usually involves monitoring activities, changes, movement and unnatural occurrences happening within a fixed area or perimeter. Deviations from the present normal behavior needs to be identified immediately and flagged off to raise an alarm to initiate retaliation, damage control or combating mechanism. Primary functionality of surveillance is to keep an eye on a volume of three dimensional space for an extended period of time. Until the space is unaffected or operations and changes happening there are in line with expected norms of normalcy, surveillance infrastructure is passive. In case of observations of abnormal or unexpected changes surveillance framework must trigger off a series of counter measures or damage control mechanisms. Classically, surveillance has always been a human managed activity, digital surveillance systems have replaced round the clock human guards effectively. However digital surveillance is limited to data collection and communication only. Analysis of sensor data and further derivation of intelligence still continue to be invested in the hands of human actors [2]. Such inevitable human involvement adds an element of error prone analysis and marginal reduction in efficiency with increase in time duration of analysis. Smart surveillance or intelligent surveillance overcomes these issues by adding the vital intelligence within the surveillance framework. Essentially it is the combination of intelligence and sensor framework. Current global events have added immense value to surveillance and reconnaissance in terms of securing public places. Types of attacks have evolved, attackers have adapted themselves to newer technologies, and in most cases cutting edge technology to perpetrate terror is applied. Such changes call for appropriate real-time and immediate counter measures to be initiated. A moment’s delay in detection, analysis and application of intelligence in combating the threat makes the entire exercise useless and ineffective. Therefore, the surveillance needs to be both intelligent and proactive. Reducing dependence on human actors leads to the setup of an independent framework [3].

Military surveillance and reconnaissance systems are built out of sensors of different types, they are typically deployed to build themselves into a network without actual human intervention. Due to the variety of parameters sensed, they are almost always in a multimodal data and information fusion state. Collaboration building, efficiency in resource control and optimal utilization are also challenges of such WSN deployments. Furthermore, sensor networks for military surveillance vitally need intelligent sensor management unlike civilian applications where sensor management is minimum and not that critical. As against the centralized surveillance framework, which is a fixed framework and less appropriate for military deployments, a distributed framework with computational capability though limited but spread across network components is a more suitable alternative. Such a decentralized framework is composed of smart sensor networks spread over large expansive regions of varying terrain. Greater the area under surveillance, larger the number and type of nodes deployed therein. Increase in number of nodes itself necessitates an element of sensor node management. Management of node resources must not be a standardized process but a proactive and dynamic situation aware activity. There is another important aspect of smart distributed surveillance, the volume of sensed data gathered and communicated across the network. Like how sensor nodes are managed using command and control, so should the huge volume of data they gather as a network must also be managed to generate useable intelligence. Sensor management consists of planning, controlling and decisive use of sensor nodes of the surveillance framework to optimize the efficiency of the infrastructure [4].

An intelligent infrastructure involving sensor management is a system designed to generate situation awareness by management of sensor nodes [5]. In building such a process, sensor node cooperation and coordination are also attained inadvertently. Such a sensor management scheme allows us to use select subset combinations of strategically chosen sensor nodes instead of redundantly using every node within the deployment. This work proposes an intelligent framework aware algorithm (IFAA) to determine shortest route from a point of strategic vantage to the boundary around intruders in a military surveillance and reconnaissance WSN. Such routes are vital to move man and machinery to aid counter action. Present work involves design of an algorithm to determine the boundary encompassing an area under attack in a surveillance network. We apply the algorithm to a WSN framework and analyze its efficiency.

The remainder of the sections of the paper's structure are section II, which discusses the related works; the proposed model is discussed in the III section. Design and implementation are discussed in the IV section. Section V, the conclusion of the work.

2. RELATED WORK

Studies related to high level sensor management are reported in [6,7] where a situation aware as well as business aware framework is proposed with improvements reported in homeland security and surveillance. They propose a high-level management approach to sensor control. With different types of sensors, an additional unit is incorporated to combine data. Additionally, an inference mechanism is also implemented to make informed decisions. Error in sensor data is also accounted for. Sensor node energy levels or general health is also an additional parameter in management decision making. Sensors deployed are not custom made and thereby bring down the cost of deployment and makes the framework affordable. Due to the inherent centralized approach, the work carried out is un-scalable and involves risk of bottleneck in exchange of control and command exchange. Similar to work in the same domain, performance analysis or testing are ignored.

The research presented in [6] proposes an abstraction approach to situation awareness in a business environment. The architecture proposed is flexible and enables scaling. Deployment of seemingly unconnected devices is achieved there by implementing service-oriented design. The work goes on to prove that higher level usable intelligence gathering need not depend upon low level knowledge.

The work [7] in particular analyses methods for optimized resource allocation in an environment having video and multimedia surveillance. The communications examined are over the internet and a wireless ad hoc network and WSN. A control-based sensor management scheme is studied in [8]. The paradigm behind the infrastructure is called holonic. Triad of sensor networks, the communication platform and the intelligence gathering group is the basis of the architecture. Sensor nodes are at the bottom of the triad. Every platform is associated with a set of sensors and controls them. Larger sensor management task is divided into functional subtasks and assigned to each one of the many platforms. This framework necessitates the increase in the number of holons as the size of network deployment also increases. Such an increase contributes to the increase in complexity also. Despite drawbacks of the work like limitations in simulation experiments where a single threat is only considered and comparison between open and closed approach of implementations, the work successfully proves the efficacy of holonic architecture in sensor management.

Multi object optimization is the focus if work in [9]. The chance of overlooking occurrence of an event and the chance of recognizing a false positive are the key parameters considered in the work. These are the two key parameters considered in the sensor management model designed. Bird’s eye view or the larger scale intelligence gathered from ground observations made by individual sensors is an NP complete problem. In this work, particle swarm optimization is applied to combat this issue of intelligence optimization. Results published in this work shows reduction in the chance of false alarm at the cost of heavy weight computation. Such large computation loads are manageable in networks with greater computational capability but unsuitable in WSNs.

Authors of [10] have worked with assignment of sensors to missions by following a natural language based approach. They base their work on a market architecture for sensor management built around a computational economy. Framework is under the control of dual managers, namely mission manager and sensor manager. Mission level decisions and intelligence gathering activities are managed by the mission manager which also assigns priority to various contending tasks. Prioritized tasks are further assigned to sensor managers which are responsible for carrying out tasks from sensor data collection, aggregation and analysis. Sensor managers in turn assign and schedule tasks to sensor nodes. Network resource management is also under their jurisdiction. In case of deadlocks or faults in communication flow, they take up the additional responsibility of troubleshooting too. Among sensor nodes under one's control, sensing tasks are universally allocated. Data aggregation tasks are however assigned to a select few sensors only based on their current physical parameters. Free slots of sensor nodes and bandwidth available with them for use in communication channels are published by all entities. This data is used to calculate consumer bid prices.

A service chart-based database along with bid formulators are used to convert sensor infrastructure into a service database. Service database is the basis of allocating resources to advanced applications like targeting, identification of intruders, environmental monitoring, and such where intelligence gathering is involved. Service chart allows us to compare all possibilities of allocations, which can further be mapped to a list of costs and thus a decision can be made on optimized allocation. After bids are placed, an auction finalizes the most profitable bid as the winner allocation. Ultimate winner of the auction is aimed at maximizing gain while restricting the number of allottees of each resource to one only. The bidding scheme requires a centralized sensor management and control. Centralized control rules out scalability and flexible deployments. Exchange of bids add communication overhead too. Further, the decision regarding the winner of bids is an NP-hard problem. Overall the scheme adds considerable complexity instead of reducing it in terms of computation and exchange of control communication.

Singh et al have presented a thorough analysis of trajectory schemes for data collection using mobile elements in WSNs in [11] among which an integrated mobile surveillance system is one. This system consists of a fixed subset of sensor deployment in addition to another subset of mobile sensors. The framework proposed is for real time applications. Its working principle is based on reactive activity. Sensor management is centralized and event driven. Management is implemented within an external server that is the focus of sensor data collection and single point of control command dissemination. System users must communicate with the sensor network via the server and receive data in usable format at the server itself. On receiving command from the server, fixed location sensors start their sensor activity and continue to transfer back sensor data. Sensor data is continuously monitored and if and when abnormalities are observed, command is sent to mobile sensors. Mobile sensor nodes respond to commands on cue. Mobile nodes have the freedom to move to locations that require attention and perform additional surveillance or reconnaissance activities. Drawback of the architecture is the bottleneck in data gathering and huge overhead in analysis on the external server.

The problem of computing the convex hull is studied in [16, 17, 19, 20]. Graham's scan is reported as having an efficiency of O(nlogn) in [21]. An alternate three-dimensional implementation of Graham's scan reporting the same efficiency is available in [22]. [23] reports Jarvis march approach having an efficiency of O(nh), its implementation is reported to have an efficiency of O(n log h) in [24]. All these algorithms which have h are output sensitive. In the military surveillance scenario, nodes detect intrusion dynamically. Due to the inherent dynamism in data collection itself, a dynamic algorithm serves the application better. A summary of literature survey is presented in Table 1.

Shortest path algorithms have wide application domains ranging over traffic management and control to network communication management. Routing protocols developed and used in computer networks also apply shortest route algorithms extensively. Dijkstra came up with a well-known algorithm that suited non negative edge costs. Floyd extended the idea to incorporate negative edge costs as well. In a military surveillance scenario, finding the shortest path is not enough. We must also find an enemy free path. The additional feature required is to account for the ability to discriminate between self and non-self-nodes while computing the shortest routes.

3. PROPOSED MODEL

We have designed the model for experimentation and simulation consisting of the following components.

U={(xi,yi)| L<=xi<=H && L<=yi<=H} is the universal set of node coordinates where i and j assume all values in the range (1,N) and N is the number of sensors deployed, L is the minimum index and H is the maximum index.

C1={(xi,yi)|L<=xi<=H&&<=yi<=H&&(xi,yi)is an element of U that has returned TRUE from negative selection} is the set of candidate points for the shortest route discovery.

Ci={(xi,yi)|L<=xi<=H&&L<=yi<=H&&(xi,yi)is an element of Hi-1 that has returned TRUE from negative selection and belongs to the candidate set identified in the i-1th iteration of shortest route discovery} is the set of candidate points for the ith iteration.

Ci+1={Ci-C U Ci+1}is the set of candidate points considered as candidates for the i+1th iteration of the shortest route algorithm.

HF={(xi,yi)|L<=xi<=H&&L<=yi<=H&&(xi,yi)is on the shortest route} is the set of all points on the route determined that satisfies two criteria, namely total cost is minimum and is also enemy free.

H1={(xi,yi)|L<=xi<=H&&L<=yi<=H&&(xi,yi)is identified as a shortest path node} is the set of nodes belonging to the set U and identified as a node on the shortest route to the boundary encompassing the area under intrusion, that are identified after first iteration.

Algorithm: Dynamic shortest route

```
S<- source of strategic advantage
D[]<- nodes on the boundary of area under intrusion
For i=0 to length.D do
Until no new routes are discovered repeat
Select two paths p1 and p2 from set of all paths p
Crossover path1*path2 to D[i]
For each child path c do
Verify if the path is enemy free
If true replace path in p with c
End if
End for
End for
```

4. IMPLEMENTATION AND RESULTS

The problem identified for implementation in the present work is incorporation of intelligence in a military surveillance scenario. Aim here is to determine the shortest enemy free route to the boundary of an area under attack or intrusion. Once an area is under intrusion is identified, further countermeasures entirely depend upon the location and extent of intrusion. These intelligence parameters are critical in mission control and management. Simulation experiments are carried out on Matlab R2021a running on Intel® Core™ i3-6006 CPU @ 2.00GHz 1.99GHz with 4.00 GB RAM. Test bed design is grid based. Extent of the grid is 100X100. Each square unit is of measure 20X20 identified as a unit cell. Every unit cell is under the surveillance of one high power node identified as the grid head.

This high-power node is represented as the red coloured circle in the fig. 2. The sky-blue coloured node is also a high-power node but not a grid head. The dark blue coloured nodes are low power nodes whose responsibility is limited to sensing of physical parameters. The screenshot in the figure is showing a sample of the outcome of one of the many simulation experiments. Green colored circles represent the boundary nodes of the minimum area identified, enclosing every node that has detected an intrusion.

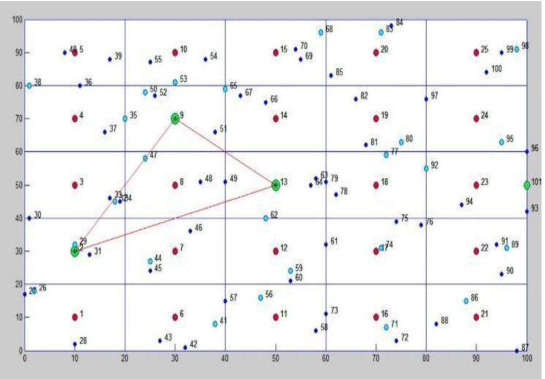
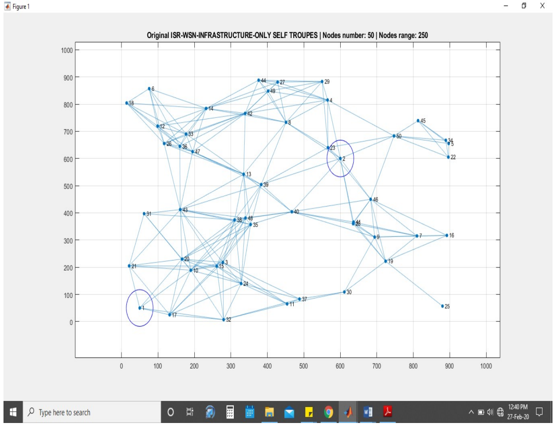


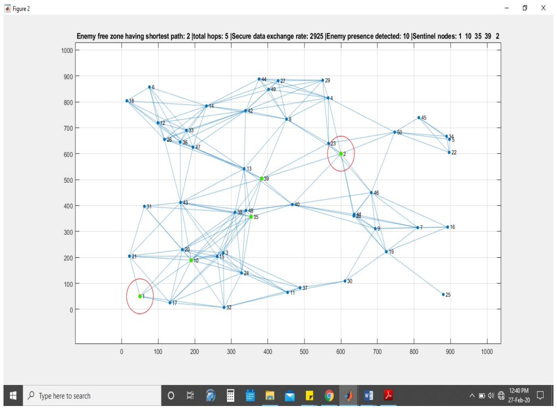
Fig 2: Test Bed Deployment

As coordinates of nodes are fixed and available in data structures, distances are computed as Euclidean distances. Algorithm applied to determine attack locations is an artificial immune algorithm of negative selection [145]. Algorithm designed and applied for determination of the shortest path is a genetic self-learning based algorithm that accepts coordinates of points identified from negative selection as input. The algorithm determines the shortest routes and returns the coordinates of nodes along the computed path. The opportunity identified here is detection of intrusion is not a synchronous event. As individual nodes detect intrusion using negative selection sequentially at different times, we have an opportunity to compute the enemy free shortest routes in increments as well. Additionally, in subsequent iterations of the algorithm every point within a previously computed shortest path need not be considered as possible candidate node. For example in instance 1, if H1 is the set of points identified as the part of the shortest route encompassing I1 out of C1 candidate points, in the next iteration when C2 is the set of candidate points we drop I1 and consider C2 along with points from H1 only. Fig 3 shows the simulation experiment result screenshot of WSN deployment. The source and node on the boundary of area under intrusion are shown circled. Fig 4 shows the candidate shortest route identified solely based on the edge costs and enemy free criteria. Fig 5 shows the simulation results of a run where enemy presence is identified and shortest route is identified while avoiding enemy presence.



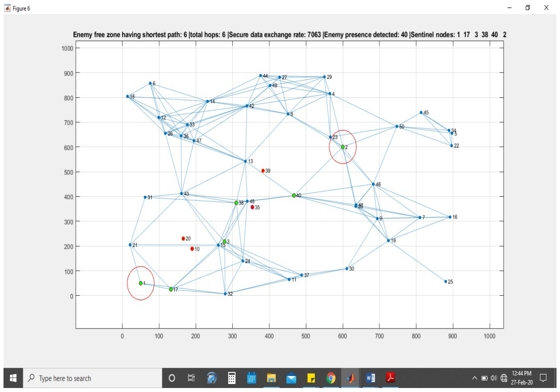
Original ISR-WSN-INFRASTRUCTURE-ONLY SELF TROUPES | Nodes number: 50 | Nodes range: 250

Fig 3. Simulation Result Showing Source And Destination Where Destination Is On The Boundary



Enemy free zone having shortest path: 2 |total hops: 5 |Secure data exchange rate: 2925 |Enemy presence detected: 10 |Sentinel nodes: 1 10 35 39 2

Fig 4. Simulation Result Showing One Candidate Shortest Route



Enemy free zone having shortest path: 6 |total hops: 6 |Secure data exchange rate: 7063 |Enemy presence detected: 40 |Sentinel nodes: 1 17 3 38 40 2

Fig 5. Simulation Result Showing Enemy Presence And A Candidate Shortest Route

We observe that up to 18% reduction in time taken to determine the enemy free route using proposed algorithm when compared with Dijkstra implementation and exhaustive search for eliminating enemy present candidates at input size 20X20 matrix input. We have observed a 10% reduction in running time when the input size is a matrix of order 100X100 as in table 2.

Table 2: Running time of proposed algorithm compared with Dijkstra's algorithm

	nodes	time
Proposed intelligent shortest route	20	260
	100	400
Dijkstra	20	1420
	100	4000

It is well evident that the runtime efficiency of the proposed algorithm is better than the existing algorithm.

CONCLUSION

In the present work we have proposed and analyzed an intelligent situation aware and deployment aware algorithm to determine the shortest route connecting points of strategic advantage to points on the periphery of area under attack or intrusion in a military wireless sensor network scenario. The algorithm is simulated on a WSN surveillance frame work and is compared with existing shortest route algorithm. Existing algorithms so not accommodate enemy free route discovery. Our proposed algorithm overcomes this drawback.

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Table 1. Literature Survey Summary

Ref.No	**Published Year**	**Methodology**	**Advantages**	**Disadvantages**
[5]	2019	The most efficient auction process for the tracking of a target.	Better performance, in terms of MSE	Need to focus on more accuracy for auction-based crowdsensing.
[6]	2020	LAURA - Lean Automatic code generation for situation-aware and business-aware Applications.	Provide better results for situation-aware or business-aware final IoT applications	Need to focus on Quality of Context parameters.
[8]	2020	To minimize the impact of vagueness and uncertainty in message exchanges based on an interconnected set of fully intercommunicating elements (peers), this paper examines holonic structures or formations that are generated when there are constraints on resources (energy, available messages, time, etc.).	Provides shortage of resources prevents communications	Produce the low-quality results
[9]	2016	Different sensor network optimization problem-solving techniques were described in the research.	Different sensor network design, operation, deployment, location, planning, and management issues may be addressed using the suggested multi-objective optimization approaches.	Need to focus on optimisation.
[17]	2019	In order to recover the original dataset, we proposed three unbalanced data processing algorithms and retrieved protein attributes from the evolutionary conservation of amino acids to develop a predictor for the identification of protein interaction locations	Improving protein-protein interaction site prediction	Need to focus on accuracy