Military Operations: Wireless Sensor Networks based Applications to Reinforce Future Battlefield Command System

Atif Ali
PMAS Arid Agriculture University,
Rawalpindi, Pakistan
atif.alii@yahoo.com

Yasir Khan Jadoon
Comsat University,
Islamabad, Pakistan
yasirjadoon@hotmail.com

Sabir Ali Changazi
Riphah International University,
Islamabad, Pakistan
mysabir.changazi@gmail.com

Muhammad Qasim
University of Wales
Cardiff UK
saqi.17@gmail.com

***Abstract*—This article outlines the military applications of wireless sensor networks (WSN). The combat activities in modern military operations are divided into different categories, which give the requirements and restrictions for wireless sensor networks. The type of sensor and its function can adjust and limit the use of WSN. A WSN military application's capacity depends on various factors, including capabilities of sensors, type of sensors, the architecture of wireless communications, its range, and appropriate data processing. We performed a categorization of WSN applications used in the military according to the strategic scenario and sensor type. In this paper, military WSN is classified, involving military combat, the sensor type, and defines the vital kind of WSN. This article introduces the research and engineering issues of next-generation WSN military applications.**

Keywords— Wireless sensor networks; battlefield; urban; other- than-war; force protection; presence; CBRNE; ranging; imaging

I. INTRODUCTION

Communications is compulsory in each phase of military missions [1]. It is necessary to deliver commands on the battlefield and guarantee delivery of commands and data via sensors. In this work, we presented an overview of military structure applications on data collection using wireless sensor networks (WSNs).

Communication in the military, by all means, must be limited to the specific zone, and it should be time bounded and used whenever needed [1]. Generally, they must be resilient to jamming the signals, direction-finding, and other Electronic Warfare threats, and provide end-to-end communication security.

There is an outstanding and well-characterized adversary in a typical war zone of military commitment, noticeable all around, ashore, or adrift. Notwithstanding, ongoing knowledge has uncovered more situations, such as genuinely overall tasks, urban conditions, and activities other than war (OTW), such as maintaining peace and debacle help [1]. We consider the utilization of WSNs in a huge territory combat zone (yet not around the world), urban fighting, OTW, and power assurance.

The abilities of military WSN uses are based not just on remote interchanges satisfying the necessities referenced above but also on the capacities of sensors. The use of sensors results in different physical wonders. Presumably, the most critical in military uses are EM waves, light, weight, and sound, resulting from gunfire and impacts. Sensors can perceive and possibly measure creation, natural and unsteady fume, similarly as proximity of people or items. We will utilize the sensor abilities as one of the essential types of military utilization of WSNs.

WSN is the least absurd strategy for gathering data about nature and on-screen characters in that condition, paying little mind to the sensor type [2].

In the battlefield, modern warfare and the protection of military WSNs are essential. The use of WSNs is effective in reducing the uncertainty where the troops are deployed and the exact location and disposition. In the OTW case, the use of WSNs can increase certainty regarding the affected areas and the population that is affected by an inevitable disaster.

The information estimated by sensors is communicated from one sensor hub to at least one gateway after conceivable pre-handling. The gateways give information combination, extra information handling, and the span back ability close to continuous association using longer run remote transmissions or satellite associations; and nonconcurrent data move to approach unmanned airborne vehicles [3].

The correspondence designs impact the inclusion and availability of WSNs, which thus set the constraints of military uses of WSNs. A study of WSNs and related issues is given in [4].

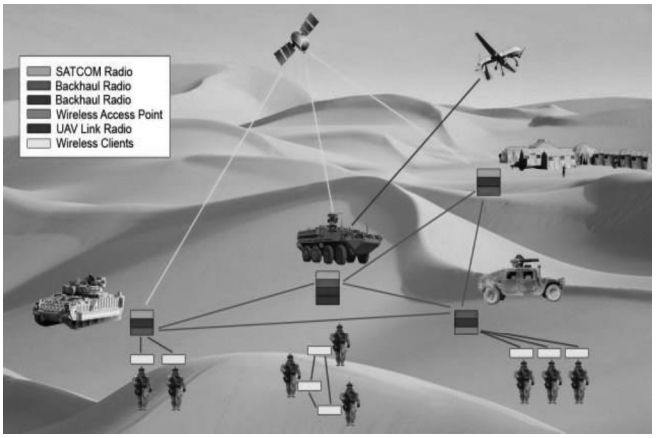

Fig. 1. Wireless Sensor Networks in Battlefield

The rest of the paper is organized as follows. Section II explains the classification of military applications of WSNs. Section III describes the main classes identified in Section II. Section IV presents a discussion of research and engineering challenges in military applications of WSNs. Section V concludes the paper.

II. CLASSIFICATION OF MILITARY

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APPLICATIONS OF WSN

A. Types of Military Operations

In current military systems, we can describe four situations: front line, urban fighting, other-than-war, and power security. These techniques characterize the stature and type relating to problems, which in gyration indicate the size notwithstanding necessities for WSNs. War zone: massive scale, non-physically introduced WSNs.

Urban fighting and power security: moderate-scale (up to a few 100s of hubs), physically executed. Other-than-war: any scale, both physically and non-physically dispatched.

B. Sensor Types

Functional prerequisite for urban combat accompanied by another military operational framework points to the practice of the following sensor modes [5]:

- Presence/Intrusion (e.g., centered on a pattern of infrared, photoelectric, laser, acoustic, vibration, etc.)
- Chemical, Biological, Radiological, Nuclear, and Explosive (CBRNE) and Toxic Industrial Material (TIM) sensors.
- Extending (e.g., RADAR, LIDAR, ultrasonic, etc.)
- Imaging (containing infrared coupled with LADAR imaging)
- Noise (auditory sensor capable of generating an acoustic stream).

C. Soldier-Worn WSNs

An outline of the WSN military apparatus is the warrior worn sensor hubs [6, 7]. This application coordinates to follow basic exercises of a trooper additionally distinguish circumstances of genuine anguish or probabilities of causality. It will be accepted as a relationship to drive safeguard situations. This item can be sourced in OTW situations and find the basic parameters described by firemen or other work taking an interest in massive hazards (for example, salvage).

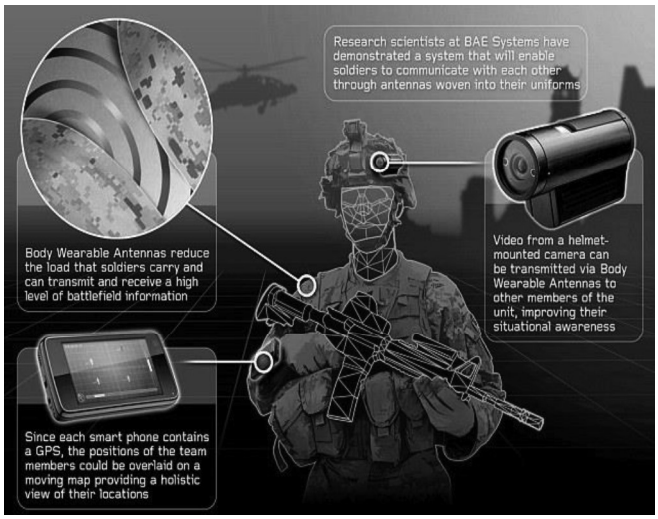

Fig. 2. Soldier- Worn WSNs

D. Classes of Military WSN Applications

An analysis of military detecting technologies offered in [8], and we count some of them appropriate for practice, including WSNs. In Table I., the categories are characterized by acronyms classified in Section III.

Sensor types	Operation scenario			
	Battlefield	***Urban***	***OTW***	***Force protection***
Presence/ Intrusion	SHLM, AAP	SDT		SHLM, AAP, SDT
CBRNE	RCS		VDM	VDM, RCS
Extending		EARS, INS	BL, INS	EARS, BL, SDL, PP
Imaging	ASW	SDL, MCM		SDL, MCM, PP
Noise		ATS	ATS	ATS

TABLE I. CLASSES OF MILITARY WSN APPLICATIONS

III. DESCRIPTION OF CLASSES OF MILITARY WSN APPLICATIONS

A. Self-Healing Land Mines (SHLM)

A system that sustained an autonomic network of antitank landmines is explained in [9]. Every antitank mine observes its neighbor's condition, senses risks to itself, and reacts autonomously towards those risks by stirring. Sensing is centered on a dispersed self-contained aural location network and accelerometer antennae. Direction for the development of the subsequent generation SHLM system is given in [10].

B. Aerostat Acoustic Payload for Transient Detection (AAP)

Acoustic sensor pack suspended underneath attached aerostats are attempted to perceive and recognize transient alerts from mortars, massive firearms, and little arms shoot. The airborne sound-related sensor registers a course and tallness to the beginning transient and genuinely flags a parallel imager. Unattended ground sensor (UGS) frameworks can improve the aerostat bundle by giving a surplus course of action vectors from different ground-based acoustic groups to achieve a 3D triangulation on a starting zone [11]. An improvement of acoustic vector sensors processes the load and the atom speed in every one of the three distinct ways, so the source course is evaluated rapidly [12].

C. Soldier Detection and Tracking (SDT)

In the defensive military, organizes, or structures, dismissed acoustic and seismic sensors are envisioned to think about centers by finding individual rival officials moving nearer [13]. A program for particular after practices a mix of acoustic sensors daytime still cameras. The remarkable blend among the acoustic and visual methods understood the camera performing at the right time and position metaphorically. The framework transmits just those similar characteristics which are sable with the acoustically made tracks, passing on a high hit rate [14].

D. Early Attack Reaction Sensor (EARS) - A Man-Wearable Gunshot

The EARS is a latent acoustic recognizing system that recognizes discharges (choke sway or perhaps shockwave) to pass on the client's gunfire source zone's relative azimuth and degree data. The EARS structure perceives with a little intensifier gathering. It has been attested in an open field additionally in military activities in the urban scene

(MOUT), including and has offered useable impact and range data in anomaly to the consummation places [15].

E. Sniper Detection and Localization (SDL)

To redesign the official's protect against marksmen, sound-related limitation of shots is developed. Adaptable, accepting wires can be presented on the warrior's crown. To recognize marksmen's in a valuable zone before troupes are course of action - two acoustic gatherings and a day-night camcorder are used. In case the benefits are arranged in an exact territory, two acoustic displays could give the purpose of the shooter and a conceivable region by triangulating acoustic data. In contrast, the day-night camera could provide a genuine vision of the operators [16, 17, 18].

Fig. 3. Sniper Detection and Localization (SDL)

F. Time Variation of Arrival Blast Localization Using a System Of Disposable Sensors (BL)

Utilizing a working system of minimal effort acoustic finders, the procedure executes a three-dimensional, Time-distinction of-appearance (TDOA) wellspring of different strain impacts in various conditions. The system is fit to work unequivocally within sight of a few wellsprings of shortcomings. Once introduced and started, each sensor hub self-build into a specially appointed, multi-bounce, hearty WSN related with at least one access hubs [19].

G. Perimeter Protection (PP)

Comprehensively utilized considerations of edge security with zone pioneers will be substituted soon with multi-sensor orchestrate. This kind of structure can oversee day/night cameras, IR uncooled warm cameras despite millimeter-wave sensors perceiving discharges reflected from target article. Close to the markers, the most crucial section that affects the framework ability is sharp information evaluation and a suitable information mix process. A similar arrangement of uniquely delegated WSN is worked for periphery recognition [20].

H. Chemical, Biological, and Explosive Vapor Recognition With Micro Cantilever Array Sensors (VDM)

A small scale cantilever-focused Self-Sensing Array (SSA) arrange measures follow the utilization of explosives, poisonous synthetic compounds, and organic operator trademark is anticipated. The model system draws in the sensor's scope and the capability to watch electrical and warm attributes of fume particles on the cantilevers [21].

I. An Inexpensive Remote Chemical Sensor for E-UAV Platforms (RCS)

An unobtrusive sensor for the constraint of deadly manufactured mixtures was made to associate extensible unmanned aeronautical autos. The sensor was proposed to distinguish substance fumes in a nadir-seeing model from a stature of 300m while skimming at a speed of 96km/h. Hazardous manufactured substances are distinguished and saw by their phenomenal infrared maintenance trademarks. To constrain bogus alerts delivering from scene contrasts, 3 concealing isolated photodiode locators were gotten together with the radar. The photodiode radar considers to be a prospect as the infrared sensors and passes on the additional scene data required to perceive scene contrasts from substance radiations [22].

J. Vital Optical Sensor Network for Missile Canisters Continuous Monitoring (MCM)

Missile protection checking significantly improves missile working assistance life, sparing many dollars and limiting the number of missiles required. This demands a quick relentless checking radar that aggregates and terminals data on common issues and vibration (up to 100 g) in rocket canisters without electrical dangers. An optical sensor sort out able to watch paralyze and vibration in rocket canisters in three estimations at quick (5 kHz) is endorsed. The structure is planned to be used in natural contact watching framework to gather and store vibration, daze, temperature, or hurting exercises data over the whole lifetime of a shot canister [23].

K. Inertial Navigation System (INS)

Time variation of arrival (TDoA) dimensions from a WSN are used to help an inexpensive INS. The use of magnetometer information in a supplement to the WSN for INS assistance is proposed. Magnetometer data targets the automobiles heading and pitch irrespective of the vehicle's true orientation, increasing orientation approximation [22, 23].

L. Acoustic Threatening Sound Recognition System (ATS)

Compromising sound acknowledgment, association and confinement can be proficiently utilized in kilter fighting and the logical inconsistency of fear monger dangers. As of late, significant research endeavors have been made in this zone utilizing WSNs. An imaginative acoustic hazard acknowledgment connects with a circulated and sorted design is envisioned. The proposed plan enables joint effort among detecting bunches to perceive target marks, limit false alerts, order target types, and figures the sound-related source position. Its points of interest incorporate vitality capability, dependable identification and association, little recognition and grouping inactivity, and diminished false cautions. [24].

IV. RELATED WORK

A. Sensor Network Architecture

1) Node Composition: In different applications, the composition of sensor network nodes is different but

generally consists of four parts: data acquisition, data processing, data transmission, and power supply.

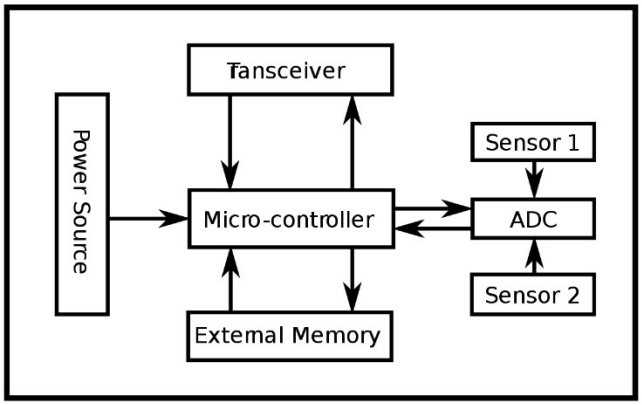

Fig. 4. Components of Wireless Sensor Networks

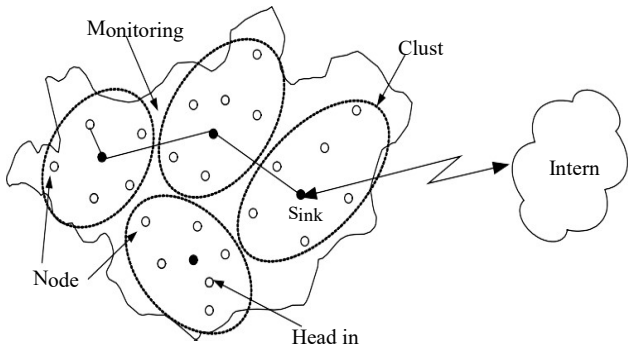

Fig. 5. The architecture of Wireless Sensor Networks

2) Network Architecture: In the sensor organize, the hubs are arbitrarily dissipated in the checked zone. This procedure is finished by methods for airship communication, counterfeit inserting, and rocket launch. The hubs structure a system in a self-arranging structure, and the observing information will be checked by multi-jump transfer. Passed to the sink node, and finally, the entire area's data is transmitted to the remote center for centralized processing by long-distance or temporarily established sink link. The satellite connection can be utilized as a sink interface, with the unmanned airplane flying over the checking zone. Reusing the information on the sink hub is additionally away. UC Berkeley used this method in the UAV field test (unmanned aerial vehicle) project [25]. If the network size is too large, cluster management can be adopted. Mode, Figure 2 describes the general form of the sensor network architecture.

A. Wireless Sensor Networks Application

The tiny sensor technology supported by MEMS and the wireless communication capability between nodes gives the sensor network a broad application prospect, mainly in the military, environment, health, family, and other commercial fields. Of course, particular in space exploration and disaster rescue. In the field, sensor networks also have their unique technological advantages.

1) Military Applications: In the military, the WSNs will are an integral part of the C4ISRT. The C4ISRT system aims to use advanced, reliable technology to modernize the future. War design A battlefield command system that integrates command, control, communication, computing, intelligence, surveillance, reconnaissance, and positioning has received widespread attention from military developed countries. Because sensor networks are dense, low-cost, randomly distributed nodes. The arrangement, self-association, and adaptation to non-critical failure make it not cause the whole framework's breakdown because of the harm of specific hubs in pernicious assaults. This is unequaled by customary sensor innovation, and it is this that makes the sensor the system is perfect for use in brutal front line conditions, including checking our military powers, gear, and supplies, observing clash zones, perceiving adversary territory and equipping, finding assault targets, evaluating harm, observation, and identification of atomic, natural and substance assaults. In the combat zone, administrators regularly need convenient and exact comprehension of soldiers, weapons, and hardware. With the stock of military materials, the sensor will gather the comparing data, and send the information to the order post through the collection hub, at that point forward it to the direction, lastly join the information from every combat zone to frame a total theater circumstance guide of our military. In the war, the observation of contention zones and military locales is additionally pivotal. By laying the sensor arrange, the adversary's equipping is firmly seen in an increasingly inconspicuous manner. The sensor hubs can likewise be legitimately sprinkled to the foe positions. Rapidly gather data that is useful for battle when the foe is as yet reacting later on. The sensor system can, likewise give precise objective area data to fire control and direction frameworks. In natural and concoction fighting, the sensor system recognizes the blast focus reasonably and accurately. Will give our soldiers necessary response time, in this way limiting setbacks. The sensor network can also avoid direct exposure of nuclear reaction forces to atomic radiation. In military applications, contrasted with free satellite and earthly radar frameworks [26]. The potential points of interest of sensor systems are as per the following:

- The blend of multi-point and multi-directional data in conveyed hubs viably improves sign-to-clamor proportions, making it difficult for independent systems such as satellites and radars. One of the technical problems overcome
- The low-cost, high-redundancy design principle of the sensor network provides strong fault tolerance for the entire system.
- The nearby contact between the sensor hub and the identification target enormously disposes of ecological commotion's impact on framework execution.
- The half and half utilization of numerous sensors in the hub is useful for improving the identification.
- Multi-node joints to form a real-time detection area with a large coverage area.
- The ability to adjust the network topology using individual mobile capable nodes can effectively eliminate shadows and blind spots in the detection area.

2) Environmental Science: With the extending respect for the earth, the degree of everyday science is progressively expansive. Social event rough data through conventional

methods is an inconvenient task. Sensor systems give comfort to securing research information in the field, for example, following the Migration of transient feathered creatures and creepy crawlies, studying the impacts of ecological changes on yields, and screen the piece of seas, environments, and soils. There are a few sensors in the ALERT framework to screen precipitation, waterway water levels, soil dampness, and foresee flare-ups. The plausibility of downpours. Essentially, sensor systems ought to likewise be valuable for the precise and convenient expectations of backwoods fires. Furthermore, WSNs may also be utilized in careful agribusiness to watch nuisances and soil pH in crops. Moreover, preparation status, and so on.

3) Medical Health: If a unique reason sensor hub, for example, a pulse and circulatory strain checking gadget, is introduced on an inpatient, the sensor system can be utilized to comprehend the state of the patient being observed and to process it in time. It can likewise be gathered by the sensor organize for quite a while. Human physiological information, which is very valuable in advancing new sedates, and the smaller scale sensors introduced on the observed items won't carry an excessive amount of bothering to individuals' ordinary life. Furthermore, in tranquilize, the executives, and so forth. In numerous regards, it additionally has novel and extraordinary applications. The sensor organize gives a progressively advantageous and quick innovation execution for future telemedicine, to put it. Therefore this is a significant application of WSNs.

4) Space Exploration: Exploring the outer planet has always been the ideal of human dreams. The long-term monitoring of the planet's surface using the spacecraft's sensor network node is supposed to be an economically viable solution. NASA's JPL (Jet Propulsion Laboratory) laboratory developed Sensor Webs is technically prepared for future Mars exploration and has been tested and refined in environmental monitoring projects around the Florida Aerospace Center [27]. Future space exploration will perform the main functionalities based on WSNs.

5) Other Commercial Applications: Self-association, scaling down, and view of the outside world are the three sensor systems' attributes. These qualities verify that sensor systems ought likewise to have numerous open doors in the business field. For instance, sensors and actuators inserted in furniture and home machines. The mix of the remote system and the Internet will furnish us with an increasingly agreeable, helpful, and user-friendly smart home environment; the sensor network is successfully applied in the urban vehicle monitoring and tracking system described in [10].

B. Hot Issues in Sensor Network Research

Up to now, the examination of sensor systems has experienced two phases. The primary stage predominantly centers on the utilization of MEMS innovation to configuration scaled-down hub gadgets. Delegate look into ventures incorporates WINS [12] and Smart Dust. Worries about the system itself. What's more, research can be considered the second phase of the sensor arrange to examine and is presently turning into a problem area in remote system inquiry. From the system layered model, each layer should be joined with the qualities of the sensor organize. The examination questions are primarily gathered in the system layer and the connection layer as far as existing exploration. Underneath, we abridge the issues that should be unraveled and the current arrangements.

V. RESEARCH AND ENGINEERING CHALLENGES

The improvement in minimal effort indicators drives investigation into arbitrary exhibit advancement (sensor and correspondences) and related assets the executives to build control/vitality, recurrence and detecting limits [1].

A. Requirements for Future Military-use WSNs

The prerequisites for military applications of WSNs in the meantime and future 3-4 years and genuine conventions are discussed in [28]. The physical mass and weight require not to be a significant boundary. Sensor nodes must be able to immediately recognize neighbors and design themselves, comparable to *ad-hoc networks*. It is expected that most of the systems will remain practically static. For most operations, the area to be shielded may be from 5 to 20 km^2. The communication span should be 250-500m, and sometimes more than 1km. Thus, the number of nodes will infrequently surpass 100, but the number and density of nodes will considerably grow in the next 5-10 years. Transmission between nodes and gateway(s) will be two-way but likely remain subjugated by node-to-gateway drift. The nodes should be concealed with a small electromagnetic radiation configuration. Data rates may persist low to medium. The steadfastness of communication, opposition to jamming and intervention, and tamper-proof communications are of vital significance. Also, the WSNs should be resilient to the damage of a certain number of specific nodes. Such systems are known as disruption-tolerant networks.

B. Engineering Challenges

Overcoming the following engineering disputes can significantly improve the potentials of the WSNs in military applications [2]: classification of several simultaneous actions and reliable association of information from adjacent nodes; classification of objects and events as well as detection; upgraded integration of distinctive types of detectors; miniaturization and improved robustness of sensors; common organizations and standards for sensor data and broadcastings.

C. Research Challenges

The research is requisite to upgrade the usability, adaptability, and safety of the WSNs. Safety issues are associated with reputation methods to defend against spoof messages or jamming. Appropriate power supplies, energy reaping, and energy-efficient procedures are mandatory for better durability of WSNs. Operational and efficient isolated air delivery of sensors enhances coverage of the supervised area.

Improvements in communication styles are possible. A two-tiered architecture with gateways as hubs and sensor nodes as spokes returns improved flexibility and agility than homogeneous (one-tier) WSN. A critical study area is covered in WSNs. It unites the sensing scale of sensors and the communication scope of radios on the sensor nodes.

Last but not least, *information processing, fusion, and knowledge generation* are research areas that can considerably enhance the potentials of military applications of WSNs. They are related to coverage because of the

demand to have the reliable correspondence of information across space and time to achieve data mining in specific and knowledge engineering in general.

VI. CONCLUSION

Numerous applications of WSNs are used in the military worldwide. New operational requirements have opened doors to the use of Wireless Sensor Networks. A WSN military application's capacity depends on various factors that mainly include sensors, type of sensors, the architecture of wireless communications, its range, and appropriate data processing. We performed a categorization of WSN applications used in the military according to the strategic scenario and sensor type. WSNs have incomparable advantages over traditional technology in special military fields, and it will also bring up many latest and valued public sector applications. We provided a detailed description of the WSN application types and relevant research and engineering experiments for the future generation of WSNs in military applications.

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