Design for the Next Generation of Wireless Sensor Networks in Battlefield Based on ZigBee

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Abstract—**This paper describes the model of ZigBee wireless network employable in the battlefield. Wireless sensor network (WSN) technology has been known for scalability, carefree operation and easy installation. This proposed scheme is planned to adopt ZigBee wireless sensors network in the battlefield scenario using mesh and other network topologies within the remote large-scale environment based on the military requirement. Many sensors types are developed to save the soldier life under various critical situations, different infrastructure of battlefield and dynamic fighting environment in the theatre of war.**

Keywords-ZigBee, Battlefield and WSNs

I. INTRODUCTION

In recent years, the high technologies have been developed for military applications ranging from soldier clothes to automated vehicle to adaptive communication systems to support warfare. The next-generation embedded sensors become the important devices to report real-time status in the battlefield, e.g., vehicle position tracking sensor, soldier movement tracking sensor or enemy awareness sensor. However, most sensor systems suffer from the limitations due to the tactical constraints and requirements, especially within the remote large-scale environments. Traditional sensors have been operated under wireless point-to-point architecture, instead of operating all sensors in the wireless networks, in order to reduce the power consumption in system and improve reliabilities.

Currently, there is a new trend to use low-power wireless network technologies instead of dedicated solutions in many applications to reduce the development costs and to facilitate the set up process. However, the problem for this system is the ability to send data over a long distance to sending data, rendering it inappropriate and difficult for use in the military application. Some wireless sensor networks (WSN) cannot be managed in the forest and non-symmetric environment. In fact, WSN technologies have many commercial uses and is already being considered in commercial settings. General Motors has introduced them to model traffic conditions [1]. In addition, several car manufacturer are jointly working on Vehicle-to-Vehicle Communications (V2V) using the 5.9 GHz frequency to reduce blind spot collisions and "tailgating" crashes [2]. Martin Preuss apply concept of V2V in Military Convoy Location and Situation Awareness [3] using wireless, mesh & Ad Hoc networks. Several research groups have paid attention to this technology for battlefield especially in the last five years. For examples, Md.Asdaque Hussain reviewed current WSN research activities for military applications [4]. Kaixin Xu [5] used unmanned aerial vehicle (UAV) to help route the path of network in large battlefield. However, most of them employed soon-to-be-obsolete wireless communication and few groups are interested in ZigBee technologies.

This paper will shortly describe the model of ZigBee wireless network use in battlefield. Wireless sensor network technology has been known for scalability, carefree operation and easy installation. These applications were planned to adopt ZigBee wireless sensors network in the battlefield scenario using mesh and other network topologies within a remote large-scale environment based on the military requirement. Hence, our main contribution in this paper will be described in the following sections. First, in order to manage and observe the soldiers and many vehicles in the battlefield, ZigBee localization technique can be used to work in cooperation with GPS. Nodes types in this system are shown. Second, the weather and microclimate around base camp can be monitored based on Zigbee WSNs, which can be used to determine the combat suitability in various operations. These sections are described as base camp technologies. For examples, intelligence fortress (E-hedge) was developed to accumulate and report real-time activities for enemy awareness. Third, the medical service and health status sensors can be networked based on the ZigBee technology. Last, basic ZigBee wireless network, ZigBee physical communication layer and basic anti-interception solution in low-power WSNs by using re-new PAN ID (personal area network ID) and re-routing technique from base-coordinator command will be presented.

II. SOLDIERS AND VEHICLE POSITION SEARCH

Since the introduction of the global positioning system (GPS) in 1994, GPS-tracking has become widely used in many application areas ranging from military, agriculture, security system to logistics and healthcare. GPS for soldier and warrior vehicle tracking has become a revolutionary tool for modernization of battlefield today. The position recognition is useful for many activities in the battlefield but data communication in the war zone frequently is too power

consuming and can be operated only in a point-to-point manner. In this paper, we present Zigbee as the next-generation battlefield communication system. One of the interesting properties of ZigBee technology is its receive signal strength indicator (RSSI) feature, which is commonly used for monitoring the signal strength between nodes in WAN.

ZigBee localization technique is developed from basic concept of GPS, using three minimally known positions to identify unknown position node. This technique use properties of ZigBee RSSI feature working together with GPS data. That is if we know the position from GPS data (latitude, longitude and altitude) of more than three nodes, we can use the receive signal strength indicator feature from each ZigBee to analyze the unknown position node immediately. During the battle time, this system can be valuable to find the suffering soldier in the war zone of whom GPS is inactive or is in the no-signal area. From Figure 1, the whole system consists of ZigBee nodes that can be assigned different functions such as:

- Node from Unmanned Ariel Vehicle (UAV) can be employed to help locate the better position based on ZigBee localization technique and to make the third dimension for node identification from sky. Moreover this node can repeat the data from other ZigBee node for extended range.
- Battlefield vehicle nodes are installed on tank, cruise or patrol car for detecting the real-time position in the battlefield
- Router node are installed in a fixed and concealed location for ZigBee localization technique and for repeating data in ZigBee WAN
- Soldier nodes are installed in the soldier helmet to work together with extend life sensor (describe in forth section). Each node consists of ZigBee module, GPS module and control unit.
- Commanding center stores and keeps real-time data for commander, medic team and strategy planning.

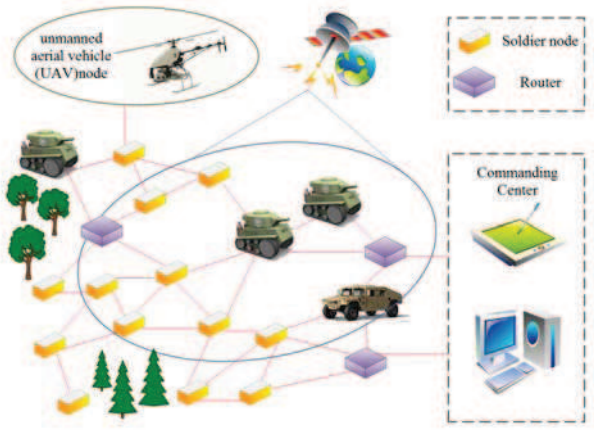

Figure 1. Soldiers and military vehicles position search structure.

III. MILITALY BASE INFRASTRUCTURE

The commanding center or base camp is the heart of the battlefield, containing secret data and very important person in there. Therefore, security system and other proper information should be reported immediately during the critical situations. The military base infrastructure consists of awareness system installed around the military base environment and weather station for monitoring the climate and using the obtaioned information to forecast the weather in the battlefield. Both systems are based on ZigBee wireless network in different group of PAN ID.

A. Enermy awareness system

The Infrared sensors are used in this system to detect the invader. All of sensors can be installed around the military base or important observing point. These sensors are like electronic hedge by positioning the infrared transmitter and receiver as a pair around the base. The transmitter is pointing the dual beam of infrared to the receiver. When enemies pass this electronic hedge (E-hedge), the sensor will send notification to alarm in military base.

The awareness system are operated based on the ZigBee cluster tree topology for reliability of the important situation and low-power consumption, because the cluster tree topology allows ZigBee to be in sleep-mode in end device but does not allow in the router node. From Figure 2., the E-hedge nodes are spread all areas around the military base by communication under the cluster NO.1. Normally, all E-hedge nodes stay in the sleep mode until Infrared sensor was interrupted. After the E-hedge alarm, commander can know the direction of coming enemies and prepare to cope with them. Based on the dynamic routing of ZigBee communication, more than 255 nodes can be installed in the same PAN ID and the range can be extended by using ZigBee router.

B. Weather information system

Weather is one of the most important environmental parameters that often determine the victory in war. The weather information such as wind map help to plan for toxic gas deployment or wind speed help to calculate best direction of cannon shoot. Sometimes commander can plan strategic operation using the climate data in the battlefield. Hence, real-time weather monitoring system is usually used as a tool for obtaining such information. Weather information system are consisting of weather node, which have wind speed sensor, wind direction sensor, temperature and humidity sensor, rain accumulation sensor and solar panel. All sensor nodes operate under solar cell power harvesting scenario and information are sent via ZigBee WSNs. In this system the suitable topology is star topology because data from each node do not travel over the long distance and most sensors always sleep until the data change in order to save energy. From Figure 2., weather information system communicates under cluster NO.1.

The weather data in the forms of temperature and humidity map, wind map, rain map around the military base or base camp can be used for planning the operations.

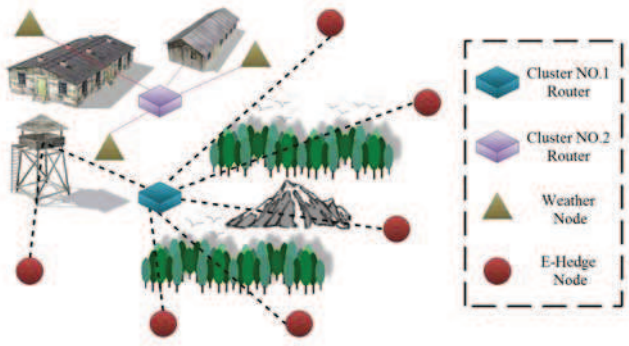

Figure 2. Real-time enemy awareness system and weather monitoring system.

IV. THE EXTEND LIFE SENSOR

Among the critical situation in the battlefield, the real-time medical information such as heart rate, saturation of oxygen in blood and posture of each soldier can significantly help commander make a new plan or better decision. Sometime on-site medical diagnostics from portable medical real-time monitoring device can alarm the medic to save soldier's life in the battlefield.

In this section, we present the new concept of intelligent health care sensor network in order to accumulate health care information and alarm the commander when the sensors find the abnormal case in each soldier. This sensor node was set-up around the waist for better result to detect and predict the soldier posture. The pulse oximeter sensor (heart rate and saturation of oxygen in blood sensor) was installed around the soldier wrist and finger tip. In Figure 3, the extend life sensor nodes consist of

- Temperature sensors mounted on the soldier skin.
- Posture recognition sensor (accelerometer and Gyroscope sensor) detects the movement and soldier action in the battlefield, such as falling down, lying down or bumping against from bomb or bullet. This posture recognition is very useful to determine whether the soldier is under a critical situation in order to make a better decision for medic team aid.
- Vital signals sensor determines pulse oximetry data and saturation of oxygen in blood. The sensor unit consists of two types of LEDs and photodiode packed in Velcro strip that is facing to a soldier's fingertip to detect the pulse centile of blood and calculate the absorption property in blood to find the saturation of oxygen. This sensor help to monitoring the important health information after meet with a mishap.
- A soldier node is the control unit accumulating data from each sensor. It stores and sends data to the commanding center via Zigbee networks when the sensors detect abnormal situation.

The data from each node can operate in a wide area by using ZigBee mesh network concept. In the case that soldier cannot communicate to send the medical information and location to the commanding center or medic team, the ZigBee network can help carry the data and find out the location of this soldier from nearest soldier and repeat the data to the commanding center or the medic team. Using this technology, the medic team and commander can help injured soldier without delay and save soldier life.

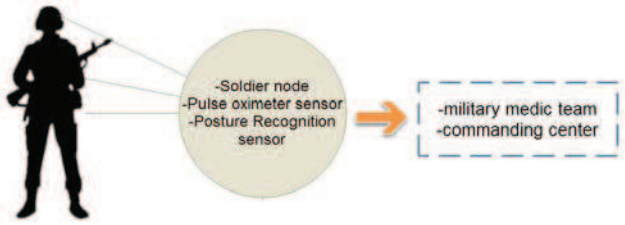

Figure 3. Diagram of the health care sensor.

V. WSNS DATA SECUERITY TECHNIC

Battlefield information is very critical that wireless sensor network must be secured. ZigBee technology is a low data rate, low power consumption, low cost; wireless networking protocol targeted towards automation and remote control applications. ZigBee technologies are best suited for low power connectivity in equipment that needs battery life as long as several months to several years but does not require data transfer rates as high as those enabled by Bluetooth or WiFi. In general, a ZigBee network topology can be defined in three types of networks; star network, tree network and mesh network. All topologies can be operated under the same personal area network identification. In this section, we propose the simple concept to protect the sensor network from data interception. ZigBee provides 16 bits and 32 bits of PAN ID to join the PAN group of data communication. The security data algorithm always changes PAN ID randomly for ZigBee coordinator and the commanding center. The new PAN ID will be sent to every node in PAN by secret package of data to tell the new PAN ID. After that coordinator are waiting for all nodes in old PAN of WSNs (router and soldier node) to reply and to verify the member of nodes in PAN. The new PAN ID was changed from coordinator node and from the commanding center to all nodes in PAN. The data transfer traces are re-new every time that PAN ID changes. Figure 4 demonstrates the secure procedure for low-power wireless sensor networks. The supposed situation is that the wireless sensor network operates on old PAN ID (0xFF00) and then the commanding center wants to change PAN ID to new PAN ID. The coordinator starts to send the new command to all nodes for new PAN ID (0x1F01) and this is changed after all nodes reply to the commanding center node.

ZigBee technology is low power wireless communication comparing with general military technology, these reasons make this system secure because the long range interceptor cannot access to this group of data communication.

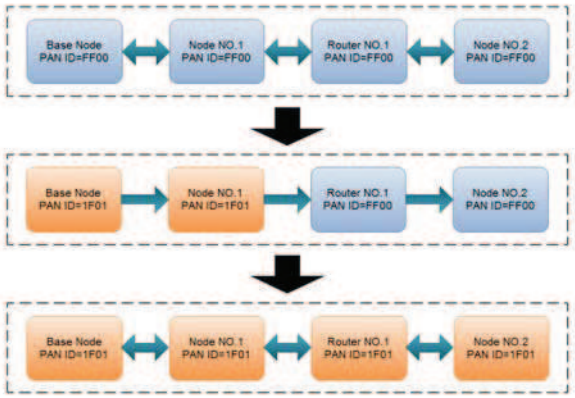

Figure 4. Process to re-new PAN ID in ZigBee WSNs.

VI. CONCLUSION

We have proposed Zigbee technology as the next generation military communication for the battlefield due to its low cost, low power consumption and easy to manage network. In addition, its flexibility in routing topology is suitable for military. In the next phase, some part of sensor nodes will be taken into the first field trials; some sensor types will be tested in the robust system and planed for real use in applications other than the military, for examples, in the healthcare project.

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