TELEGRID Technologies, Inc.

WZRDnet®

A Low-Power Wireless Ad-Hoc Mesh Network for Austere Tactical Environments

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1 ABSTRACT

This white paper describes WZRDnet™, a low power wireless ad-hoc mesh network developed by TELEGRID Technologies, Inc., to provide communications in Austere Environments without existing infrastructure (i.e. no cell towers or satellites required). The network is composed of lightweight handsets, which can operate for 38 hours between battery charges and provide a range of 2km per hop and up to 32 hops per call, thus creating a sizeable network over a considerable area. The WZRDnet Handset's software-based design allows simple addition of user-defined applications. WZRDnet is based on the IEEE 802.15.4 low-power standard which allows routing within nodes as opposed to other mesh networking protocols which require access points or central routing tables. WZRDnet can operate as an isolated, stand-alone network serving a large number of nodes or it can access nearby Wide Area Networks (WANs), by utilizing the WZRDnet Gateway to provide seamless interoperability. The man-transportable WZRDnet Tactical Kit (WTK-350) has been purchased by units of the US Army and tests were conducted by the US Marine Corps.

2 INTRODUCTION

An Austere Environment is defined as a geographical area devoid of a communications infrastructure such as cell towers or satellite coverage. This environment is common in areas of military conflict where support is not provided by service providers and the tactical environment is continuously shifting and changing. For a network operating in an Austere Environment, the Key Performance Parameters (KPPs) are as described below.

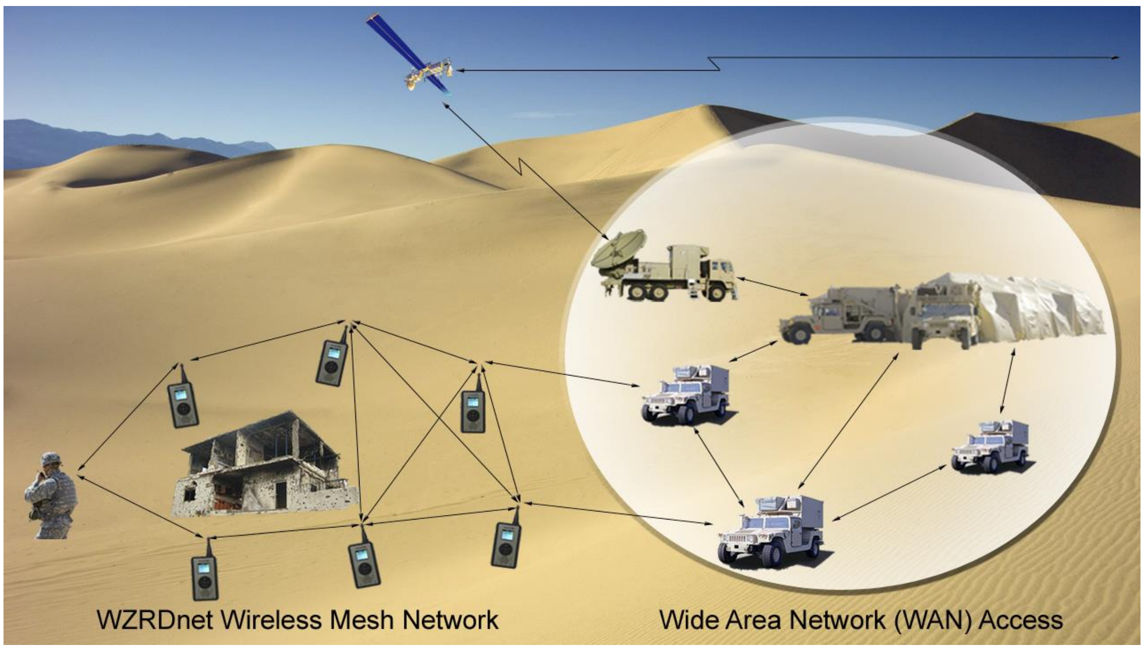
The first KPP is that the network shall be independent of any infrastructure such as fixed or mobile cell towers or satellite links. This independence allows the network to be deployed in any location on the globe regardless of the state of available infrastructure. It also allows any node to join the network, leave the network or move to any geographical location covered by the network.

The second KPP is that the network shall employ a standards-based communications protocol. The use of a standards-based protocol is critical because it facilitates interoperability between this network and other established external networks. It also ensures that no untested or proprietary protocols are used which will affect reliability and limit future incorporation of user equipment into the network. Additionally, it is essential that the network operate in an internationally unlicensed frequency band.

The third KPP is that the network shall provide services including, as a minimum, voice communications and text messaging, in a reliable manner to every node regardless of its physical location. It is essential that network communications shall be based on a peer-to-peer protocol rather than on a "net radio" protocol where all users share a small number of channels. Peer-to-peer communications simplifies interoperability and improves command and control.

The fourth KPP is that network nodes shall support low power operation and be designed with a focus on power conservation. Low power operation is critical for Austere Environment operations since it can be assumed that in an Austere Environment the availability of power sources, batteries or battery charging stations will be limited. The capability to support low power operations limits additional spare batteries and lightens the soldier's load.

As described in the following sections, WZRDnet was designed to operate efficiently and effectively in an Austere Environment. The design satisfies all KPPs, all essential requirements and all desirable features listed above. The architecture selected for the network is mesh architecture where every node is independent and can communicate with every other node in the network. The IEEE 802.15.4 standard was selected for the WZRDnet because it has proven effectiveness in low power operation. The resulting battery life for the WZRDnet Handset is more than four times that of other communication devices. WZRDnet can operate as a stand-alone isolated network or it can easily interoperate with a WAN thus allowing each user to communicate with almost all military and commercial networks.



Potential WZRDnet Deployment

3 THE WZRDnet NETWORK

3.1 WZRDnet Architecture

3.1.1 Architecture Design

Comparative analysis of Austere Environment requirements relative to today's advanced architectures for communications networks led to the selection of mesh technology as the optimal approach for WZRDnet. The analysis showed that mesh architecture supports all KPPs by providing an infrastructure-free network which is scalable, self forming, self healing, and with true ad-hoc characteristics. Additionally, the self-healing, ad-hoc characteristics eliminate the need for additional overhead and external monitoring which would burden the network. When mesh architecture is combined with the capabilities of carefully designed handheld user devices, i.e., nodes, the network is able to satisfy other requirements such as low power operation. Mesh architecture provides flexibility and ease of implementation with the result similar to that of having hundreds of mini cell towers rather than a single large fixed site.

3.1.2 Selected Standard

WZRDnet design required determination of the best standards-based protocol that will support real time communications, mesh architecture, ad-hoc operations and low power transmissions. The IEEE 802.15.4 standard was selected as the preferred protocol for WZRDnet because it is digital, packet-switched and promotes low-power operations. Whereas 802.11 and 802.16 can be used for wireless mesh backhaul (i.e., access points) where a constant power source is available, their high power requirement makes them untenable for mesh routing within small form factor battery powered devices.

802.15.4 has gained in popularity in recent years and is widely used commercially in sensor networks and home automation. Its use in voice communications is minimal outside of WZRDnet since it requires a high degree of design sophistication, especially in the implementation of the voice Coder/ Decoder (CODEC). TELEGRID has achieved voice over 802.15.4 through our patent pending low-latency voice coding/ decoding technology which supports real time multi-hop communications over low power networks. This technology enables quality voice communications using low power transmitters and receivers in a battery powered system.

3.1.3 Selected Frequency Band

The important selection criteria included available number of channels, range of operation, required transmission power, RF interference, licensing regulations (worldwide), and size of receiver/ transmitter components (specifically antenna size). The study performed resulted in the selection of the frequency band of 2.4GHz (2.400 – 2.500GHz with center frequency at 2.450GHz) as the band of choice for this application. This band is one of the license-free Industrial/ Scientific/ Medical (ISM) RF bands and is approved for unlicensed use worldwide. An added major benefit of the 2.4GHz band is that it is regulated and many of the devices using this band implement some type of collision detection/ avoidance. Indeed WZRDnet allows 14 channels to prevent interference.

3.1.4 Secure Communications

Under 802.15.4 the physical layer is secured using DSSS (Direct Sequence Spread Spectrum) where a signal is transmitted using pseudo-random sequences to suppress detection. At the MAC and Network layers messages are encrypted using AES-128 encryption with packet authentication.

3.2 Access to External networks

A key feature of WZRDnet is its packet-switched design which provides interoperability with external networks (e.g. PSTN, cellular networks, VOIP phones, military tactical networks, etc.). Calls can originate in WZRDnet and terminate in the external network or they can originate in the external network and terminate in WZRDnet. The latter capability is due to each WZRDnet node being distinctly identified by a 64-bit IEEE defined MAC address.

With WZRDnet an individual several kilometers from back-haul communications can access the WAN by hopping over intermediate users through the mesh. Rather than necessitating a physical connection or staying within line-of-sight a user can now travel multiple hops from back-haul communications.

The capability to connect and interoperate with external networks is made possible by the WZRDnet Gateway (P/N WGW-330). The Gateway establishes a presence for WZRDnet on the WAN and provides the physical layer connection to back-haul communications. The Gateway's design supports a simple connection to a WAN via a multitude of connection options including RJ-45 Ethernet, Wi-Fi, RS232, USB, and RJ-11 analog. These options allow the Gateway to connect to multiple networks, for example, a tactical IP router via Ethernet or Wi-Fi. Alternatively the Gateway can attach to a PBX directly via a simple analog connection. In addition to connecting to the WAN the RS-232 serial and mini-USB can be used as data inputs for the attachment of sensors. The Gateway allows flexible power input selection including 88-264V AC or 18-36V DC.

WZRDnet Gateway (P/N WGW-330(V)1)

3.3 WZRDnet Handset

3.3.1 WZRDnet Handset Design

The WZRDnet Handset (P/N WHD-310) is the key element of WZRDnet, performing both as a router in the network and as a user interface device. The essential requirements driving the design of the WZRDnet Handset were small Size, low Weight, low Power (collectively known as SWAP). The WZRDnet Handset weighs only 0.6 pounds and measures 1.3 x 2.8 x 5.4 inches. The Handset also includes a detachable dipole antenna with a length of 2.05 inches.

Flexibility was an overall driver in the design of WZRDnet, especially the WZRDnet Handset. Early on in the development process it was decided to make the Handset a software-driven machine and thus minimize the amount of hardware necessary to the basic essential functions. The product of this decision was to focus all Handset operations around a color LCD display and a set of menu-driven control buttons. This, it was felt, gives users easy access to all Handset features and reduces training times.

The WZRDnet Handset includes a mini USB port for charging and communications. When attached to a PC, a user can communicate with any node via the attached handset. WZRDChat, a Java-based application, provides a user-friendly PC interface that can be used to text message or query the GPS coordinates of every handset within range. These coordinates can then be stored in a comma delimited format file (.csv) where they can be uploaded into any mapping utility. It is also possible to send data files between PCs by attaching handsets and forming a data bridge.

Power conservation was a major focus in the design of WZRDnet Handsets. In addition to careful selection of hardware components throughout, power management software was specifically designed as an integral part of the device. The result is a device which can operate for 38 hours between battery charges as opposed to commercial two-way radios which operate for 8-10 hours (this considers a duty cycle of 5% talk, 5% listen and 90% idle – an industry standard).

3.3.2 WZRDnet Handset Performance

In initial testing WZRDnet Handsets have reached distances of over 2km per hop in line of sight. For mesh networking it is important not to focus only on the distance per hop but also on the number of hops which can be executed per call. The 802.15.4 standard allows for 32 possible hops per call. The true impact of increasing the number of hops is the delay per hop as each router decodes a message to determine its destination. TELEGRID's patent pending low-latency voice coding/ decoding technology has dramatically reduced latency with delays of only 12-14ms with security enabled.

3.4 Direction Finding Application

WZRDnet's software based design allows straightforward addition of user defined applications. The Direction Finding Application depicts a user's GPS position and a graphical image of their direction of travel. It allows saving of position coordinates for storage, transmission and analysis. The Application also provides users with direction toward a specified target whose coordinates are preset manually or received dynamically over the air. The Direction Finding Application depicts a simple compass-like image showing direction of travel in degrees, distance to target and position. The Application is extremely useful in cases where dispersed dismounted soldiers have to be directed towards a specific assembly point. In these cases, the leader of the deployment sets the assembly point manually or via the embedded GPS receiver and sends its coordinates as a broadcast message to all users. Since the Application is dynamic, a leader can update the target location at any time and all users' handsets are automatically revised with the new information.

WZRDnet Handset with Direction Finding

4 SUMMARY

WZRDnet presents a superior solution to the problems associated with providing communications in an Austere Environment. It does not require any infrastructure in order to operate and provides high-quality communications with low power consumption. WZRDnet utilizes small, feature-rich handsets that function as nodes/ routers in the mesh network thus removing single points of failure. WZRDnet also includes gateways which provide a seamless interface to external networks and allow users to send and receive voice and data messages from any subscriber on these networks.