White Paper

TELEGRID

WZRDnet®

A Low-Power Wireless Ad-Hoc Mesh Network for Shipboard Applications

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1.0 INTRODUCTION

This white paper presents the benefits of upgrading current US Navy shipboard voice/ data communications with the WZRDnet low-power wireless mesh network. WZRDnet is a mesh network designed to operate in demanding environments where supporting infrastructure does not exist. These characteristics make WZRDnet an ideal candidate for shipboard communications, especially as a simple to install upgrade to existing vessels. When compared to competing systems which require an installed infrastructure such as Distributed Antenna Systems (DAS) or Radiating Transmission Line (RTL) systems, WZRDnet has shown to be clearly superior. By eliminating the need for infrastructure WZRDnet eliminates the high costs and complexities associated with DAS and RTL systems which typically require leaky feeder coaxial cables installed throughout the ship.

Due to the unique characteristics of Navy ships, specifically the presence of munitions and explosive gases, the use of high power transmitters is not permitted. Therefore, leaky feeder coaxial cable have been deployed which provide coverage and overcome RF obstructions (e.g., bulkhead doors) present inside of a ship. WZRDnet solves these problems by employing wireless mesh networking technology that allows messages to reach their destination while keeping transmit power below 100mW. This conserves power and prevents Hazards of Electromagnetic Radiation to Ordinance (HERO) and to Fuel (HERF).

WZRDnet is composed of lightweight handsets, which operate both as user interface devices and repeaters in the mesh network. If a destination is not in line-of-sight, a handset will automatically route communications through other handsets or stand alone repeaters. WZRDnet can operate as an isolated, standalone network or it can access Wide Area Networks, including PSTN, VOIP and radio networks, via the WZRDnet Gateway to provide seamless interoperability.

Costing less than $1,000 per handset in small quantities, WZRDnet provides internal ship voice and data communications without the expense of installing any infrastructure.

WZRDnet aboard USS Peleliu LHA 5

2.0 THE WZRDnet NETWORK

2.1 WZRDnet Architecture

Comparative analysis of demanding environment requirements led to the selection of mesh technology/ architecture as the optimal approach for WZRDnet. This approach provides an infrastructure-free network which is scalable, self forming, self healing, and with true ad-hoc characteristics. True mesh architecture, which is present in WZRDnet, does not have a central controller but rather allows each node to determine its optimal route. This removes the single point of failure problem and 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.

2.2 Selected Standard

WZRDnet design required selection 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. Additionally, while the bandwidth of 802.11 and 802.16 is higher than 802.15.4 their range is extremely poor, especially within a ship.

IEEE 802.15.4 Standard 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.

2.3 Selected Frequency Band

The key criteria in selecting the operational frequency band included number of available 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 12 channels to prevent interference.

In addition to 2.4GHz, WZRDnet is also capable of operating in the 900MHz ISM band. WZRDnet handsets operating in 2.4GHz and 900MHz were tested aboard the USS Peleliu.

3.0 BENEFITS OF USING WZRDnet

The following paragraphs detail the benefits of using WZRDnet in place of current wireless/ leaky-coax phone system.

3.1 **Lower Installation Cost**

The WZRDnet operates in areas that have no infrastructure where the existence of supporting elements (e.g., leaky feeder coax or cell towers) cannot be guaranteed. Since it was designed not to rely on these supporting elements the WZRDnet removes one of the largest cost factors associated with the current wireless/ leaky-coax phone system. Reduction in installation costs is clearly WZRDnet's greatest benefit. To deploy the WZRDnet in a shipboard environment, repeaters are simply mounted on walls and provided with AC power. With WZRDnet there is no need to run leaky feeder cable, drill through bulkhead doors or worry about the weight implications of the coax cable. Indeed removing coaxial cable removes long term fuel costs associated with the increased weight of the ship.

3.2 **Flexibility**

3.2.1 Modularity

The modular design of the WZRDnet, where coverage can be increased by simply adding handsets or repeaters, is a benefit over the current wireless/ leaky-coax phone system. Once the latter system is installed, it is expensive and difficult to increase coverage within a ship. With WZRDnet coverage can be increased by mounting a repeater on a wall or placing a handset in a stairwell. This means that disparate sections of the ship (e.g., engine room) can be incorporated into the network without having to run an entire length of coax for one or two users. Indeed if a section is far removed from the rest of the ship an expensive leaky coax amplifier may be required as opposed to the WZRDnet which would only require another repeater. With a cost of over 10 times that of a WZRDnet repeater, inline amplifiers are an expensive requirement of the current wireless/ leaky-coax phone system.

As a scalable network, the capacity of WZRDnet can be increased by simply adding handsets. With the current wireless/ leaky-coax phone system, more handsets would require a network redesign to satisfy the increased traffic capacity needs.

3.2.2 Mobility

WZRDnet handsets do not need to be in range of a repeater or base station in order to operate. If a group of handsets are out of range they can still communicate amongst themselves as a local area network. This means that a group of users can leave the ship to perform port security and still be able to use their handsets to communicate. If they want to tie into the ship network then a handset or a repeater can be placed on the stern of the ship as a pathway to the ship's mesh network. The current wireless/ leaky-coax phone system, on the other hand, would be unable to communicate without access to a base station.

For WZRDnet, the mobility concept also means that elements of the network have a useful life even beyond that of the ship. For instance, if a ship were to be decommissioned, its network could be easily reinstalled in another ship to save money.

3.3 **Reliability and Survivability**

WZRDnet is a self-healing mesh network where communications are automatically rerouted if any path is broken. This is a benefit over the current wireless/ leaky-coax phone system where a break in the leaky feeder coax would cut an entire section of the ship off from communications. Additionally WZRDnet's unique design, where each node performs its own routing, does not require a central controller which presents a single point of failure in the current wireless/ leaky-coax phone system. Finally WZRDnet handsets were designed for harsh environments and therefore have features including IP67 ingress protection that protect against water and dust that are not standard features on cordless phones.

3.4 **Security**

WZRDnet packets are encrypted via an embedded hardware-based cryptographic engine. The network is encrypted with 128 bit Advanced Encryption Standard (AES-128) with a possible upgrade to AES-256 bit encryption. Additionally, the physical layer is secured using DSSS (Direct Sequence Spread Spectrum) where a signal is transmitted using pseudo-random sequences to suppress detection. An additional security feature is that lost or stolen handsets can be sent a wireless "poison pill" that would remotely disable them.

3.5 **Operational Benefits**

3.5.1 Group/ Broadcast Calling

WZRDnet was designed for military and industrial applications and therefore provides operational benefits which are not present in current wireless/ leaky-coax phone system. The most important of these operational benefits is group and broadcast calling. This capability facilitates communication with an entire department or division at once, in addition to peer-to-peer communications. Most cordless phones are designed for peer-to-peer connectivity and do not offer group and broadcast calling. By providing peer-to-peer, group and broadcast calling the WZRDnet provides for all types of communications.

3.5.2 Text Messaging

Text Messaging is one of the key benefits of the WZRDnet since it allows sending text in addition to voice transmission. Text messaging allows transmission of important information both on a peer-to-peer basis as well as a group and broadcast basis.

3.5.3 Contact Lists

WZRDnet handsets include the capability of loading Contact Lists by the user. These Contact Lists eliminate the need for the user to remember specific phone numbers.

3.6 **Applications**

3.6.1 Software Applications

WZRDnet is a packet switched data network which facilitates transmission of other forms of information in addition to voice and text messaging. This allows for the creation of applications including the WZRDnet Command Center which is a java based program that allows a PC to chat with any handset on the network. The program also allows an administrator to request a handset's GPS location for tracking on Google Earth. While GPS is not available on a ship, the program can be adapted to request the location of the nearest repeater to a handset and then plot its position on a floor plan of the ship. This is just one of many applications that can be designed on the WZRDnet and are not available with the current wireless/ leaky-coax phone system.

3.6.2 Hardware Peripherals

With WZRDnet additional hardware peripherals can be included in the network. For instance, a barcode scanner can be connected to the handset via USB and the handset can be used as a transmission medium to relay information to a central location. This allows real time scanning of crates for anti-piracy operations. Additionally, since the WZRDnet is based on sensor network technology, sensors (e.g., temperature, motion, etc.) can be incorporated into the network for real time monitoring of environmental and security conditions.

4.0 WZRDnet EQUIPMENT

4.1 **WZRDnet Handset**

The WZRDnet Handset (P/N WHD-310) shown in Figure 4.1 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 inches. Despite their small size WZRDnet Handsets are fully ruggedized meeting MIL-STD-810G requirements for Mechanical Shock of 26 drops from 4 feet onto concrete covered by 2 inches of plywood. Additionally, handsets are designed to meet Ingress Protection requirements for submersibility up to 30 minutes at 1 meter (i.e. IP67).

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.

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 at a duty cycle of 5% talk, 5% listen and 90% idle (industry standard).

Handsets provide peer-to-peer, multicast and broadcast voice and text messaging capabilities. Handsets can be assigned a level of preemption between 1 and 5 which allows higher ranking officers to break through communications. The level of preemption is clearly visible on the front screen of the handset.

Figure 4.1 - WZRDnet Mesh Handset (P/N WHD-310)

4.2 WZRDnet Repeater

WZRDnet includes standalone repeaters to increase RF coverage. WZRDnet repeaters transmit at 100mW and can easily be mounted on a wall or ceiling. The repeater is an intelligent device which includes a microcontroller programmed to aid in mesh routing. Repeaters are powered by either 85-264VAC and include a lithium ion battery backup to guarantee service in cases of power failure. The size of the Repeater is 3.25 x 6.2 x 1.65 inches.

Figure 4.2 - WZRDnet Mesh Repeater (P/N WRN-320(V)2)

4.3 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, Iridium satellite phones, military tactical networks, etc.). With WZRDnet an individual far 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. 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. This capability allows external callers to dial individual handsets via an extension automatically assigned by the WZRDnet Gateway.

Figure 4.3 - WZRDnet Gateway (P/N WGW-330(V)1)

The capability to connect and interoperate with external networks is made possible by the WZRDnet Gateway (P/N WGW-330) shown in Figure 4.3. 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 PBX telephone network via a simple analog connection. By dialing into the Gateway an individual will either be directed to a specific handset or reach a call attendant where they will be prompted to dial a handset extension.

The Gateway was designed for flexible integration including power input selection of 88-264V AC or 18-36V DC. It is a small form factor device that fits in one half of a 19 inch 1U rackmount.

5.0 WZRDnet PERFORMANCE

While undergoing testing aboard the USS Peleliu WZRDnet handsets were capable of communicating through 4 decks with doors open and 2 decks with doors closed. Coverage within the ship was dependent on architecture with the officer deck (i.e., 02 Level) containing more RF obstructions than the Flight Deck. Despite the amount of obstructions WZRDnet handsets were able to transmit 150-200 feet within the ship and clear across the ship's 820 foot Flight Deck. As Figure 5.0 shows, only five repeaters

were required to provide coverage throughout the officer's deck. Full reports for the USS Peleliu test are available upon request.

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 allowing for communications across the ship.

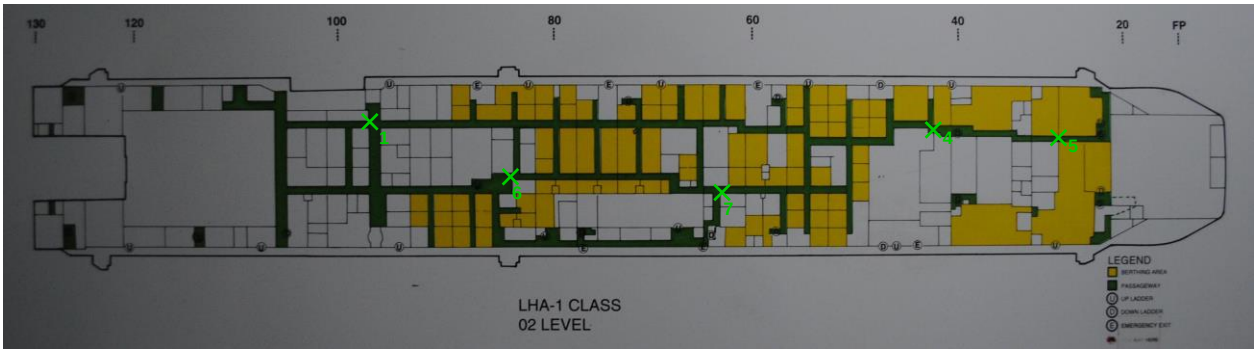

Figure 5.0 - Placement of WZRDnet Repeaters aboard USS Peleliu 02 Level

6.0 SUMMARY

WZRDnet presents a superior solution for communications in a shipboard environment as compared to the current wireless/ leaky-coax phone system. It does not require any infrastructure in order to operate and provides peer-to-peer, group and broadcast voice and data communications. WZRDnet utilizes small, feature-rich handsets and repeaters that function as nodes/ routers in the mesh network thus eliminating the need for expensive radiating transmission line installation. WZRDnet also provides seamless interoperability with external networks via the WZRDnet Gateway. By simplifying installation WZRDnet provides an inexpensive solution to high quality voice and data communications.