END-TO-END WIRELESS NETWORKING SOLUTIONS

Paper Presented by:

Peter Willington

Author:

Peter Willington, *Field Sales Engineer,*

Eaton

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ABSTRACT

This end-to-end wireless networking solutions paper provides an overview on how to deliver a complete networking solution for differing water applications. Such applications can include: pump station control, real-time treatment plant monitoring, early flood-warning systems, level monitoring/alarms, and infrastructure upgrades. This paper covers how to scope the application requirements, details on frequency spectrum and protocols; followed an application example of a water and wastewater system.

1.0 INTRODUCTION

The first step in designing a wireless solution is to establish the application scope including why the wireless network is required, the client's expectations of the solution, project location, feasibility and of course, budget.

Water/WasteWater (W/WW) systems generally rely on wireless networks to communicate over vast distances of difficult terrain that are often heavily obstructed, and with differing noise from wireless communications occurring around the sites. Typical application examples where wireless is employed include:

- Water quality monitoring,
- Tank level monitoring,
- Early flood-warning systems,
- Pump station control,
- Valve positioning,
- Monitoring of reservoirs and dam levels,
- Surveillance of assets.

Traditionally W/WW networks contain key infrastructure such as: reservoirs, water storage tanks, piping networks, associated pumps, and treatment plants. There are variations of equipment in potable water systems compared to wastewater systems, for example a potable treatment plant could have: a chlorination plant, filtration plant, ultra-violet disinfection plant and equipment for additional treatment to disinfect the water in preparation for public distribution. For wastewater, the treatment plant is a combination of primary, secondary and/or tertiary treatment before discharging the clean water into a lake, river or the ocean.

When establishing the scope of the application, each treatment plant has its own characteristics, for example piping networks are defined by their distance. They collect sewage while also delivering potable water, service every neighbourhood in a city or regional town/area. This demands the wireless communications to cover short, commonly heavily obstructed distances, as well as vast distances to link the system across hundreds of kilometres. Such applications require higher transmit power radios, taller antenna masts, lower frequency radios, and the use of repeaters. However, for treatment plants that cover short distances only, wireless communications is used for measuring instruments throughout the plant such as pH sensors and chlorine sensors, which are sent back to the control room SCADA. With applications of this nature, lower transmit power radios can be used without the need of high masts or licensed frequencies.

Every application requires careful design to meet customer expectations and budget. Combining the best combination of technologies is essential in forming a reliable network as provided in the following examples.

- Treatment plant networks can utilise both wired and wireless systems, comprising of Local Area Network (LAN) based systems with fibre optic ring backbones for redundancy via managed switches and wireless systems with much lower transmit power required such as WirelessHART™, ISA100 and other proprietary protocol devices. Wireless communication solutions like these have become popular due to reduced cost as well as ease of installation and commissioning, as digging trenches to lay conduit is no longer required.
- In piping networks covering a large scale metropolitan network, a combination of intermediate LAN connections acting as consolidation points for centralised wireless networks, licenced radios and Cellular based systems could provide a reliable solution. Moreover, a wireless communications solution for a smaller piping network, covering a low density area, could implement licence-free radios with meshing and repeater functionalities and achieve an equally robust wireless network.

Figure 1: ***Burying Conduit***

2.0 FREQUENCY SPECTRUM

The Australian Frequency Spectrum is governed by the Australian Communications and Media Authority (ACMA) where guides are set as to which frequency, power limits, and modulation types can be used. In the Industrial Scientific Medicine (ISM) frequency spectrum the common frequencies used in the W/WW industry are the 150MHz & 400MHz Fixed Frequency, 900MHz Frequency Hopping Spread Spectrum (FHSS), 2.4GHz & 5.8GHz Direct Sequence Spread Spectrum (DSSS), and more recently the Cellular bands through the use of both public and private cellular connections.

Fixed frequency radios are typically licenced radio bands providing users with a set list of allowed frequencies that will not be used by any other system within the geographical area. These licence radios also typically allow for higher RF power allowing for greater geographical distances to be achieved and assist in areas of dense obstructions over long distances. FHSS and DSSS radios on the other hand are typically licence-free with lower RF power limits and being licence-free, the spread spectrum technology allows for the radios to either change frequency within their set parameters to avoid interference or provide a greater bandwidth for low latency systems.

Radio modulation schemes continue to evolve resulting in higher throughputs, greater distance ranges, increased performance in the presence of interference and better co-existence with nearby radio networks. We have seen this evolution change dramatically in the public arena especially in the cellular world with 2G being surpassed by 3G, and now 4G. Advances are also occurring in the popular open 802.11 standards with 802.11b being surpassed by 802.11g, and now 802.11n. The result is a wireless network that is increasingly more reliable with superior performance.

3.0 PROTOCOLS – PUBLIC OR PROPRIETARY

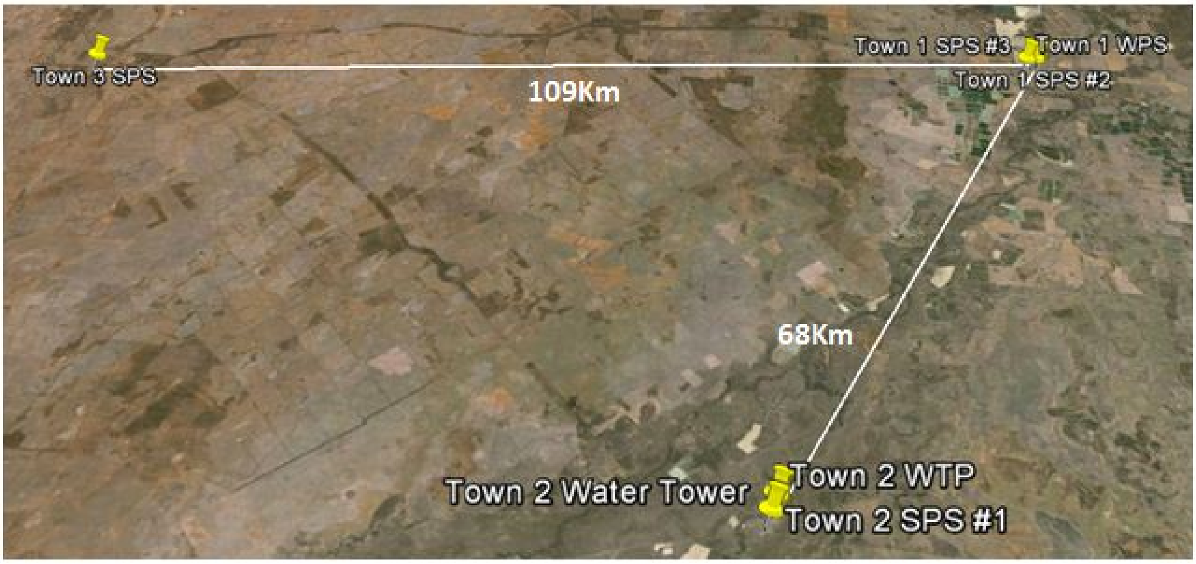
Many users wish to utilise public wireless protocols for compatibility with multiple manufacturers, for example 802.11a/b/g is a public protocol that enables say a laptop, made by company X, to communicate with a wireless router, made by company Y.

The 802.11a/b/g protocol is available using many wireless modules, however many are not designed for harsh environments or critical control and monitoring that is required in W/WW applications requiring a robust, reliable and adaptable system.

Many manufacturers of industrial wireless equipment have produced their own proprietary protocols that are optimised for a specific application. The benefits of using a proprietary protocol include: more secure data transfer, reduced overheads, allowing more throughput for actual user data and smaller data frames allowing better penetration of signal and optimised message handling for critical assets.

4.0 APPLICATION

The following application depicts an installation for a W/WW system linking three rural towns together which comprise Sewerage Pump Stations (SPS), Water Treatment Plant (WTP), and Storage Facilities. The scope of the application included upgrading an aging intermittent system, servicing additional new facilities and designing with provisions for future expansion. The three towns are monitored from a central location SCADA system. As can be seen in the below figure, the distances between each of the towns are typical of applications in remote regional areas in Australia.



<u>Figure 2:</u> ***Application Area***

4.1 Design Phase

From the initial scope request the design phase comprised of two parts:

1. The backhaul transfer of local sites between each town.
2. The local connectivity required for the SPS and WTP systems back to the SCADA.

A desktop survey was conducted to determine the feasibility of linking the towns back to a central location. Due to the vast distances involved, the two primary options were a licenced radio system or a private 3G Cellular transparent backbone. Due to suitable 3G coverage in each area, this was the preferred option utilising a private network secure from any public internet connections. Initial I/O data calculations proved to be fewer than 50MB per month at each location and with current charges being $10 per month for up to 150MB of data per site, this allowed for online maintenance and diagnostics when required without adding extra charges for the data.

The overall data charges would equate to be $360 per annum and no additional towers or masts would be required as the radio path to the nearest cellular tower is within line of sight. For a licenced radio system in this network with distances of 100Km and 60Km, the antenna heights required would out cost the project with the additional expense and logistics for a suitable mid repeater site which was proving difficult to locate. 3G Cellular was the clear answer for this application.

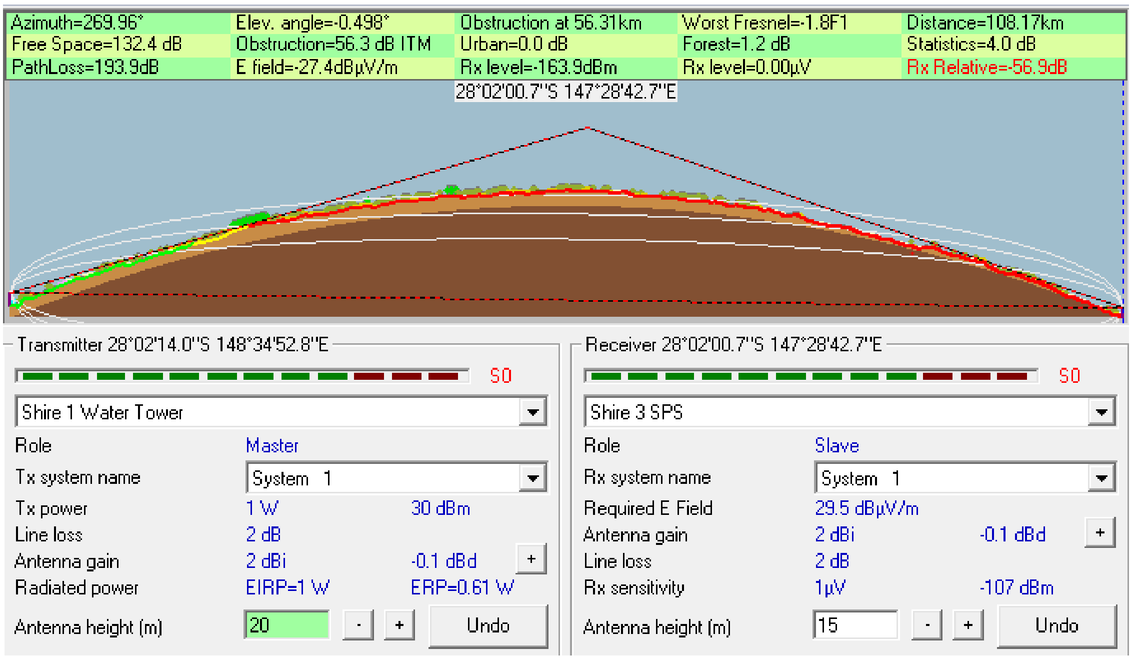
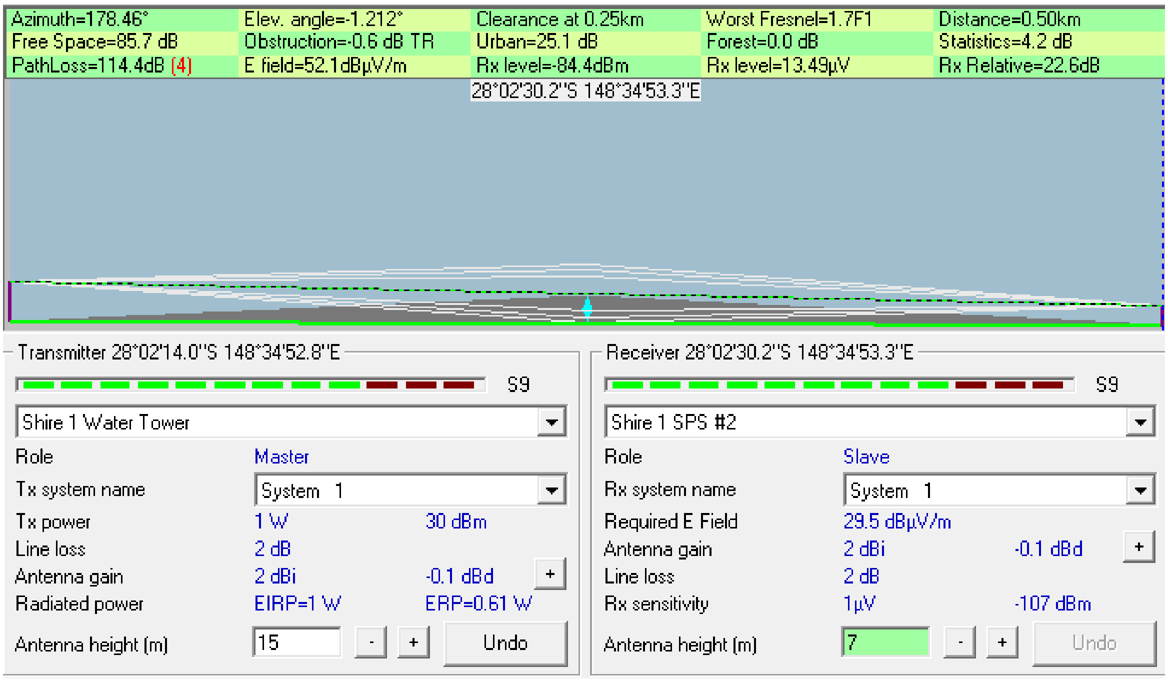


Figure 3: ***Radio Desktop survey***

Within each town, radio paths are all short distances and within a few kilometres of each other, allowing the use of licence-free technology. Although several licence-free frequencies were available, the 900MHz FHSS radios were selected for their proprietary protocol as it would have the least interference from other wireless networks within each town. Radio desktop studies proved that strong radio paths were achievable using the licence-free radios and water towers for repeater and data collection sites due to their higher elevation providing greater coverage.



<u>Figure 4:</u> ***Local Area Radio Desktop Survey***

For SPS and WTP locations, the interface to existing equipment can be via serial or Ethernet modems if PLCs or RTUs are already installed, or via direct hardwired I/O based radios eliminating the need for PLCs and RTUs. The existing WTP and SPS facilities were a combination of discrete I/O and dedicated pump controllers linked via modbus. New modules had I/O based radios with protocol functionality which provided commonality across all sites throughout the 3 towns reducing the need for spares. The I/O based radio signals at each SPS and WTP was to be sent to the main town's water tower either directly within the local network or via the cellular backbone from each remote town.

Furthermore, the new modules selected were IP based I/O radios allowing for future expansion capabilities, the opportunity to connect remotely and diagnose each town's connection saving time from lengthy and at times unsafe driving to each site. And, being I/O based, this also allowed for local control in the event of unforseen network outages.

The use of managed Ethernet switches at each town connection point and at the main SCADA location acts as consolidation points; joining I/O based 900MHz wireless and 3G Cellular. Managed Ethernet switches ensure the SCADA network can operate on a separate VLAN if required in the future preventing non-SCADA traffic onto the network.

4.2 Commissioning

While the existing ageing and sometimes troublesome network was in place, a staggered migration was planned for a simple installation process to commission the new/upgraded network. During commissioning, engineers highlighted that as a result of no civil infrastructure or trenching being required, there being no need for obtaining licences from the ACMA, and the combination of Cellular and licence-free Spread Spectrum technologies being straightforward; this all resulted in a short installation period.

4.3 Application summary

Overall costs to upgrade the W/WW system were kept to a minimum by leveraging different wireless and wired technologies. The system resulted in a reliable design and staged commissioning so system operators now receive real-time readings and diagnostics that are now managed from the centralised SCADA control room. Operator safety, productivity and efficiency have been improved with seldom travel required to remote sites.

5.0 CONCLUSION

Wireless networks in W/WW systems offer significant cost savings and operational flexibility, productivity increases and greater resource efficiencies; which has led to their wide scale deployment around the world. Smart installation designs leveraging multiple wireless and wired technologies and features, can deliver cost effective, reliable and robust systems. Working with experienced design and installation engineers will deliver seamless deployment and future proof the system for scalability as needs grow and technology advances.