Industrial Wireless Meshing Application Paper

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Great advancements have developed in wireless Ethernet networking over the last few years. Higher data rates have allowed for wireless Video Monitoring and Voice over IP (VoIP) applications which have been too costly in the past and increased output power on the radio transceiver and outdoor mounting options has allowed for much greater communication distances. One of the most power features available to modern wireless Ethernet networks is Meshing Technology. Meshing technology provides wireless communication with multiple pathways that can remedy line-of-sight obstructions and single points of failure while providing build-in redundancy and self-healing for network reliability. Although commercially available by many different names, Mesh technology for industrial applications has completely different considerations in network design and hardware selection. This article will outline how these modern advances can greatly improve communication in critical industrial networks and the requirements to designing these Wireless Mesh networks for industrial applications.

The wireless industry loves "buzzwords". In a world of acronyms and numbers it is easy to understand how phrases such as WiFi can easily replace IEEE 802.11g, 802.11b and 802.11a; Bluetooth replace IEEE 802.15 and ZigBee replace 802.15.4 thus making remembering these types of technology easier. The latest buzzword to generate a lot of interest is Mesh. Wireless Mesh networks provide multiple redundant communication pathways between remote locations, but the concept for redundant communication has been used in wireless systems for many years.

Redundant communication networks use to require multiple radios and antenna systems at a much higher cost, where as the Mesh network has the individual radio modems in the system make these intelligent networking decisions as part of their normal operation.

Wireless Mesh Technology

The terminology "Mesh" comes from a recently approved IEEE standard (802.15.4) better know as ZigBee. ZigBee networks are primarily composed of low power transceivers, such as wireless sensors, where the purpose for the Mesh type of network allows these low power radio devices to bridge longer distances and identify like devices in the radio network by relaying their information through multiple units, if necessary. If any of the pathways in this network were to fail, alternate communication links were always available and used. The more ZigBee devices in a given area will allow for more possible communication paths and greater redundancy. The network created between all these potential wireless links resembles a spider web mesh pattern (Figure 1).

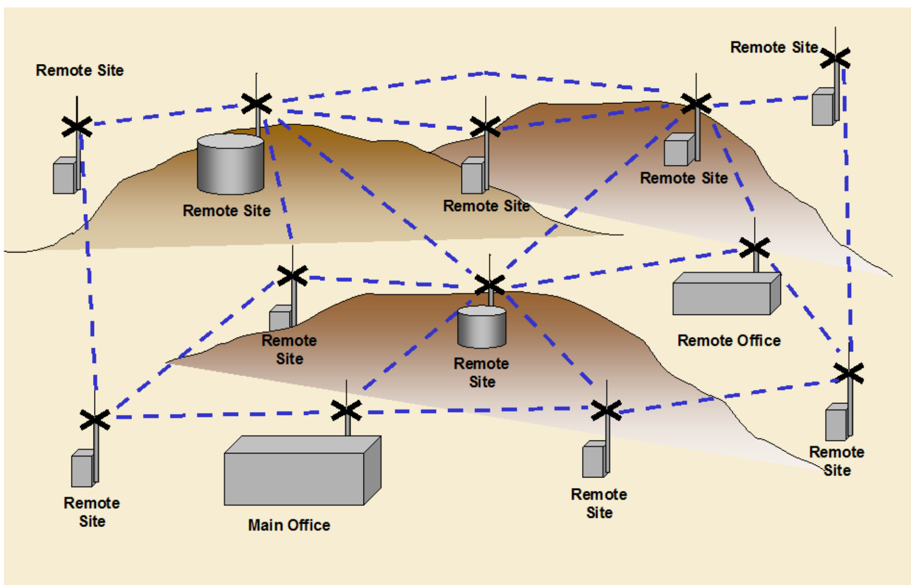

Figure 1 – Mesh Network Pattern

The latest implementation of Mesh networking uses higher output transmitters to extend the range over much larger geographic areas. Office buildings, school campuses, and even entire cities are using the Mesh concept to provide a wireless canopy across these areas for consumer access to the Internet. When Mesh networks are used as a "back haul" to link to 802.11 WiFi Access Points, also know as "Hotspots", the network coverage area of the wireless canopy can be greatly extended and provide a much higher signal density at a lower cost than a hardwired backbone. The problem associated with these larger commercial Mesh networks is that there are no current standards governing how the Mesh should operate. One vendor's wireless Mesh network backbone will not necessarily function with another. There is an IEEE working group for standardization of the Mesh network called "AP Mesh" that is attempting to standardize the "last mile" access to homes for ISP vendors, but currently network operation is up to the manufacturer.

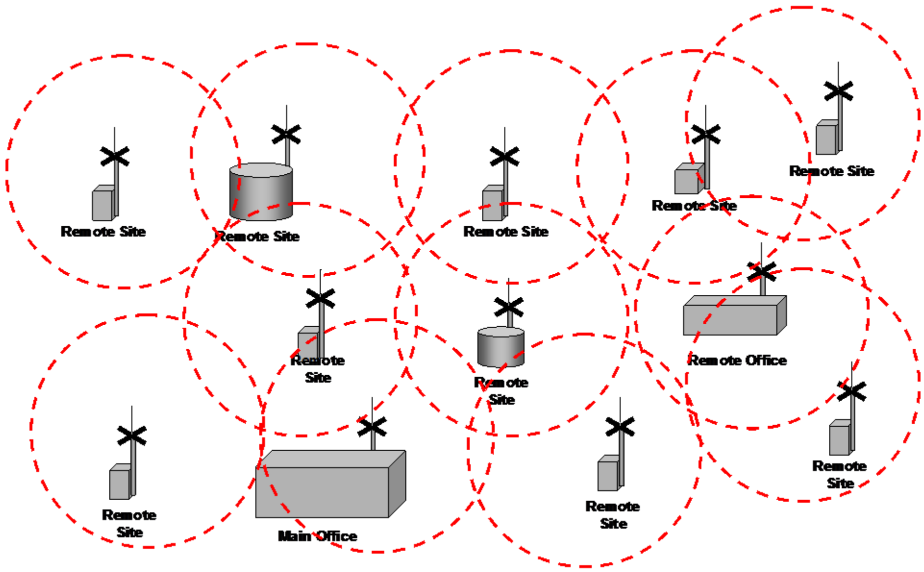

Figure 2 – Overlapping Coverage Area

Commercial Mesh networks are being taken very seriously as a business venture by large wireless companies such as Motorola ®, who just purchased a meshing technology company, Mesh Networks, for $170 million as reported in the July 4, 2005 issue of Forbes. These commercial Mesh networks are primarily used to allow wide-band Ethernet access to remote locations or Internet access in a mobile environment. The main purpose for the Mesh backbone is to provide overlapping coverage areas to increase the density of the RF signal (Figure 2) and provide easy configuration for the installer. A self-healing commercial Mesh network employs, on the average, 10 radio transmitters for every square mile of coverage. The individual units determine the redundant pathways through many methods such as signal strength, shortest route to destination or link quality. These methods of pathway selection are different per manufacturer and can subject the overall network to high communication latency. When the purpose of the network is to send e-mail or surf the web these latencies can be overlooked.

Industrial Mesh Technology

Using Mesh technology in an industrial communication network has a completely different purpose. The industrial communication network is not concerned with covering large areas with Internet access, but movement of critical data for control and system monitoring. The redundant Mesh links will be used as backup to the primary communication path in case of failure. The self-healing Mesh network can be used to guarantee data integrity between industrial controllers, but the determination of these communication routes should never be by arbitrary decisions.

Wireless networks have historically been a perfect solution for Supervisory Control and Data Acquisition (SCADA) systems. One of the largest changes coming to the classic SCADA network will be the requirement for higher security at remote locations. Remote video is an effective means of increasing security without wasting valuable manpower. Many of the security cameras are now Ethernet based and as most industrial controllers are now coming equipped with an Ethernet interface, a wireless Ethernet solution that can support both the camera and controller on a single network is ideal. One requirement for remote video is an increased bandwidth over the typically lower data rates required for the industrial controller. The distances from the master location to the remote sites are usually greater when covering an entire city so minimal latency will be required to make these long-range Ethernet SCADA networks function efficiently.

Another key difference in an industrial Mesh network is that most industrial communication networks are much smaller in the number of connected devices (Clients) than a commercial Enterprise based network. Data reliability with a minimal latency is the primary purpose for the network. Mobile coverage, although available within proximity of any fixed site over the entire city, is seen as a luxury and rarely a design requirement.

Network security in an Industrial Mesh is not a lower priority, but the implementation has to be different. With the finalization of the IEEE 802.11i Wireless Security Standard in the summer of 2004, wireless network security was increased substantially. Many of the changes to the wireless security model require using encryption or authentication servers rarely available in an industrial network. These higher security methods, such as TKIP, must be managed in the radio equipment itself and support multiple modes of operation such as router and firewall modes.

The rugged conditions in an industrial environment require the wireless hardware to be much different than that used in a commercial Mesh network. The wireless hardware must survive high and low temperature extremes (environmental protection ratings such as NEMA-4 or greater are required) and have multiple mounting options. The wireless hardware should mount both in an enclosure with the antenna remotely located and also mount outdoors directly to the antenna to greatly reduce the signal loss in the coax cable and system costs. Most modern wireless Ethernet modems should have the ability to run both power and data on the same cable (Power over Ethernet – PoE) for this remote unit mounting.

Mesh Network Design

The benefits of a Mesh network is to not have to be abandoned when applying them in an industrial network, but the communication network design will be critical to the reliability of the network. One of the key differences in a commercial Mesh network and what is required in an industrial network is the selection of the communication routes.

Although easier for configuration, the automatic selection of the communication path by the radio themselves ***should be avoided***.

When the communication routes are automatically selected, the radio will be required to make a decision based upon either the shortest route to a destination, best signal strength or best signal quality. The problem is not that any one of the above methods of selection is better than another, but that more than one is necessary when designing a reliable wireless network. For example, Figure 3 shows a typical wireless Ethernet system used in the Water/Waste Water Industry. Notice that the communication between the Water Plant Site A and Pump Site D has a marginal link, but it is the most direct route between the Ethernet devices. In addition the communication link from Pump Site D to Pump Site C will have the best receive signal and quality, but will require the most repeating to the Water Plant (Highest Latency). This scenario poses the question, which path will the network select? In our example we would want the primary link to go through Tank Site B (Repeater) and use either Pump Site C or the direct link only if this primary link fails. It is easy to see how automatic selection can lead to selecting a poor communication path or adding more system latency by selecting multiple radio hops. The constant changing of network parameters to find, add or subtract alternate routes can be inefficient and takes valuable bandwidth from the network. These discussions are further complicated in a communication network where the data rates will be constantly changing based upon environmental conditions.

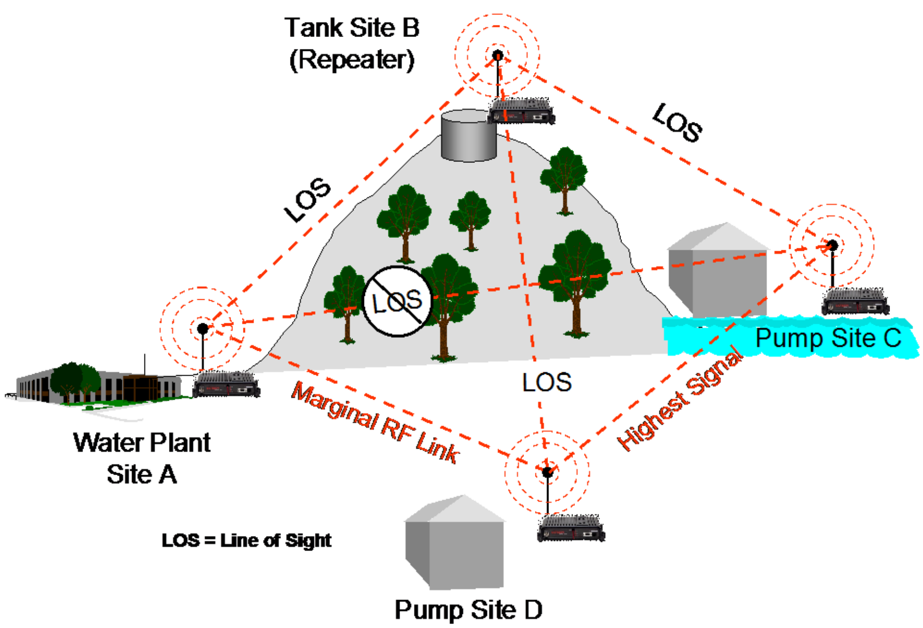

Figure 3 – Alternate Routing Example

The rules for reliable system design are the same when designing an industrial Mesh network as they are for any other wireless system. The following are the steps required when designing a reliable RF System:

1. **RF Design Program -** The first step in radio system design is reviewing all communication paths with a RF System Design program. All potential primary and alternate radio paths should be evaluated with the software program allowing a good fade margin for network reliability.
2. **Radio Site Survey** – The results of the RF design program need to be confirmed with an on-site radio survey. The radio site survey will also allow for testing of the marginal or none line-of-site links found in the RF Design Program.
3. **Site Commissioning -** After final installation of the system, all radio parameters will be tested once again with the installed hardware. Only after all the above steps are completed can the wireless network be certified for reliable operation.

The decision of network routes should be based upon the most reliable routes tested during the survey. These routes should then be input to each point in the industrial radio Mesh network and prioritized by the best radio communication routes. This process can take some additional time during installation, but the efforts will be greatly rewarded with a more efficient and reliable communication network.

The wireless Ethernet Mesh network will be the backbone for the entire communication system and any problems in the wireless system design will ripple through to the control system. The communication paths should never be a mystery and should follow specific rules for path configurations. Although the same basic concepts of a self-healing redundant network are used in an industrial Mesh network, the differences in the network design and configuration can make major differences in the performance of the system.