C1 - Wireless Networks in High Reliability Applications

The use of wireless control networks is becoming increasingly attractive in industrial applications but implementing reliable networks is not trivial.

Background

Optimal lighting solutions demand continuous control of lighting spectrum and intensity in order to better suit the task being performed, the ambient light levels and the time of day (circadian timing).

This control function cannot be adequately performed within a single light fitting because the illumination from adjacent light fittings overlap to evenly fill out the working spaces. Additionally work areas need to be pre-emptively illuminated to provide safe and pleasant working conditions. It is therefore necessary for *groups of lights* to interact to combine their total output to suit the tasks or dynamic environment being illuminated.

Historically, lighting control has been attempted by a wired control system using the Digital Addressable Lighting Interface network (DALI). DALI originated in 1984 as a successor to 0-10V analogue control of lighting intensity. Over 30 years old, the DALI system struggles to support the rapid advance of AI (Artificial Intelligence) and Networked Intelligence (Swarms) where dynamic control and interaction is required not just between light fittings, but also between sensors and other building systems. The DALI system has limited value in a modern building environment.

DALI systems have considerable limitations and cost. Up to 64 slave devices can be wired to one controller, multiple controllers are then interfaced to gateways in order to make up larger systems. The whole system is critically reliant on copper cable connections. The DALI system is static (each fixture programmed to operating in a set way, then left unchanged for years). Considerable maintenance time and cost can be invoked by any change in the arrangement of the lighting fixtures, any change in the desired operation of the task lighting, any change to the area occupancy over time, and even the simple replacement of a faulty light. Just the failure of one connection can jeopardise groups of luminaries or even the entire system and are often very difficult to diagnose and repair.

In order to improve flexibility and reduce installation complexity (cost) lighting manufacturers are offering wireless control options. Like the DALI offering, wireless control comes with its own set of reliability issues and other hidden issues.

Standard WiFi is generally not suitable, both because it is a point to point protocol, and because it impinges on the customers data networks which are security critical to their company's systems.

The most common wireless protocol offered is ZigBee which was designed for battery powered residential sensor networks. A ZigBee network may be limited to a simple point to point application (remote control and light fixture), or it may be expanded to try to achieve a wide scale mesh (where multiple nodes can talk to each other across the network). ZigBee generally uses the global standard Industrial Scientific & Medical Band (ISM) at a frequency of 2.4GHz using the IEEE 802.15.4 protocol. Built on top of this base level protocol is the ZigBee "stack" which details specific methods for connecting and communicating between nodes.

As a residential focused solution, the ZigBee protocol is a poor fit when pressed into use in high reliability industrial applications.

Firstly, the lighting manufacturers do not generally control the "protocol stack" which defines how the ZigBee devices will communicate. Buying this building block from a third party means they are at the mercy of "undetermined states" within the protocol stack which can produce "lock up" or "drop out" conditions. Any such event may require the customer to initiate a complete reboot of the network which typically involves power cycling the entire site simultaneously. (The fixture supplier will have no idea this problem has occurred or why it has even occurred, it will be left to the customer to sort out.)

Secondly, the scale of the network that ZigBee can produce is limited to about 240 nodes. Many industrial applications require over 1,000 nodes. Further, the range between nodes is typically limited to 10-20m, making setup tricky with range issues not being apparent until commissioning.

Thirdly, ZigBee mesh networks are generally static to prevent having to constantly recalculate data routes through the mesh. Therefore they struggle in managing real time dynamic networks.

Lastly, a network will consist of nodes, routers and gateways which complicates setup and maintenance. A node cannot talk to another node, except through a router. If for some reason a router node "goes down", then all its dependent nodes will drop out of the network. This so called "Orphan Problem" can involve a few nodes or a complete branch of the network. This fractures the network into multiple discrete branches. The only solution is to initiate a complete network re-boot.[1] Re-booting requires all nodes and routers to be reset and synchronised so that they can "find themselves" in the correct order to reconstruct the mesh. This is not a trivial task.

The Compuspec Adaptive Mesh Network

To meet customer demand for a reliable wireless network, Compuspec Industries developed an IEEE 802.15.4 based 2.4GHz networking solution which has now been in proven use for over ten years.

At its foundation, this solution is similar to the ZigBee protocol, in that it used the IEE 802.15.4 2.4GHz standard, however it uses higher power transceivers than normal ZigBee nodes, enabling a range of up to 1km between nodes, allowing hops from building to building and making the system immune to signal shielding and reflections produced by racking and building structures.

It is dynamic and real-time. Nodes can be fully mobile allowing forklifts or people to be part of the network. This allows lights to "Swarm" as dynamic groups follow and illuminate dynamic activity.

The system is constantly "self healing" as it monitors its own performance and detects anomalies on an individual node level. The system never needs a global "re-boot".

Nodes (light fixtures, sensors or forklifts) can be added or subtracted at will, with no reconfiguration or programming necessary.

The system is self configuring and each node is autonomous and identical, dramatically reducing installation times. Unlike Bluetooth and Zigbee networks, it has no need for special relay nodes, controller nodes or "friend" nodes and therefore no single point of failure.

It has no theoretical limit on size, supporting thousands of nodes, with the largest system to date over 2,000 nodes.

[1] The Orphan Problem in ZigBee Wireless Networks. IEEE Transactions on Mobile Computing, TMC-2007-09-0291.R1