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SURVEY ARTICLE

Wireless Mesh Networks: The Survey of Andover Continuum Wireless Technology and CyberStation Wireless Control

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Abstract — In this paper discusses how to use the next evolution of network technology - wireless mesh technology - to help improve the automation and control of a dedicated HVAC network, while also saving costs and the overhead expenses of a typical hard-wired network. The Andover Continuum solution results in cost reductions for installation, maintenance and distributed control over hard-wired HVAC controllers and devices. Building automation companies looking for an energy efficient, competitive edge are developing wireless network products for the complex internal HVAC, lighting, and safety systems of urban buildings. Andover Continuum's building automation control system has developed wireless technology.

Keywords: CyberStation; HVAC network; radio frequency; Wireless mesh Networks; Cyberstation control

I. INTRODUCTION

The brief introduction to wireless networking and how the technology is applied, as an Andover Continuum solution, to control a network of HVAC controllers. The concept of a wireless network and presents an overview of wireless network components, different types of wireless networks, and the benefits of wireless over hard-wired networks. And finally, the manual describes the Andover Continuum application of wireless technology for controlling and deploying a wireless HVAC solution. The Andover Continuum solution results in cost reductions for installation, maintenance and distributed control over hard-wired HVAC controllers and devices.

Wireless technology is based upon embedding RF components (low-cost, low-power radios and microcontrollers) directly into a product. Embedded RF uses high quality, low-cost, radio frequency integrated circuit (RFIC) technology.

The basic wireless terminology definitions are:

- **Node —** An addressable device on a wireless network. The wireless node can sometimes be defined as both an adapter and a controller. The distance between each node is called a "hop". The following illustration is a representation of an Electric wireless node.
- **Repeater —** A node that strengthens a mesh network.
- **Link —** In a mesh network, a link is a single hop relationship between neighbor nodes. A link is duplex and travels in two directions.
- **Link Strength —** The quality of the reception signal from a neighbor node
- **Link Quality Indicator —** Link strength and other factors that indicate a node's ability to receive error free messages
- **Asymmetric Link —** A link where one side has drastically poorer reception quality than the other side. Reasons for this type of link include loud noise near the node with the poorest reception, multipath problems in one direction or power output differences.

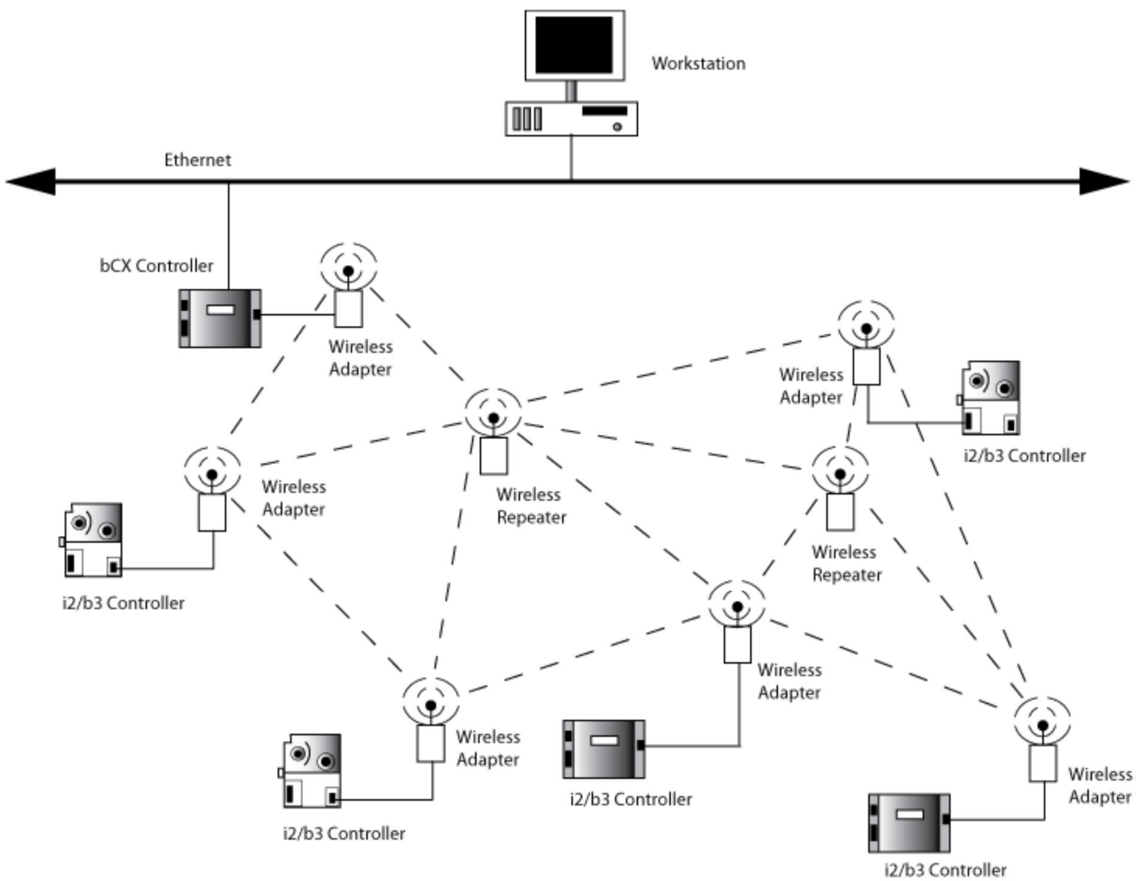

Figure 1: Wireless repeaters and links in a typical Andover Continuum mesh network

II. CHALLENGES IN WIRELESS MESH NETWORKS

A. Wireless propagation changes over time

Propagation fluctuates moment by moment due to changing natural and manmade conditions. For example, links in a factory that appear strong and reliable during deployment may be rendered completely unusable after the installation of a new industrial machine.

B. Background noise

All communication depends on separating the useful radio signal from the background noise, and when there is a lot of background noise, it is difficult to get signal through. The ambient noise level is due primarily to atmospheric conditions and local noise sources. In actual deployments the noise floor is varying constantly, and the intensity of the noise can rise and fall by tens of decibels. Very often, this is the major reason for changes in link quality.

C. Obstacles in proximity with the network

Propagation can vary due to obstacles moving in and out of proximity with the network. For example, networks set up in modern office buildings can vary dramatically when cubicles are rearranged. RF is affected by walls, doors, windows, concrete, metal objects, and even people. The higher the frequency, the greater the impact; most importantly, the greatest impact is on range limitation. Sometimes an obstacle is obvious, such as when a delivery truck blocks an access point.

At other times, an obstacle is more subtle, such as when reflective surfaces, such as water pipes, create multiple pathways for the radio waves. This condition is called “multipath”, and it can degrade link quality through destructive interference of the signal traveling via two paths of different lengths.

D. *Network Topologies*

A wireless network can have different topologies, or *organizations*, depending on the ways in which messages need to flow from one node to another. A topology is established, based on answers to fundamental questions, such as:

- Will a number of sensors report their controller data to an aggregation point?
- What happens if a message destination is out of range of the message originator?
- How will messages be relayed?
- How will the network recover from the loss of a route?

This section covers the following links and topologies:

- Point to point links
- Point to multipoint links
- Star networks
- Mesh network

E. Point to Point

A point-to-point link, also called a *wireless bridge*, connects two nodes. It serves as a wireless replacement for a single communication cable, as shown below.

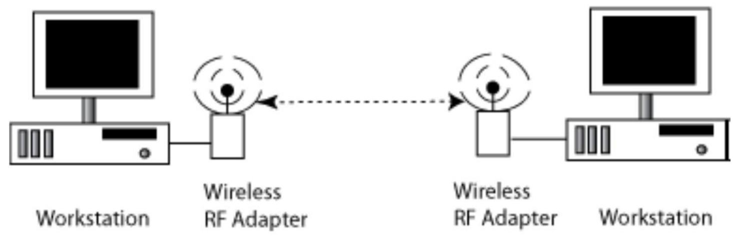

Figure 2.1: Point to Point Connection

Point-to-point links can communicate reliably, as long as the two nodes are located close enough to one another to escape the effects of RF interference and signal path loss. As with all wireless communication, if a reliable connection is not achieved initially, it is sometimes possible to relocate the radios or boost the transmit power to achieve the desired result.

F. Point to Multipoint

Point-to-multipoint links, also called a *hub and spoke*, have one central-point node that controls communication with all of the other wireless nodes in the network. Signals in point-to-multipoint communication converge at the central-point node. The reliability of this communication depends on the quality of the RF link between the central point and endpoint. Point-to-point communication is used in star network topology.

G. ***Star Network Topology***

Networks based on star topology provide efficient, localized ("one hop") communication. In these networks, a hub node arbitrates all communication with other nodes. All traffic to and from end nodes flows through the hub.

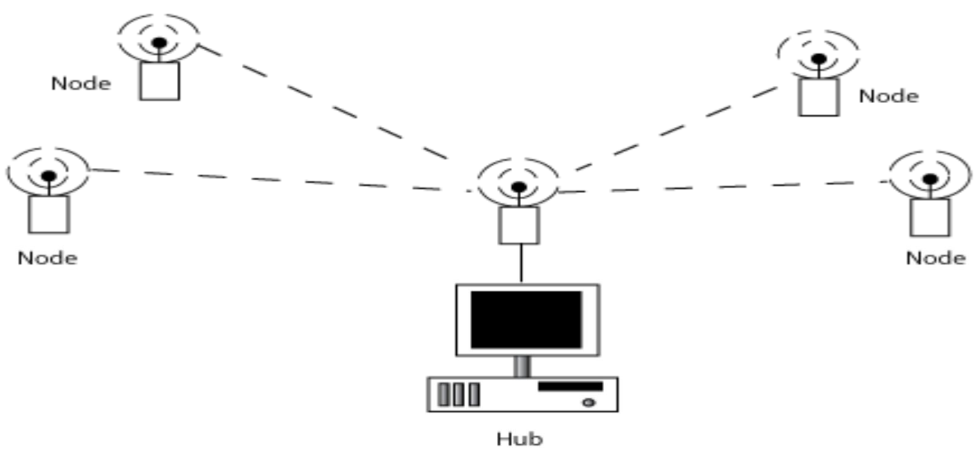

Figure 2.2: An example of a star network topology would be a Wi-Fi network where the access point is the hub and a laptop may be a node. It shows star network topology.

H. Mesh Network Topology

Mesh (multi-hop) networks are different from Star networks because every node can communicate with any other node or multiple nodes within the network. This form of communication is called *routing.*

A node can send and receive messages, but in a mesh network, a node also functions as a router and can relay messages for its neighbors. Through this relaying process, a packet of wireless data finds its way to its ultimate destination, passing through intermediate nodes and repeaters with reliable communication links.

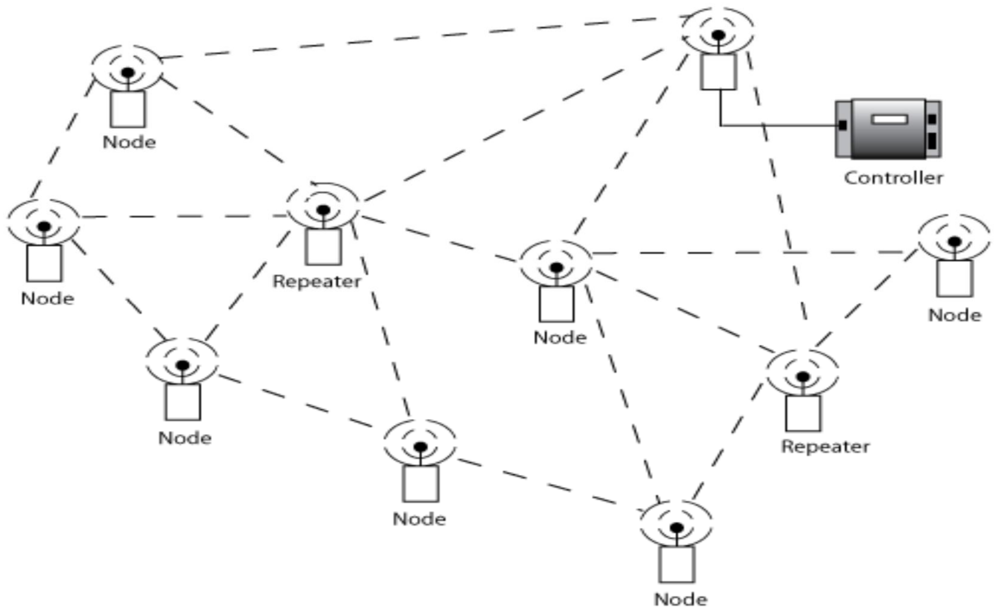

Figure 2.3: Example of Wireless Mesh Networks

III. ANDOVER CONTINUUM WIRELESS TECHNOLOGY

A. Continuum Wireless Devices

Continuum wireless devices allow Continuum controllers to communicate with other controllers across a wireless field bus mesh network. The Andover Continuum Wireless Adapter is a single device that can perform two roles — adapter and repeater.

B. Wireless Adapter

As a Wireless Adapter, the device is attached to the RS-485 Service (Comm) Port of the BACnet/Infinet bCX1 controllers, Infinet II (i2) field bus controllers, and BACnet (b3) field bus controllers. This allows the field bus controller to communicate with other controllers across a wireless mesh network.

C. Wireless Repeater

As a Wireless Repeater, the device is used to provide redundant links between Wireless Adapters connected to field bus controllers. When used as a Wireless Repeater, the device is not connected to a controller, and can be installed anywhere.

A repeater may be needed when there are long distances between wireless-enabled controllers, to add additional network paths for redundancy, or to compensate for obstacles, such as pipes or walls that can attenuate or weaken the wireless signal between controllers.

The repeater requires a 3.3 — 5 VDC ± 5%, 75 mA power supply.

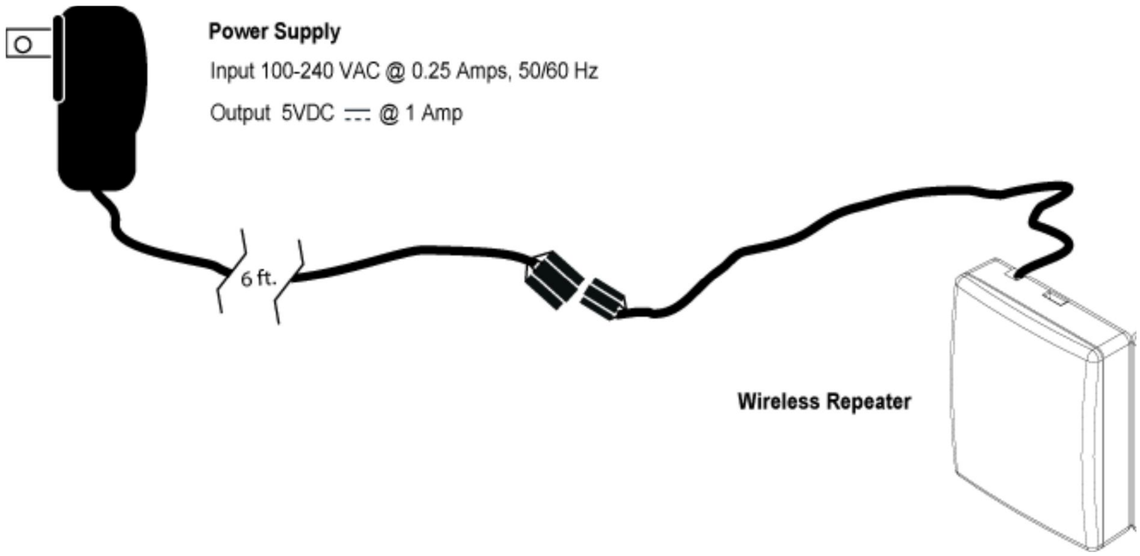

Figure 3.1: Wireless Repeater Connected to a power supply

D. Wireless Maintenance Tool

The Wireless Maintenance Tool (WMT) is a Windows-based application that shows you a wireless mesh network of adapters and repeaters in an interactive graphic display. From the display, you can gather information and monitor the communication details and signal strengths for each Wireless Adapter and connection. You can also use the WMT to change the Wireless Adapter settings for transmission power, RF channel, and PAN ID. You can also update the adapter firmware from the WMT.

The user interface is classified into two main areas:

- Wireless Adapter Display (the graphical window)
- Wireless Adapter Table (the table below the graphical window)

E. Wireless Adapter Display

This area graphically displays the Wireless Adapters within the mesh network and indicates their connectivity levels with neighbor adapters. When you right-click on any host or adapter icon, you can filter the display or access the properties for that adapter. You can move icons with the cursor or the Nudge tools. You can also add background images or floor plans to accurately reflect the location of each adapter. Indicators at the bottom of the user interface display the following data:online/offline status, filter status, number of connections, and the IP network address of the Electric controller that is the entry point into the wireless mesh network.

F. Wireless Adapter Table

The Wireless Adapter Table lists each adapter in the Wireless Adapter display area, along with all their property values. Can select each property and access object menus to filter the table and view or edit the properties of the selected Wireless Adapter.

G. Adapter Service Cable and Service Software

The Adapter Service Cable and Service Software that is embedded in the Wireless Adapter enable you to make changes to selected Wireless Adapter properties and to upload new adapter firmware. The cable and software are available in addition to the WMT for changing Wireless Adapter settings and updating firmware. You may want to use them to specify settings in Wireless Adapters that are not yet online in your mesh network or that are unable to communicate with other Wireless Adapters in the network.

The Wireless Adapter Table lists each adapter in the Wireless Adapter display area, along with all their property values. You can select each property and access object menus to filter the table and view or edit the properties of the selected Wireless Adapter.

Preventing RF Interference with Other Wireless Devices

When you are planning the installation of a wireless building automation system (BAS) it is necessary to consider the possibility of interference with other wireless devices and systems in the building.

Most BAS wireless devices utilize the IEEE 802.15.4 standard including ZigBee, while wireless local area computer networks utilize the IEEE 802.11 standard (also known as Wi-Fi). Because both networks occupy the unlicensed industrial, scientific, and medical 2.4 Ghz band, interference among them can occur when they are in close proximity and/or when their deployment is ungoverned by a channel utilization plan.

Both the IEEE 802.15.4 and IEEE 802.11 protocols are based on the carrier-sense multiple-access/collision avoidance (CSMA/CA) channel access method. By using this method, each node listens for another node’s carrier before transmitting a request to assert itself as the transmitting node. All nodes of that protocol within receiving distance refrain from transmitting for a random period of time, thus allowing the transmitting node to occupy the channel.

Because IEEE 802.11 RTS messages are protocol-specific, they are not understood by IEEE 802.14.5 nodes and vice versa. But, if an 802.11 node and an 802.14.5 node transmit at the same time on the same channel, they will interfere with each other. This is how interference between the two networks can occur.

Testing shows the two factors that affect the performance of IEEE 802.14.5 networks in the presence of Wi-Fi are:

- Proximity to the Wi-Fi nodes
- Traffic volume on the Wi-Fi network

Electric Wireless Adapter/Repeater RF Channel Considerations

The default radio frequency (RF) channel for the Electric Wireless Adapter/Repeater is 25, but you can change the RF channel. Electric chose channel 25 because the frequency is beyond the frequencies of commonly used Wi-Fi channels, eliminating many potential conflicts.

Other suggested alternative RF channel selections include:

- Channels 15 and 20, which are clear channels between common Wi-Fi channels
- Channel 26, which are beyond the frequencies of commonly used Wi-Fi channels but has a maximum power limitation of 0 dBm (Most other Electric Wireless Adapter/Repeater channels have a maximum power limit of 6 dBm.)

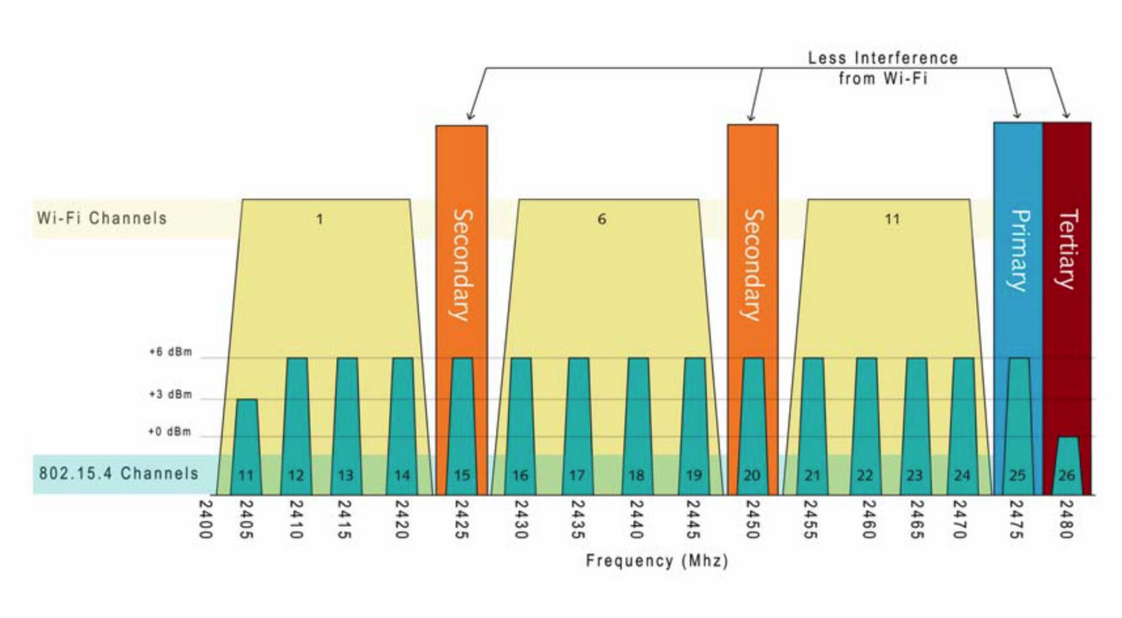

Figure 3.2: A comparison between the IEEE 802.14.5 RF channels and common Wi-Fi RF channels.

IV.CYBERSTATION WIRELESS COMMPORT CONTROL

A. Setting the CommPort

The two CyberStation software attributes of wireless networks:

- The CommPort on your network controller must have the Default Mode set to "Wireless."
- The software must "Learn" (discover and integrate) all the network controllers into a Continuum network. These attributes are set using the CommPort editor in CyberStation.

When you create a controller object, CyberStation automatically creates appropriate CommPort objects for each of the CommPorts of that controller. To change the default communication mode for the CommPort to which the Wireless Adapter is connected. In CyberStation, open Continuum Explorer, and then double click the controller CommPort need to edit.

B. CyberStation Control of Wireless Network Traffic

The wireless mesh network can be controlled by CyberStation in Data traffic using one of the methods

- Data collection
- APDU (application protocol data unit) transmission timeouts

C. Wireless Network Traffic and Data Collection Methods

As with a wired network, it is necessary to consider – and if needed, adjust – how the changing values of objects are transmitted on a wireless mesh network. The accurate data collection method can reduce network traffic. First, perform a charge of how data will be changing, how frequently data will be changing, and how much memory will be used for any given application – whether you have a lot of changing points on graphics panels and etc.,

In CyberStation, there are two general methods for collecting data:

- Change of Value (COV) – Data is collected as values change. (You can set an incremental threshold for data collection.)
- Periodic polling – An object is polled for its value at a specified interval.

COV – The COV method (available only for BACnet objects, such as AnalogInput, AnalogOutput, and AnalogValue) is generally more efficient when values do not change frequently. If, for example, values change three or four times per minute, COV typically increases network traffic. For example, values transformation three or four times per day, COV typically minimizes traffic. For more information on COV, please see the Continuum online help for the AnalogInput, AnalogOutput, and AnalogValue object editors.

V. CONCLUSION

In this Wireless controls reduce installation costs and permit controls to be installed in areas that would otherwise be difficult to wire. The cost of running wire is often the most expensive component of a controls installation, especially in large cities where labour costs are high and electrical codes require conduit. The technology has now reached a maturity level where these goals can be met at an attractive cost point for a wide range of applications. A wireless mesh does not require an infrastructure to be created; the total cost savings over wired networks is more easily realized.

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