WHITE PAPER / **CONSTRUCTION SITE CONNECTIVITY**

TESTING THE PRACTICAL LIMITS OF MESH NETWORK TECHNOLOGY

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Construction companies require a reliable data connection to capitalize on new technologies, but job site networking presents unique challenges. Our testing indicates that mesh network technology now provides optimal network performance for many applications.

The number of devices and use cases for construction technology continues to expand. Existing technologies allow project managers to track workflow and improve efficiency, discover and address safety violations, and increase security to reduce loss and waste. However, all of these technologies require a reliable network or data connection to update applications, feed data for monitoring systems and receive updates themselves.

Previously, there were two common solutions. An information technology (IT) team could set up a network that would meet the demands of the specific construction site, or the company could find a workaround, like placing a consumer wireless router in the construction trailer. The first option, while robust, is typically expensive and time-consuming. The second, while cost-effective, is rarely able to meet the demands of today's connected world. Fortunately, mesh networks can now provide a more effective solution.

Mesh network technology isn't new, but it has recently become robust and accessible to every level of construction. To determine the practical limits of wireless mesh networks, we conducted several tests simulating familiar construction environments. The results indicate that although autonomous excavation and real-time remote control will have to wait for 5G networks, construction companies can use mesh networks to begin capitalizing on many other technologies right away.

JOB SITE NETWORKING CHALLENGES

Achieving reliable network connectivity on construction sites is challenging for several reasons. Construction sites vary in size and shape. They can be short with a large footprint, tall with a small footprint, or both short with a small footprint or tall with a large footprint. In addition, construction sites are constantly changing, unpredictable and not conducive to complex electronics. They have high peak demands and require high availability. Furthermore, networks are often deployed at a remote, temporary site where there is little to no IT support available. Wireless mesh networks are uniquely suited to address these challenges.

KEY VARIABLES TO CONSIDER

- **WAN/LAN connection, including type, speed and location.**
- **Surface area and topology, including total square footage and whether the network is mesh or linear.**
- **Power sources available at mesh points, which could include stationary 120-volt, mobile vehicle 12-volt, or remote battery or solar.**
- **How the network will be used, such as for video monitoring, general application access or a corporate VPN.**

These variables will help determine if mesh networking is right for a given project, as well as what configuration — including number of nodes and distance between nodes — is needed to maintain adequate connectivity.

THE MESH NETWORK SOLUTION

A wireless mesh network is a self-organizing network that is able to distribute the connectivity and workload for devices across both the network and a diverse geographic area. Unlike traditional networks, for which every access point needs to be wired to the wide area network (WAN) or a local area network (LAN) switch, mesh network nodes utilize a separate wireless network to communicate with each other. Traffic is then passed back to a central node that is connected to a WAN or the internet.

Nodes can be set up in a closed circuit for traditional, large site construction or in a linear configuration for transmission and distribution construction. All that is required is power and a place to mount the nodes. Network nodes will accept 120-volt AC or 12-volt DC power. They can be powered by a vehicle, a small solar array, a battery pack or another power source, and they can be either stationary or mobile.

For example, if the project is the construction of a four-story building or a transmission or distribution line, teams can simply move the network as the project progresses. In addition, if the mesh network is paired with a cost-effective wireless-to-Ethernet bridge, it can be run from a smart phone or MiFi device then moved from job to job.

SIMPLE CONFIGURATION

Configuring a mesh network is straightforward, particularly in comparison to previous network technologies. While installing a legacy system requires an IT group to customize and maintain the network, a mesh network can be configured from an app on a smartphone in about an hour. If an IT support team is available, the network can still be available from home base for monitoring and troubleshooting.

Current mesh network technology also provides sophisticated diagnostics and control. Separate networks can be set up independently for different subcontractors with controlled bandwidth and user access. Once programmed and initialized, the nodes maintain their settings almost indefinitely. The system can be configured in the office, then stored for weeks or months before being deployed on-site simply by plugging in the devices.

TESTING THE LIMITS OF MESH NETWORKS

Recently, we conducted several tests to evaluate the effectiveness of mesh network technology. Each test used three DeWalt DCT 100 Jobsite WiFi Access Point units, a standard Verizon Jetpack MiFi device and a Linksys E2600 router as a wireless bridge. The bridge simply connects to the MiFi device and provides a hardwired connection for the mesh node. In this case, an Ethernet bridge is required because the DeWalt product only supports an Ethernet connection (RJ45).

In the first test, we configured the network as a triangle to simulate a large job site. For the second and third tests, we created a linear network to simulate transmission or distribution construction projects. In each case, we established a baseline by measuring the network connectivity between the MiFi device and the Linksys bridge. Then we tested connectivity speeds at various nodes and distances to determine usability.

FIGURE 1: *Primary node setup.*

PERFORMING THE TESTS

We chose the DeWalt DCT 100 because it is IP67 rated to protect against water and dust and is therefore well-suited to many construction sites. It also comes with a free, user-friendly app for configuration. However, similar access points from Aruba Networks, Cisco Systems, Ubiquiti Networks or other manufacturers might perform just as well at comparable or lower cost. Likewise, the Verizon MiFi device and Linksys router used in our tests could be replaced with similar products based on availability and your company's hardware standards.

NODE SETUP

Each of our tests used three network nodes. The primary node shown in Figure 1 includes the DeWalt access point, Verizon MiFi device and Linksys router. On an actual job site, the network equipment serving the primary node would be secured in an enclosure. We would also recommend replacing the inexpensive Linksys bridge with a purpose-built device, such as the IOgear Ethernet-2-WiFi Universal Wireless Adapter. Typically, the node would be mounted on a pole, likely at the job site trailer or as close as possible to the WAN/LAN providing access.

It's important to note that you must check the speeds for each device, as you do not want to introduce a bottleneck at your primary connection.

FIGURE 2: *Stationary node setup.*

FIGURE 3: *Mobile node setup.*

Mesh network nodes can be mounted on any stationary or mobile platform connected to a power source. Figure 2 shows the stationary setup used in our tests.

Our mobile node setup is shown in Figure 3. Again, on an actual job site the node would be mounted on a pole, though in this case it would be attached semipermanently to a construction vehicle. Each device comes with a standard threaded connection for pole or tripod mount, as well as a robust steel hook to hang the device via rope or cable.

MONITORING CONNECTIVITY

The DeWalt Wi-Fi app provides a simple but robust interface for monitoring network connectivity. In Figure 4, a sample screenshot indicates the status off all connections from the internet through each of the three test nodes.

The app also allows you to monitor the performance of individual nodes. The sample screenshot in Figure 4 shows the current health and diagnostic information for node B, as well as network connection speeds within the mesh.

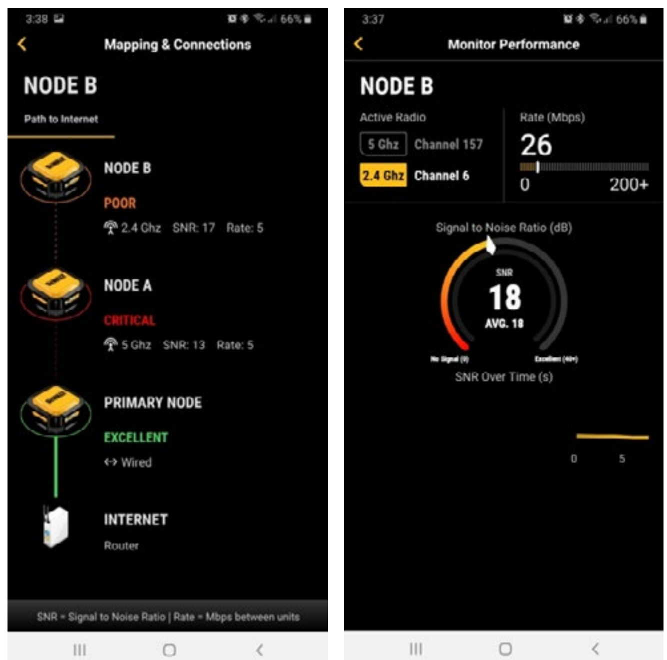

FIGURE 4: *DeWalt Wi-Fi app mapping and connections interface (left) and DeWalt Wi-Fi app performance interface (right).*

FIGURE 5: *Enclosed site test location.*

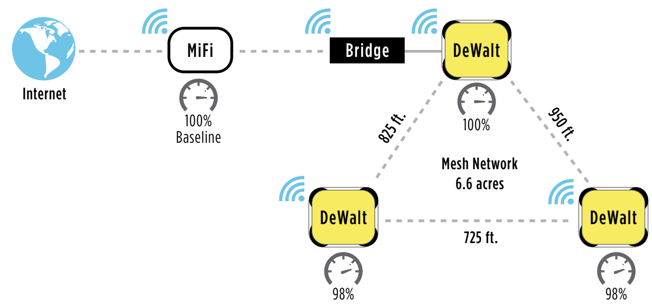

FIGURE 6: *Enclosed site test results.*

ENCLOSED SITE TEST

Our first test was designed to measure mesh network coverage of a large, enclosed space similar to a building construction site. The test was conducted at a simulated rural agricultural construction site, as shown in Figure 5.

The test site has approximately 10 to 15 feet of elevation change, but it is large and open, as is typical when prework is being conducted before the structures have gone up. If the site were located in an area already densely populated with buildings, one or two additional nodes might be required.

As shown in Figure 6, nodes A and B were placed 725 feet apart at 825 feet and 950 feet from the primary node, respectively. Connectivity at both nodes was measured at 98 percent of the baseline. In other words, with only three nodes, the performance of the wireless nodes within the mesh network was almost as good as connecting directly to the WAN.

At 6.6 acres, the test area could accommodate reasonably large construction projects. We believe this space could be increased substantially while still providing adequate connectivity for all applications.

LINEAR SITE TESTS

Our second and third tests were designed to measure network coverage of a linear construction site, similar to that of a transmission or distribution construction project. Both linear tests were conducted at the same rural construction site used in the enclosed site test.

Linear Test 1

Linear test 1 is shown in Figure 7. As shown in Figure 8, node A was placed 900 feet from the primary node and node B was placed 1,435 feet from node A. Connectivity at node A was measured at 98% of the baseline, whereas connectivity at node B was 61%. While this may seem like a significant loss of bandwidth, 61% was more than sufficient for typical job site data gathering and use of online applications.

When the mesh is stretched into a line, the performance drops noticeably as the distance between nodes is increased. This is to be expected, because relays back to the primary node and signal losses compound for each additional node.

FIGURE 7: *Linear test 1 location.*

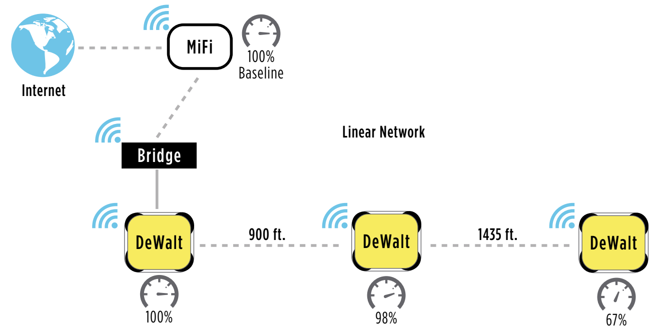

FIGURE 8: *Linear test 1 results.*

FIGURE 9: *Linear test 2 location.*

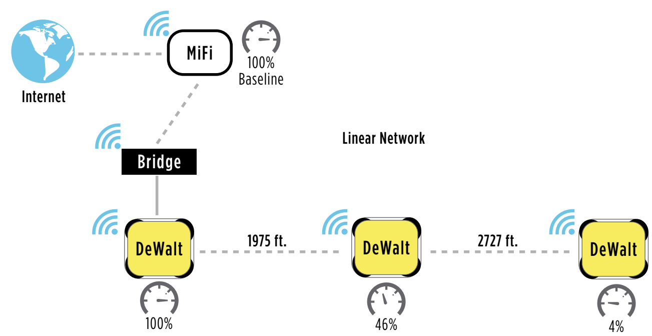

FIGURE 10: *Linear test 2 results.*

Linear Test 2

Linear test 2 is shown in Figure 9. In this test, we increased the distance between nodes. As shown in Figure 10, node A was placed 1,975 feet from the primary node and node B was placed 2,727 feet from node A. At this distance, connectivity at node A was measured at 46% of the baseline, but connectivity at node B was only 4%.

Bandwidth of 4% was enough to send email, search the internet and use mapping services, but it would not be enough to support video applications in critical use cases. However, few applications would require linear networks of almost a mile in total distance.

CONCLUSION

Maintaining network connectivity on construction sites is a known challenge. Until recently, the available solutions were either robust but costly, or ad-hoc and unreliable. Wireless mesh network technology addresses this problem by providing rugged, reliable network connectivity in an affordable, off-the-shelf solution.

Consumer-grade mesh network technology can now support many sophisticated applications, including video safety monitoring, machine diagnostics and progress tracking. It can easily be deployed and managed by on-site personnel, or remotely if IT support is available. Moreover, it can be configured to suit a variety of construction projects.

Our tests indicate that wireless mesh networks can provide optimal connectivity for even the largest traditional construction sites. While performance did drop across long, linear networks, this problem could be resolved by using more nodes and decreasing the distance between them. For relatively low-cost, commercially available mesh network systems perform admirably and could easily fulfill the needs of most construction sites.

BIOGRAPHY

WOODS DENNY, PE, is manager of technology innovation in the Business & Technology Solutions Group at Burns & McDonnell. In this role, he is responsible for developing growth initiatives through innovation programming, product development, investments and partnerships. Woods has extensive experience designing industrial control systems and working on generation stations powered by fossil fuels. He has also played a key role in developing and deploying internal engineering and design tools utilized throughout the company's Energy Group. Woods has a Bachelor of Science in electrical and electronics engineering from the University of Kansas and is a licensed professional engineer in Kansas and Oklahoma.