Using Redundant Wireless for Reliable Heavy Industry Automation

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Heavy industry often makes use of large machinery such as boom bucket wheel stacker-reclaimers. These are massive, distributed systems that could improve their productivity and efficiency with modern wireless networking technology, such as a WLAN link between the operator's cab and the end of the stacker arm. However, if the connection is unreliable, then the advantages of introducing wireless communications are lost. This issue is perhaps best illustrated in a thought experiment known as "The Two Generals' Problem."

The Two Generals' Problem

Communications unreliability within a system can compromise the operations of the entire system, so it is important to find ways to decrease the unpredictability of your communications network.

Imagine that two allied generals are each camped with their armies on two hilltops, with enemy forces filling the valley in between. The first general sends her best scout to sneak through the valley and deliver this message to her counterpart: "Our only hope is a coordinated assault—a mistimed attack would be disastrous. If I have been assured that you will join me, I will attack at midnight tonight." The second general responds by sending a messenger with a reply to the same effect. However, the appointed time comes, and both generals find themselves unsure about whether or not the agreed upon attack will actually take place. What went wrong?

The problem with this scenario is that due to communications unreliability, even if both messages get through, neither general could have absolute confidence in the attack. The

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second general may have sent the confirmation message, but he does not know if his reply was received, and consequently he does not know how the first general will act. Meanwhile, even as she holds the reply in her hands the first general knows that the second general will be uncertain about the status of his reply. This uncertainty compromises the confidence that both generals need to attack.

The startling truth is that no matter how many messages the two generals send neither can ever be absolutely confident in the attack, because the status of the last message in the exchange will always be in doubt. This dilemma exists any time communications reliability is uncertain, and illustrates the importance of finding strategies to increase the reliability and decrease the unpredictability of a communications system

Industrial automation may not appear to have the gravity of armies and generals, but coordinated activity is just as crucial to successful management of an intricate industrial process. More and more, system integrators are turning to wireless communications as a coordinated solution for highly distributed or mobile applications, such as massive stacker-reclaimers or underground mine cart systems. Common to these systems are constantly moving components, whether they are mine carts or the arms of cranes, which make wired networking impractical. However, reliable communications haven't become any less important just because you have switched to a wireless system. A network interruption can cause costly downtime and expensive damage, or even threaten the safety of your workforce.

The Three Major Causes of Wireless Packet Loss

In order to create a reliable network, we must recognize the various challenges of wireless communications. Even in a properly configured wireless network, there are three primary sources of communications errors: collisions, weak signal, and environmental interference.

Collisions are a particularly acute problem in wireless communications because it is more difficult to detect when they have occurred.

Collisions occur when multiple devices compete simultaneously on the same network segment. For wired Ethernet, transmitting stations can listen for incoming signals and notify the network if a collision is detected. Confident collision detection is rarely possible in wireless networks. While transmitting, a wireless station will most likely receive only the signal from its own transmitter, which is located closest to its corresponding receiver. This obscures any collisions from other stations. As a consequence, if packet loss is detected in a wireless network, the 802.11 protocol assumes that a collision has occurred, and responds with exponential backoff and adjustments of the retry counts.

Weak signal issues force networks to compromise data rate.

In addition, packet loss can occur due to a **weak signal** if the signal strength at the receiver is too weak for the data rate of the packet. Weak signals can be caused when the network attempts to transmit at a data rate that is too high for the signal strength, or because physical obstacles are making the signal weaker. Simple movement could also be the culprit in mobile applications if the client has moved farther away from the access points. The 802.11 protocol only begins to tune the data rate and power, or consider AP hand-offs after a collision has been ruled out as the cause of packet loss.

Wireless interference from other devices hinders 802.11 communications on the same spectrum.

Environmental interference also contributes to wireless unreliability. Electronics such as cordless telephones, Bluetooth devices, industrial microwaves, or video senders all create interference on the 2.4 GHz band used in most 802.11 wireless networks. This co-channeling and radio interference reduces band availability and also causes more error packets.

Wireless Redundancy—Always Have a Spare

Adding a redundant wireless link increases reliability, but the switching process from one link to another adds its own complications.

Redundancy is a common strategy to increase the reliability of a system, including wireless networks. At its simplest, redundancy is simply the technological application of a basic concept: always have a spare. Redundancy can be implemented on many levels. Power redundancy, which provides devices with a backup power supply, is fairly common

and relatively simple to implement, while complete system redundancy, which provides a top-to-bottom duplicate of the entire system, is extraordinarily expensive and frequently impractical.

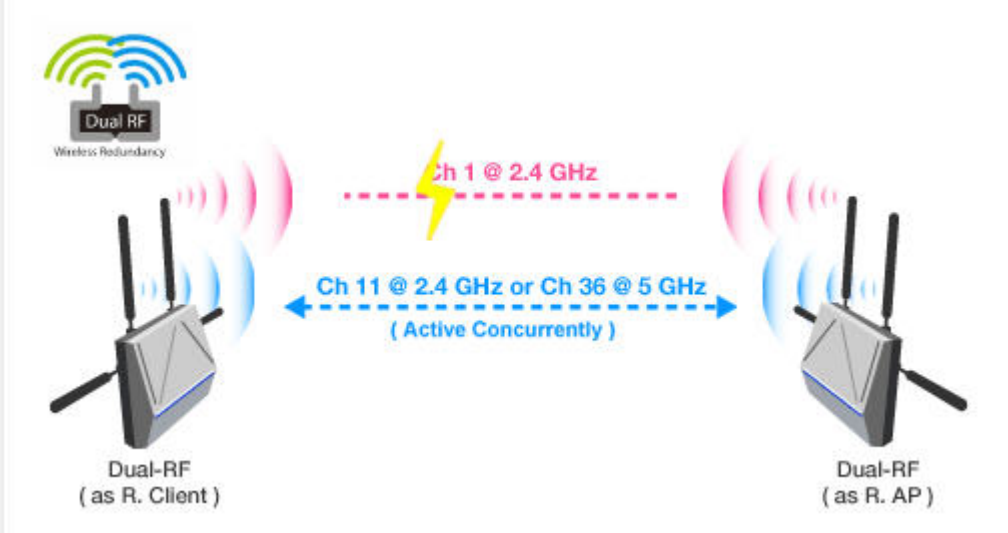
The second wireless link restores communications once activated, but some packets may be lost

Creating a redundant wireless link does add a layer of redundancy to the system and increase the reliability. While one wireless link is active and transmitting, the other is on standby on a different channel, ready to take over if transmission quality drops below a certain threshold. However, this solution has its limits. First, it takes time to switch to the new link. Some packets will invariably be lost during this transition period. Second, if the threshold for activation of the standby link is set too low, then communications will need to drop to a low data rate before the current link is disconnected. This is unacceptable for applications that require a continuous and high level of performance. However, if the threshold is set higher to avoid this very problem, the "ping-pong" effect—where the wireless connection constantly switches back and forth between the two links—becomes a potential problem, dramatically increasing the complexity of the switching mechanism.

Advanced Wireless Redundancy

Concurrent dual RF wireless redundancy duplicates all wireless transmissions to achieve the highest level of reliability.

In order to avoid these complications, Moxa's wireless products add advanced refinements to redundant wireless link technology. The AWK-5222 and 6222 features two independent RF modules. This means that both modules can be activated simultaneously. By working concurrently, the redundant wireless link duplicates the data transmissions, which eliminates any packet loss from waiting for the connection to switch links. The ability to broadcast simultaneously on two distinct channels, and even two distinct bands (2.4 GHz and 5 GHz), also bypasses any interference that might exist in one band.



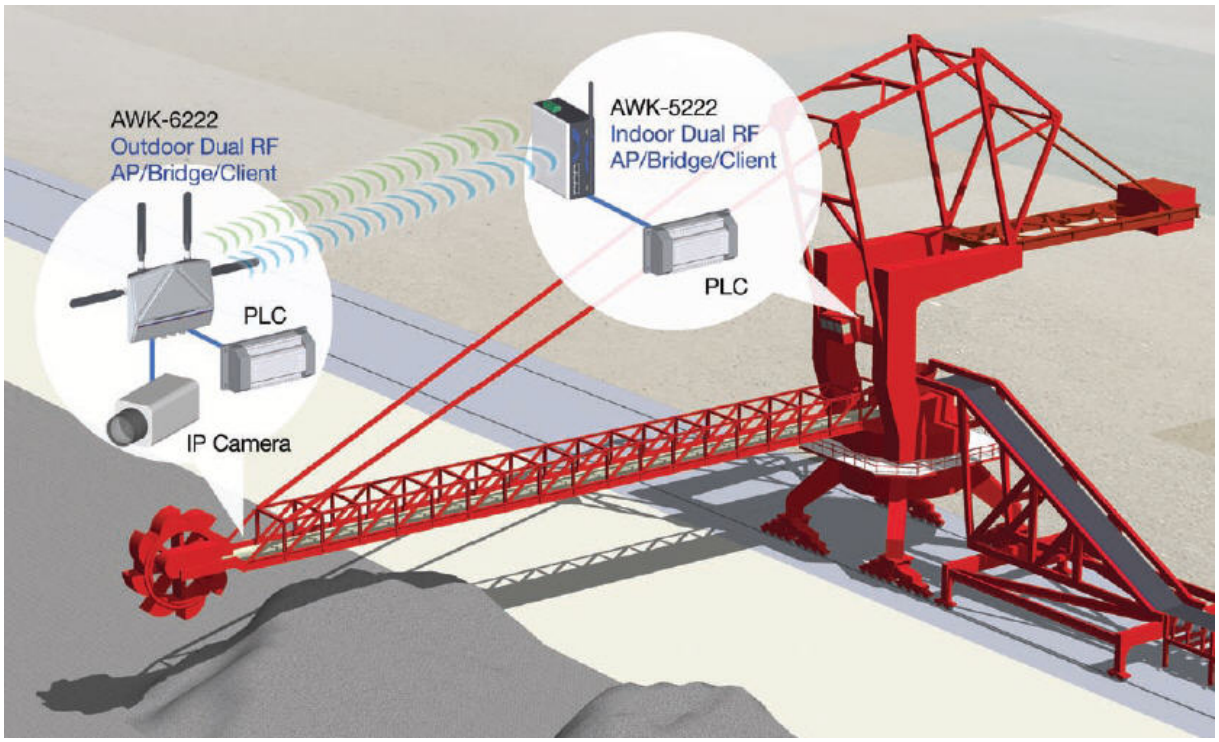
The concurrent second wireless connection provides seamless failover if the first connection is interrupted.

Simultaneous dual redundant links also increase the throughput by reducing the number of resend requests. Throughput is the average rate with which messages—the data that the user is actually interested in—are delivered over a path. It's possible to have high data rate yet unsatisfactory throughput if a lot of communications "overhead" is consumed on information such as frame headers and retransmission, leaving little room for actual message data to be delivered. Resend requests, which are a particularly prodigious source of

overhead in wireless applications, can adversely affect throughput. Fortunately, with dual redundant links, data packets do not need to be resent as long as they are received on one of the two links. This minimizes communications overhead, optimizes bandwidth utilization, and maximizes throughput at any data rate and under any conditions.

Industrial facilities are hectic places, with large machinery constantly in motion. The quality of wireless communications can be compromised by equipment failure or a simple repositioning of the client's physical application space. Moxa's redundant clients are sufficiently flexible and adaptable to respond promptly to device failures or movement relative to APs, and to prevent packets from being lost. Moxa's redundant clients combine Turbo Roaming technology and redundant wireless technologies to proactively search for APs in concert. When wireless performance drops below a certain threshold, the client will identify an optimal AP and switch immediately instead of waiting for the existing AP signal to be completely lost.

The advantages of these advanced redundancy technologies become clear once they face the challenges of a demanding real world application such as a stacker-reclaimer. Moxa's industrial 3-in-1 wireless AP/Bridge/Client products are ideal for the rigors of this type of application. The outdoor AWK-6222 can be installed as a client at the end of the belt conveyor to link the material handling PLC and IP camera via its dual Ethernet ports for video monitoring and data collection of bucket wheel status and digging conditions. This data can be transmitted to an AWK-5222 unit in the operator's cab in both the 2.4 GHz and 5 GHz bands. The resilience of the redundant wireless connection and IP68, wide-temperature wireless devices make them capable of overcoming the exposed, busy, and outdoor environments that stacker-reclaimers operate in.



A stacker-reclaimer is a large but mobile system that benefits from advanced wireless networking technology

For Every Problem, a Solution

The two generals' plans were frustrated by a valley full of enemy forces that compromised the reliability of their communications. Establishing industrial wireless networks can sometimes feel just as daunting, as they may need to confront challenges such as exposed operating conditions, interference from other devices, and a network of clients and APs that is in constant motion. Fortunately, Moxa's industrial wireless products come equipped with an answer to every potential source of wireless packet loss.

Cause of Packet Loss	Moxa's Solution
Collisions	• The second wireless link bypasses any collisions on the first link. • Fewer resend requests reduces the number of collisions
Weak Signal	• Redundant wireless increases throughput and reduces overhead • Turbo Roaming™ proactively connects to the optimal AP
Environmental Interference	• Utilize two different bands: 2.4 GHz and 5 GHz

See how Moxa's AWK-5222 and AWK-6222 maximizes heavy industry productivity or request pricing information at **www.moxa.com/event/IW/2010/crane**. US customers can quickly and conveniently obtain evaluation units using our Moxa Online ordering service available at **store.moxa.com**.