WHITE PAPER

802.11 Network Design: Document Number 112911-01 Revision 1.0

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Introduction

In 2011 3D-P introduced to our customers the 802.11n equipped Intelligent Endpoint product line, along with the Motorola 7181 802.11n Access Point. The combination of these products can provide mobile networks with data rates up to 300Mbps, and complete mine-wide coverage. In order to achieve these benefits, the wireless network must be deployed correctly and with clearly defined coverage zones. This document helps describe this correct network deployment. 3D-P Support services can assist customers in designing and deploying these networks, as well as re-deploying their existing network in order to get the maximum benefit from 802.11n equipped Intelligent Endpoints.

The Evolution of a Network

In real-world outdoor deployments of wireless networks, most infrastructure deployments begin with a network design covering primary areas of coverage, and allowing overlap to secondary areas. As the client's coverage and throughput requirements mature beyond the initial scope of the network, network blind spots and areas of low throughput are typically found. New infrastructure is often deployed to cover these holes.

While covering blind spots and increasing throughput was the objective of adding this infrastructure, these new devices actually increase the noise floor in the network coverage area. In an 802.11 network, there is no coordination between neighboring AP's, or 802.11 clients who are associated to separate AP's. When a single channel or a neighboring, but overlapping channel is used in a single coverage area, communication from a neighboring device is only seen as noise to the devices around it. For example, device A may begin to send data to AP A, only to have device B begin to communicate to AP B. The signal from these two devices is effectively noise to the other, and results in dropped packets and dropped communication.

802.11 attempts to solve the above problems through the use of the CSMA/CA and RTS/CTS mechanisms. However, in these outdoor, open pit environments even these systems are often defeated by the large number of clients and infrastructure located in close proximity. The problem is a noise floor problem, rather than a congestion or hidden node type problem.

In RF environments such as our outdoor deployments, the noise floor is often much more important than the receiver sensitivity when calculating fade margin. In order to take optimum advantage of a radio signal, that signal must be above the designed fade margin. Fade margin is an expression for how much margin (in dB) there is between the received signal strength and the receiver sensitivity of a radio. When the noise floor is so high that signals near the receive sensitivity of a device cannot be heard, the noise floor is a more realistic bottom for the fade margin calculation. The fade margin equation becomes received signal – noise floor. If we generate a high noise floor due to neighboring cells using the same or overlapping channels, our signal strength must be much higher in order to get optimum throughput from the radio. If we can reduce the noise floor it is much easier to get full fade margin and thereby optimize the throughput of a radio.

Adding higher gain antenna's and amplifiers on the clients, and the addition of even more infrastructure is typically the attempted solution for problems such as the above example of device A and device B talking over each other and creating coverage and throughput concerns. While these solutions will certainly increase signal strengths in some areas, they will also drastically increase the noise floor and actually cause additional coverage and performance issues. These new issues typically show up in slightly different areas of the network. For example in some areas we may have new coverage issues due to the fade margin being eroded to the point that signal strength is less than noise floor. In other areas we may have performance issues due to the fade margin being low enough that high data rates are no longer available. A vicious cycle has begun, as the network maintainer is tempted to go add more infrastructure to these new problem areas, or get stronger signals from the client devices.

Solving the Coverage and Throughput Problem

The solution to this problem involves reducing the coverage areas of individual access points, and reducing the power on individual clients, quite the opposite of the typical solution. Individual coverage zones for each AP must be designed. Terrain, antenna selection, and output power should be utilized in the building of these coverage zones. Individual coverage zones should have an overlap at the edges of each zone, but should not completely overlap each other. This way a client traveling between the two zones will have a single AP which is the obvious choice for communication. When the unit leaves this coverage zone, there will be an overlapping zone where the device will be able to see both AP's, and as it continues on it will switch to the new coverage zone.

A wireless connection manager has been designed to monitor the signal strength from the connected AP. This is designed to keep the unit connected to a single AP until the unit reaches the boundary of the AP's coverage zone. It also ensures the connection is above the noise floor, ensuring the unit does not try to continue communication to an AP that has no fade margin.

When working with existing networks, where the infrastructure is deployed with the typical deployment scheme, i.e. high noise floors, and multiple devices visible at the client level, the 3D-P Intelligent Endpoints will work only as well as the deployed infrastructure allows, and certainly only as good as other radios currently deployed. The real advantage of using the 3D-P Intelligent Endpoints, and the 802.11n speeds that are available with the IEP product line, will only be obtained by re-designing/re-deploying the network infrastructure in a manner that reduces the noise floor and creates these individual coverage zones.

Figure A

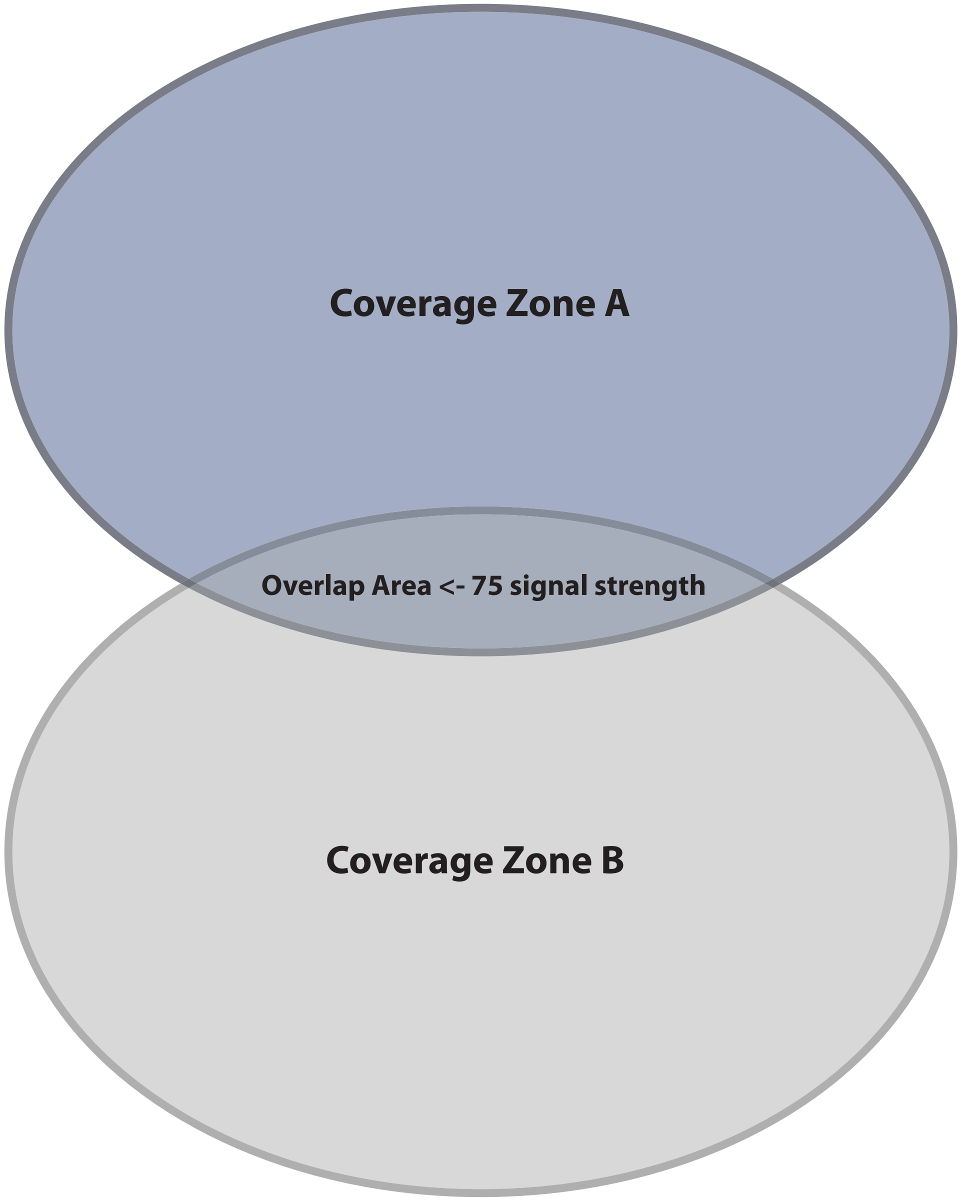


Figure A provides an example of two Access Points, each having an appropriate coverage zone. Clients traveling through Zone A will communicate with the AP from Zone A until they reach the overlapping coverage area between Zone's A and B. In this area the connection manager will begin to force a scan for a new AP. Once the Zone B AP is received as a stronger signal than the Zone A AP, the client will associate Zone B. When the client has departed the overlapping coverage area of both AP's, it will be receiving the Zone B AP strong enough that it will no longer search for additional AP's. Also, the communication to the Zone B AP will not be interfered with by the communication in the neighboring Zone A, as the margin between Zone B's signal strength, and that of the Zone A AP will be great enough the client will be able to communicate with minimal interference.

Figure B

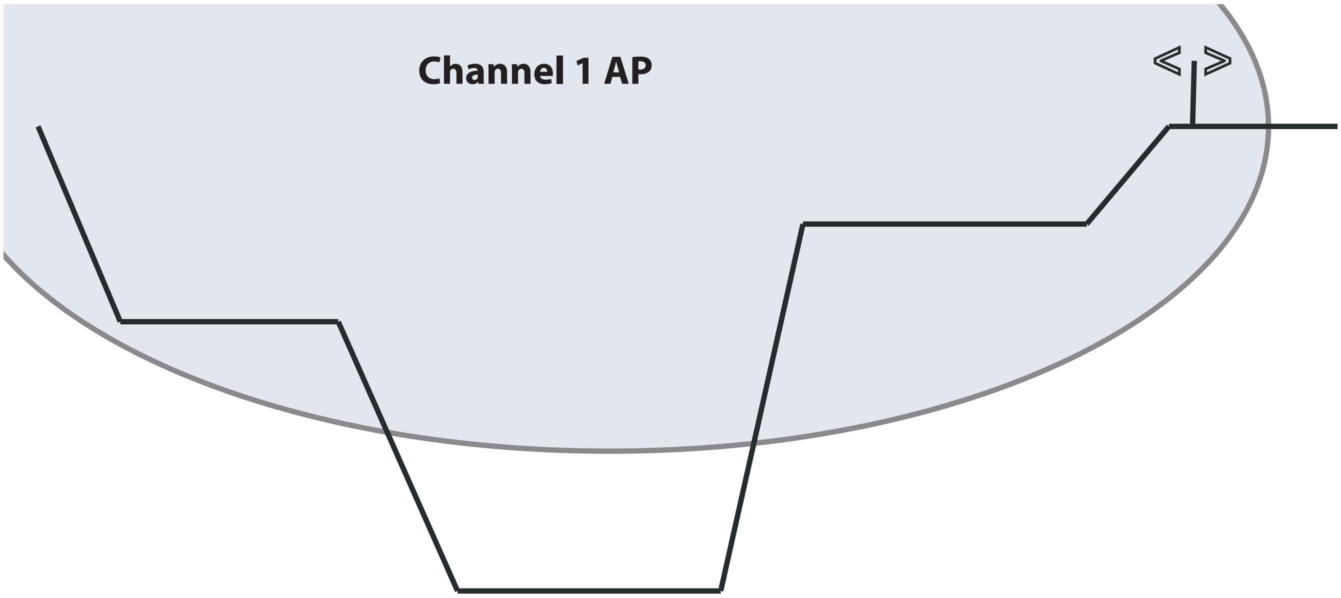
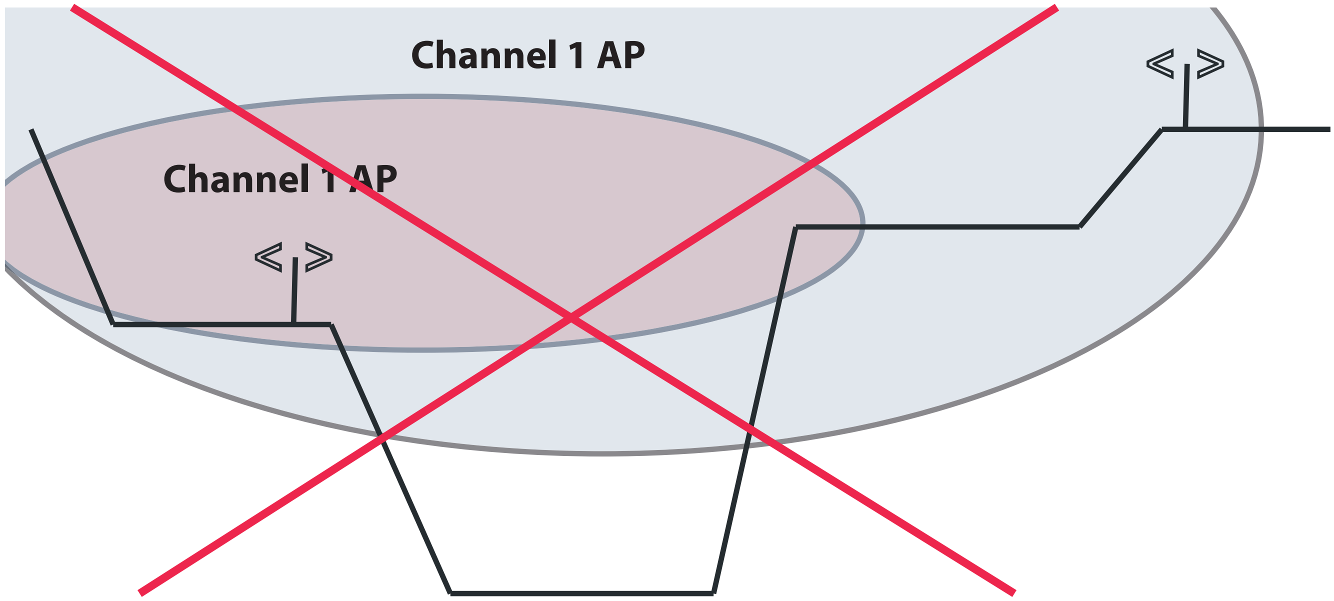


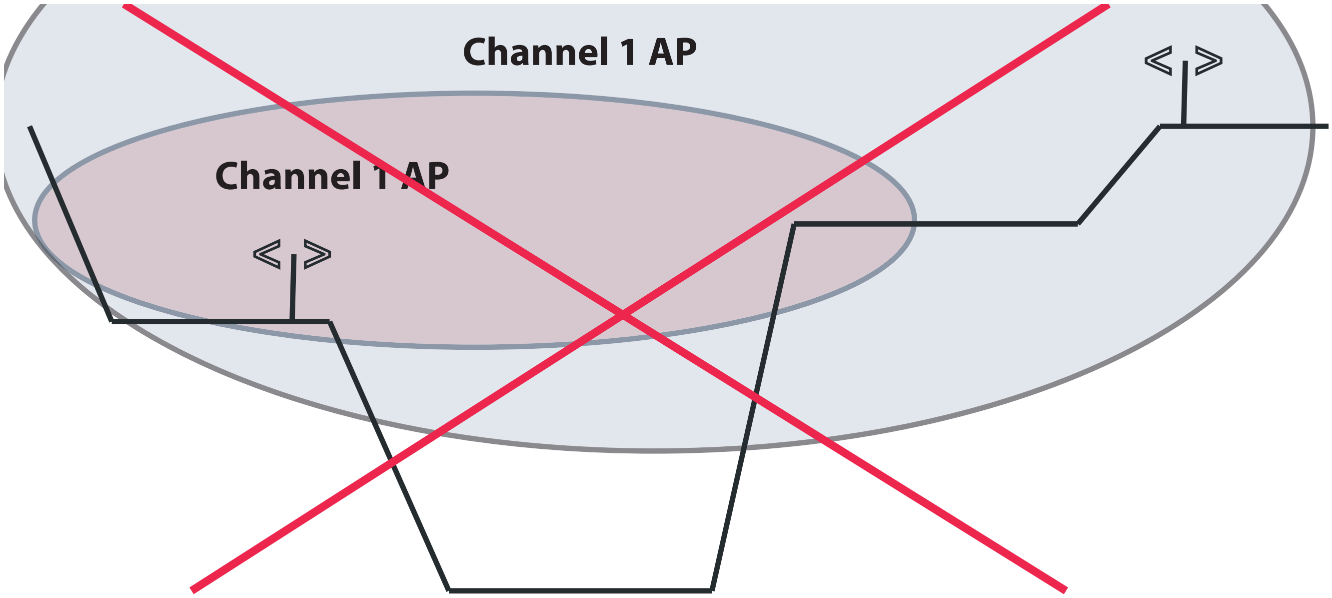
Figure B Shows an example of a cross section of a pit. In this example, a single AP is utilized to provide a coverage zone over the entire pit. This is often the original deployment plan in many networks. This deployment plan may work well in the instance where few clients will be working in the coverage zone, or where the throughput requirement of those clients is very minimal.

Figure C



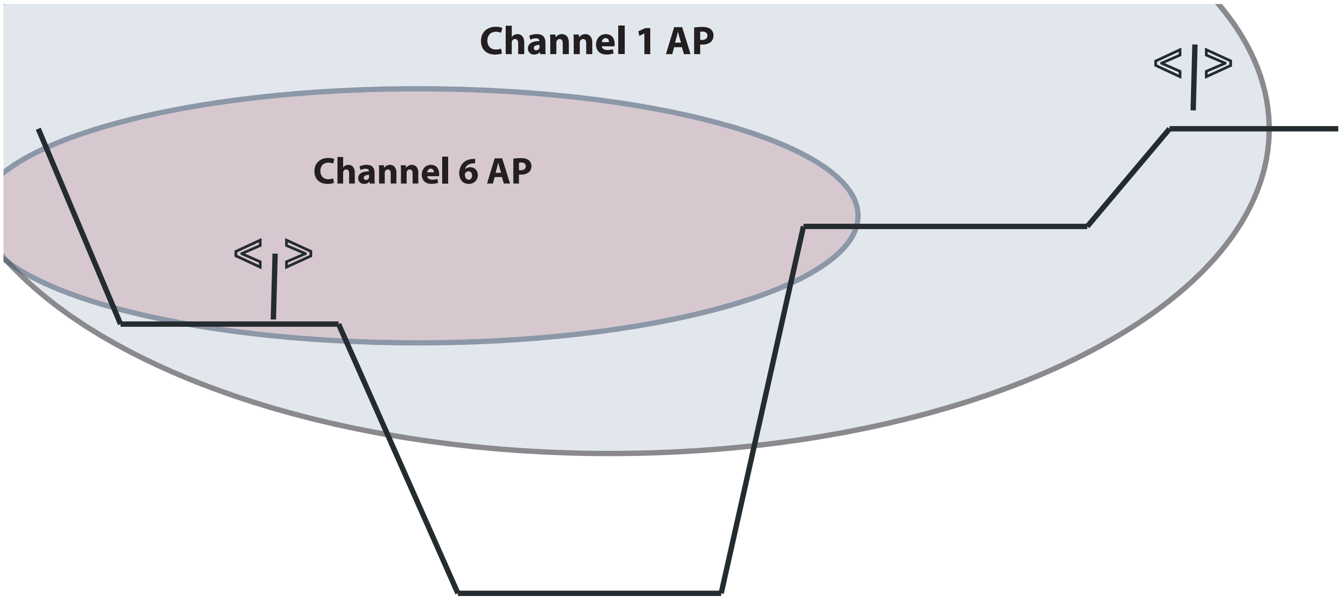
As the throughput and client count of the pit increases, the typical solution is that shown in **Figure C**. A new AP is added to the pit to provide additional throughput/coverage. However, the interference this new AP creates is often cause for new trouble. Clients traveling through the pit will perceive a higher noise floor and have trouble communicating clearly to either AP. Often increasing the gain of the antenna on the client is attempted to get communication from this client out of the noise. This again aggravates the problem for other clients in neighboring pits as their effective noise floor has been increased by the higher gain antenna on this client.

Figure D



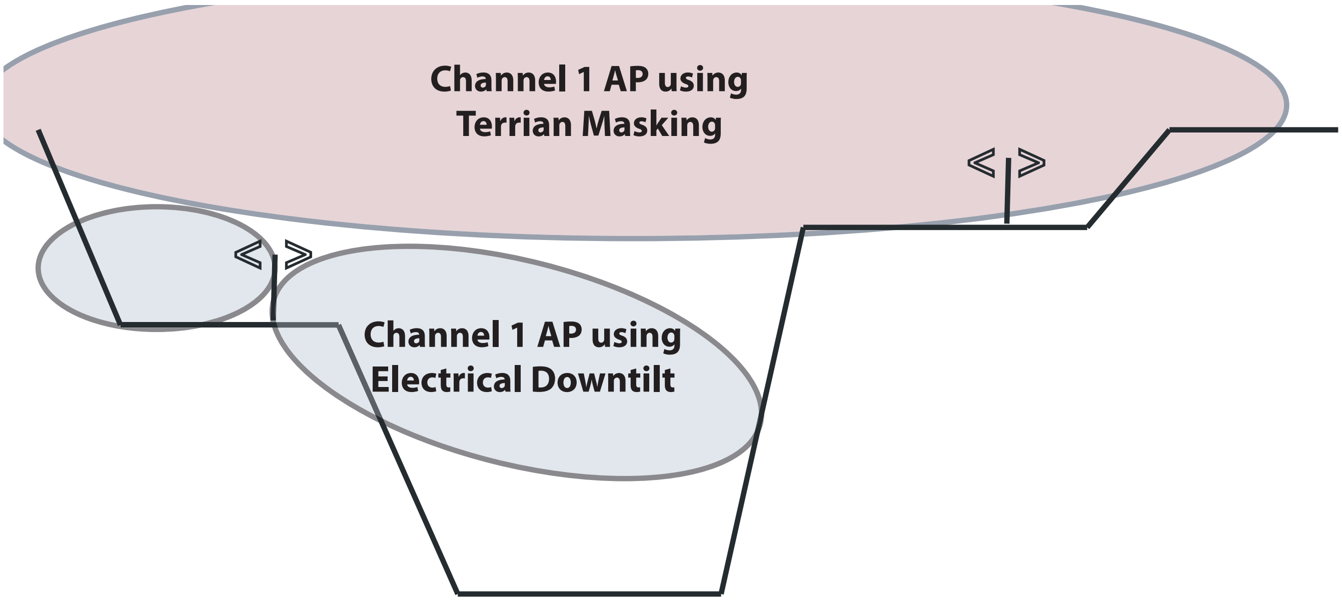
Another faulty deployment scenario has networks utilizing multiple overlapping channels in the pit. **Figure D**. shows this scenario. This deployment has the same problem as Figure C., since 802.11 channels 1 and 2 are overlapping channels. Traffic on Channel 2 is seen as noise to devices utilizing Channel 1. The result is a high number of dropped packets on both AP's.

Figure E



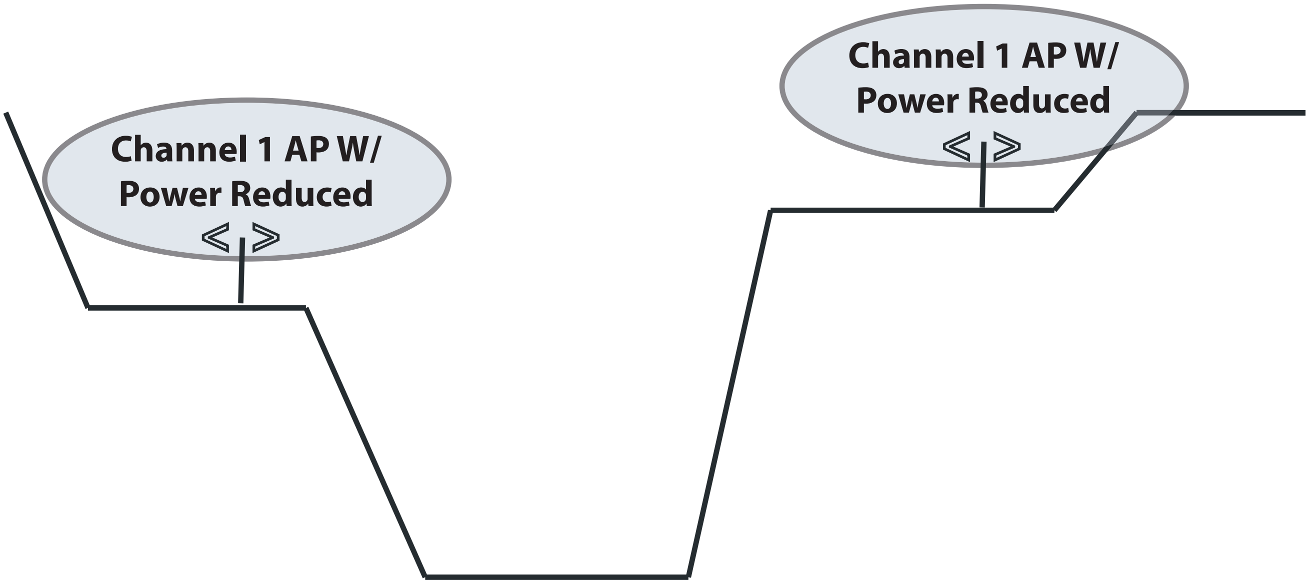
A potential solution is to utilize non-overlapping channels on these two AP's. This will allow the AP's to be deployed in these areas, and their traffic to be segregated so they are not generating noise for each other. **Figure E**. has an example of this deployment scheme. While this solution works in many scenario's, it does have the disadvantage of slowing the association time of devices when they scan for a new AP since they now have to scan more than one channel. There is another potential disadvantage in this type of design. It is possible for the client to try and "flap" between the two AP's. The connection manager is designed to prevent this, but in some situations, such as shadowing from other mobile equipment, vehicle orientation, etc. a handoff between the two "good" AP's can cause momentary loss of communication, which could have been prevented had the unit simply stayed with the first connection until the shadow or orientation is corrected.

Figure F



Using Terrain and Electrical Down tilt on one of the Access Points can provide two non-overlapping coverage zones for these AP's. This is shown in **Figure F**. This is a good solution as clients working on the two benches of the pit have a clear choice of AP to utilize for their communication, and the overlapping interference is minimized.

Figure G



Power can also be utilized to reduce the interference between two adjacent coverage zones. **Figure G** Shows an example of this.

3D-P Upgrade Path

3D-P offers an upgrade path from 802.11bg networks to the high performance 3D-P 802.11n network and the Intelligent Endpoint product line. The upgrade path for these networks involves not only upgrading the client radios to 3D-P 802.11n equipped Intelligent Endpoints, but re-designing and re-deploying the existing wireless infrastructure to optimize the throughput and connectivity for the Wireless Clients. This re-deployment can also include upgrading to the Motorola 7181 AP, a high performance 802.11n Access Point that can provide up to 300Mbps data rates for the Intelligent Endpoints.

It's important to note that simply adding 3D-P Intelligent Endpoints to your network will not improve the throughput/coverage of your network. You can still take advantage of the open networking and computing platform that the Intelligent Endpoint provides, but it won't improve your network connectivity. In order to get improvements, the network must be designed and deployed correctly.

Summary

With proper network design, and the use of the 3D-P Intelligent Endpoint, and Motorola 7181 Access Point, an 802.11n mobile network can be deployed providing data rates throughout the mobile network that are much higher than have previously been available. Using these tools, customers can now deploy multiple onboard applications, including Dispatch, High Precision GPS, Machine Health, operator management, and in some cases, even video. All this data will pass through a single onboard network management tool, and over a mobile wireless network.

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