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Simply Better Wireless.

solution brief

Designing for Density

Introduction

The tremendous acceleration in data traffic that is being driven by the proliferation of smartphones and cellular attached tablets and laptops is beginning to overwhelm mobile networks. Operators are looking at a variety of different options to address the network capacity challenge in a cost effective manner. The most compelling option involves the use of heterogeneous networks made up of Wi-Fi and small cell technologies. These HetNets can greatly increase capacity in network hotspots, which are usually located around airports, convention centers, train stations, downtown metro areas, stadiums, etc. They increase capacity through very high spectral reuse. In all other parts of the network, the normal macro cellular infrastructure enhanced with LTE can usually be counted on to do the job. The design principles in macro cellular networks are well known, but how do things change when designing for density? High spectral reuse involves deploying large numbers of small radios in close proximity to each other. There are a host of issues that must be addressed if these deployments are to be successful. This paper will take a look at the challenges associated with "designing for density".

The Density Challenge

Most mobile networks are built to provide coverage, which entails making sure the user can pickup a wireless signal from almost any location. To be successful with these kinds of deployments it is best to use a smaller number of very powerful base stations with antennas that are mounted high above ground. They transmit in the licensed bands (lower the frequency the better) and can easily cover many tens of square kilometers. When designing for capacity, all the rules must change. It is best to use a large number of smaller radios deployed in close proximity to each other to get the necessary capacity. These radios should be mounted close to the ground, and should use the higher frequency bands. It is also best to use low power technologies like Wi-Fi, so the signal doesn't propagate to far. When deploying APs in close proximity to each other use equipment with sophisticated interference mitigation technology. The Ruckus family of carrier class APs, have proven to be very adept in handling these kinds of challenging environments, and the story just gets stronger with the introduction of the ZoneFlex 7782-N Access Point. This is the world's first outdoor AP with an integrated 30º narrow beam antenna. Let's look in a bit more closely at what makes Wi-Fi and Ruckus the right solution when network capacity is of paramount importance.

It all starts with spectrum

The normal practice when designing for coverage is to use lower frequencies, because they propagate much further then higher frequencies. These lower frequencies can also penetrate deep inside buildings. The 700 MHz licensed bands are a great choice when coverage is the objective. When designing for capacity it is best to use higher frequencies and the unlicensed 5 GHz bands are a great choice. Signals in the 5 GHz band don't propagate all that well and are easily absorbed by physical structures, both of which are very desirable qualities in high-density deployments. A central tenant of high-density design is to constrain RF energy to a limited area so that other APs in close proximity will not see this as interference.

When designing for density the limiting factor is interference, whereas when designing for coverage the limiting factor is link budgets.

In addition to the desirable propagation characteristics of the 5 GHz unlicensed bands, there is also a great deal of available spectrum, and when designing for capacity there is no such thing as too much spectrum.

While the 5 GHz story is compelling, a major issue in the industry is its availability on devices. 5 GHz is now available on most high-end data centric devices including the new Apple iPhone, most Android models, and of course tablets and laptops. Given the incredible value that is offered by the 5 GHz unlicensed bands, it is best to always deploy dual-band 802.11n AP's when designing for density. Most Ruckus APs, including all the high-end indoor and outdoor models are 802.11n dual-band enabled.

Antenna technology isn't everything… it's pretty much the only thing

If you don't have good antenna technology then not much else really matters. A key part of a successful high-density deployment is to use an assortment of different antennas based on the situation. The most useful of which are AP's with narrow beam antennas, defined as having a 30º azimuth. These antennas can be external or they can be designed into the AP, with the latter being the more desirable option. Narrow beam antennas are an especially compelling option in arenas and stadiums because of the large crowds. In an arena, narrow beam APs can be mounted in the catwalks high above the floor and can direct RF energy into a specific section of seats. Narrow beam antennas are extremely important in this application, as there will be other APs in very close proximity that are directing RF energy into an adjacent seating areas. Every effort should be made to limit the overlap in coverage from adjacent APs, and a narrow beam antenna can do the job. AP's can also mounted under the overhangs in stadiums and arena. A small form factor AP with integrated antennas really helps in these situations. As the AP's get closer to the users, it is often necessary to shift to a wider beam antenna, something closer to a 120º azimuth to get the proper coverage. In convention centers, train stations, and airports the deployments can often be a bit more straightforward as there are often ceilings and walls that can be leveraged. When deploying in downtown metro areas, a small form factor is often a requirement to get permission to mount on light poles. The Ruckus 7782-N is the most compact, and highest performing narrow beam AP on the market.

Leveraging the 5 GHz band

The 5 GHz bands can deliver as much as 500 MHz of additional spectrum depending on geography. This can translate into as many as 24 non-overlapping channels. This is an enormous improvement over the 3 non-overlapping channels that are available in the 2.4 GHz band. The more channels that are available, the easier it is to densely pack AP's together without creating a lot of co-channel interference. In an arena deployment, 24 AP's can be mounted in the catwalks high above the floor and each can transmit on its own 5GHz channel. When transmitting on the 2.4 GHz band there will be significant spectral reuse, which can increase interference unless mitigated to a great extent with adaptive antenna technologies like BeamFlex™. This is a Ruckus Wireless patented technology, that provides the industry's most advanced adaptive antenna implementation. BeamFlex combines a compact internal antenna array with sophisticated control software to continuously optimizes the connection by steering RF energy toward the user and away from other AP's in close proximity. The latter provides the interference mitigation that is essential in high-density deployments..

Given the compelling nature of the 5 GHz bands in high-density applications, Ruckus has developed band steering technology which can detect dual-mode devices and "push" them into the much higher capacity 5 GHz band, and that leaves the lower capacity 2.4 GHz for legacy and low-end devices.

Access Point Placement

There are some general rules that can aid greatly in access point placement. Normally when designing for coverage you want clear line-of-sight in every direction and thus you deploy your radios on a mast or a rooftop. When designing for capacity you want to do just the opposite and deploy your APs down near the ground. Structural separation

TABLE 1: The 5 GHz band

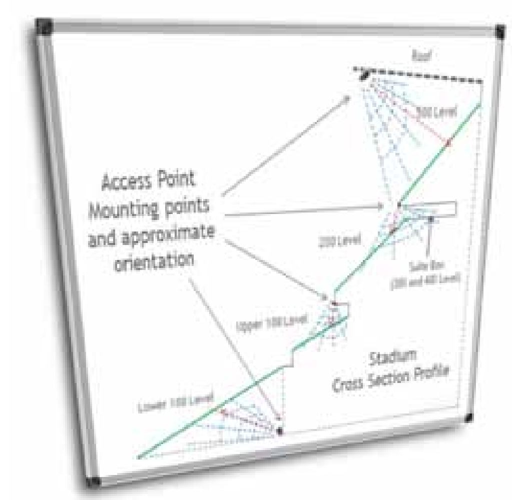
Channel	Frequency	USA	Europe	Japan
34	5170	No	No	Client Only
36	5180	Yes	Yes	Yes
38	5190	No	No	Client Only
40	5200	Yes	Yes	Yes
42	5210	No	No	Client Only
44	5220	Yes	Yes	Yes
46	5230	No	No	Client Only
48	5240	Yes	Yes	Yes
52	5260	DFS	DFS	DFS
56	5280	DFS	DFS	DFS
60	5300	DFS	DFS	DFS
64	5320	DFS	DFS	DFS
100	5500	DFS	DFS	DFS
104	5520	DFS	DFS	DFS
108	5540	DFS	DFS	DFS
112	5560	DFS	DFS	DFS
116	5580	DFS	DFS	DFS
120	5600	DFS	DFS	DFS
124	5620	DFS	DFS	DFS
128	5640	DFS	DFS	DFS
132	5660	DFS	DFS	DFS
136	5680	DFS	DFS	DFS
140	5700	DFS	DFS	DFS
149	5745	Yes	No	No
153	5765	Yes	No	No
157	5785	Yes	No	No
161	5805	Yes	No	No
165	5825	Yes	No	No

Note: Selected countries in Europe have lightly licensed the 5.8 GHz band

is also a good thing, use walls and ceilings at every opportunity to limit RF propagation. Anything that soaks up and absorbs RF energy is a good thing. Concrete is your friend!

1. When deploying in stadiums and arenas a good option is to place APs under an overhang, especially if it is made of concrete. From there an RF signal can be directed down into the seats below. Deploying in the catacombs under seats is another good option. In this case the signal must pass through concrete to reach the fans siting above which helps greatly in limiting how far the signal can propagate. The concrete and steel support in the catacombs allows APs to be placed under each section with little if any co-channel interference. Arenas and stadiums with roofs also enable AP's to be deployed in the catwalks high above the ground. In these deployments the APs will typically use power-over-Ethernet (PoE).

FIGURE 1: Mounting options in an arena



2. In downtown metro areas a great high-density deployment option is to use light poles (aka street furniture). They offer numerous advantages such as AC power, ubiquity, and

they are usually the right height (you typically want AP's about 6 meters above ground). When deploying on street furniture it is absolutely essential that the AP have a minimal form factor (almost camouflaged) as this is usually a condition of the entity that owns the poles, and it also makes them less likely to be tampered with if they can go unnoticed. Interference mitigation is also an issue as a city street might easily see a hundred or more SSIDs coming from surrounding buildings. These signals will be somewhat weakened from having to go through the walls of buildings and are therefore less likely to be a real problem for APs mounted on light poles. When deploying on light poles it is usually necessary to use smart mesh technology to backhaul traffic to a point where Ethernet becomes available. Smart mesh technology uses the 5 GHz band to backhaul through intermediate hops (if necessary), and can automatically route around any congested links to enable a highly available connection.

The ZoneFlex 7782-N comes standard with AC and PoE-in power, it has a very minimal form factor that is ideal for light poles, is environmentally hardened, and has the narrowest beam antenna of any integrated AP in the market. It was purpose built for high-density applications.

3. Train stations are another very popular high-density venue as they attract huge crowds during the morning and evening rush hours. In a large station there can be a large number of platforms that must be served and a good option is to deploy a pair of narrow beam ZoneFlex 7782-N APs about halfway down the platform. These can usually be mounted to whatever has been put in place to cover the platform. One AP points up the platform and another points down the platform. As there can be quite a few parallel platforms in a big train station the narrower the beam the better. As these stations are almost always out of doors, environmental hardening is a must.

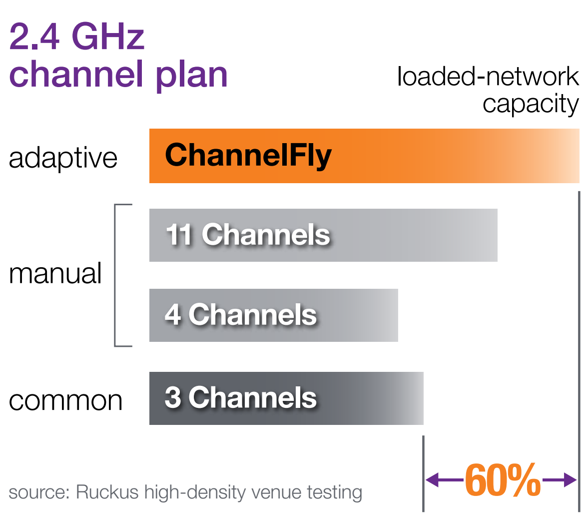
Self-organizing high density networks

A big part of minimizing co-channel interference in a congested environment is the use of non-traditional channel plans as part of a self-organizing network (SON) architecture. The 2.4 GHz band is of greatest concern as it has limited spectrum and it is very congested. The traditional rule of thumb in this band is to deploy on channels 1, 6, and 11 as that gives three non-overlapping bands. However, since all AP's use these bands they can be quite noisy. A lot can be gained by shifting to other channels. Ruckus ChannelFly™ technology- has been specifically designed to enable a self-organizing network where APs automatically select the best channel for the situation. As circumstances changes the channels will change. ChannelFly is used with both the 2.4 GHz and 5 GHz bands.

Self-organizing networks also greatly simplify the deployment process in high-density networks, as it would be very difficult to manually select channels for a hundred or more APs in close proximity to each other. Plus the channel selection will need to be constantly updated as RF conditions change. One thing that changes RF conditions is the size of the crowd, which will ebb and flow over the course of the day. With ChannelFly this is automatic, all that is required is for the units to be powered up and have connectivity to the network.

In figure 2 we se an example of how ChannelFly works in an actual deployment in a large arena. ChannelFly provided a substantial improvement in throughout over alternate approaches to channel selection.

FIGURE 2: ChannelFly in an actual deployment



The rise of the smartphone and the tremendous acceleration of data traffic is starting to overwhelm today's mobile data networks. HetNets are seen as the solution to the network scaling challenge as they can offer a great deal of capacity through high spectral reuse and very dense deployments. However, the rules for high-density deployments are very different from those used with maco cellular deployments over the past 2 decades. We summarize the key differences in table 2.

TABLE 2: Key differences between designing for capacity and coverage. Ruckus has long been a leader in deploying Wi-Fi technology in some of the most challenging venues imaginable. With the launch of the ZoneFlex 7782-N the story gets even stronger.

	Coverage	Capacity
AP count	prefer low	prefer high
Limiting factor	Path loss	Interference
Obstacles	bad	Good
Frequency	lower better	higher better
Antenna pattern	omni better	sector better
AP placement	higher better	lower better
Design metric	SNR area	SINR area

For more information on Ruckus high density solutions see www.ruckuswireless.com/carriers.

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