

The Business Case for Service Provider Wi-Fi

ADDRESSING THE TREMENDOUS GROWTH IN MOBILE DATA TRAFFIC IN A SCALABLE AND COST EFFECTIVE MANNER

The mobile industry is seeing rapid growth in data traffic. This started with the launch of the iPhone back in 2007 and has continued unabated for the last 5 years. Most industry pundits are expecting mobile data growth to continue at rates well in excess of 50% annually through the end of the decade. While it is nice to have a popular service, there can be some serious challenges in keeping up with the demand. This paper will explore some of the tools that can be used to cost effectively scale network capacity. Before delving into that analysis, it is worthwhile to get a sense for the size of the problem.

In **Figure 1** we plot mobile data demand under two possible scenarios; the first being a compound annual growth rate of 20% and the second a growth rate of 40%. These numbers are well below what many are forecasting, but the results are still very interesting. With a 20% CAGR, the network would need to add 1.5 times as much airlink capacity as presently exists in the network over the next five years. With a 40% CAGR that number grows to 4.5 times what presently exists over the same five year period. The implications on the network from this simple example are staggering. With a 40% CAGR in bandwidth demand, an operator would have to add an amount of capacity that on average would equal 90% of what they have today, and they'd have to do it for each of the next 5 years.

Capacity would not need to be added across all cells (or sectors) or even across all parts of a cell at equal rates. There will be hotspots that need to add capacity at an even higher rate and other cells that need to add it at a much lower rate. Mobile network engineering teams report that on average 20% of the cell area produces 50% of the traffic load. It is that 20% that really needs our attention. These hotspots are typically located around stadiums, convention centers, train stations, malls, airports and other areas where people congregate. Often the heaviest loads are generated indoors. Let's now take a look at what we can do to increase airlink capacity, especially in these hotspots.

There are three knobs that can be turned to increase airlink capacity. These include acquiring more spectrum, increasing spectral efficiency, and getting greater spectral reuse.

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Acquiring more licensed spectrum

If we assume for the minute that unused spectrum exists, the idea of having to acquire it at auction and build-out existing base stations with new equipment to light up these carriers would be prohibitively expensive. But the reality is that spectrum suitable for mobile communications is in very short supply. In most geographies it must be refarmed, which takes a lot of time and a lot of money. At best we might see a 5% CAGR in mobile spectrum depending on the geography over the next decade. This will tend to be very lumpy as spectrum is freed up rather sporadically. This process also takes a very long time if the digital TV dividend is any indication. Adding spectrum is a tool in our toolkit, but it doesn't come close to solving the problem by itself.

Improved airlink efficiencies

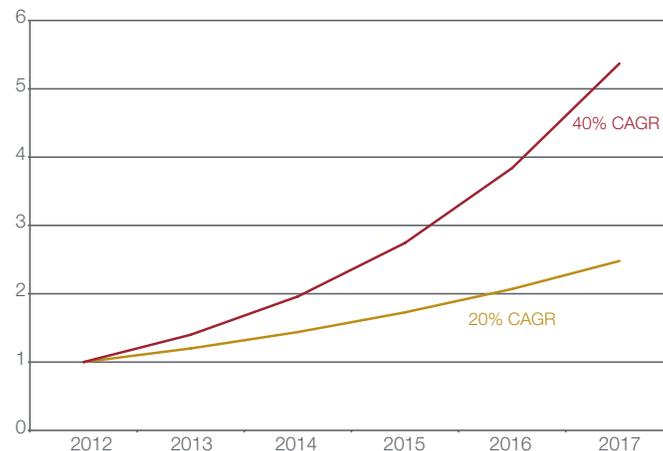
Greater airlink efficiency is another tool in our toolkit. This usually comes through a combination of new modulation technologies and more advanced antenna techniques. The former comes through the use of OFDMA (orthogonal frequency division multiple access) technologies like LTE and the latter from MIMO (multiple input, multiple output) antennas and beamforming. The next few years should show some steady improvement here as LTE rolls out worldwide, but LTE on average only offers about a 50% improvement in spectral efficiency over HSPA. Continued gains in this area are starting to become very difficult as the industry is already starting to bump up against the theoretical limits of what can be done in the airlink. Nonetheless a tool that can help, but it can't do the job by itself either.

Greater spectral reuse

The potential that comes with greater spectral reuse is almost limitless. Options for greater spectral reuse include small cells (femto, pico, and micro)¹, cell splitting of macro cells, and Wi-Fi. They all have a role to play in mobile networks. The industry often calls this approach "HetNet" or heterogeneous networking. In Figure 2 we show a HetNet consisting of a macrocell providing broad coverage across a wide area and underneath that coverage umbrella we have picocells and Wi-Fi APs addressing hotspots in the cell. The remainder of this document will look more closely at these different methods for increasing spectral reuse. We'll start by looking at the role that Wi-Fi can play in addressing the airlink capacity challenge.

¹ Picocells will typically cover a radius of up to about 200 meters. A microcell can cover a radius of up to about 1 kilometer. A femtocell is a user-installed device that can cover a radius of approx. 10 meters.

FIGURE 1: The Impact of Continued Data Growth on Airlink Capacity



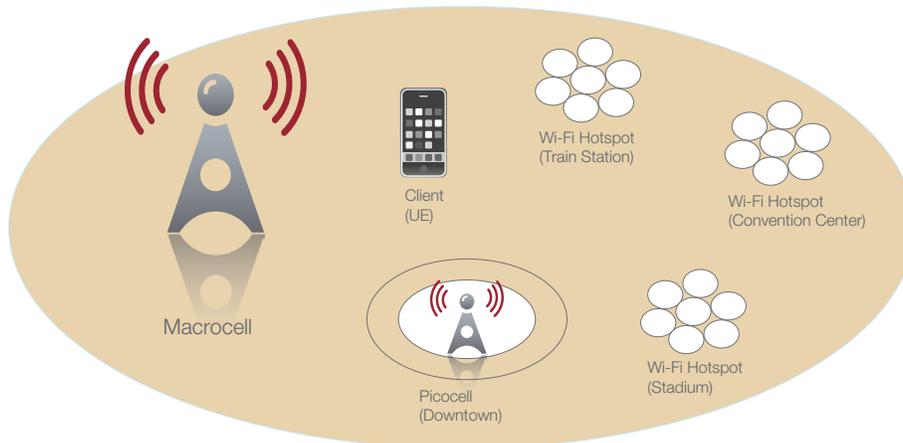
Wi-Fi can leverage a huge amount of unlicensed spectrum (>600 MHz), is broadly deployed wherever people congregate, and is very inexpensive to deploy. The downside of Wi-Fi is the potential for interference that comes with unlicensed spectrum and a more challenging user experience as compared to cellular. As regards interference, if you control the real estate this issue can be mitigated to a great extent and if you don't, there are a variety of techniques that can be utilized. As regards the user experience, there is a major industry effort known as Hotspot 2.0 that is focused on automating the process of connecting to Wi-Fi networks.

Small cells are another option that is best suited to outdoor locations. This is largely because those who control indoor venues want an operator neutral solution that supports all their customers and not just the subscribers of one particular mobile operator. Hence the dominance of DAS (distributed antenna systems) in most in-building mobile deployments. Wi-Fi has no such issue as it uses unlicensed spectrum and easily supports wholesaling to other operators. Small cell options include microcells, picocells, and femtocells. In some cases small cells are deployed to fill gaps in coverage and in other cases as an underlay to a macro network to greatly increase capacity. In the latter, great care must be taken when deploying an underlay so as to limit interference with the macro cells. This assumes that the small cells are using the same carrier as the macro cells,

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FIGURE 2: Heterogeneous networking



which will usually be the case. Small cells also have all the usual challenges associated with outdoor deployments including site acquisition, backhaul, and power. That said, they are a very useful tool to meet bandwidth demands in major metro areas.

The splitting of macrocells will continue, this increases spectral reuse and is extremely well suited to addressing the other 80% of the cell area that produces the other 50% of the traffic. In these spots we really need good coverage more than extremely high capacity.

Let's look more closely at where and when to deploy each of these options. It is always best to start by looking at the hotspots within a cell or sector. These are the locations where we have very high concentrations of users in a small geographic area. This includes convention centers, train station, stadiums, airports, etc. In **Figure 3** we list venues by the amount of traffic they generate. These locations will figure prominently in cellular hotspots.

As stated earlier, 50% of the traffic within a cell originates from less than 20% of the area of the cell. It is that area that we need to target with small cells and Wi-Fi. The other 80% of the cell is best handled with macrocells. At most we might want to split those macrocells. The first step for the operator is to identify those cells or sectors that are under the greatest strain. From there we identify those hotspots within the cell or sector that are causing the overload condition and then settle on an approach to mitigate the problem. This is a more tactical approach to the problem. The other is to identify locations where large numbers of people congregate and proactively add capacity to these locations. If we refer back to **Figure 3** we will see that all but one

of the locations on this chart are indoor venues. Data tends to be consumed far more heavily when people are indoors. That would tend to position Wi-Fi as a very strong solution to our scaling challenge.

Addressing cellular hotspots with Wi-Fi

There is tremendous interest in the industry on using Wi-Fi as a mobile offload technology. It is a very inexpensive local area technology that is supported on all smartphones, tablets, and laptops. It is also deployed wherever people congregate. While Wi-Fi has some obvious advantages, there are also some areas of concern. Much of this concern revolves around interference, as it does use unlicensed spectrum. This can be mitigated in a number of different ways. Since most Wi-Fi is deployed indoors, the entity that controls the venue can minimize co-channel interference by limiting the number of Wi-Fi operators it allows into its facility to just one. If that operator is seeing a lot of co-channel interference, it can be addressed by improving their network design or by moving to carrier class APs. RF interference is also easily dealt with by having the venue owner limit the use of equipment like cordless phones and microwave ovens. A single network deployment in an airport or convention center should provide a very compelling user experience under the heaviest load, if done right. Since the venue owner doesn't want more than one operator deploying a network in their facility, this will be the case in most installations. Other operators can purchase capacity on that network and advertise their own SSIDs. It is the perfect operator neutral solution and unlike DAS it offers a tremendous amount of capacity.

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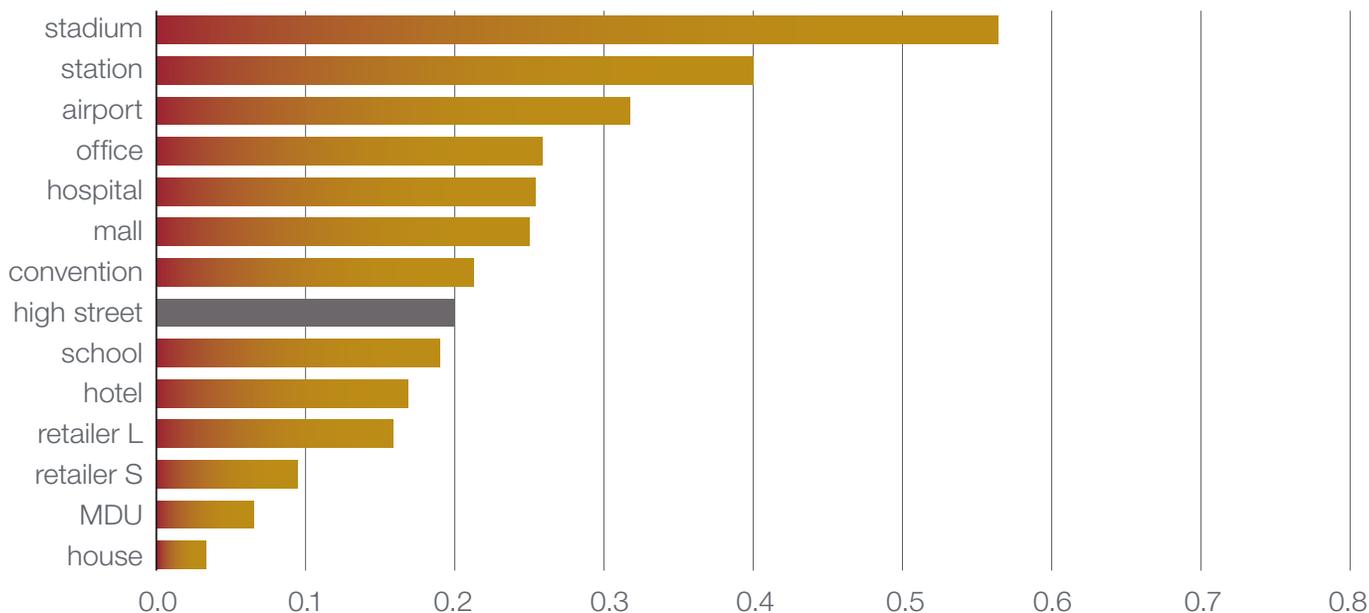
If you control the real estate you can get a very compelling user experience, but what if you don't? There are a number of things that can be done to mitigate the problem. One of the most compelling is to use Wi-Fi APs with software steerable dynamic antennas. This approach is somewhat similar to beamforming, as it focuses most of the RF energy at the user that is receiving the data. This greatly reduces the "radio fog" that can cause interference for other APs in the area. The normal Wi-Fi solution when another AP is on your channel (interference) is to switch channels. If that doesn't help, then the APs simply share that band and performance drops. Best to minimize the problem by being very careful in the steering of RF energy. Directional antennas have proven to be very effective in high interference environment such as what might be encountered in a downtown street corner.

If we stick with the example of an airport we can quickly make some estimates on deployment cost. There is a labor component here that will vary greatly by geography. If we assume a typical airport has 100,000 square meters of terminal space (where travelers congregate). That area can be covered with approximately one hundred 802.11n dual band carrier class AP's that

can each provide 50 Mbps of capacity. That comes out to 5 Gbps of capacity spread over 100,000 square meters or 50,000 bps per square meter which should be more than enough for even the busiest airport. Now how much might such a deployment cost? AP's can be deployed for approximately \$1000 per unit all up (again this can vary greatly by geography and venue). That includes the AP, installation, professional services, backhaul, controller ports, etc. A full airport deployment would cost approximately \$100,000 or \$1 per square meter of coverage.

The venue owner may require that the operator wholesale services to other service providers. This is accomplished by partitioning the APs so that each operator can broadcast their own SSIDs (service set identifiers). This also generates an additional revenue stream for the operator that deployed the network. This is an emerging opportunity, but early indications are that the revenue stream can approach \$50 per AP per month (this too will vary by geography). In our airport example it would come to \$5000 per month per operator. The possibility exists to resell capacity to more than one operator. Leasing capacity on the network to other operators should defray the operating costs.

FIGURE 3: Demand density by venue, average busy-hour Mbps per 10 m2



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Addressing hotspots with small cells

Another effective option for addressing hotspots is small cells. They are almost always deployed outdoors because they are mobile operator specific. Most venue owners only want an operator neutral solution deployed on their premises. That said, small cells deployed outdoors can drive signals into nearby buildings. If a microcell is deployed, it can typically cover an area of up to 3 square kilometers at a cost of about \$100,000. If the microcell provides 2 sectors, with each sector being able to provide 10 Mbps (5 MHz LTE carrier at 2 bps/Hz), that gives us 20 Mbps per 3 square kilometers or 7 bps per square meter. This is much less than the 50,000 bps per square meter we were getting in our airport example with Wi-Fi, but we can cover a much larger area with a single node. Picocells can provide much greater density by covering much smaller areas (greater spectral reuse). They typically cover about a 200 meter radius with a single sector. That translates into about 10 Mbps of capacity across 120,000 square meters or about 80 bps per square meter. In this analysis we always come back to bps per square meter as we are after capacity and not broad coverage. The latter is best provided with macrocells. The only exception here is deep inside buildings where macrocells can often have a problem with coverage.

In Figure 4 we plot capacity (bit/sec/\$) versus coverage efficiency for the various HetNet technologies². Wi-Fi and macrocells sit at opposite ends of the spectrum with one providing coverage while the other provides capacity. Wi-Fi also has the advantage of being able to operate under the umbrella of a macrocell without causing any interference issues as they operate on very different RF bands.

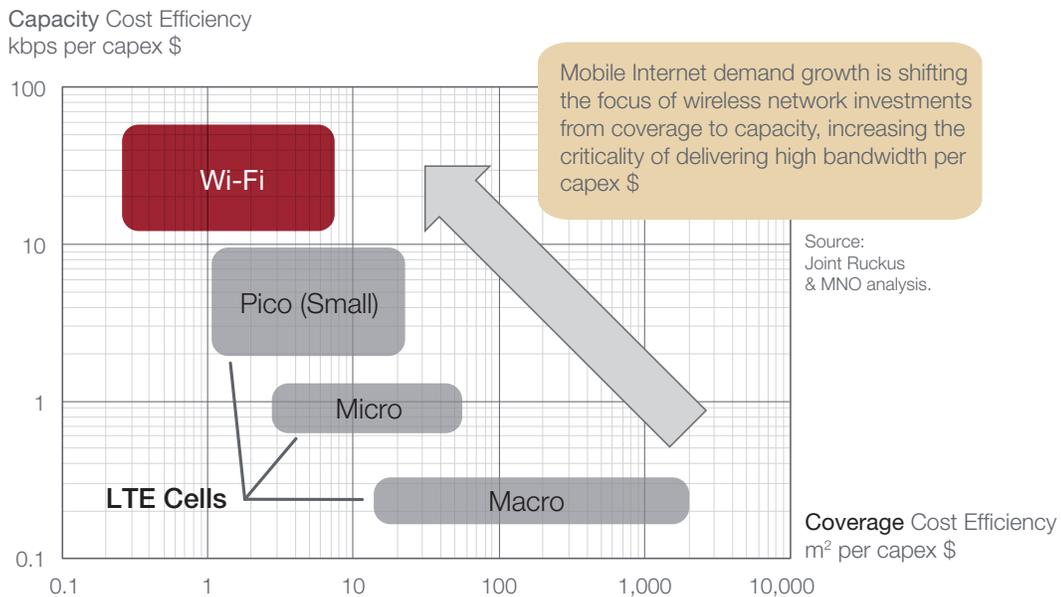
Small cells are not without their interference issues and if they are deployed as an underlay to a macro cellular overlay, they can interfere with the overlay. Great care must be taken in network design or the underlay should use a different carrier. The latter is of course at odds with high spectral reuse.

Outdoor small cell deployments will involve site acquisition challenges and some rather significant site acquisition costs. These should be less than when installing a macrocell, but they are still significant and include the site lease, backhaul, and power. Indoor deployments have different site acquisition challenges. The venue owner will usually allow the operator to deploy in exchange for capacity on the network for their internal needs. However, they only want one Wi-Fi network in their facility so it pays to be first.

² Capex, coverage, and capacity per node type based on joint analysis with a North American MNO. This is the full burdened cost and includes equipment, installation, backhaul, professional services, etc. These numbers will of course vary by geography, but the ratios should be fairly consistent.

FIGURE 4: Coverage versus capacity efficiency for various HetNet technologies

ECONOMICS OF COVERAGE AND CAPACITY FOR MOBILE INTERNET INFRASTRUCTURE



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Conclusions

Mobile operators will need to use the full set of tools in their toolkit to address the tremendous growth in data traffic. Options here include more spectrum, greater spectral efficiency, and greater spectral reuse. All will play a role going forward, with spectral reuse offering the greatest potential. The two technology options here are Wi-Fi APs in the unlicensed bands and small cells in the licensed bands.

For indoor applications Wi-Fi is the best solution as it can provide the kind of capacity that is required through very high spectral reuse and access to a tremendous amount of unlicensed spectrum (>600 MHz). When deployed indoors, interference can be minimized by only allowing one network to be deployed at a venue. In our airport example it is possible to get upwards of 50,000 bps per square meter. That scalability really helps in high traffic venues like train stations, convention centers, hotels, etc. Wi-Fi also provides an operator neutral solution with order of magnitude more capacity than the traditional DAS solution.

For outdoor applications microcells and picocells offer a very good solution when trying to fill coverage gaps. When building an underlay for more capacity, picocells, Wi-Fi, or both can offer a very strong solution. The Wi-Fi/picocell combination is especially interesting as it provides more coverage and capacity than either technology could do on its own, and since we are deploying outdoors there is usually no requirement for an operator neutral solution.

FIGURE 5: Rules of thumb for low power deployments

Indoor — Operator Neutral (typical)	Wi-Fi	Tremendous capacity
Outdoor — Coverage Gaps	Micro or Picocell	Both are good options for filling gaps in coverage
Outdoor — Underlay for Capacity	Wi-Fi and/or Picocell	A powerful underlay can be had by combining Wi-Fi and Picocells

In Figure 5 we compare the various low-power spectral reuse options.

Heterogeneous networks combine the strengths of Wi-Fi with the strengths of 3G/LTE, to enable a very powerful architecture that can offer both coverage and capacity in a cost effective manner. For that 20% of the area of a cell that drives 50% of the traffic we have Wi-Fi and small cells. For that other 80% of the area that drives the other 50% we have macrocells.

Heterogeneous networks are the future of the mobile industry and Wi-Fi is set to emerge as a peer technology to licensed RF.

