Architecting Small Cell Licensed and Unlicensed Networks

David Park
BelAir Networks

Abstract

The advent of the smart phone and more recently the rise of the tablet has transformed the demand side of mobile networks. The end user's relationship with their mobile operator is driven by the data user experience they experience. This drives a need to fundamentally change the mobile network architecture from a macrocell based system to a small cell architecture. The fundamental challenge of increasing the cell density is where to put the basestations, how to power them and how to backhaul them. Cable Operators have a unique opportunity to leverage the Hybrid Fibre-Coax network and enable the deployment of 100s of thousands of cell sites. This opens up new business models and new capabilities for delivering wireless services for MSOs and Mobile Operators that could transform the mobile world.

THE RATIONAL FOR SMALL CELLS

The Data Explosion is Here!

It is now universally acknowledged by both analysts and mobile operators that the data consumption is rising exponentially while data revenues are growing linearly. AT&T [1] has made statements that wireless data traffic grew by a factor of 80 times over the period of 4 years and most sources show a double digit annual growth rate. Gabriel Brown from Heavy Reading put this data usage into perspective when he stated that "95 percent of mobile data traffic is best effort Internet." So, the problem becomes how to deal with this deluge of data as cost-effectively as possible, while delivering a high quality user experience. This challenge will come as no surprise to most mobile carriers, especially those who were first movers with the iPhone, iPad and other smart devices.

Much has already been written over the last few years about the demands that this increased data traffic is placing on the mobile carriers" backhaul requirements, but that is a simplification of the overall problem, which is the need to place many more cell sites, closer to the end users. One of the ways that mobile carriers are dealing with their requirements is by leveraging fibre infrastructure from the local cable operator to backhaul their mobile traffic.

In their May 2010 report [2] Visant forecasts that cable operator share of mobile wireless backhaul market will grow by more than five times by 2016, generating more than $3 Billion in annual service revenues to cable operators by 2015. So, mobile carriers will be doing more backhaul on cable networks, but is there more that mobile carriers can be doing to leverage these networks?

What Do the Economics Look Like?

…..While data consumption has been growing exponentially, growth in mobile carrier‟s data ARPU (average revenue per user) hasn‟t come anywhere near the levels required to offset declines in voice ARPU. CTIA‟s semi-annual survey [3] shows that US monthly post paid ARPUs have remained between $47 and $50 since mid 2002, and that during the start of the massive data growth period from 2006 onwards, ARPU was flat.

Of course, 4G technologies, such as Long Term Evolution (LTE), hold the promise of increased mobile network capacity. But, it‟s important to remember that an LTE network deployed in today‟s standard macrocell architecture, with base stations installed on towers and rooftops, will at best increase capacity by 2 to 4 times (depending on the carrier‟s spectrum allocation). Compare this with the exponential growth in data usage that is driving the requirement for mobile network capacity increases on the order of 10 to 100 times, and it becomes clear that a simple 3G to LTE macrocell swapout won‟t address the capacity challenge. To sufficiently increase capacity, cell sizes need to get smaller. Essentially, more base stations need to be deployed in more locations. But, remembering that this increased capacity must be accomplished within an environment of reduced ARPU, the time and cost involved in building more towers (if you can even get approval for them) and securing more rooftops could result in installed costs that just can‟t deliver a reasonable return on investment (ROI) for the carrier. And that assumes that increasing macrocell density is feasible from a spectrum reuse point of view.

The Capacity vs. CapEx Challenge

The conundrum of more capacity for less capital expenditure (CAPEX) is beginning to be addressed by the category of small cell base station known as outdoor metropolitan picocells. If you‟ve been following the small cell market, you may have noticed that there‟s some naming confusion out there. Cell size naming (and associated base station equipment) follows a hierarchical methodology with the traditional large cells being macro and reduced cell sizes denoted as micro then pico and, finally, femto. While that‟s generally the case, you may hear outdoor metropolitan picocells also being referred to as Class 3 femtos. One important distinction is that a femtocell is usually associated with an in-home device that is deployed to improve coverage, whereas a picocell is an inherent part of the radio access network that includes that ability to support full handoff, from pico to pico and from pico to macro and back again.

…..According to In-Stat [4] outdoor metropolitan picocells “will allow an operator to provide excellent coverage, capacity, and data speed to users in dense areas and other public spaces”. In-Stat‟s report also points out the critical role that these picocells will play in delivering on the promised benefits of 4G:

…..”Where 4G technologies differ from older technologies is that a very strong signal and a close proximity to a base station, and few users per cell are all requirements if users are to experience the ultra-fast broadband speeds and high-capacity that wireless operators have been promising, and this can only be accomplished with small cells.” The fundamental reason for this is that the promised higher speeds are delivered by higher order modulation rates such as 64QAM and those require higher signal to noise ratios that mean being closer to the end user.

…..The concept of a small cell architecture has been proposed before, but has never been successfully exploited until now. When you consider that many mobile carriers in North and South America, Europe, Middle East and increasingly in Asia, already find themselves with a pressing need to augment capacity in areas of high user concentration, it may seem strange that picocells have not yet achieved widespread adoption. The reason for this is less technical than it is operational. Picocells have typically presented deployment challenges for mobile carriers in terms of how to mount, power and backhaul the base stations. The typical tower and rooftop installations with which mobile carriers are most familiar don‟t suit the picocell architecture which aims to bring coverage closer to the user to mitigate the service degradation that occurs, in macrocell coverage, as users move towards the outside edge of a cell.

So, the question becomes, how can the mobile carrier find and secure appropriate mounting sites that offer readily available power and backhaul? But, wait, there‟s more. It‟s not enough to find appropriate mounting sites if it means that the mobile carrier has to negotiate with multiple different property owners, utilities or government departments to secure them. The cost and time associated with these sites will have a negative impact on the success of the deployment.

THE STRAND PICOCELL

Leveraging the HFC

As we‟ve already noted, many mobile carriers currently leverage cable operators‟ fibre plant to backhaul their macrocell base stations and are expected to do more of that in the future. So, why not leverage the HFC to solve the problem of where to put small cells as well?

This leads us to the strand-mounted picocell, a new class of outdoor metropolitan picocell that leverages available HFC infrastructure (aerial, pedestal, cabinet or vault) for power, mounting and backhaul. The strand picocell can incorporate licensed or unlicensed radios. In fact, a combination of licensed cellular technology (3G or 4G) with Wi-Fi, in a single picocell, as illustrated in Figure 1, presents a very compelling business proposition for both the mobile carrier and the cable operator.

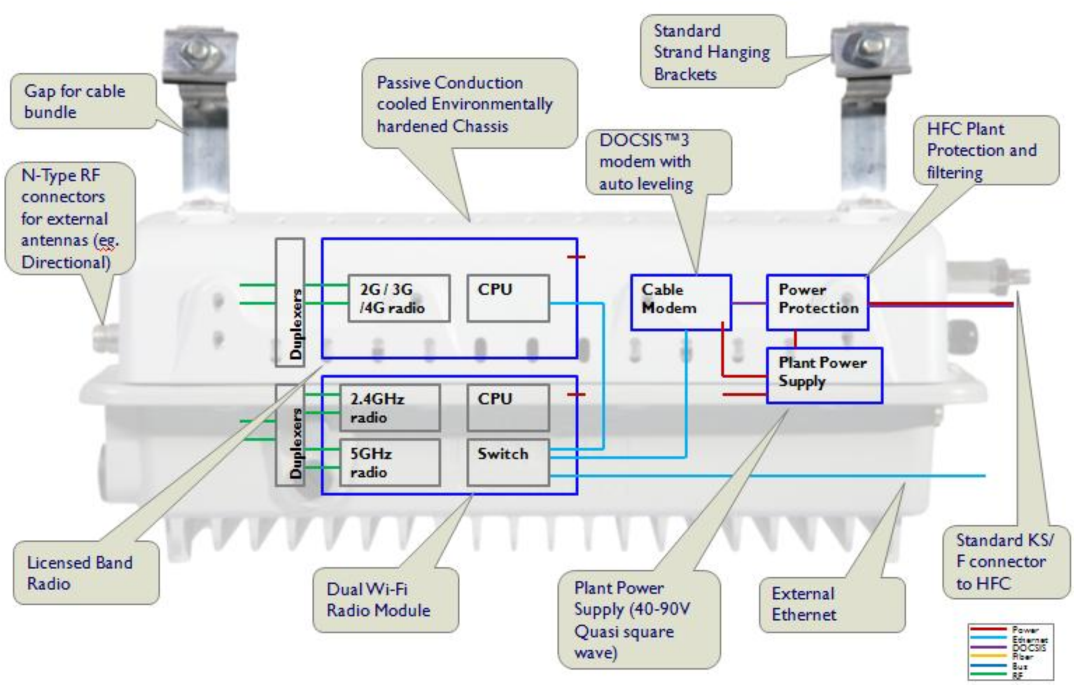

Figure 1: Strand Mounted picocell

The strand picocell is fed from the HFC from a standard power passing tap. This feeds power and DOCSIS to the unit. A power conditioning circuit provides surge protection and prevents and of the RF from the picocell leaking back onto the plant. Power is split from DOCSIS inside the unit and is fed to a plant power supply that uses the standard 40-90V quasi square wave that is used to power nodes and amplifiers. The DOCSIS signal goes to a specialized modem that is designed for operation on the main line. That feed Ethernet to a control card containing a managed Ethernet switch and dual band Wi-Fi radios. This card provides power and control to a picocell radio. The control card performs autoconfiguration of the picocell, and provides prioritization of the cellular traffic over the Wi-Fi. The various frequency bands are duplexed together and fed to the antennas.

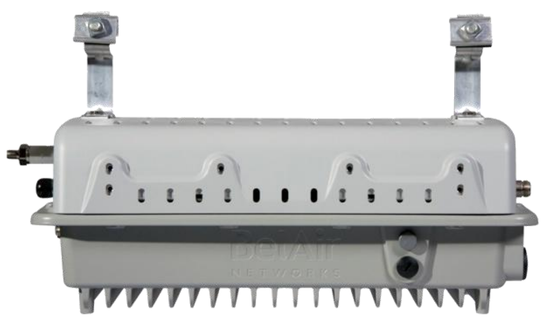

Figure 2: Strand Mounted Pico Cell

The strand picocell can be mounted directly on to the messenger wire of aerial HFC plant, or attached to the HFC inside cabinets, pedestals or vaults. These installation variants are shown in Figure 3.

Figure 3: Installation locations

By leveraging the ubiquity of HFC plant, the mobile carrier is able to quickly and cost effectively add picocell capacity to areas where the high volume of mobile users and their associated data traffic is creating service-affecting congestion in the macrocell network. These high usage areas tend to be busy downtown traffic corridors and shopping districts, parks, arenas and special events, hotels and convention centers, university campuses, and mass transit stations.

Figure 4 shows a strand mounted picocell being installed. A power passing tap is used to drop both power and DOCSIS to the unit and the messenger wire is used to physically hang the unit

Figure 4: Installing a Pico Cell

In the traditional 3G macrocell network we see the NodeB connecting to the RNC and then diverting voice and data traffic to the PSTN and Internet, respectively. In addition to the operational issues that it solves, another benefit of integrating with the cable network is that it‟s an all IP network, end to end. The cable network also includes features such as auto configuration servers that simplifies the process of deploying picocells.

The DOCSIS ® 3.0 cable modem in the picocell plugs directly into the cable network where it autoconfigures like any modem. Once connected to the cable operator‟s backhaul network, the red arrow in Figure 6 shows how 3G voice and data traffic is handled as it travels between the picocell, the cable network and the mobile network, effectively bypassing and offloading traffic from the existing 3G or 4G radio access network (RAN). By leveraging the unlicensed Wi-Fi radios in the picocell, data traffic can also be offloaded from the operator‟s core network, as indicated by the green arrow.

Policy enforcement in the picocell, in conjunction with policy management in the cable network and the mobile network, enables intelligent, real-time decisions to be made with regard to switching traffic between the networks, depending on network loading, QoS service parameters of the customer and other variables.

The cable operator can also leverage the network to deliver branded Wi-Fi services to their own customers, as indicated by the light blue arrows. In fact, multiple cable operators can utilize the same Wi-Fi infrastructure while providing unique, differentiated services to their respective customers.

So, with one picocell platform a whole range of service options are enabled for delivering a true mobile broadband experience while offloading both the RAN and the 3G core.

Figure 5: Strand Pico Cell in service

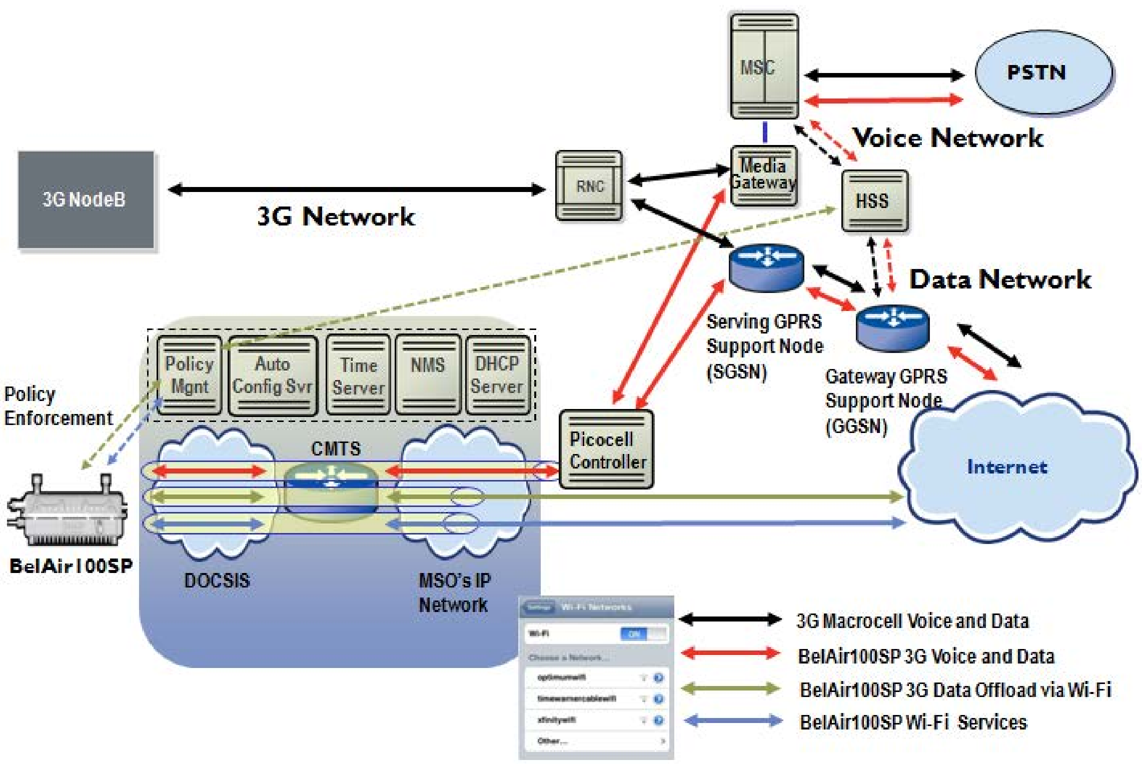

Figure 6: Network Architecture

THE BUSINESS MODEL

How Does the Mobile Carrier Benefit?

For the mobile carrier, a strand picocell deployment represents a future proof architecture to address the huge and continued growth in mobile data demand and resultant network traffic. By solving the traditional challenges of small cell deployment, the strand picocell enables the mobile carrier to establish the new network architecture that will be critical to their LTE success, while also addressing the capacity challenges they face in their network today. As already noted, the concept of mobile carriers leveraging the cable network is not new – mobile carriers already partner with cable operators, leveraging the hybrid fiber coax infrastructure to backhaul mobile traffic from 2G and 3G macrocells.

The deployment of strand picocells just extends this mutually beneficial relationship to enable widespread small cell deployments that enhance the capacity of 3G and LTE macrocell coverage. Of course, there may also be common ownership of the mobile and cable entities, which facilitates this cooperation. In either case, the mobile carrier benefits from a network model and a business model that are very compelling.

Meanwhile the mobile carrier‟s customers benefit from a better user experience with consistently higher speeds and broadband throughput throughout the cell coverage area.

How Does the Cable Operator Benefit?

For cable operators, the BelAir100SP establishes a new business model whereby the cable operator operates as a managed wireless service provider with a hosted base station offering for the mobile carrier – a higher value and more differentiated offering than basic mobile backhaul. And, because the strand picocell requires no additional cable infrastructure, it effectively leverages existing HFC assets for additional revenue and subscriber retention benefits. Strand picocells are fast and easy to deploy, commission, operate and manage, so time to revenue is quick while CapEx and OpEx are low.

Of course, the cable operator can also leverage the strand picocell deployment to provide a mobile broadband complement to their residential subscribers, to encourage new subscriptions and reduce churn. And for the MSO with spectrum, the Strand picocell offers a rapid way to deploy and maximize the use of limited spectrum resources.

SUMMARY: THE FUTURE IS A SMALL CELL WORLD

With the increased data demand and the advent of high order modulation advanced wireless systems, the need for change to a „small cell‟ architecture is evident. The traditional barriers to adoptions have been location, power and backhaul and the MSO has the unique asset to solve that problem.

The strand picocell offers a transition to a new architecture that is forward looking and moves wireless networks to the next generation.

REFERENCES

[1] Mobile broadband explosion and pressing demand for spectrum AT&T March 2011.

[2] "US Mobile Wireless Backhaul 2011" Visant

[3] CTIA‟s Semi-Annual Wireless Industry Survey.

[4] "Worldwide Femto, Pico, and Microcell Market Analysis" Instat

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