Opportunities And Challenges of Implementing Wireless

Small Cell / WiFi / IoT

A Technical Paper prepared for SCTE•ISBE by

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Today's Evolving Network

This has been a truly amazing industry to watch over the past twenty years. The pace at which it evolves and recreates itself is amazing. Five years ago, the general thought was that FTTH was the only way to go and if you weren't going FTTH, you were basically going to be extinct. The telcos spearheaded the charge to bring life to their aging assets and "leapfrog" cable. Once they started slowing down, a well-known search engine decided to jump into the fray. Through it all, CATV plants continued to upgrade and push fiber deeper understanding that the key to the whole equation was data. Not necessarily the speed of the data but keeping ahead of the consumer demand for data. It didn't take long for DOCSIS™ to catch up and enter the world of 1Gig by 1Gig but at the end of the day, typical consumer demand is not driving the need for a 1 Gig symmetrical service.

There will always be a need to upgrade the network. Consumer demand will continue to evolve and in general people will continue to drive to faster service. The question is fairly simple – What else can drive revenue and growth in the industry? In the past twelve months, a new growth engine has materialized – wireless. This engine is not new to the industry as there has been a few forays into the cellular space over the past twenty years; however, up until now the value sale hasn't been there. As the cellular networks evolve, the number of small cells will drastically increase per mile to support 5G. The cellular leaders have been discussing the challenges of deploying small cells for the past few years. Where are they going to get the power, real estate, and backhaul to deploy 10X the number of small cells? The answer is fairly simple, the HFC network. FTTH was once a major threat to the industry and now it is turning into an advantage. What is missing with a FTTH network? **Power!** Power is a key factor in building a small cell network and what doesn't FTTH have? **Power!** In the past year, Sprint has signed two deals with MSOs to utilize the HFC network to deploy 4G radios. Expectation is that there will be over 20,000 small cells deployed this year to support Sprint's 4G LTE network. In rough numbers, if the LTE radios are consuming ~75W per radio, this is roughly 1.5MW of load being added to the HFC network. This type of load profile hasn't been contemplated and added to the network since circuit switch telephony was rolled out in the early 2000s.

Small cell is just one of the many wireless technologies which will create many revenue driven opportunities as well as a few operational challenges. 4G LTE is predominantly being utilized by the mobile network operator (MNO) and is on licensed spectrum. Citizen Band Radio Service (CBRS) technology is being investigated by the MSOs to provide small cell coverage in the unlicensed spectrum. WiFi will continue to rollout and either compliment or compete with small cell technology as the technology advances. Last but definitely not least, is Industrial Internet of Things (I-IoT) technology, there are a number of Low Power Wide Area Network (LPWAN) technologies which will drive the adoption of machine-to-machine technologies.

It is an exciting time for the industry and with that excitement there is going to be significant opportunities and challenges to deploy.

Understanding the Network

The first step in tackling a new challenge is to understand where you are today. In this case, it is really about understanding the current state of your network specifically with regards to power and coverage. There are hundreds of thousands of miles of coax in existence in the US alone. This vast amount of coverage makes it ideal as a backbone for all of the new wireless networks. With the majority of the network continuously monitored, there is a lot of information available which can be utilized to better understand characteristics such as the load on the network, amount of current available for new services, plant voltage, and heat mapping of the network. Almost all MSOs utilize an EMS (Element Management System) to manage and monitor their outside plant HFC power network. A proper EMS system, at a minimum should contain the following information:

- power supply location
- power supply output voltage
- power supply current draw
- information on backup battery run time
- outages per year.

For this paper, the focus will be on the initial three items as these will give a good sense for the type of services / load which can be supported by the current power grid.

1. Power Supply Current Draw

In the past twenty years, the typical HFC power supply has 15A of available current. Over this time period, roughly 83% of the power supplies are 15A with 11% supplying 18A of current. In the past five years, this metric is shifting to the 18A power supply. From 2013 to present roughly 67% of the power supplies are 15A and 26% are 18A. The remaining 7% account for the bookends, power supply sizes above and below 15A – 18A. In general, the trend is to deploy larger power supplies - thus increasing the amount of power available for the network. Last year's Expo paper, *'Fiber Deep and Lesson's Learned from the Field'* highlighted the need for additional power to support Remote PHY deployments. The same can be said for supporting new revenue generating services such as small cell, WiFi, IoT, and security and surveillance.

The best place to begin is to pull information from the EMS. A typical profile of the amp draw of a network is shown in Fig. 1. As can be seen from the graph, the typical load on a standard HFC power supply is 6A. The average for a segment of network tends to be between 5A and 7A. Taking a conservative approach to understanding the available power, assume that all of the power supplies are 15A power supplies. This gives roughly 9A of excess power. A good rule of thumb is to maintain 3A of overhead thus there are 6A available for next generation architectures or revenue generating services.

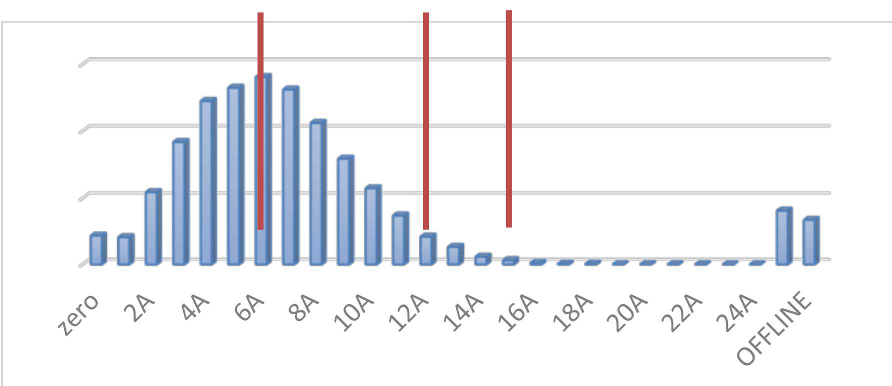


Figure 1 - Typical Current Draw

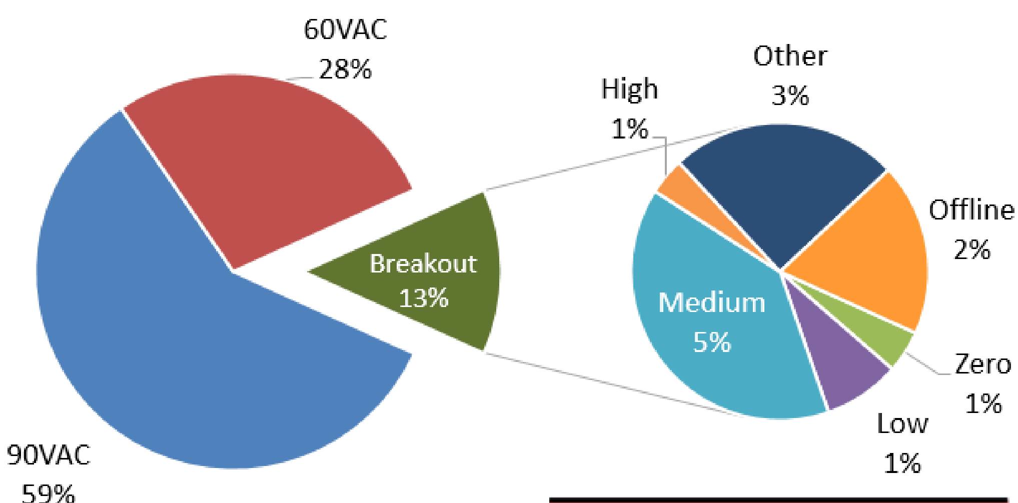
It is good to maintain a minimum level of overhead for future capacity and to support hot days. This will increase resistance in the coax, thus increasing the load on the power supply. 3A or ~20% of maximum current rating are good rules of thumb.

Once the amount of available current is determined, an operator can calculate the total amount of available power for a given network, section of a network, or a specific region. Assuming that a particular section of the network has 5000 power supplies, a simple calculation to understand the amount of available power is to multiply the # of power supplies (5000) by the amount of current available (6A) by the voltage (89.5V) which equals 2,685kW (Assuming 90V plant).

In the early 2000s, the HFC plant was built out to support circuit switched telephony. This is fundamentally the foundation for why the bell curve shown above is centered around 6A instead of 9A. The network was built to support a terminal at every house. On a positive note, it built a power base which provides the HFC networks a competitive edge to deliver the next generation of services. This is one of the main drivers why the telcos are interested in partnering with the MSOs to deploying the next generation of wireless devices. The HFC networks have a broadband powered network designed to support next generation services such as small cell, WiFi, IoT, security and surveillance.

2. Plant Voltage

The distribution of 60V versus 90V varies significantly between sections of the network. Based on previous research, the amount of 60V plant can vary from less than 5% to as high as 53%. A typical profile can be seen in Figure 2. It is worth investigating what is happening with the categories in the breakout section. Modern power supplies should have output voltages which are either 60V or 90V. If there is something else showing up in the EMS system, it is worth a look to understand what is going on. At first glance, it appears there is a portion of this network which is legacy 75V plant. This can be seen with the 5% in the “medium” category. There are 5.6% of the power supplies contained in the zero, low, high, and other categories which do not have a simple answer and require investigation.



Output	Percentage
60VAC	28%
90VAC	59%
Other	13%

Output	Percentage
ZERO	0.6%
LOW (1V – 60V)	1.1%
MEDIUM (65V – 88V)	5.3%
HIGH (>90V)	0.5%
OTHER	3.4%
OFFLINE	2.5%

Figure 2 - Power Supply Voltage Profile

In general, it is better to move the plant to 90V as quickly as possible. A plant running at 90V provides longer reach and better efficiencies over the coax. It is all about the I^2R losses in the coax. The higher voltage reduces the current thus reducing the load the coax has on the power supply. There are also a number of small cells which work from 75V to 90V. These small cells will not work on 60V plant without up converters. The primary reason that 60V plant is still in operations today is due to legacy actives in the network. Mostly these legacy actives are being removed over the years but they still exist and need to be accounted for during engineering work on new services. On the positive side, fiber deep / N+0 virtually removes the remaining amplifiers from the network which eliminates the reason for 60V plant. As plant is migrated to fiber deep, it is a general rule of thumb to transition it to 90V.

3. Heat Maps / Geographical Maps

Now that we understand both the amount of power available and the plant voltage, there are ways to apply this knowledge to better understand the capacity to deploy new services.

3.1. Heat Maps

Definition - *A representation of data in the form of a map or diagram in which data values are represented as colors.* (www.google.com)

A properly implemented and maintained EMS will also contain the location of the assets. Available current, locations, and voltage provide powerful information which can be represented utilizing heat maps. To start though, the key is to understand what question is being answered. Is the interest in understanding the amount of power available in an area or to understand the amount of coverage which can be overlaid with a specific technology? The following examples provide a quick idea of the capabilities of heat maps.

3.1.1. Current Availability

Figure 3 shows the amount of available power available at each power location. Each colored circle represents the excess power available at a site. The colors are represented as follows:

- Blue (>12 Amps)
- Green (9 – 12)
- Yellow (6-9)
- Orange (3 – 6)
- Red (<3)

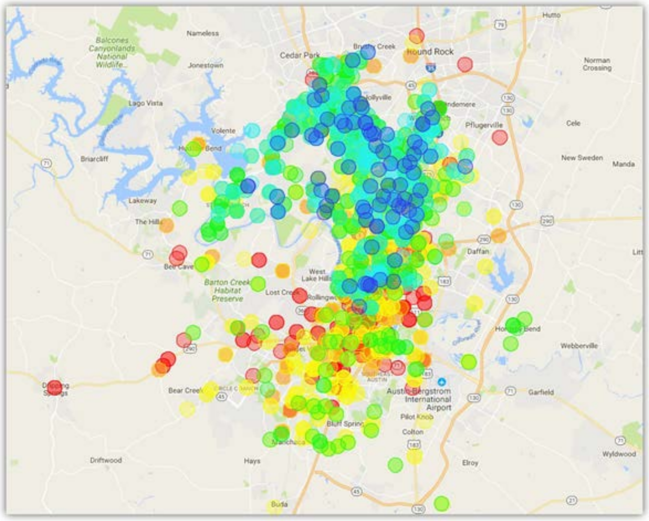


Figure 3 - Current Available Heat Map

Depending on the type of service being deployed, one can get a quick understanding if additional power is required. This heat map can also be used to trend power consumption overtime. As new services are deployed, it is beneficial to revisit the heat map and compare initial to current over regular 3 month / 6 month intervals to better understand how the load on the network is affecting the power system.

3.1.2. Wireless Coverage

The map in Figure 4 is an example of wireless coverage based at a power supply. Locations of the power supplies were utilized and then overlaid with a 2.5km circle to represent a LoRa wireless radio 20 feet in the air. The purpose for this heat map is to get a feel for coverage provided by mounting the LoRa radio at a power supply location. The advantages would be utilizing the existing location without having to cut into the strand as well as utilizing the existing DOCSIS modem at the power supply location. As can be seen in Figure 4, there is significant coverage provided in urban areas with minimal impact to the plant.

Figure 4 - IoT Coverage

The power supply cabinet is a valuable asset in an HFC network as it provides power, backhaul, and real estate in a single location.

Heat maps are fairly simple to utilize and implement. Programs such as Google Maps can upload Excel data files which will then plot the power supply locations over a geographic map. Color-codess, symbol types and sizes can provide a high level of flexibility and information for quick understanding of the information.

Planning Ahead

Every day there are technicians in the field performing some sort of maintenance on the plant, installing new power supplies, or mitigating outages. Are the technicians doing the same thing as they did yesterday or is there a master plan in place to upgrade the network every time a technician is at a site? Labor is one of the largest expenses an operator has; therefore, it is key to utilize that resource in the best way possible. There is no question that changes are coming for the HFC network. New partnerships are announced regularly between mobile operators and MSOs. The mobile operators understand that a key to their success is utilizing the power, backhaul, and real estate capabilities of the HFC network. To make this happen cost effectively, it is better to plan ahead and start upgrading the network every time a technician is in the field and working on the plant. There are a couple of simple items which if planned properly will help prepare the plant for the future demand.

4. DOCSIS™ 3.X Backhaul

Data Over Cable Service Interface Specification (DOCSIS™) has been critical to the evolution of the industry. DOCSIS™ has provided a means of communication which rivals fiber and supports today's and tomorrow's data demands. As with everything though, there is a significant number of legacy devices in the field which will not support tomorrow's demands. DOCSIS™ 1.0 and 2.0 devices have been the prevalent devices utilized in the network for monitoring power supplies. In most respects, this is all that is needed to monitor a power supply. The challenge is that more and more power supply locations are being utilized for new services. Services such as small cell, WiFi, IoT, and security and surveillance require more bandwidth than can be provided by a D1.0 or D2.0 modem. Along with the bandwidth, D3.X devices also provide additional proactive network maintenance (PNM) features which support troubleshooting and plant maintenance. Every time a technician is at a power supply site, the current transponder should be upgraded to a D3.X transponder. This is a simple way to prepare the network for next generation services.

Figure 5 - D3.0 Transponder

5. 6 Battery Cabinets

When deploying new enclosures, the standard methodology is to deploy the appropriate enclosure for the task at hand. In most cases, this would be a 3 battery enclosure to support a 15 Amp power supply with 2 – 4 hours of backup power. As new services are deployed, additional power will be required to support the new loads on the network. There are a few advantages to deploying all six battery cabinets. A six battery cabinet provides room to grow. If a 21 Amp or potentially a 24 Amp power supply is required in the future, the six battery cabinet can house 4 or 6 batteries to manage 48V or 36V battery strings (respectively).

Figure 6 - 6 Battery Enclosure

The larger enclosure also provides additional space for placing equipment for new services. The additional battery shelf can be repurposed for active equipment to support new services. An example of this can be seen in Figure 7. A global quad player has both HFC assets as well as wireless spectrum. Changing local regulations which restricted the placement of new wireless towers created difficulty for the operator to extend their wireless network. Their solution is to place 6 battery cabinets and utilize the 2nd battery shelf to house their wireless equipment. The solution provided multiple benefits. The primary benefit being the ability to extend their network in areas which were previously uncovered. Secondary benefits include: hiding the equipment from potential thieves, providing backup power for increased reliability, utilizing the D3 modem for cellular back and front haul, and placement of the antennas at the bottom of the enclosure. A simple solution to a complex problem which allowed the operator to build out their wireless network. Note: when looking at this type of solution, make sure to run thermal calculations for the specific region to guarantee neither the power supply nor the active equipment overheat.

Figure 7 - Enclosure with Wireless Equipment

As technicians are out in the network every day, make sure that their focus is to build a better and more reliable network. Every time a power supply is maintained, make sure that there is the latest DOCSIS technology installed. Whenever a new enclosure is placed, consider a six or eight battery cabinet along with a 240V service or the ability to upgrade to 240V service. These two simple upgrades will make it easier to support new B2B services.

Powering New Services

Network powering has been a growing point of discussion over the past two years. As the network re-architects itself from a centralized/headend centric platform to a distributed architecture with Remote PHY, the power distribution within the HFC plant is also changing. Initially, operators planned a N+0 strategy but were quickly overwhelmed with the number of CMTSs required within the headend or hub. It was quickly realized that remote PHY is a solution to the growing number of CMTSs within the headend. With remote PHY, the PHY layer of the CMTS is placed in the OSP close to the customer. This technology is great for pushing fiber deeper into the network and reducing the amount of equipment within the headend. Remote PHY also takes advantage of digital optics within the OSP thus reducing the impact of noise on the network. The key is managing the changing electrical load as it moves from the headend to the OSP. As discussed previously, the HFC plant typically has excess capacity today to support the rollout of remote PHY. Even though Remote PHY will increase load on the OSP roughly 40%, most operators only expect a 10% increase in the number of power supplies required to implement remote PHY. If operators were only planning on deploying remote PHY, the network would be relatively well positioned. The challenge being that operators are also actively pursuing new revenue generating services or cost avoidance initiatives. In the past twelve months, the first of these type of services can be seen through recent deployments of new technologies. In general, these type of services can be broken into four segments – small cell, WiFi, IoT, security and surveillance.

6. New Services

6.1. Small Cell

Small cells are by far the most talked about new service over the past twelve months. Operators are typically looking at two types of services. The first type of service is to support an MNO with deployment of either 4G or 5G small cells. This service would be a revenue stream for the operator while also allowing an MNO to quickly deploy additional coverage or new services. The benefit to the MNO is significant reduction in deployment timelines and cost. In 2018, over 20,000 4G small cells were deployed on a MSO network. The business opportunity is real and the MNOs are looking for partners to support their 4G and 5 G rollouts. In international markets, there are many times when an MNO is the operator (quad player) thus they get both advantages. The second type of service is to support an operators mobile virtual network operator (MVNO) agreement. With an MVNO agreement, an operator will deploy their own mobile service and pay the MNO for cellular and data usage. To reduce the fees to the MNO, an operator can deploy a wireless network on top of their HFC network. This is usually done via open spectrum such as the CBRS 3.5GHz – 3.7GHz band. There are a number of operators in trial reviewing the technology and understanding the business case for rolling out their own wireless cellular network. Key to success will be understanding the business model which fits the MSO.

6.2. WiFi

WiFi in the OSP has typically been a “sticky” service. It is a service which is designed to maintain customers but not grow revenue. This has done very well over the years and there are two new business cases which are starting to emerge which make WiFi relevant again. Both business cases are based on cost avoidance. The first business case is targeted at operators who are managing inflating costs with their mobile provider. Deployments of WiFi at a power supply site provides a technician with quick access to the network for downloading and uploading reports, metrics, and service logs. The site can also be provisioned to support customer access. The second business case is cellular offload. Similar to the CBRS business case, operators are utilizing WiFi to offload data from the cellular network. The cost of the cellular data is significant enough that operators are working to get calls and data onto their own network as efficiently as possible. When planning the power consumption of either business case, the WiFi radios themselves are typically low power - in the range of 15 Watts to 25 Watts plus the DOCSIS modem, the total budget will be under 40 Watts. The challenges of WiFi are in the coverage range. When talking about WiFi, coverage range is talked about feet and not miles. The outdoor environment typically provides much larger coverage than indoor. Estimating a 250’ coverage range per radio, a typical power supply would need to support 10 to 20 radios depending on the density of the network.

6.3. I-IoT

Industrial Internet of Things (I-IoT) is a growing market which allows the ability to transmit small bits of information over long distances utilizing very low power. The applications are endless from tracking your pet, to monitoring the flow of a river, the use cases are just starting to be conceived. For an operator, simple internal applications would be adding tamper sensing equipment to products in the outside plant or tracking vehicles via an internal network versus paying for the service. There are also a number of operators utilizing an I-IoT network to build a new business model. The challenge faced by the industry is the readily available Narrow Band IoT (NB-IoT) technology available to 4G operators. 4G operators will be able to deploy NB IoT quicker than MSOs; however, there is already proving to be unique business opportunities for both technologies. Key to success will be building networks quickly and gaining customers. There are a number of technologies being utilized to deploy an IoT network. Long Range Wide Area Network (LoRaWAN) is one of the leading technologies in the US for MSOs. From a powering perspective, this is a low power technology which has fairly significant coverage. On average, a LoRa radio set at 20 feet will cover roughly two miles of space in a rural environment. In a heavy urban environment, it will cover roughly one mile. For a typical HFC network, this would require one to two LoRaWAN radios per power supply. With an average of 80W per radio, an operator should plan on average roughly 120W of power per power supply.

6.4. Security and Surveillance

In today’s world, the ability to offer security and surveillance is a significant business opportunity. Traditionally, this opportunity has been owned by the telecom operators. With the invention of new hardened modem gateways, the HFC network is becoming a much more preferred network for the placement of security cameras. In the typical telecom deployment, non-backed-up utility power is utilized - -thus, when it is critical, emergency based situations and the power is out, so is the surveillance equipment. The HFC network provides a highly reliable, battery backed-up network which utilizes a single connection to both power and backhaul a camera. Power, backhaul, and real estate are essential elements to every security and surveillance business opportunity. It is hard to predict the number of cameras which could go on a network. For cold environments, a camera can use up to 60 watts. The 60 watts covers the camera power, the heater, and the pan/tilt/zoom function. For tepid environments, a camera will typically utilize about 30 watts.

Conclusion

HFC networks are poised to be the network of choice over the next ten to fifteen years. The key differentiating factor from standard fiber networks is power availability. With the next gen DOCSIS technologies rolling out, the HFC network will compete head to head with fiber networks and in general will provide more bandwidth than the typical customer will use. The key to success is understanding the business opportunities which are available in the market. Focus time on understanding each of the technology families which are emerging and how the network can support these technologies. It is also important to understand where the network is at today and what options does an operator have for supporting these new services. There are a lot of tools available today to help facilitate an understanding of the network today and also many options to plan ahead for the next generation network.

Abbreviations

B2B	Business to Business
CBRS	Citizens Band Radio Service
DOCSIS	Data Over Cable Service Interface Specification
EMS	Element Management System
FTTH	Fiber to the Home
HFC	Hybrid Fiber Coax
I-IoT	Industrial Internet of Things
LoRaWAN	Long Range Wide Area Network (Type of LPWAN)
LPWAN	Low Power Wide Area Network
MNO	Mobile Network Operator
MSO	Multiple System Operator
MVNO	Mobile Virtual Network Operator
PNM	Proactive Network Maintenance
SCTE	Society of Cable Telecommunications Engineers

