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HYBRID FIBER-WIRELESS NETWORKS: THE PATHWAY TO COMPETITIVE ADVANTAGE

Executive Summary

The last 1,000 feet of a gigabit-to-the-home (GTTH) deployment is normally the most expensive and time consuming of any overall gigabit network rollout. Providers spend a lot of time determining how connect the main networks to consumers in the fastest and most cost effective way possible, while still delivering on their promise of speed and reliability. Though attractive, all-fiber access networks or a combination of deep fiber and twisted pair are still expensive alternatives for delivering gigabit access to many consumers. Millimeter wave technology will allow the deployment of less expensive, hybrid fiber-wireless (HFW) access networks to provide a compelling alternative to purely fiber solutions.

The business case for last mile deployments in urban or sub-urban areas – where there is a high percentage of multiple dwelling unit buildings (MDUs) – is a challenge for providers. The time and cost to market in these areas puts providers' gigabit expansion plans at risk.

A Hybrid Fiber-Wireless (HFW) strategy solves the two problems associated with last mile deployment: cost and time to deployment, while providing the bandwidth and reliability consumers demand.

Background on Millimeter Wave (mmWave) technology

Millimeter wave radios use ultra-high spectrum frequencies in the 60, 70 and 80 GHz bands to transmit data. These high frequencies are free from interference and congestion and have very wide channels, allowing multiple gigabits per second to GTTH networks.

This spectrum is exceptionally well suited to the GTTH environment since it enables delivering multi gigabit capacity at a very low cost. The radios can be installed on rooftops, towers, building facades, residential homes, as well as at street-level locations to connect buildings to existing fiber, in an HFW network.

HFW is set to revolutionize GTTH availability by providing fiber-like wireless technology for the last task of network construction: lateral construction, drop installation and outside plant construction on private and on public property.

Challenges to building a gigabit network

Over the past year, the number of proposed and lit gigabit networks has accelerated. But building a GTTH network is an exercise in optimization: bringing service to the most customers, as quickly as possible and in the most affordable way. In this case, the latter is a function of the two preceding issues. So most providers pursue two different, but related strategies: either get to consumers faster or get to more consumers.

In the first instance, the strategy requires a series of tactics driven by the basic economic factors underlying a GTTH project: scope, existing community assets, regulatory structure, project timeline, labor, competition in the market, etc.

Dimension 1: Deployment costs

1. Project Scope: Coverage area, number of buildings, penetration goal, landscape
2. Existing Infrastructure: Education, community owned etc.
3. Regulation: Rights of way, permitted construction types
4. Community economics
5. Other: Project timeline, labor, competition

A number of models have emerged over the last few years to help providers (and communities) optimize networks to reach consumers. Build-to-demand models, public private partnerships, trends in regulations like “one touch make ready” and “dig once” policies influence how fast (and how affordably) a provider can build an all-fiber gigabit network. All of these strategies seek to reduce the costs associated with time to deployment and overcome the challenges of getting to the last mile consumer.

At the same time, providers must optimize across another dimension: building a network to reach the most customers. There are few strategies that optimize the network provider’s ability to connect premises within a service area to the network, as well as to expand a coverage zone and densify an existing one in a shorter time.

Dimension 2: Deployment methods and time to deployment

1. Network Deployment Duration: Broadband service coverage
2. Penetration level
3. Beginning of cash flow stream

Most models focus entirely on the first dimension and any improvements in the second dimension are marginal. But HFW focuses on both.

Distance, the complicating factor

Distance is the complicating factor in the optimization equation. While fiber to the home is the preferred method for extending ultra-high speed broadband access, it is not always the most cost effective. In dense urban areas – particularly areas with a high number of MDUs – or rural locations with scattered residential areas, the business case to bring fiber to the unit is difficult. The costs to deploy a GTTH network in these areas are influenced dramatically by the cost per foot of fiber construction.

Distance is a risk-contributing factor as well. For most GTTH networks, time-to-market is the biggest challenge. In some markets, the time between the initial planning and the start of deployment spanned multiple years. This is a risk for network providers – in the time between announcing a deployment and turning the service on, they are exposed to outside competitive pressures. Will another provider announce a project and cherry-pick planned service areas? Will an existing provider step up with a competitive service offering or price? Each of these questions could impact the profitability of the network.

Hybrid Fiber-Wireless (HFW) strategies for deployment

The following list presents the list of tasks to be accomplished in order to deploy an outside plant broadband network. It is based on a [report](#) that was conducted by the advisory firm CTC Energy and Technology¹ for the City of Santa Cruz in 2015. The cost share of each task is presented below.

Task	Estimated % of Cost
Engineering and network design	5%
Quality control	1%
Special crossings	1%
Backbone and distribution plant splicing	2%
Backbone hub, termination and testing	5%
General outside plant construction	62%
Service drop and lateral installations	24%

The scenario above illustrates the case of the City of Santa Cruz but probably fits other cases as well. HFW is a strategy that focuses on the last two main tasks, that put together are responsible for 86 percent of the entire project cost.

The “general outside plant” task consists of the cost of labor and material related to fiber deployment construction such as: aerial installation and utility pole make ready (if needed), underground installation requires conduit placement and digging.

The last task: “service drop and lateral installations” is responsible for all the costs related to the delivery of broadband network to the building from the nearest “demarcation” point in the backbone network.

Fiber-like wireless, using millimeter wave technologies, reduces construction costs materials and labor. As well, it enables faster reach to consumers due to simplified planning and easy installation.

An HFW strategy also makes existing network assets more valuable, such that, each connected building becomes an extension of the network which enables further expansion through roof tops, using the aerial line of site with fiber-like wireless technology as a passive infrastructure.

Be there cheaper

Network providers can use fiber-like wireless to complement fiber in their networks and deliver fiber-like capacity quickly and with minimal construction costs. The costs to construct fiber varies sharply in different metropolitan environments, so the distance from buildings to a fiber node can vary from half a mile to 2 miles in any given metropolitan area in most neighborhoods. And as noted above, a range of objective and

¹ City of Santa Cruz, May 2015, CTC

subjective factors influence the time it takes to connect each customer and, thus, the feasibility of the entire project.

MDUs

MDUs present an opportunity and a potential risk for GTTH providers. On the one hand, each MDU represents a large potential demand for services. MDUs represent about 30% of the total residential market for GTTH. But on the other, MDUs are difficult and complex to reach with fiber. More than 83% of MDUs were built before 2000 and more than 50% were built before 1980. That means providers are dealing with infrastructure that predates the internet, not just fiber. And each MDU is different, ranging from small row houses to larger, high-rise buildings with more than 100 units. So GTTH providers need to be able to handle the challenges of getting permission to enter each building or unit to install a technology, and then deal with the physical challenges of getting the fiber dropped.

To be successful in the residential market, a GTTH service provider may use fiber-like wireless multi gigabit technology ([Broadband Communities](#), October, 2015). Fiber-like wireless is quick and easy to install and configure, letting service providers add MDUs to their network with minimal effort.

An HFW business case

To show how HFW reduces costs and time to deployment, we have developed a business model using materials from [CTC Technology & Energy](#) and data collected and provided by the Federal Communications Commission ([FCC](#)).

Technological Options for Deployment of GTTH

- a. Fiber – the most reliable signal transmission technology transmits at high bandwidths, and is immune to electromagnetic interference but its costs per foot rise as it gets closer to end customers
- b. Fiber-like wireless - Millimeter wave technology (mmWave) using higher frequencies of 60, 70, 80 GHz ensuring a highly reliable, scalable, and easy to-deploy end customer acquisition
- c. HFW – A Paradigm that which enables more fiber deployment by leveraging the benefits of both technologies. Wireless complements fiber where a fast, cost-effective, dynamic and reusable solution is needed

Fiber Networks

In urban and suburban areas, buildings or neighborhoods can typically access the fiber network from the closest network point. A typical fiber node is located between a half a mile to two miles from residential premises. Metropolitan areas typically host a variety of densification levels -- from extremely densified downtown areas to less dense residential area and suburbs.

The average cost to construct 'last mile' fiber is typically more expensive in densified metropolitan areas since labor costs for construction are higher, which increases the cost per foot to deploy. In less dense, suburban areas the distances between premises are typically larger, increasing the costs of materials. We used data that is averaged and adjusted between these different environments.

Existing infrastructure assumptions

Many metropolitan areas have either existing underground or aerial infrastructure of electricity or telecommunications. In some cases a partial fiber backbone or fiber to the premises infrastructure is already in place, but in many cases, there is only a central office that exists.

Some cities who own their infrastructure are able to share with network operators. Sharing poles and conduits or even dark fiber (dig once) with a GTTH service provider improves the attractiveness of an area.

The following analysis illustrates how a smart use of technological tools addresses each of these differences and improves the feasibility of connecting individual residential buildings and an entire neighborhood or city to GTTH services.

Network Construction Model

Our model assumes equal weight between existing infrastructure and new infrastructure, since existing poles and conduits exist can lower cost per foot of deploying fiber while some areas require new infrastructure, which would increase the cost per foot.

The Information is normalized and averaged according to fundamental assumptions about population density, aerial or underground construction in metropolitan areas. All of the assumptions are referenced and free to access in both the FCC’s and CTC’s databases.

Deployment Methods

We focused on the cost per foot for fiber constructions. Which is determined typically by the labor and materials cost needed for each fiber optic construction type. The construction categories we look at are:

- a. Aerial – where permitted
- b. Underground – where relying on existing infrastructure
- c. New underground - where new infrastructure is needed
- d. Fiber-like wireless- where point-2-point extension possible

Construction Cost Models Comparison

The following table compares the cost per foot to deploy fiber-like wireless with aerial or underground fiber.

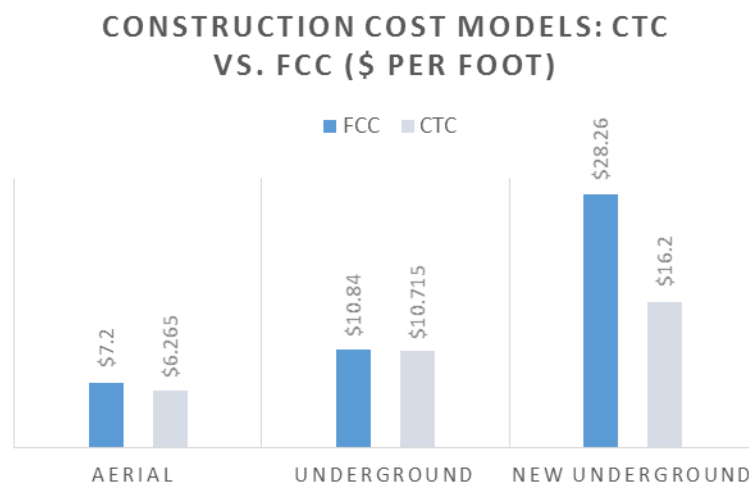


TABLE 1 : CTC² & FCC³ MODELS

The above *Table 1* represents ‘last mile’ cost analyses for the three types of fiber deployments in urban areas. Aerial and underground construction typically include a variety of parameters. The costs for each parameter may vary widely based on local environment and existing utilities.

²[A Model for Understanding the Cost to Connect Schools and Libraries with Fiber Optics, CTC, October 2014](#)

³[Alternative Connect America Cost Model Overview, FCC, April 1, 2015](#)

Deployment Methods – Cost Components

Assuming fiber deployment costs from CTC, which consist of the following factors:

Aerial Construction components: \$6.265/ft. for aerial fiber

Labor

- Network Planning and Design
- Placement of Cable Length
- Splicing
- Quality Control

Material

- 12 count fiber including slack
- Strand wire (if needed)
- Splice cases (if needed)
- Snowshoes

*Make Ready (Only if creating space on poles is needed)

Underground Construction components: \$10.715/ft. for existing underground fiber

Labor

- Planning and Design
- Conduit Plowing / Trenching
- Boring
- Placing Inner Duct
- Placing Vault
- Rod and Rope Conduit
- Place Fiber
- Place Splice Case
- Splicing
- Quality Control

Material

- 2" Rolled Duct
- 12 Count Fiber
- 1" Inner Duct
- Ground Wire (If Needed)
- Vault
- Splice Case

Fiber-Like Wireless :

V-band fiber-like wireless link, assuming high volume prices in large scale deployment, suitable for distance up to 1,600 ft.	Starting from \$2,200
V-band radio installation cost and the installation materials (mounting pole, cable, power supplies etc.) assuming in-house installation team of 2 people	\$300
E-band fiber-like wireless link, assuming high volume prices in large scale deployment, suitable for distance beyond 1,6000 ft.	Starting from \$4,500
V-band radio installation cost and the installation materials (mounting pole, cable, power supplies etc.) assuming in-house installation team of 2 people	\$500

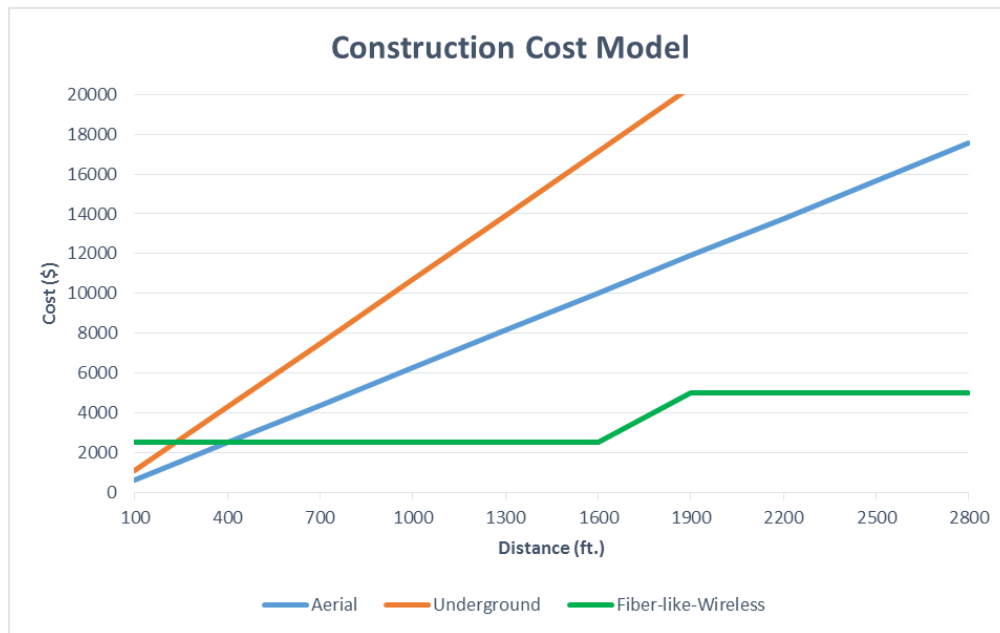


FIGURE 1 – CONSTRUCTION COST MODEL

Figure 1 above illustrates the cost to deploy fiber optics based on the numbers presented by CTC compared with the cost of fiber-like wireless. Fiber-like wireless cost effectiveness superiority to traditional, all-fiber deployments are correlated with the increasing cost per foot.

Fiber-like wireless technology covers a wide range of scenarios network builders face. The choice of which radio to use is subject to the distance of the building from nearest fiber PoP. Fiber-like wireless V-band links are suited for up to 1,600-1,900 ft. to deliver reliable gigabit connectivity whereas the E-band is suitable for much longer distances.

Compared with fiber optics cost per foot, at greater than 230 feet, the fiber-like wireless is cheaper than underground constructions. At greater than 400 feet, fiber-like wireless beats aerial constructions. **The fiber-like wireless is complementary to a service provider's existing network, serving more residential premises in a specific area or extending the reach of a given served zone.**

As seen above, a Hybrid Fiber Wireless paradigm reduces the cost of lateral construction, drop installation and outside plant construction, reducing the overall cost to deploy GTTH. Furthermore, HFW provides significant speed upgrades with a less expensive upgrade path by minimizing the permitting process and negotiation process with building owners because installation is less invasive. HFW enables Gigabit connectivity in urban surroundings using a fixed cost structure to reduce the average cost per home connected in the entire project.

To illustrate the huge costs savings while implementing HFW topology, let us consider a simple case of 10 buildings, located at distances ranging from 100 feet to 1,000 from the existing fiber PoP. The following table summarizes project costs estimates using the models presented above:

Deployment topology	Estimated project cost
Underground fiber	\$58,933
HFW with Underground fiber	\$23,215
Aerial fiber	\$34,458
HFW with Aerial fiber	\$21,259

It can be easily seen that the combination of HFW with underground fiber can cut project costs by more than half, and this is when considering relatively dense deployment and close proximity of the buildings to the existing fiber PoPs.

Be there quicker

Today, while FTTH projects are the favorite solution for gigabit service delivery, the timeline for these projects include a long period of network planning and design (~1 year) and even longer deployment periods (~2 years). This puts a network builder in a high risk situation where it can only hope competition does not push prices down. And a network provider can only begin returning the investment when the last strand of fiber is deployed to the premises.

To realize infrastructure projects with high risk, a network provider may secure both a contracted subscriber base and a gigabit service much earlier using fiber-like wireless as a last mile connection technology. Fiber-like wireless installation takes less than a day. Including planning and design it may take anywhere from several weeks to a couple months to connect a building and begin collecting revenue to the gigabit service. So instead of being forced to wait to deploy a gigabit while negotiations over pole attachment agreements and make-ready is in process, using fiber-like wireless, the entire construction timeline is dramatically accelerated.

Shorter deployment advantages

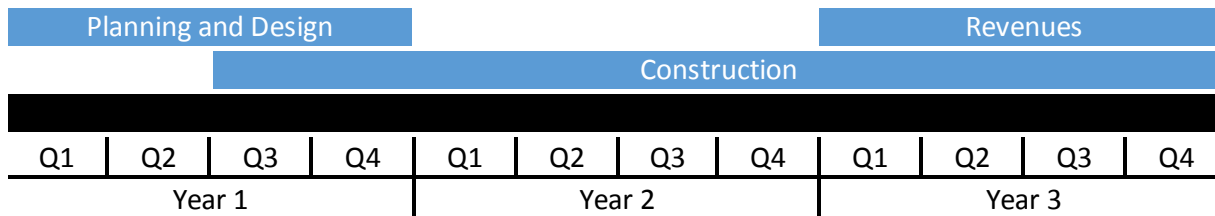
HFW can take the risk embodied in lengthy deployments and turn it into an advantage:

1. Higher internal rate of return (IRR)
2. Faster return on investment (ROI)
3. Increased Penetration
4. Network Densification
5. Increased Coverage Zone
6. Reduced Risk from competition by anchoring customers to the service

Monetize faster

Using fiber-like wireless, a network provider can reach more customers, quicker. A network provider with immediate access to the fiber backbone in an area can begin serving customers within weeks, offering service in a radius from fiber end points to points within the community and beyond. Generally, the length of construction on a project determines how quickly a GTTH service can come to market. This waiting time is a risk in building a network: it is time without cash flow, it determines the cost of money and can expose the project to “poaching” from competitors.

Standard Fiber Timeline -



Hybrid-Fiber wireless Timeline -



FIGURE 2: BEATING TIMELINE

Figure 2 illustrates how the smart implementation of fiber-like wireless technology disrupts the standard project life cycle. Generating revenues in an early stage of a project’s life cycle is game changer for the following:

1. Construction and coverage – Since time to gigabit service is reduced sharply, a network builder can quickly deploy to more customers. Fiber-like wireless technology lets the network builder use the same amounts of fiber to serve more buildings and more neighborhoods.
2. Financial case – Faster time to market leads to better Internal Rate of Return (IRR) and greater Return on Investment (ROI).

The following illustration shows how fiber-like wireless links enables using the same amount of fiber to increase the coverage area, densify a served area and expand the network by taking advantage of rooftops line of site with fiber-like wireless point-2-point technology. This makes a providers’ existing assets more valuable and expands the coverage area with very small CapEx and OpEx. Reducing the time-to-market for broadband services enables a cash flow stream that reduced the costs of money for further deployments and enable densification of served areas.

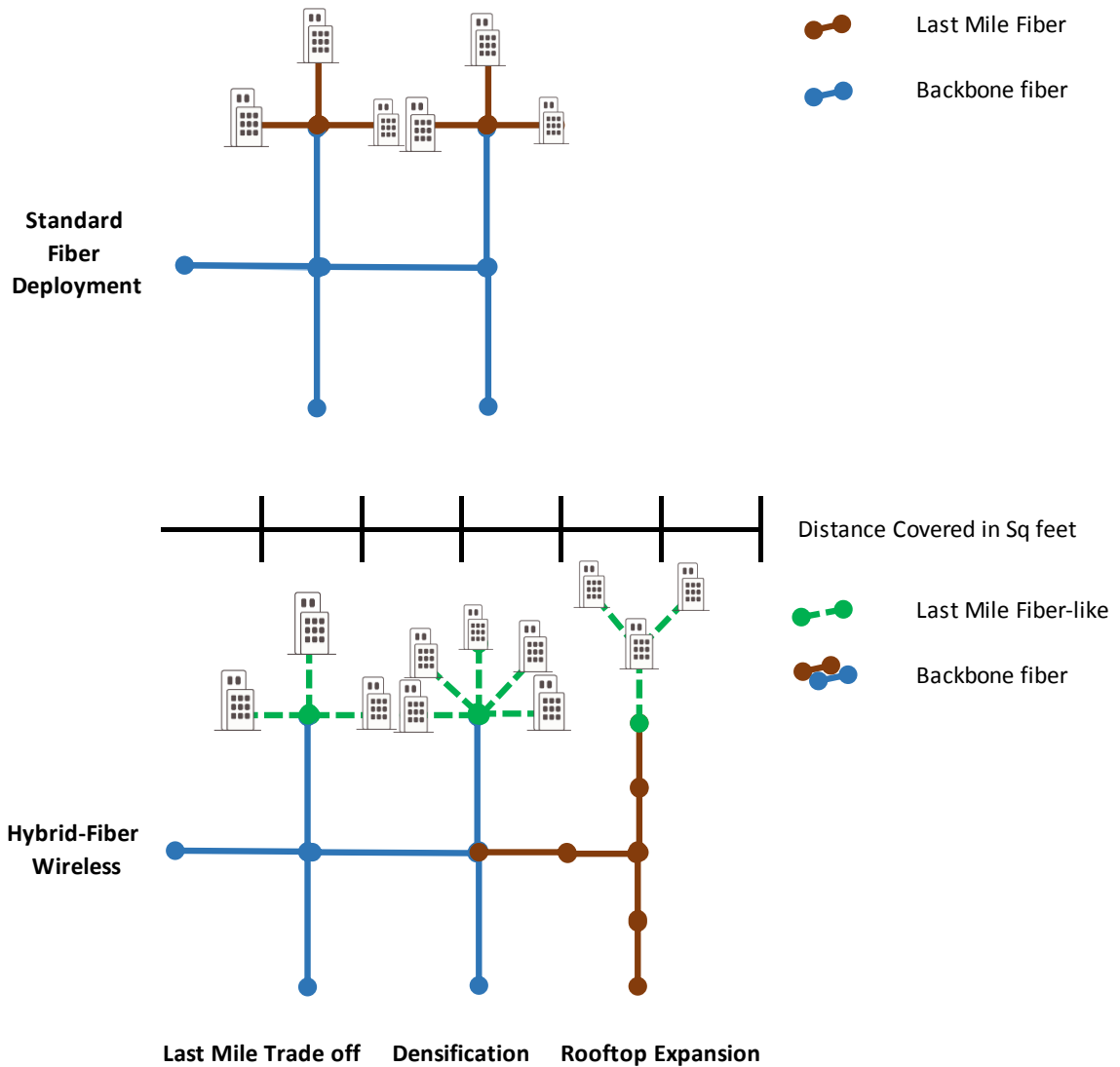


FIGURE 3: HFW TIMELINE - DEPLOYMENT BREAKTHROUGH

Financial implications of HFW

Each type of broadband infrastructure technologies has its own pros and cons. From strategic level point of view, deciding the infrastructure type drives implications on the investment model, business model and the choice of financial tools to use.

The time to breakeven in fiber deployments could easily extend 5 years, and the time to cash flow generation starting point could reach several years as well.

With the help of the “[FTTH Financial Analyzer](http://www.bbcmag.com/FTTHAnalyzer/)”, developed by Steven Ross and published in Broadband Communities Magazine⁴. The model is developed to analyze different deployment scenarios and based on

⁴ <http://www.bbcmag.com/FTTHAnalyzer/>

some general assumptions about the demography, geography and commonly accepted service prices and financing assumptions. For more information about the model, please refer to the link above.

We used this data to analyze financial outcomes and the benefits from deploying HFW network.

Project financing is a mission that could be done in different ways, but mostly as a mix between financing sources. The initial source for project financing is a combination of equity and debt. The amount of initial funding needed for the project, which is the hardest to come by, is determined by the extent to which the later stages of the project can be financed by the revenue stream created from services delivered by the project.

Case 1

The following case (originally presented in the FTTH analyzer tool) illustrates a scenario in which a FTTH network provider is looking to provide fiber into 18,250 households.

For that, the network provider’s funding includes 20% equity and 80% as debt. The debt capital costs is calculated for a 15 years term with 12% interest rate. Typically, FTTH projects take are spread over a few years, which this financial model takes into account, and the cost to connect homes after the first year is partially funded by the revenues generated from providing the service.

Since the model is designed for a 4-year project and each year more homes and businesses are passed, only an incremental part of the capital is invested.

Case 1: Fiber Only - 20% Equity/80% Debt	Year 1	Year 2	Year 3	Year 4
Total homes and businesses passed	10,000	16,000	18,250	18,250
Total subscribers at year end	2,500	6,000	7,300	9,125
Equity	5,000,000	5,000,000	5,000,000	5,000,000
Debt, principal not including financing fees	20,000,000	20,000,000	20,000,000	20,000,000
Total cash on hand at year-end	6,770,046	3,622,115	1,683,879	635,045
Cashflow Statement				
Monthly cash flow per subscriber	-16.54	17.94	20.74	23.79
Annual cash flow per subscriber	-198.44	215.31	248.88	285.43
Annual cash flow for system	-496,090	915,055	1,655,021	2,344,067
Annual EBITDA	1,903,910	3,315,055	4,055,021	4,744,067

Case 2

Hybrid Fiber-Wireless implementation results in: an accelerated deployment schedule and a (very modest) 10% saving on the deployment cost.

In Case 1, we considered a “fiber-only” project, followed by Case 2 illustrating HFW implementation that consists of a combination of fiber and fiber-like wireless technologies. Deployment costs saved through lower deployment and material costs is explained in the [construction cost model](#).

The project’s IRR has improved drastically with the addition of fiber-like wireless technologies, and is followed by an early increase in revenues generated from broadband services. In the standard fiber only approach there is no income during deployment at all.

Case 2: HFW - 20% Equity/80% Debt	Year 1	Year 2	Year 3	Year 4
Total homes and businesses passed	14,000	18,250	18,250	18,250
Total subscribers at year end	3,500	7,300	9,125	9,125
Equity	4,250,000	4,250,000	4,250,000	4,250,000
Debt, principal not including financing fees	17,000,000	17,000,000	17,000,000	17,000,000
Total cash on hand at year-end	5,023,041	2,251,923	612,955	760,415
Cashflow Statement				
Monthly cash flow per subscriber	8.88	27.32	29.90	26.40
Annual cash flow per subscriber	106.56	327.88	358.79	316.83
Annual cash flow for system	372,966	1,770,556	2,946,562	2,891,082
Annual EBITDA	2,412,966	3,810,556	4,986,562	4,931,082

Implications of HFW implementation:

1. Reduced equity and debt raised: the original project required overall investment of \$25M, while implementing HFW, requires only \$21.5M, total saving of \$3.75M. Literally, it means easier financing and reduced risks.
2. Cash flow positive from day one. The monthly cash flow from subscriber during the first year is \$8.88 comparing to loss of \$16.54 in fiber only solution.
3. More Homes passed
4. Bigger subscribers base
5. Positive cash flow from the very first year

By reducing the capital needed to finance new projects, the HFW paradigm enables new deployments and reduces financing risks.

The time required to start generating revenue from the project shrinks dramatically.

The HFW paradigm can make some projects that were considerable not profitable in the past, affordable and financially profitable, This is extremely important in order to connect low income family housings, distant neighborhoods, other unconnected areas and fight digital divide.

By rapidly connecting additional customers to the existing fiber core, HFW actually leverages the value of the existing fiber network and expands the footprint and the market share of the service provider.

Conclusion

[Hybrid Fiber-Wireless \(HFW\)](#) is a disruptive model for providing GTTH built on proven technology. This model adds high frequency wireless radios to a fiber network, drastically reducing deployment costs, time to install and with the potential to provide multiple gigabits directly to the consumer. Simply put: using HFW, providers can deploy a gigabit first and far cheaper than competitors. Using an HFW connectivity model in a residential market would result in a quantum leap in profitability.

Benefits of Hybrid Fiber-Wireless at a glance:

- You can be there first
 - Consumers – and communities – are demanding Gigabit speeds and higher today, and it is no longer enough to be the first to announce plans. You need to be better than “fiber to the press release.”
 - Providers need to be the first in the area offering and providing actual service.
 - And that service needs to be able to scale – a gigabit today may not be enough speed tomorrow.
- HFW makes your network more valuable
 - The way a network evolves is directly tied to its profitability, but it’s difficult to predict -- HFW is flexible enough to keep up
 - mmWave radios supplement standard Ethernet points – the consumer needs nothing new.
 - A provider can be anyone: Can be connected to Copper (using xDSL or G.fast), Coax using DOCSIS, or Wi-Fi.
- You can be there cheaper
 - HFW provides significant speed upgrades with a less expensive upgrade path
 - HFW means lower equity required and lower debt
 - An HFW project can be cash flow positive from Day One
 - HFW reduces total cost of ownership
 - HFW minimizes the permitting process and negotiation process with building owners because it’s less invasive
 - OpEx: installation of a radio link can take 15 minutes; and for CapEx: silicon radios are low cost, getting cheaper every day