Operational Expenses for All-Fiber Networks are Far Lower Than for Other Access Networks

Fiber Broadband Association

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1. Executive Summary

Fiber has been deployed for decades, first in the core of the world's networks, and then to individual homes, businesses, and wireless cells and nodes. Over this time, fiber has gained a well-earned reputation for far superior performance and reliability versus copper-based and wireless communications media, such that fiber is the basis of the majority of global communications networks of various types.

Many network operators have reported that low operational expenses are among the greatest benefits of an all-fiber network.

> This study confirms what network operators have reported about OpEx savings using FTTH versus other technologies, with savings ranging from 40-60% versus copper-based networks. This savings is primarily accrued from the maintenance, powering, customer experience, support, and churn advantages of fiber.

The Fiber Broadband Association, with hundreds of members operating networks of various types, developed a methodology to quantify the OpEx impact of the 3 different network media. This methodology used a combination of primary and secondary sources of quantitative data, consumer feedback and network operator survey data.

This first round of the study focused on the most common wired technologies – DSL over copper, HFC, and Fiber to the Home. However, as more data becomes available for fixed wireless technologies such as 5G and/or low earth orbit satellite, this data can be incorporated into the study.

The results of the study clearly identify that fiber is the answer for substantially lower operating expenses.

What is the problem?

Network Operators and Policy Makers need to understand the quantified operating expenses (OpEx) for Hybrid Fiber Coax (HFC), DSL over Copper, and Fiber to the Home (FTTH) – to help guide network investment decisions.

Key Takeaways

We analyzed different components that contribute to OpEx. and determined that truck rolls to address network problems and churn management are the main OpEx drivers, and all-fiber networks, due to a simpler, more reliable, and higher-performance infrastructure, can save $54/yr/home passed vs. HFC and $91/yr/home passed vs. DSL. Over a 10 yr period the savings accumulate to $540 per home passed vs DSL and $910 per home passed vs. DSL.

Fiber is clearly the answer to lower OpEx expenses and lower lifecycle costs!

Key Words: Coax, HFC, Copper, DSL, FTTH, Churn, Maintenance

2. Background on Access Network Operational Expense

This study focused on Operational Expense, and did not study Capital expenditures.

- **Capital expenditures include**:
    - Materials – access equipment, fiber, coax, copper, test equipment etc.
    - Back-office software and tools – management, troubleshooting software etc.
    - Backup equipment – batteries, generators etc.

- **Operational expenditures include**:
    - Operations – powering and maintenance of access elements
    - Customer and network maintenance – trouble calls and truck rolls
    - Churn management – costs to add and remove customers

For a perspective on CapEx refer to [1] to understand triggers for access network transformation.

Access architectures explained

Basic network components

As shown in Figure 1, the access network has three components – the Central Office or Headend (CO/HE), the outside plant, and the in-home network. The CO/HE components may include a Cable Modem Termination System (CMTS), a Digital Subscriber Access Multiplexer (DSLAM) or an Optical Line Terminal (OLT) for a Cable Operator using HFC, for a Telco using DSL, or for a Fiber Operator respectively. Other metro interconnect related components are not included in the current analysis.

Outside plant includes all the infrastructural components such as the shared Hybrid Fiber Coax (HFC), point-to-point DSL, shared Fiber plant, and the relevant actives/passives, as shown in Figure 1 below. To fairly evaluate the effect of infrastructure type, we focused from the CO/HE to the demarcation point at the customer drop.

Headend/Central Office/Facility
(Temperature controlled building)

Network Type	Equipment
HFC	Aggregation Router, CMTS, CIN, Optical Network
DSL	Aggregation Router, Optical Aggregation
FTTH	Aggregation router + Opt. Aggregation, Centralized OLT

Outside Plant
(Interconnection between hub and home)

Network Type	Equipment
HFC	Actives: Nodes, Amplifiers Passives: Coaxial Cable, Taps
DSL	Actives: Main or subtended DSLAM, in powered cabinets with battery back-up Passives: Copper Cable.
FTTH	Actives: Remote OLT (sometimes) Passives: Fiber Cable, Fiber Splitters

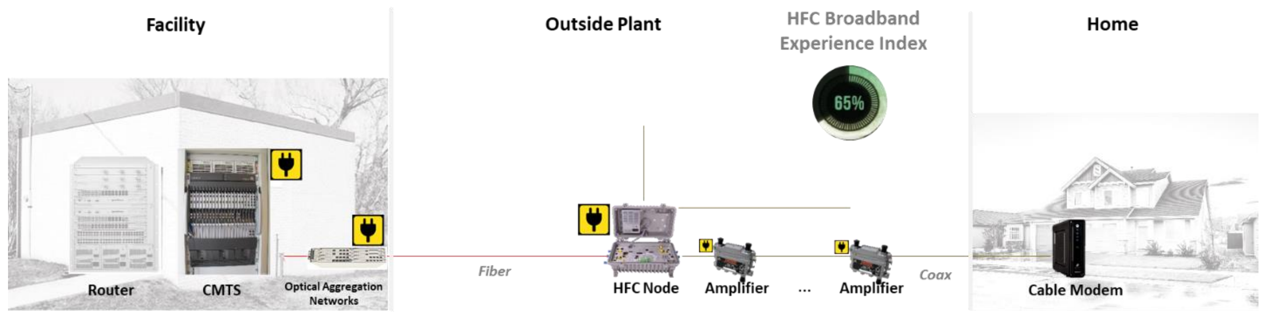
In Home
(Residential and commercial end points)

Network Type	Equipment
HFC	Cable Modem, Router
DSL	DSL Modem, Router
FTTH	ONT, Router

Figure 1 Access network components in Cable, Telco and Fiber Operator environments

Coax-based networks

Today's coax-cable-based architectures are configured in a Hybrid-Fiber Coax (HFC) architecture as shown in Figure 2, and continue to migrate towards more fiber, deeper in the network. This is good news. However, even in the best case with a "fiber deep" or "Node + 0" configuration, at 2 km, the distance from the last powered node to the home is roughly an order of magnitude less, than all-fiber networks. Older networks may have 4-5 amplifiers from the final node to the home, each of which is a potential failure point and consumes power.

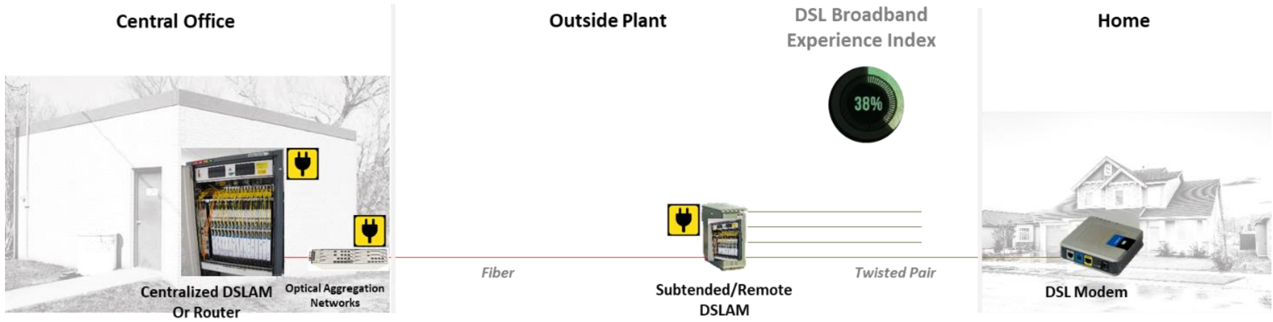


Technology	# of actives	Coax miles/node
N+5	5 per leg	~ 5
N+0	Zero per leg	~1

Figure 2 - Hybrid Fiber Coax-based access network architecture

Copper-based networks

When DSL was first introduced, it was to provide internet and phone service to a service area of approximately 4 km. With the introduction of IPTV video, DSL evolved to FTTN (Fiber to the Node), with homes in a 1 km radius connected with copper. These terms of DSL and FTTN are used interchangeably in the paper. DSL networks use a combination of fiber and twisted pair copper cables to deliver service with a dependency on remote power to the Node to deliver service (as shown in Figure 3). Given the inherent low capacity and high loss of copper in comparison to fiber, DSL has been losing market share to Fiber, thus FTTN networks are rapidly being upgraded to all fiber. To put the copper-based network in perspective, the maximum distance to deliver gigabit services over new copper is roughly 1000 feet (300 meters), or roughly 5% of the distance of a PON network. Older copper will likely have even worse performance. Some network operators may still deploy new copper to and inside buildings, but even these are begin phased out in favor of fiber.



Technology	Max. Distance to Sub	Data Rate
ADSL2+	< 16Kft	10 – 20 Mbps
VDSL2 35b	< 3Kft	100 – 150 Mbps
G.Fast	< 800 ft	0.5 – 1 Gbps
XG.Fast	< 150 ft	10 Gbps

Figure 3 - DSL based access network architecture

Fiber networks

The all-fiber (FTTH) network, as shown in Figure 4, is typically configured in a passive optical network (PON) architecture. The typical PON range is around 20 km (12 miles) from the Optical Line Terminal (OLT) to ONT, with no active components in between. Extended range PONs can support up to 40 KM reach. Other fiber-based protocols can support even longer distances.

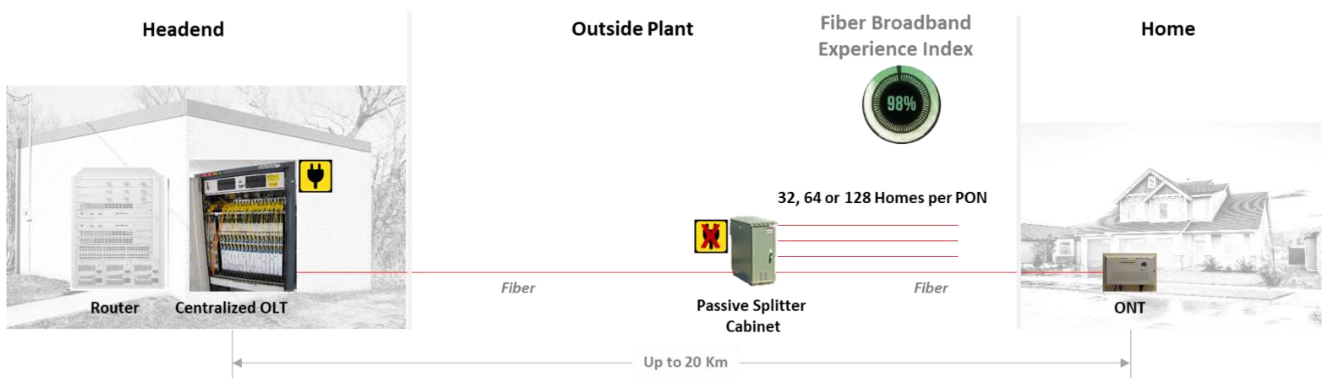


Figure 4 FTTH access network architecture

Of the three access network types, FTTH networks are the simplest. A good proxy for operational costs is the number of active (powered) components in a network from headend or central office location to the home. As the number of active components increases, potential failure points, powering costs, and maintenance costs all increase.

Figure 5 illustrates the number of active components for the various network types. It's apparent why a fiber network is the best solution for higher reliability, lower operational costs and future upgradability when comparing the number of active components required for fiber (1) vs. HFC or DSL (100s) within the service area.

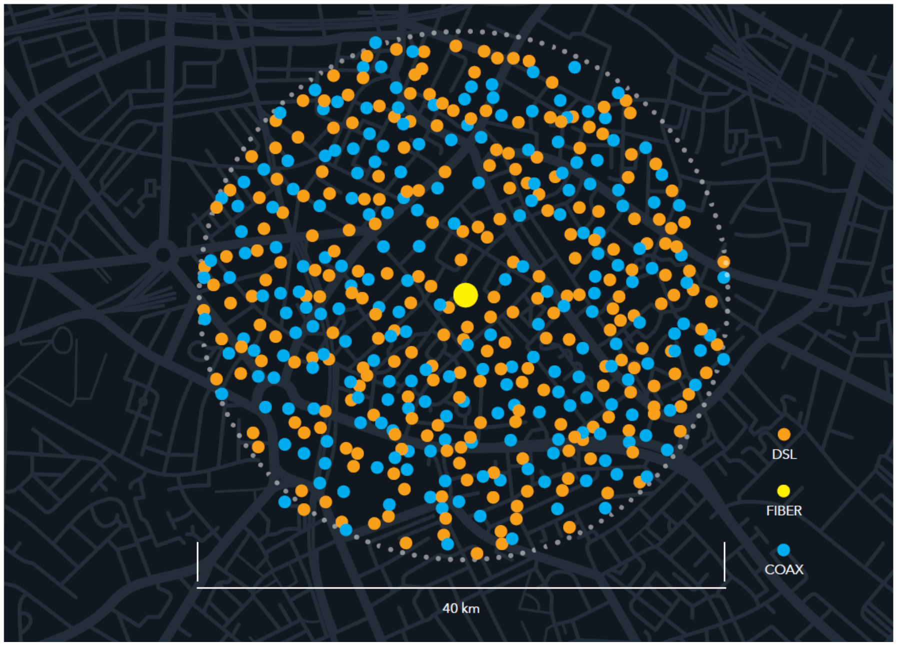


Figure 5 Typical powered equipment locations in a 40 Km area. Note the hundreds of powered nodes required for Coax and Copper based networks versus one powered location for FTTH. Each powered node is a potential network failure point

Wiring media differences – Fiber versus copper

Due primarily to its inherently high bandwidth and low loss, fiber already forms the core of all wireline and most wireless networks today. Copper based cables require powered amplifiers on the order of every 100 meters to 2 KM, while fiber can support 100 KM with no amplifiers. For copper-based cables, the industry has recognized decline of performance over time. Fiber cable is immune to environmental effects that plague copper-based cables, leading to performance that is far more reliable and consistent over the lifetime of the network. The inherent properties of glass fiber, such as the lack of electrical conductivity and corrosion seen in metallic cables, as well as experience of operators, suggests that fiber deployed today will not experience a decline in age related performance as has been seen previously with copper-based cables.

Although it is somewhat intuitive, copper-based networks which require either more frequent maintenance or more individual powered devices are likely more expensive to maintain. Those networks are also more likely to have problems experienced by customers, potentially resulting in churn.

For these reasons, fiber is the answer for long-term reliable network performance.

Equipment Powering

The cost to power active equipment in the access network is a component of OpEx. As highlighted in the previous section, following are the powered components for the various technologies:

- FTTH: OLTs, with a range of up to or beyond 20 km range. There are no other powered components in the outside plant in a typical network
- Hybrid Fiber Coax: In the coax network, there a several powered elements from the head end to the subscriber, including the CMTS, HFC nodes spaced roughly every 2 km, and coax line amplifiers, with up to 4-5 on a path to a home.
- DSL: DSLAM equipment, with an approximate 5 km range delivering limited bandwidth, or VDSL2+ cabinets with range if approximately 1 km.

In addition to electrical power, maintenance is required for all active power components, including inspections, repair, and periodic replacement of backup batteries, generator components and fuel sources.

Most of the assumptions used in this study for network equipment and powering are referenced from the Code of Conduct on Energy Consumption of Broadband Equipment (refer to [2]).

Given the large number of active devices in HFC or DSL networks, it's easy to see why fiber is the answer for lower power costs (and a greener world).

Existing and future maintenance

Maintenance costs for copper-based networks will increase over time due to the combination of plant aging, availability of skilled labor, material supply and knowledge to manage the network. The existing copper network has been in place for multiple decades. As these networks continue to reach end of life, it's a reasonable assumption that the end point equipment will also reach end of life and be discontinued.

DSL (Digital Subscriber Loop)

Future investments in DSL technology will continue to likely be reduced over time, due to increasing OpEx and decreasing market share of DSL. Based on annual RVA LLC Internet consumer studies, DSL market share peaked in 2009 and has been steadily declining since. Costs will continue to increase to manage aging DSL remote sites, including ongoing maintenance of heat exchangers, cabinet appearance and disposal and replacement of batteries.

HFC (Hybrid Fiber Coax)

HFC networks will continue to evolve. DOCSIS upgrades, deep fiber architectures, and node splitting will require adding a great number of new nodes that will serve fewer homes per node as fiber is placed deeper towards the customer. These additional nodes are heavily dependent on additional power from the electrical grid and batteries for backup.

Another influence will be an apparent increase in the number of extreme weather events that damage electrical and communications networks for extended periods. Cabinet sites with batteries are vulnerable during these events. Recently after a weather event in Canada, the Public Safety minister intervened with

Canadian communications companies after Hurricane Dorian knocked out cell sites due to a power outage. (refer to [5] for details).

FTTH (Fiber to The Home)

Fiber as a medium rarely requires maintenance and has a reliable track record over the past 40 years. FTTH is more dependable compared to the other access technologies, especially during extreme weather events. During recent hurricanes Sandy and Harvey, the FTTH networks fared better than other networks, with an example being that submerged fiber cabinets did not lose service (refer to Verizon initiatives after Hurricane Sandy at [3]).

When considering maintenance and resilience, fiber is the best solution.

Customer Issue Management

Customers are becoming ever more dependent on their broadband connection for a variety of everyday activities and are becoming more vocal regarding the quality and reliability of their connection.

A significant OpEx component in the access network is trouble call resolution. Trouble calls can be due to customer specific issues or network related issues that generate alarms. Some of these trouble calls cannot be solved over the phone or using the fault isolation tools in the Network Operations Center. In such cases, Truck rolls are required to deploy network or in-home service technicians to trouble short and resolve the issue. Truck rolls are expensive both due to travel time to the incident location and the time it takes to solve the problem on site. As we will observe in the rest of the paper this is the most significant driver for OpEx performance. In summary, in access networks, reduction in trouble calls, reduction in conversion of trouble calls to truck rolls and the time taken to resolve an issue are essential drivers of lower OpEx.

A key assumption of trouble tickets is that inside-the-home issues are technology-neutral, since WiFi availability, computer issues, etc. are independent of the technology used to deliver the content.

With higher performance and higher reliability, fiber is the answer to reducing truck rolls across the network.

Churn Management

Operators add and remove subscribers regularly. Some of this churn is related to home moves, but much is related to customer-initiated provider changes due to poor experience and dissatisfaction with network service. Such churn can also impact OpEx due to provisioning and deprovisioning of the customer, customer acquisition costs, and average revenue lost due to churn out. These components are considered in our analysis.

The ability for network operators to turn up speeds easily will be a competitive advantage helping them to increase share and reduce churn going forward as new higher bandwidth applications are desired by subscribers. Business cases for broadband going forward will need to consider increasing customer requirements for bandwidth. For example, several FTTH providers are now offering 10 gigabit per second service to the home, and future generations of FTTH equipment will support up to 200 gigabit per second services, without any change to the fiber outside plant.

Due to its almost unlimited bandwidth and easy upgrade path, fiber is the answer to keeping customers satisfied with their service and reducing churn rates.

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3. OpEx Analysis Methodology

A multi-step process was followed in this study:

- The key broadband technologies were identified along with the most common network architecture used for each technology
- The potential primary influencers of OpEx cost differences were identified and listed (such as truck rolls, churn management etc.)
- Basic assumptions were set, such as each broadband technology covering up to 512 homes with a 50% take rate
- Data was developed on the cost per unit of measurement used for each home passed for each OpEx component via original primary research or secondary identification of existing published research (such as the typical cost for electricity: i.e. the average cost per KW for high volume use)
- Data drivers were collected through primary or secondary research on the relative usage of each OpEx component unit of measure (such as what is the typical usage of electricity per individual home-passed by each technology)
- An extensive model was developed to analyze the impacts of all these OpEx components on average costs per broadband technology

After data was collected on all the potential OPEX cost components discussed above, a model was built to test and analyze the impact of all these potential OPEX costs. To accomplish this task, a robust excel model was developed by Sudheer Dharanikota, one of the authors of this paper.

4. Observations and Conclusions

Several important observations can be made based on this project.

A. Truck rolls and Churn are the most significant OpEx components

The project highlights the relative overall significance of the various OpEx components to total OpEx.

As shown in Figure 6, on average across all access technologies, and somewhat to our surprise, powering and battery maintenance costs are less significant influencers of total OpEx compared to other costs. Truck rolls and churn management costs contribute ~85% of the OpEx.

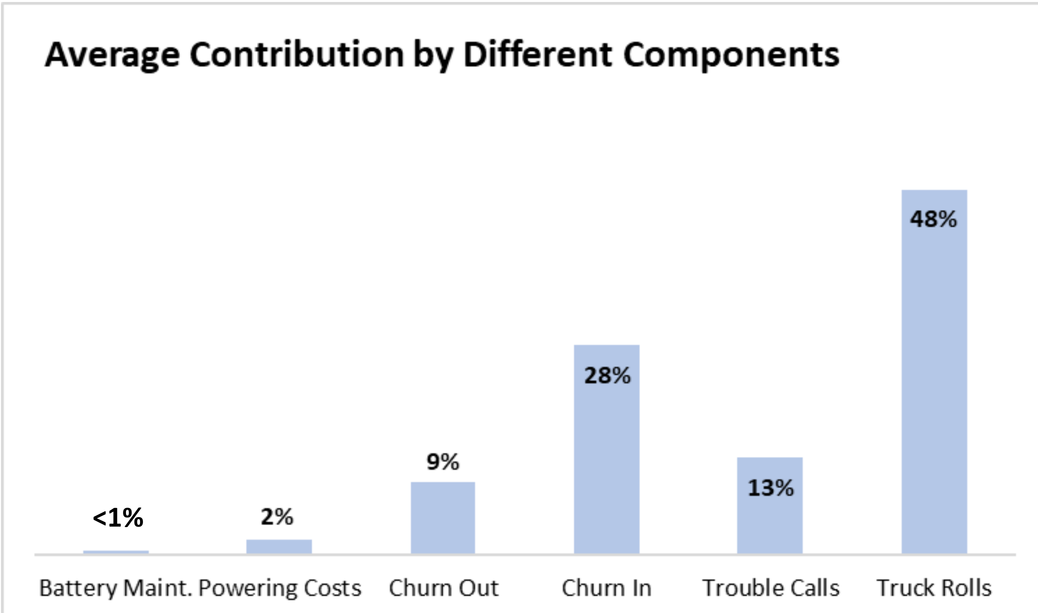

Figure 6 Average OpEx component contribution across analyzed categories

There is another additional benefit for fiber: Though not included in the analysis, reducing truck rolls in Canada can reduce carbon compliance costs. (refer to [4]).

B. Trouble calls and truck rolls have significant variability between technologies

Secondly, we can determine which OpEx components have the most variance in per customer costs between technologies. Here, we can see that trouble telephone calls and truck rolls have the most variance in terms of percentage differences, and churn costs and truck rolls have the most variance in terms of per customer dollar differences

	Minimum Costs		Maximum Costs		Variance	
	Cost	Technology	Cost	Technology	Cost Diff.	Percentage Diff.
Battery Maint.	$0.00	FTTH	$0.86	HFC	$0.86	
Powering Costs	$1.18	FTTH	$2.39	HFC	$1.21	102%
Total Churn	$25.34	FTTH	$61.35	DSL	$36.02	142%
Trouble Calls	$6.77	FTTH	$19.34	DSL	$12.57	186%
Truck Rolls	$19.24	FTTH	$68.20	DSL	$48.97	255%

As shown in the table above, there is significant variance within all the OpEx components, including the power component. Thus, although changing power will not have a significant influence on OpEx costs, in the aggregate it does have a significant influence on environmentally based concerns.

C. Fiber to the home offers 50% OpEx savings over HFC and 63% over DSL technologies

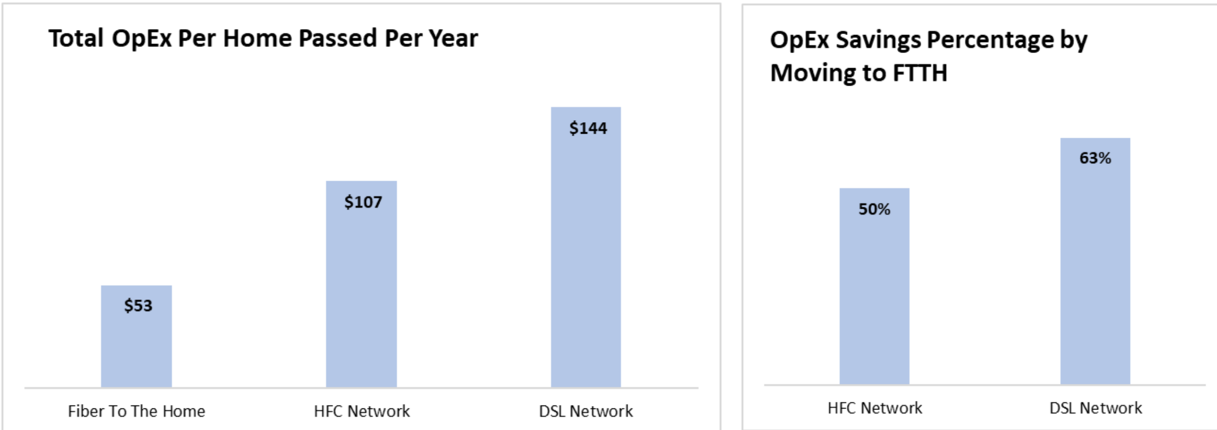

Figure 7 OpEx per technology per home passed per year and the projected savings deploying FTTH

As shown in Figure 7, OpEx savings are **$54 per home passed savings per year for FTTH vs. HFC**, and **$91 per home passed savings per year for FTTH vs. DSL**. This translates to 50% - 63% savings for FTTH, compared to HFC and DSL respectively. Over a 10 year period, the savings are projected to be $540 per home passed for FTTH vs. HFC, and $910 per home passed for FTTH vs. DSL. [i]

This study confirms what other sources have reported about OpEx savings using FTTH versus other technologies. Verizon has cited 60% OpEx Savings versus DSL (Refer to [6]). Smaller providers with both FTTH and DSL or HFC have estimated OpEx savings of about 40% in RVA surveys (most making estimates without formal measurements). Altice, a major MSO cable company overbuilding FTTH in many areas (but still running a major HFC network) noted in its Q3 2019 investor presentation *"FTTH network to significantly reduce long term costs: Better customer experience driving fewer interactions, lower technical service visit requirements, and structurally lower maintenance and power costs."*

Based on this study, the OpEx cost savings all-fiber networks should certainly be considered by network operators and policymakers when evaluating different broadband technologies for future deployment. Further, OpEx considerations should influence the timing of capital expenditures to upgrade broadband delivery. For example, if end-to-end fiber delivery is on a long-term roadmap for a network operator, fiber's OpEx savings (along with maintaining or growing the customer base) could certainly justify faster transition.

In summary, fiber to the home is without question the answer to reducing operational expenditures in the access network.

5. References

[1] Dharanikota, S. (2017, June). "Understanding the Basics of Transformation in Telecom," Duke Tech Solutions White Paper

[2] "EU Code of Conduct on Energy Consumption of Broadband Equipment" JRC Technical Reports, 2017

[3] "Verizon accelerates copper-to-fiber transition, sets new network resiliency practices," Nov 2017

[4] "Pricing carbon pollution in Canada: how it will work," June 2017

[5] "Dorian's impact: Maritimers complain about cellphone service failure," Sept 2019

[6] "Verizon Saves 60% Swapping Copper for Fiber," Light Reading, May 2015

6. Appendix: Assumptions used in the current analysis

Source of data for **the cost per unit** of measurement includes the following:

Item	Source	Cost per unit of measure
Battery maintenance (battery and labor cost per event)	Publicly available network maintenance data	10% of battery cost per year ~$20/year/battery location
Powering/electric costs	2018 US EIA data for industrial uses	$.07 per Kwh
Cost per trouble ticket (Call center)	RVA review of published data, and Duke Tech data	$12.50 per call
Cost per truck roll	RVA review of published data and Duke Tech data	$100 per truck roll
Churn related OpEx costs: customer recaptured	Several published sources (deprovisioning, acquisition, provisioning)	$665 per customer lost and replaced
Churn related OpEx costs: customer not recaptured	Several published sources (deprovisioning, six months lost revenue)	$384 per customer lost and not replaced

Source of data for **the units of measurement** used in this analysis includes the following:

Item	Source	DSL	HFC	FTTH
Battery maintenance events per node	Duke Tech Analysis	$0.4	$0.9	$0 – OLT is assumed in the CO
Powering: Kw per month per subscriber	RVA Review of published data	3.066	4.161	2.409

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Trouble calls per node per month	RVA consumer study 2018, 2019	66	42.4	23.1
Truck rolls for outside plant per node per month	Average of RVA provider research and RVA trouble calls from consumer study times 30%	19.4	16.7	5.8
Percent of customers churning overall	RVA consumer study 2018, 2019	22.80%	9.79%	7.62%
Percent of customers churning and recaptured	RVA consumer study 2018, 2019	7.80%	9.79%	7.62%

It should be noted that average and typical values were used for each data point listed above. Actual OpEx values for any given project will certainly vary by factors such as regional or local costs, differences in actual technical architectural design methods within each broadband technology, etc.

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[1] [i] Assumes Opex increase for copper-based networks over time increases at the same rate as the discount rate.