Fiber Network Planning Options for Rural Communities

Remote OLT (rOLT) Use Case Comparison and Analysis

A Technical Paper prepared for SCTE by

Adam Soccorsy
Director of Sales FTTX Systems
Technetix
Technetix Ltd.,
Innovation House
Technetix Business Park
Albourne, West Sussex
BN6 9EB
United Kingdom

Adam.Soccorsy@technetix.com

Luc Absillis Ph. D
Chief Operating Officer
First Principles Innovation
111 Fieldbrook Court
info@fpinno.com

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1. Introduction

Advances in semiconductor technology and the relentless progression of Moore's Law have enabled ever more capable smart devices in every aspect of our lives. Chips enabling network functions to be miniaturized and compressed into pluggable devices are encouraging innovation in the access network space. Being able to move a single optical line terminal port (OLT) out of its normal position inside a rackmount chassis and place it in a small, hardened node enclosure on a telephone pole, or other remote exterior mounting, is a new concept that was not possible a few years ago. These same advances in semiconductor technology have also benefitted other network construction types such as Fixed Wireless Access (FWA).

Multiple vendors have launched remote OLT (rOLT) products with new dimensions of price and capability that take advantage of the new lower power, higher capability chips.

This paper uses the generic dimensions of a synthetic remote OLT and combines them with several computer models that utilize geographic information system (GIS) software to assess the overall impact of constructing greenfield fiber connectivity projects in the United States with remote OLT technology.

What is a Remote OLT (rOLT)?

There is more than one standard covering the technology. The International Telecommunication Union (ITU) is the body that covers the passive optical network (PON) standards under their remit. However, the standard for XGS-PON, G.987[1] does not cover the physical characteristics of an OLT device but rather describes the architecture and communication protocol. The American National Standards Institute (ANSI) also has a standard entitled the Generic Access Platform (GAP)[2] which partially covers rOLTs; but this is more concerned with mixing DOCSIS and PON in a modular format. It does not cover PON-only devices that were not technically feasible at the time of writing. Remote OLTs operate in a grey area between two standards; standards that are effectively defined by the technology vendors operating in this space. There are several vendors now selling or designing remote OLTs operating solely with xPON, but also some that are mixing DOCSIS and xPON.

The rest of this paper will focus exclusively on remote OLTs that only serve XGS-PON technology.

Taking a wider look at trends, we will assess the remote OLT across some broader goals broken down into three areas: lowering the cost of connecting our rural communities; lowering the complexity of the network; and ensuring fundamental digital equality across society. Specifically, we reference the Federal Communications Commission (FCC)[3] finding that there are more than 19 million American homes without access to broadband. This represents a basic number: it does not include the many millions more of underserved connections.

Looking internationally, we highlight a recent report by Gigaclear in the UK[4], which studied the technical and commercial aspects of using remote OLTs in their network. The report established that smaller, more integrated solutions are required for serving rural communities. This paper will go into more depth about these requirements.

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[1] ITU G.987: 10-Gigabit-capable passive optical network (XG-PON) systems: Definitions, abbreviations, and acronyms

[2] ANSI/SCTE 273-2 2021: Generic Access Platform (GAP) Modules Specification

[3] FCC Website. www.fcc.gov

[4] Gigaclear, Small Coverage OLT Report (Internal), Tim Durkin B. Sc, M. Sc, MIET, 2023

2. Section 1 - Reimagining the network with rOLT

A rack-mounted OLT is normally constructed to fit into a 19” rack, and usually contains several slots where cards can be installed. A typical minimum installation would contain one card, consisting of eight ports, with expansion slots capable of accommodating up to a total 32, 64, or 128 OLT ports. Although different network designs utilize different split ratios, a typical 64-way split architecture would imply a minimum capacity of 2,048 end user homes that could be connected within a 20-mile radius of the device. Using a 32-way split architecture would imply a capacity of 1,024 end user connections for a minimum capacity rackmount installation (eight ports of a 32-port chassis). At the time of writing, a consensus indicates that the approximate cost of installing a field installation OLT cabinet, with all the necessary accessory equipment, currently costs somewhere around $70,000 - $100,000 for the capability to connect between 256 and 2,000 homes. This includes installation cost.

A rOLT by contrast follows a different set of dimensions. It can have between one and four OLT ports but does not need to be installed in a cabinet. However, using the 32- and 64-way architectures, it is possible that the rOLT can serve between 32-256 (1x32- 4x64) homes. Since rOLTs require far fewer accessories and much less power, we assume a cost of $20,000 to acquire and install a rOLT that can serve between 32-256 homes within a 20km radius. Since this paper is addressing new construction areas, we would also like to suggest the following comprise part of the ‘wish-list’ for an ideal device: low power consumption, minimal installation complexity, robustness, and subsidy-awareness.

The compact size of the newer rOLTs enables many more mounting options for active equipment. In this computer model we assume equal parts aerial and underground construction. Roughly $15k of the total $20k deployment cost (see Table 1 below) is attributed to a remotely mountable device kit, with $5K for its installation. Cabinet mount options require more kit, planning and concrete costing - around $45K and roughly $25K to mount. These costs were benchmarked across several tools and market information sources.

Table 1 – Basic assumptions for GIS computer modelling

Technology Type	Homes	Power	OLT Ports	Cost to Deploy (est.)
Rackmount OLT	256-2048	1050 Watts	8-64	$70,000
rOLT	32-256	48 Watts	1-4	$20,000

Taking these parameters of the equipment into consideration, we can create a template profile in a GIS tool that is used to calculate the cost of constructing and operating different types of networks. Washington County, North Carolina was chosen as a rural county for some initial comparisons. The county contains around 11,000 households passed (HHP) in around 76 square miles. The graphics below show the estimated topology locations of the equipment for the network types: Rackmount OLT, rOLT, and FWA.

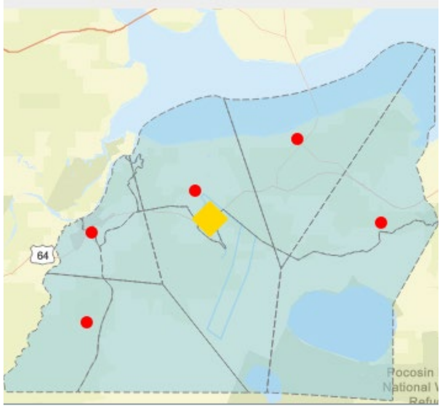

Figure 1 - Rackmount OLT topology map of Washington Country, North Carolina

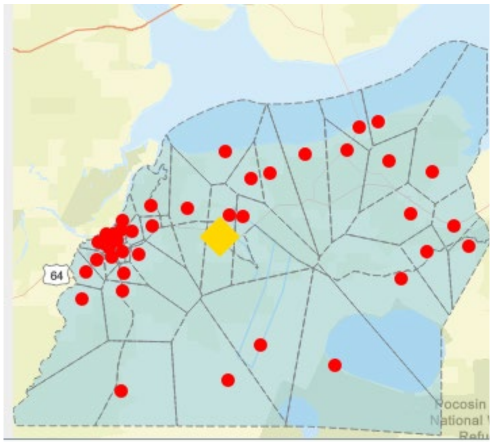

Figure 2 - rOLT topology map of Washington County

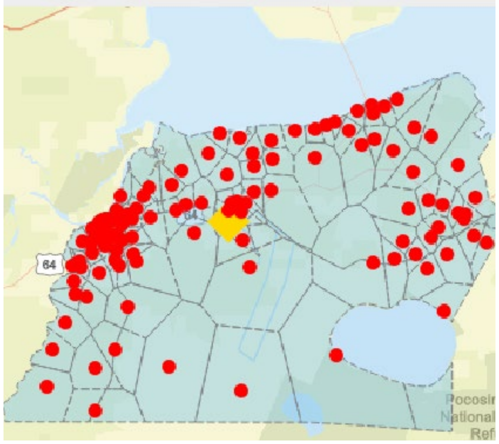

Figure 3 - FWA topology map of Washington County

Figures 1, 2 and 3 demonstrate the difference in topology types using different types of network construction. In this model, we also take future traffic growth into account when looking at the long-term cost. As Table 2 shows, FWA initially costs substantially less to construct ($28M). However, it ultimately could cost substantially more ($65M) if a constant combined annual growth rate (CAGR) for bandwidth growth is assumed.

Our comparisons conducted in Washington County established two significant findings. Firstly, the behavior of the GIS systems in plotting the equipment against the census derived geodata works and appears to follow common sense assessment of location. Secondly, this first analysis changed the perception that rOLT construction would be more expensive in large HHP areas. Washington County showed that, when starting from scratch, the costs are on a par.

Table 2 - Initial comparison of 10-year total cost of ownership (TCO) and details[5]

Technology Type	Number of Units	TCO 10 Year
Rackmount OLT	5	$39M
rOLT	59	$40M
FWA	FWA + 59 rOLT	$65M ($28M)

3. Section 2 - Lamoille County, Vermont

Lamoille County, Vermont has been selected as the second area for comparison of network construction projections. Using the GIS software, we will select a smaller rural sample area to understand if there is economic threshold, and where it becomes cheaper to build a network using rOLT rather than with a rackmount OLT. Bringing in another GIS tool that can create low level designs (LLD), we will conduct both high level design (HLD) and LLD analysis of the same area to study the economics.

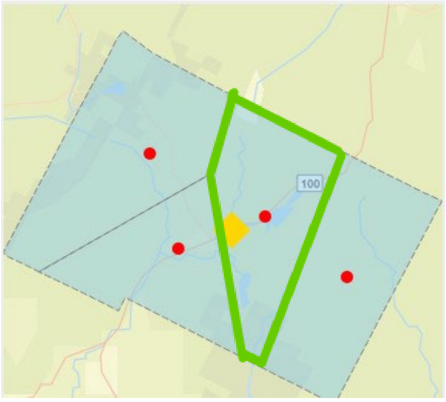

Figure 4 - HLD of Lamoille County, Vermont

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[5] AP-Jibe, www.fpinno.com

Lamoille County contains around 912 households passed (HHP) and is a predominantly rural county with some lakes and a nature reserve. Figure 5 shows a yellow square in the middle: this represents the location where a rackmount OLT could be installed to serve this area. The small red dots represent the locations of the rOLT devices that would require installation to serve this area. Each of these rOLT devices sits within an area that has been created to allow equal division into blocks of roughly 228 homes. Each one of these 228 home segments has its own rOLT serving symmetrical 10 Gbps.

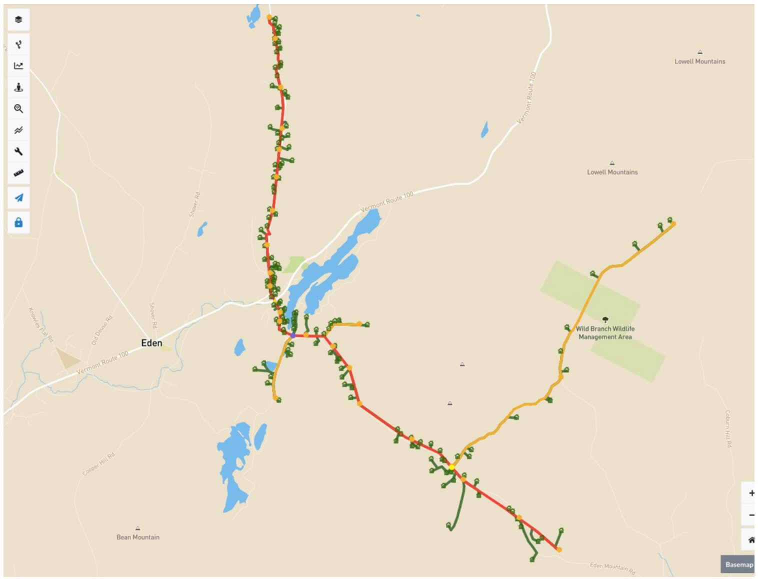

Figure 5 - LLD Eden Mills, Vermont (courtesy of Vetro[6])

Both the HLD and the LLD designs contain projections of the costs of constructing a greenfield FTTX network, including projections for cash flow and revenue. The LLD area is roughly equivalent to one section (the highlighted green section of Figure 4) of the HLD design; essentially, 224 homes and, which provides robust comparison. In addition, we can model the cost of constructing with a greenfield FWA, and a DOCSIS network.

Combining the HLD and LLD of fiber construction, along with FWA and DOCSIS construction, allows us to calculate the following results:

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[6] Vetro fibermap, www.vetrofibermap.com

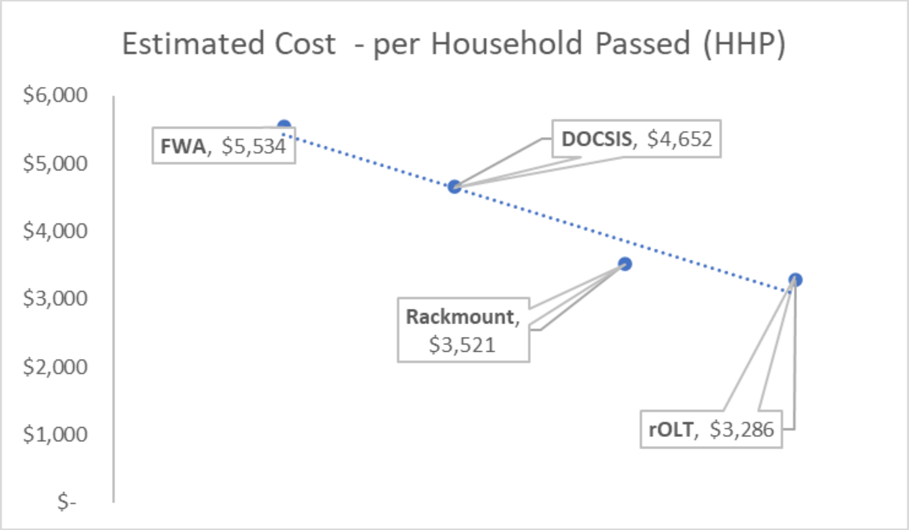


Figure 6 - Estimated cost per HHP in Eden Mills, Vermont

Figure 6 above shows the trend graph with the different build types listed in descending order showing a modest advantage of 6.6% for building with rOLT. In addition, we note that placing four rOLTs in different locations should also save miles of plant construction: we call this ‘topology saving’. However, we do not endeavor to prove topology saving here.

Table 3 below provides a more detailed examination of total project cost for Eden Mills:

Table 3 - Construction cost comparison

Equipment Type	HHP	Cost to Construct
rOLT	228	**$806,070.90**
rOLT	912	$3,011,253.00
Rackmount OLT	912	$3,218,741.00

When looking deeper into the detailed bills of materials that sit behind the calculations, it is apparent that the cost of building rural network is largely driven by a few variables, including the number of feeder and trunk miles that need to be constructed. For clarity, our model assumes 50% aerial and 50% underground construction.

Looking at the first row of Table 3 based on our previous assumption that the equipment costs $20k, most of the remaining balance ($786,070) applies to the miles of construction required to reach end users.

This same financial data is reflected in the color bars on the charts (Fig. 7). The equipment requirements are represented by the pale orange segment at the top of each bar; the black section directly below represents the customer premises equipment (CPE); with the miles of construction below in green.

The left-hand chart (Fig 7) contains four roughly equal bars that are each valued at around $750K. The Eden Mills LLD project would represent one bar (1/4) of this potential four-part project.

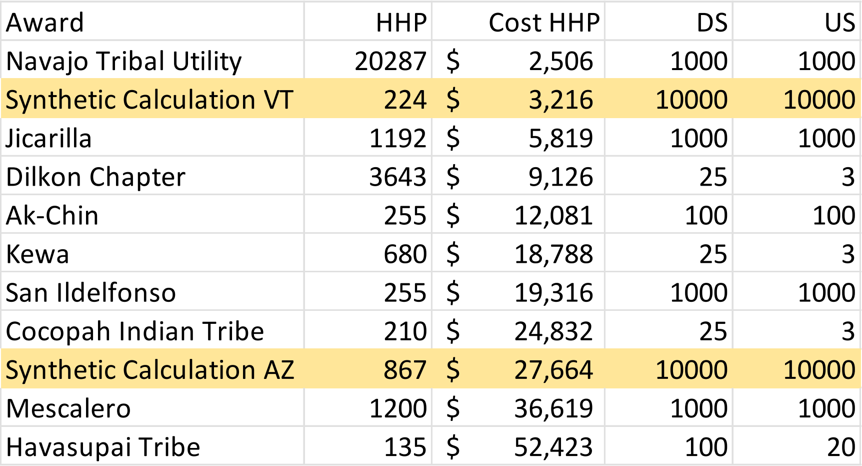
rOLT

Rackmount OLT

Figure 7 - CAPEX comparison Lamoille County

Imagine for a moment a community backed project raising funds for their own fiber network, they would now be able to raise a much smaller amount of money to begin their rOLT based project. If this same project succeeds, it can then continue expanding into the 3 other areas of their county. In contrast, a rackmount OLT project would need to account for the full construction cost at the beginning of the project. This cash flow improvement is potentially immensely valuable for projects that struggle with funding or require greater financial or technical flexibility for completion. Community projects looking to fund or construct their own network can gain a good advantage with a smaller capital expenditure (CAPEX) profile.

Looking more broadly within the United States then, how does our HLD and LLD analysis compare with real projects already in process?



Award	HHP	Cost HHP	DS	US
Navajo Tribal Utility	20287	$ 2,506	1000	1000
Synthetic Calculation VT	224	$ 3,216	10000	10000
Jicarilla	1192	$ 5,819	1000	1000
Dilkon Chapter	3643	$ 9,126	25	3
Ak-Chin	255	$ 12,081	100	100
Kewa	680	$ 18,788	25	3
San Ildelfonso	255	$ 19,316	1000	1000
Cocopah Indian Tribe	210	$ 24,832	25	3
Synthetic Calculation AZ	867	$ 27,664	10000	10000
Mescalero	1200	$ 36,619	1000	1000
Havasupai Tribe	135	$ 52,423	100	20

Figure 8 - Mixed synthetic and real project costs per HHP with speeds

Figure 8 is a sample of real projects costs in Arizona and New Mexico published on the Government's Internet For All website[7]. The yellow rows are synthetic calculations for both Vermont and Arizona using the same methodology used earlier in this paper. Looking closely at the detail of these projects, it is apparent that, in many cases, the connections created are between vital institutions and places of learning - not solely residential. Using a cost-per-HHP as the benchmark, there are compelling indicators that rOLT would be a highly viable option for projects like the above, depending on the topology.

4. Section 4 - Power consumption

Although some variance can be observed in the power consumption of rOLT products already on the market, it is worth noting that some of the most recent models have significantly lower power consumption than Rackmount OLT versions. This is because newer rOLTs are passively cooled. Indeed, the power-saving in a rOLT is because the device does not consume energy running fans, since moving parts have been eliminated from the OLT design.

If we connected the 19M unconnected homes in the USA now, what would the power consumption be?

Table 4 - Power required to serve 19M homes with symmetrical 10 Gbps for one year

	Watts	OLT Ports	Watt/Port	GB/Watt	kWh 1 year
Rackmount OLT	1050	64	16.4	0.61	42,666,503.91
rOLT	48	4	12.0	0.83	31,207,500.00

Another possible benefit may be since the rOLTs are spread out geographically. This could be ideal for solar panel power generation, producing an ecologically friendly method of connecting homes and reducing further the carbon footprint. Directly comparing the Gigabit (GB) per Watt column in Table 4, we understand that we are pushing over 30% more GB through the network for the same amount of power consumed.

5. Conclusion

Circling back on the wider trends in networking mentioned at the beginning of the paper, let us review.

In terms of lowering the cost of connecting rural communities, there is a strong case that rOLT could be the cheapest method of connecting many for these rural communities with the lowest cost per HHP on some topology types, particularly low density. Looking at the question of CAPEX, having a device that is aptly sized for serving 256 homes, lowers the financial bar for many projects.

Lowering the complexity of the network is difficult to prove. However, we can demonstrate that a large-scale deployment of rOLTs would create a measurable and desirable improvement in the power consumption needed to close the digital divide without compromising on network speed. Lowering the year-on-year power consumption lowers the future complexity of owning and operating any network, in addition to lowering the environmental cost.

Digital equality is a significant goal of the government broadband stimulus. The role of industry is to support the initiative with customer-centric innovation that lower the cost per HHP, and enables the spending to reach more places, faster, and at the best cost.

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[7] Internet for All – U.S. Government Website www.internet4all.gov

rOLTs present a strong solution for network planners and operators looking to construct areas of network of 1000 HHP or less. For a small community project, rOLT provides an affordable starting point to bring fiber to small numbers of isolated or difficult-to-reach homes. For the network planners of the future, the ability to connect communities at a lower dollar and environmental cost are both tangible benefits. rOLTs bring with them the potential to reimagine a lower power, lower impact network helping us build a better future for all.

Abbreviations

ANSI	American National Standards Institute
AZ	Arizona
CAGR	Combined Annual Growth Rate
CAPEX	Capital Expenditure
CPE	Customer Premises Equipment
DOCSIS	Data Over Cable Service Interface Specification
FCC	Federal Communications Commission
FWA	Fixed Wireless Access
FTTX	Fiber to the x
GAGR	Compound Annual Growth Rate
GAP	Generic Access Platform
GB	Gigabits per second
Gbps	Gigabits per second
GIS	Geographic Information System
HHP	Households Passed
HLD	High Level Design
ITU	International Telecommunication Union
gWh	Gigawatt Hours
kWh	Kilowatt Hours
mWh	Megawatt Hours
LLD	Low Level Design
OLT	Optical Line Terminal
OPEX	Operating Expenditure
PON	Passive Optical Network
rOLT	Remote Optical Line Terminal
SCTE	Society of Cable Television Engineers
TCO	Total Cost of Ownership
VT	Vermont
xPON	Any version of PON technology

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ITU G.987: 10-Gigabit-capable passive optical network (XG-PON) systems: Definitions, abbreviations, and acronyms

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