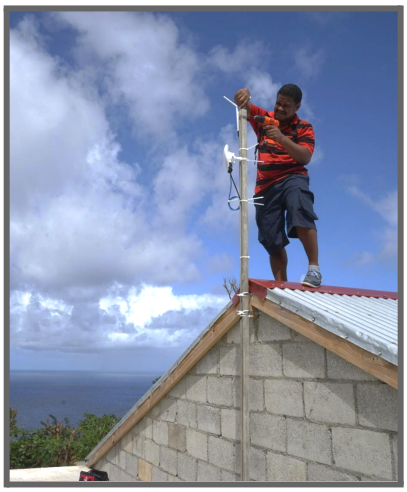


Boom or Bust

A Tale of Rural Connectivity, the Business of Micro ISPs, Community Networks, and the Backhaul Conundrum

Author: Edwin Reed-Sanchez, City University of New York (CUNY) *ereedsanchez@gmail.com*
Technical Advisor: Daniel German Martinez, Universidad Nacional del Nordeste (Argentina)
Advisor: Nigel Cassimire, Caribbean Telecommunications Union

Table of Contents

Foreword

This research's initial spark is to understand the utilization or underutilization of Subsea cable systems, especially in Bluefields, Nicaragua. Bluefields is the location of a landing station for ARCOS I, an international subsea fiber optic system. Bluefields is a city of approximately 100,000 people located on the Caribbean Coast of Nicaragua, a traditional indigenous and afro-descendant region. The region itself lacks a lot of infrastructure. There are several indigenous communities located along the coast, but they are only accessible via boat despite not being islands. Nicaragua, in 2017, had a 29% internet penetration rate[1], and this region fares much worse, especially in the rural indigenous communities.

Now to be open and clear, I am an internet infrastructure researcher, a proponent of community networks, and a part-owner of a MicroISP called SayCel based in Bluefields, Nicaragua. With in-depth knowledge of internet infrastructure in rural and indigenous communities, the purpose of this article is to truly understand constraints for Micro Internet Service Providers and Community Network. To many, including LACNIC, The Internet Society, and the International Telecommunication Union, MicroISPs and Community Networks are considered one of the solutions for the proliferation of internet connectivity in rural areas. Despite the millions of dollars spent on improving rural infrastructure, areas like Bluefields are plagued by low-quality, low access, and expensive internet. This is ironic because theoretically, its location with a subsea cable landing station should have one of the best internet connections in the world.

There are economic and technical problems that plague connectivity in regions like Bluefields. This article will attempt to demystify these problems and provide insight for entrepreneurs and Community Network initiatives to understand the business for internet distribution. My goals are to:

1. Understand why backhaul is so expensive from the backhaul provider's perspective.
2. Elaborate on the specific difficulties and challenges for MicroISPs and Community Networks.
3. Produce a real-world packet route map for traffic to and from Nicaragua, using custom-built software to capture and evaluate traceroutes.
4. Prove the illogical nature of data traffic patterns in Nicaragua and the subsea cable system's limited use.
5. Provide potential solutions to increasing connectivity in areas physically close to the subsea cable system.

[1] https://www.statista.com/statistics/1055491/internet-penetration-nicaragua/

Edwin teaching at Bluefields Sound System

Introduction

“Let me reintroduce myself, my name is …”
Edwin Reed-Sanchez

I just sampled those lyrics from one of Jay-Z's most famous songs: Public Service Announcement!

I know it's strange to talk about a rap musician in a technical paper about subsea cable operators and backhaul providers. But before I get into the technical nitty-gritty, let me explain how I got here.

I grew up in the age of Hip Hop, in an inner-city neighborhood of Chicago. At the age of five, I first encountered the entrepreneurial spirit of the hood. Hidden in the bushes in my front yard, I, the curious child, found a discretely discarded cigarette box. It looked like garbage, but to my surprise, the box was filled with smaller plastic baggies that were filled with some green and white substances. Not thinking this piece of interesting garbage had much value, I placed it in another bush. I didn't think much of it. Until a young youth who couldn't be older than 16 was fully decked out in a black and green Starter Jacket, with shoes to match. That outfit was fly! He scrambled everywhere, looking for the box. Freaking out, saying, "They'll kill me, that's a s*** ton of money, where is the s***!"

It was only years later that I realized the entrepreneurial nature of that youth. He was already working at the age of 16. His company was the Spanish Cobras of Humboldt Park. And that little box I found was a commodity of the hood. It had traveled a long distance, probably Mexico or Colombia, and was a very profitable product that people would drive up in their car and pay $10, $20, even $100 for a little packet. His company, the Spanish Cobras, was one of many other entrepreneurial gangs peppered throughout Chicago.

At some point, my mother decided I would not be allowed to play out in the front yard. It was around that same time my father bought us a Comodore64. And we spent hours writing BASIC and attempting to run a software program. I mostly just used the computer to play games… but it was the beginning of my fascination with computers and the burgeoning digital technology of my era.

As I grew older, Jay-Z and Wu-Tang Clan became the superheroes of my hip-hop generation. Both were rap institutions: Extremely creative artists and gritty hustlers who could turn their talents into multimillion-dollar conglomerates. They ruled the game mostly outside of the constraints of the traditional music industry. Their entrepreneurial spirit I understood and wanted to emulate. They, in fact, probably started their careers doing much of the same thing like that 16 year old I encountered in my childhood.

I graduated college right after the housing market crash. With fewer opportunities statewide and a great adventurous spirit, I followed my dream. I decided to move to Bluefields, Nicaragua to start a recording studio and multimedia center in a remote indigenous and afro-descendant region of Latin America. The local culture and musical heritage inspired me—a place where they equally speak Spanish, a regional Creole English, and a splash of Miskito. The communities in the region were only accessible by boat, and this was not an island. Infrastructure was not great. But the magic lay in the music heard on the streets: Reggae, souls, ballads, and some good old twangy country. Unlike any I had experienced, it was a unique atmosphere, and I met local arts, youth, and even old classic crooners. The city was filled to the brim with talent, but in the mid-2000s, there was no recording studio or cultural center in all Bluefields or the entire Caribbean Coast. That's when my partner Alexander Scott[2] and I started Bluefields Sound System. And for eight years, we ran the only center where we recorded talent, represented musicians, toured the country, and developed an educational multimedia program, including audio production, video production, graphic, and web design. Despite getting grants from the United Nations and other multilateral institutions, this venture was by no means financially fruitful. Much of our project funding was spent on communications; at the time, cellular calls were $0.50 a minute. Any project we would want to coordinate would require buying prepaid minutes, both for ourselves and our local partners.

Despite the challenges, those were some of the happiest days of my life. I was fortunate enough to have the digital skills to be able to work online and make pretty good money as a remote

[2] Alexander Scott is now a digital entrepreneur, and founder of OnLevel Solutions (onlevelsolutions.com) an innovation and talent hub providing operational and business solutions for a network of strategic partners in Bluefields and abroad. Their company was a location for one of our traceroute nodes.

programmer and project developer. Furthermore, I dreamt that I could turn culture and music into some worldwide conglomerate and become a world music mogul of sorts like Jay-Z or Wu-Tang. Okay, that was a dream, which I knew was not entirely true, but one has to dream big!

After eight years, without real financial growth with Bluefields Sound System, I decided to get my Master's Degree at New York University Interactive Telecommunication Program. The program is an Arts degree in technology and is a playground for technology experimentation. It is there I became obsessed with open source networking. Home Brew Infrastructure. I did my thesis on Open Source Cellular networks and helped install a system in an indigenous community. And when I could not get residential Internet at my house in Bluefields, I decided to build out my own Fiber to the Home ISP.

I had a new dream. SayCel would be the first local Independent Internet Service Provider for the Caribbean Coast of Nicaragua. We would offer affordable connectivity and have a mission to connect all the smaller communities and Bluefields and thus provide the same digital educational and work opportunities I had growing up and as a remote programmer.

The idea was simple. The Internet is a commodity and product, something people love and can't get enough of. The smartphone and laptop were the vehicles that, as an ISP, I could use to push the data commodity to them and for them. I had a window into their brains. In many ways it was not that different from the basic entrepreneurial premise that my hood entrepreneurs followed.

In the rest of this article, I will break down the business of the Internet from the perspective of the Micro ISP and Community Networks. I am very well acquainted with both. In addition to my ISP work, I have installed community networks in the Indigenous Kalinago Region of Dominica, Ongata Rongai, Kenya, and provided emergency communications resilience workshops in Puerto Rico. The Micro ISPs and Community Networks are entities that most emulate the hip-hop ethos, marginalized communities, full of artistic ingenuity, and mission-driven to build a business and rise to the top.

The Research Method

"I wanna sit behind the scenes and see nothin' but the greens."

Method Man

For this research, I took a quantitative and qualitative approach. As a Micro ISP owner and collaborator on several Community Network initiatives, I know first hand the most significant barriers to success are:

1. Cash - Investment for equipment and infrastructure build-out.
2. Product - Access to quality affordable backhaul internet.
3. Rules - Friendly regulatory environment.
4. Relationships - Building personal and digital relationships.

This research will break down each of these factors to provide insight for potential entrepreneurs, researchers, backhaul providers, regulators, and international organizations like LACNIC.

Cash - Plain and simple, an ISP or Community Network needs money to get started and a business model to survive. This section will elaborate on the MicroISP business model pulling from SayCel's own experience in the industry.

The Product - Affordable internet backhaul is essential to providing internet service. The drivers of affordability will be explored through interviews with UFINET, the largest terrestrial backhaul carrier in Central America, C & W Networks, the owners of ARCOS I, and Telegeography, the premier telecommunications research company.

Rules - The regulatory environment and getting the right permissions and licensing are essential, necessary components to a meaningful distribution of the internet in a community. Through personal experience and an interview with Samoza Wilberforce John, the leader of Kalinago Community Network in Dominica, I will explore how regulators confront a lack of connectivity in rural regions.

Relationships - Building personal and digital relationships are equally crucial to the technology that builds out infrastructure. In section, I will examine the business-to-business relationships and technical relationships from the smaller network to the large provider and decipher how packets travel throughout the internet.

I will examine traceroutes from several nodes in Nicaragua, including the SayCel Network (Bluefields), Claro Network (Bluefields), Tigo Network (Little Corn Island), and a Miami-based server. I will dissect how BGP models, business-to-business relationships, and acquisitions affect routing and quality service in the region.

Cash
“C.R.E.A.M. - Cash Rule Everything Around Me”
Wu-Tang Clan

Cash rules everything around me, especially when it comes to creating an Internet Service Provider.

Primarily cash is required to purchase the equipment needed to provide service. Here is a rough breakdown of the budget needed to offer a PON Fiber to the Home network for 100 Clients. I start with 100 clients because it is a nice round number and a reasonable amount for an initial investment. It must be noted that at 100 residential customers, barely enough clients needed to stay afloat, balancing revenues and expenses from our experience. Any significant problems or disaster could take the company out of business, without a safety net or outside financial backing. A more realistic minimum needed for profitability is in the 300+ customer range.

Investment 100 Clients		
Item	Details	Total Cost
Client Equipment	Average cost per client $100 - $150 and includes Core routers, Fiber Optical Line Terminals (OLT), the client Optical ,Network Units (ONU) SFPs, fiber cables, and other misc cost for installation.	$10,000 - $15,000
Staff Salaries	$2000 - $5000 per month including an accountant, an installation team of 2, and the owner who will also be working as part of the technical team. These costs are highly variable and dependant on minimum wage rate for the country where you will be deploying a network*.	$24,000 - $60,000
Legal + Licences	All the legal and licenses required to run start and run a company including: lawyers, telecommunication national and municipal licenses: fees to form a company, getting a bank account, and ongoing taxes.	Free - $10,000+ Varies based on country
Backhaul Internet	Backhaul cost for the year. Installation plus monthly costs.	$12,000 - $20,000
Total Costs		$56,000 - $97,000

The above is a relatively accurate ballpark cost to start a fiber to the home ISP in a country similar to Nicaragua. I started SayCel ISP as a combination of winning an Entrepreneurial award from NYU Berkley Center Social Venture Award of $25,000 and financing a large portion of equipment purchase through 0% interest credit cards.

Based on the experience from SayCel, 100 clients was the breakeven point. Our ARPU was about $40 per customer, so a monthly revenue of about $4000. Monthly expenses at about $3700: $2000 for salaries, $1000 for backhaul internet, $700 in fees, taxes, and licenses.

At this Micro ISP level, the business is not great, and profits are slim, if any at all. The only way to truly become profitable is to scale. Still, scaling requires additional funding, especially for equipment, and to cover some financial burn from additional staff needed to cover the growth in customers. On average, I would estimate every 100 customers would require an additional $15,000 investment.

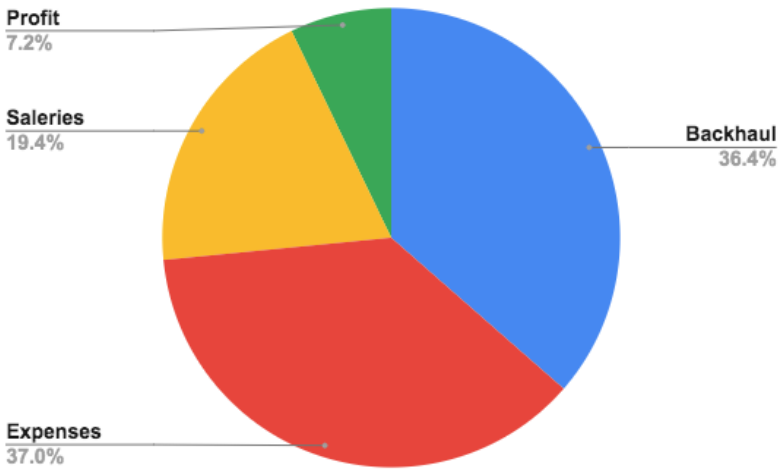
In regards to the product, when we first started, we had a 2 MB (U$25) plan - but those clients tended to have more problems paying on time or complaining about slow service. These clients cost us more due to the increase in customer service than what we would gain from them, and thus we now only offer a minimum of 3 MB ($35) clients and highly prioritize 5MB ($50) clients and corporate clients of 10MB ($100) or more.

Product

(Un)affordable Internet Backhaul

As a MicroISP entrepreneur, our basic **product** or commodity is the internet and the movement of our clients' packets to their desired locations, mostly google, Youtube, Whatsapp, and Facebook. Any ISP or community network needs quality, affordable backhaul internet.

I will clearly state our backhaul internet is not affordable!



A financial quarter from 2020 (SayCel)

I am not disclosing real dollar revenues for security reasons, but I hope this chart exemplifies the shocking amount we spend on our backhaul product. SayCel currently spends 36.4% of the total monthly revenues on backhaul internet. This is greater than our core personnel salaries

and nearly identical to our monthly expenses, including network consultant, taxes, licenses, maintenance, and office expenses.

I am officially not at liberty, based on an NDA with my provider, to say what I pay for backhaul. It's a mutual NDA, so they will not turn around and disclose our business secrets, so that's good. But this lack of transparent pricing is one of several reasons that affect backhaul prices, especially for small operators like SayCel.

TeleGeography

I made several attempts to get additional backhaul pricing information from other locations along the ARCOS Subsea Cable route. I wanted to compare pricing from one country to another and examine whether different factors contribute to pricing differences. The places I was requesting were:

Image: J.P.Lon~commonswiki[3]

Initially, I reached out to TeleGeography, a renowned resource for Telecommunications data. It is owned by Primetrica, Inc., a US-based Market Research & Polling Services company that generates $5.48 million in sales (USD). TeleGeography has a product called the pricing suite with backhaul and other IP services pricing data from 160 countries. The “Dedicated Internet Access Pricing Data - Data Cut” had a list price of $10,000, and I was given a discount price of $3,000. This was way more than the original LACNIC grant, so I begged and pleaded.

In my email I wrote:

“Who could I appeal to try to get the data at a more equitable price? We are not a large corporate entity.

The research I am conducting is to promote last-mile connectivity in rural regions for under-connected communities located next to fiber-optic landing stations. This is a huge problem where under-connected communities - sub 30% penetration rates - pay the highest connectivity cost.

My entire research grant is $1500.

The data points I would request could even be less than 10 locations.

I hope that TeleGeograhpy would be sympathetic to goals to promote the internet for all and promotion of last-mile connectivity for indigenous communities.”

[3] https://commons.wikimedia.org/wiki/File:ARCOS-1-route.png

My appeals did not work, and the best offer I received was for a slice of data for $1000. I couldn't afford the data, so I asked for an interview to understand their pricing model and business.

I got radio silence.

Cash rules everything around me!

C&W Networks

The Holy Grail of Backhaul Service

I had much better luck with C&W Networks, the largest subsea provider in PAN Americas. I was honored with an interview with Eduardo Gandarilla, Vice President of Sales and Marketing. I am always quite surprised when people of this magnitude offer up an hour of their time for me, the researcher, the microISP owner, and the kid from the hood.

A company like C&W sells to large conglomerates, and yet as I realized throughout the interview, they can see a value to Micro ISPs as an avenue for growth and future sales. Especially in rural markets like the Caribbean Coast of Nicaragua, where the full potential of internet penetration has not been realized.

My first question was, "What are C&W keys to success?"

Eduardo responded, "Well, first of all, is our customer experience. We provide the best service, and this means pricing, invoicing, and response times. All of this is everything for the customer. In the region, we have three types of customers we sell to the carriers, we sell to businesses, and in some countries, we sell directly to the customer".

In Nicaragua, C&W only sells to carriers, and according to Eduardo, only about 50 Gigabits are sold through their network landing stations in the country. This is compared to 40 gigabits sold in Dominica and the island with a population of 70,000, one-tenth the size of Nicaragua.
C & W sells 200 Gigabytes in Honduras, a country about Nicaragua's size, and 1 Terabyte in Puerto Rico.

50 gigabits sold seemed remarkably low to me. So I asked, "what percentage of total capacity available to C&W are they selling in Nicaragua".

Eduardo laughed "Maybe 1%. We have unlimited capacity on the network. Technology is improving; before the [fiber technology], we could only service 1 gig, it turned into 10 gigs, and now it is 100 gigs. Soon we will be upgrading to 400 gigs. With the technology improvements, you have pretty much unlimited capacity."

This was a revelation to me but also confusing. If there is unlimited capacity, then “What determines the pricing model?”

“Offer and demand” was Eduardo’s answer. “whatever is the offer and whatever is the demand. If the demand is too low, then the price per MB will be high. If the demand is high, then the price per MB will be low. It is cheaper to buy a Terabyte than a 1Gb.”

Of course, this makes sense. The greater the demand will drive down the price per Magebyte because more Megabytes, Gigabytes, and Terabytes can be sold. That’s why pricing is so cheap in the USA, where you can get a Gigabit backhaul connection from Florida (Hurricane Electric) at $400 and one terabyte at $1500 per month. This comes in at a starting price of about $0.40 per Mbps. This is in comparison to an average price in the region of about $10 Mbps. Eduardo assured me that most pricing in the region is about the same. This is as close as I got to verify an accurate price comparison that I tried to ascertain from TeleGeography.

So, in essence, the truth of backhaul pricing is based on the capitalist market. Pricing is determined by the economics of what the market will bear in each country or region. Are the local Internet Service Providers and corporate entities willing to pay $10 per Mbps? In short, yes. Without any real additional competitors in the region, the pricing model is not going to change.

Eduardo, and by extension, C&W view internet and backhaul service within a business framework. Which, of course, makes sense as it is a business, not a non-profit.

Eduardo passionately talked about the purpose of C&W Networks “Our mission is to connect people, we exist to connect people, that’s the only thing that we do. We do not give it away. We make money connecting people. I can make big money, or I can make little money, but I will always look to make money.”

As an entrepreneur myself, I am learning this lesson the hard way. I first got involved in networking to solve a problem. I was fueled by a passion for providing connectivity to disenfranchised communities. To give their youth and their populations the digital opportunities I had growing up. SayCel and I are constantly challenged by the economics of providing internet service. The statement **“We make money connecting people”** now resonates with me in a way that I was naive to realize when I got started in the internet business.

Eduardo went on, “We do not enable the internet for free. There was an initiative from Facebook looking for the internet for free. Our response was, ‘well, you build your internet for free.’ I mean, we don’t have investors that are for free…Facebook is doing it because they sell to advertisers, so you are not paying, but somebody else out there is paying; someone always pays for the network?”

This is true! Networks have costs; between workers, maintenance, and investors; networks are like children; you need to nurture them and take care of them to survive and flourish.

Despite my real understanding of the internet marketplace, there is still a driving nagging feeling of discontent. Everything Eduardo says is true but also unfair.

The market is still failing indigenous, rural communities. This is just a fact.

The capitalist nature does not drive any incentives for large ISPs to invest in these rural areas - the economics are not as good as providing service in large metropolitan areas.

They systematically depress the demand through their high prices, which keeps backhaul prices high, and competitors at bay. The current conditions are also not favorable to Micro ISPs or Community Networks to disrupt the industry. Most networks of my size are trying to solve a problem, not just maximize profits. Sure, we also want to make money. We need to make money. But we are also competing against large providers and buying market-driven expensive backhaul. This is a recipe for potential failure in a market-driven strategy to connect rural communities in Latin America. It is in the best interest of large providers for small providers to fail. Large providers do not want competition and can continue to maximize current pricing models. It's in the incumbents' best interests to keep backhaul prices high, and currently, there is no driving market force to drive these prices down.

Either way, there must be some middle ground where economic forces intersect with rural market initiatives that positively affect smaller communities. And this is where MicroISPs have a potential advantage.

In his final rejuvenating remarks, Eduardo said to me, "You can ask for a quotation. That's easy; we can give you a price. What we need are ideas. What do you want to do to develop an area? Let's talk about it. Let's see what you can offer, what we can offer. We are open to ideas."

And that's where it stands. I have many ideas, and I will soon present them to Eduardo. But I also know that my thoughts can not just be social-driven but must encompass a proper market strategy, not to connect a few hundred households, but the entire coast of Nicaragua. The whole segment of rural communities along the ARCOS I fiber optic route. That is the size of the economics I must pursue to truly succeed in the current rural internet service provider climate.

While this is contrary to the grassroots nature of Micro ISPs and Community networks. Building strong partnerships with subsea cable operators is equivalent to Jay-Z being a board member in Square, one of the largest mobile payment systems in the world, and having a partnership with the NFL.

UFINET

The Grow With You Backhaul Provider

UFINET is the largest backhaul provider in Central America. They service 18 countries and account for 70,000 km of terrestrial fiber stemming from Mexico to Ecuador. They were SayCel's first backhaul provider, as they were the only ones to offer an affordable connection fee and prices that allowed for a minimum of 10Mbps and increased as the business grew. At this low level of traffic, the backhaul pricing was not cheap, but it was "affordable", and we were able to get started with an initial $1000 deposit. One of UFINET's strongest points is their personal relationship with their clients, and Silvia Diaz Ulloa, Nicaragua's Commercial manager, graciously accepted my interview request. As we caught up, we talked about my family, and she mentioned a small gift, unique honey, and a care package was waiting for me. Each year a UFINET provides Christmas gifts to their clients. This is a lovely little personal touch that shows UFINET's personal commitment and appreciation to their customers.

My first question to Silvia was, "What has made UFINET one of the most successful backhaul carriers in the region?"

Silvia responded, "First and foremost, we are a carrier-neutral provider, and we provide service to 98% of all ISPs in the region. What sets us apart from other backhaul carriers is that we will never compete with them. We sell to them as backhaul carriers, but we do not sell directly to consumers. By selling to carriers and not to end-users, this helps us understand our customers' needs in terms of coverage and robustness of services. We dedicate ourselves to sitting down and speaking with our intermediary customers and produce products for their needs."

"Also our regional interconnectivity is the best. We have over 20 years of experience and grew out of having several national networks, Nicaragua, Colombia, Panama, and others, and put them together to build a strong regional network. All of these factors allow us to be flexible with our clients and our network. We negotiate terms with our clients, and we don't just pigeonhole ourselves or our clients into contracts. We try to work with them as best we can. This is true in terms of business relationships and service."

UFINET does have good customer service. In times of need, like when the pandemic hit and our bandwidth needs went through the roof, they provided us with a discount. A smaller discount than we have liked, but they did work with us to find a solution. I understand why they have had success, especially when it comes to the personal relationships they built with us as clients.

I went on to ask, "Who are your greatest competitors in the market?"

Silvia answered, "Well our biggest competitor is ENATREL, the national electrical company, and Cable and Wireless. What sets us apart from ENATREL is that we believe we can provide better customer service as a private company. With Cable and Wireless (C & W Networks), well they are also our customers. They buy transport from their landing station [in Bluefields] to the capital Managua. They are competitors but not as direct because they sell at their point of

presence in Bluefields and Puerto Cabezas. UFINET's focus is the entire region in Nicaragua and Latin America. There is also REDCA, (Red Centroamericano de Telecomunicaciones) and they also work with the energy companies in all of Central American. But their network is very linear and just goes north to south in Central America. While their network might be affordable, the linear nature makes them less appealing than our distributed network."

I continued to ask, "What about Claro, or Tigo, which are the major Internet Service Providers in the country? Do you see them as competitors?"

Silvia "Not as direct competitors, but as indirect competitors. If you [SayCel] go to the market and want to obtain an end customer, that customer will compare your offer with an offer from Claro or with the offers from Tigo. The prices do not compare, they offer much bigger packages, but you also can't compare their quality of service UFINET provides".

This is so true. We are continuously competing with Claro and Tigo, and their packages that claim to offer 10, 20 Mbps connections. But their service is of inferior quality, but the Mbps difference is contributing factors to market competition for us as a provider.

"So, how do you compete with this secondary competition?" I pondered.

Silvia "We started offering clients a new product which we call "Best Effort", it does not offer the same SLA we give to you [SayCel]. It is a product for limited clients, who don't have overly demanding needs. For example we don't offer "Best Effort" to a University because we do not provide the same amount of service. Of course we try our - best effort - to solve the problem, but not with the same urgency as our SLA clients."

"So, what determines your pricing model?" I asked.

Silvia, "Without a doubt, the market. UFINET provides a high-quality service, and we have to value our service at a premium price. But it's the market that produces the price which we have to use as a standard. We still sell according to the value of what you [customer] are receiving. But we had to adjust to market prices and that is where we have had to create new products. For example, Best Effort, is UFINET adapting to the market. There is a demand for quality high-speed broadband services at a more affordable price point. I usually compare with vehicles: it is like you want to sell a Mercedes or a BMW, at a price of Lada? We are selling a Mercedes, so we can't have prices for a Lada, but we can also offer you another premium car that is not as expensive as the Mercedes, but similar in speed and quality. We have to adapt to the market trends. In Nicaragua, the last mile prices, not the backhaul prices, are set by or imposed by Claro and Tigo. They are the ones who have the greatest number of end customers, and in turn, our customers, like yourself, compete directly with them. So they really set the prices".

I also wonder about the UFINET network's capacity, if they were similar to C & W, who theoretically has endless backhaul capacity. "Is there a limit to your bandwidth that you can offer?"

Silvia "Yes, of course, based on our equipment, there are areas where we are really about to become saturated. Then we will have to do a construction and create new fiber routes. In other areas like the Caribbean Coast of Nicaragua, we have a lot of capacity because we don't have many clients."

So I must say, if there is so much capacity on the coast, I wish UFINET would give SayCel a better price. But as with everything else in the Internet Service Provider business, I am still constrained by the "market" and the basic economics supply and demand. The economics of buying the only affordable Mercedes that I have available at the moment. This had me wondering about Silvia's of Nicaragua's lack of internet penetration".

"Why do you think Nicaragua has one of the lowest rates of connectivity and one of the highest prices in the region?"

Silvia" I do not agree so much about the highest prices, because I see with my regional colleagues, we have more or less the same market prices. In some areas, the prices are higher than here. But when it comes to penetration rates, the biggest factor is the country's poverty. Nicaragua is the poorest country in the region. The country's poverty does not allow everyone to have the internet because it is still seen as a luxury, and we see it with this situation of online classes that began last year due to the pandemic, where students from private schools had no internet at home."

I continued to inquire, "Do you think there is a lack of infrastructure in Nicaragua?"

Silvia "There is a lot of infrastructure in Nicaragua; we have network coverage in most of the country. But there lacks commercialization options for clients, and in some areas, there is a lack of infrastructure. Take a look at Puerto Cabezas. [UFINET] looked into it; we could build a fiber route there, which would cost $3,000,000. But there are only a few communities on the way there, and they are poor, and Puerto Cabezas would be the only place to try to recoup the investment. And how long would it take to recoup the investment? A long time."

I understood the economics of fiber builds. Puerto Cabezas and its surrounding areas are indigenous communities, where Spanish and Miskito are spoken side by side. They are even more rural than Bluefields, but statistically, they have a greater population. The theoretical market is there, but like most indigenous regions, they are poor.

I moved on to try to understand the network topology.

"I would like to know a bit more about the management of the network, where are you NOCs, and do you get service from C&W?"

Silvia “Our NOCs are located in Guatemala and Colombia. So for Nicaragua, everything is managed out of Guatemala. When it comes to bandwidth, we are part of a consortium with Maya Subsea cable, so for traffic via a submarine cable, we offload in Costa Rica or Honduras”.

Silvia had a great interview, and I learned a lot about their network, traffic patterns, and the local business of backhaul providers. UFINET is a quality business, and its customer service is, without a doubt, top-notch. But they are not without flaws. The biggest problem is the lack of redundancy on the Caribbean Coast. When their cable gets cut to Bluefields, the whole region's service is disrupted. This is not only true on our network, but we have also noticed service disruptions in other commercial providers. According to Silvia, traffic patterns would go through Honduras or Costa Rica and not use the C&W subsea system in Bluefields. This is a significant flaw in the network, not just for us but the entire country. Interconnectivity between these two providers would theoretically provide a better service regionally, especially on Nicaragua's Caribbean Coast. In the final section of this report, I will try to understand the traffic routes and validate some of the information provided by UFINET.

Rules, Regulators, and Rural Connectivity

Rules, regulatory environment, getting the right permissions, and licensing are critical components to a meaningful distribution of the internet in a community. Meaningful I define as providing internet services to the public, with a long-term financial and management plan to keep the service running.

There have been many projects that merely entail setting up free internet hotspots at schools, parks, and public areas. As Eduardo mentioned - even Facebook has gotten into the mix by offering “Free Basics” or free internet in certain communities. These projects are initially very popular, especially in rural communities, and the youth are yearning to surf the web, check Facebook, post pictures, and communicate with others. In the most economic, and hood sense, “it’s a taste”. Imagine endless internet at your fingertips. The latest dancehall songs, Bluetooth to your dual 15” woofers, pounding. Of course, the service might be slow at times, might not even work all the time, but when it does, it’s sweet and free!

In rural and underserved communities, the major problem with public hotspots is they are typically donor-funded and have a limited budget. If they are tied to international project funding from the World Bank, the United Nations, or any other sizeable multilateral organization, the sweet public internet might last a little longer. But when the funding is done, the internet stops flowing.

The economics of this are simple.

- Funding gets allocated.
- Project managers purchase the internet from a large provider.
- Funding is completed.
- Large internet provider shuts off free service.

Large internet service providers continue to offer expensive, limited MB-based prepaid internet packages, usually attained via smartphones. They got paid to run the free internet service and continue to profit from the end-users after being hooked on Facebook and Instagram.

Give anyone a taste, and you'll know selling the Internet is a great business!

Most regulators, as well as international organizations, are interested in finding solutions to connect the disconnected. In fact, much funding has gone to regulators and, by extension, to large MNOs as incentives to create infrastructure for rural communities. There is currently a $20 Million investment from the World Bank for the Caribbean Regional Communications Infrastructure Program (CARCIP).[4] [5]

A recent blog post from the World Bank "Access to Internet broadband is less than 50 % in the (Latin American) region, which leads to digital exclusion and limited opportunities for many". Especially with the advent of the COVID-19 pandemic, "Job creation is the most effective way to eradicate poverty, making it essential to invigorate the economies ...and to take advantage of the growth opportunities in many economic sectors, we must promote innovation, improve productivity and - above all - boost digital inclusion" This most certainly includes " Guaranteeing better Internet access for everyone is equivalent to multiplying educational, training and employment opportunities for the population. In other words, it will equip the population with more tools to address the enormous challenges of the future."

In many ways, it is a foregone conclusion that access to the internet can lead marginalized communities out of poverty, increase job growth and self-reliance.

I believe that along with investment in infrastructure there needs to be investment in building local Micro ISPs or Community Networks with sustainability plans. These entrepreneurs are the basic building blocks to having long-term sustainability by introducing real alternatives to existing MNOs, thus breaking the semi-monopoly cycle of high internet prices, limited demand, and low connectivity. Although I would argue the demand is actually high, the costs are also high for the end-user. Which in turn artificially depresses the demand and purchasing power for high-speed backhaul.

The Indigenous Kalinago Community Network of Dominica

In 2019 I participated in the development and deployment of a community network in Dominica. It was part of Garrett Huff's High School March Madness independent study project, SayCel, and the local community. Garrett Huff is an adventurous and kind-hearted student who was inspired by Hurricane Maria's events, which completely decimated the island of Dominica. He

[4]https://www.worldbank.org/en/news/press-release/2016/08/17/banco-mundial-apoya-banda-ancha-mejorada-y-nuevas-industrias-tic-para-nicaragua
[5] https://projects.worldbank.org/en/projects-operations/news-media/P155235

wanted to effect change and believed that helping a community rebuild its internet infrastructure was a way to assist in the aftermath of the Hurricane. Together we collaborated with Samoza Wilberforce John from the Kalinago territory and developed and deployed a network in their indigenous community. The planning took several months, but the trip and installation took about a week. We installed hotspots at the primary school, the Salybia Community Center, the Salybia clinic, and a local shop. The initial budget for the network install was around $25,000 for equipment, travel, and installation costs and was financed through an independent donation.

The Kalinago Territory also referred to as the KT, is similar to Nicaragua's Caribbean Coast. It is an indigenous community that historically lacks infrastructure and separated from the rest of the country in many ways. The Kalinago Territory was formed in 1903 by the British colonial authorities in a remote and mountainous area of Dominica. The land itself is of low quality, with limited access to the ocean, and susceptible to erosion. The Kalinago remained primarily isolated from the rest of the island, and remnants of this continue today. Most Kalinago don't participate in the formalized economy of the rest of the island. Hurricane Maria had a direct hit on the Kalinago Territory and completely decimated power and communications systems.

The Community Network has been operational, through volunteer support, mostly through Samoza's leadership, myself, and a few other community members. This has not been without its challenges: technically, socially, and significantly financially: There is currently a project to expand the network through the National Telecommunications Regulatory Commission (NTRC) of Dominica. They are providing additional equipment 26 additional hotspots, along with another management server.

My first question for Samoza, was "What has been the greatest challenges in building out the community network?"

Samoza "Our biggest social challenge is making people understand what and why we are putting the network together. Right now, we have the equipment, and people in the community still don't understand that this will be a community-owned and operated network. It's for us and good for us to maintain. This will give us control and sovereignty. This is the purpose of the network, but it is also a bit outside of what people understand about the internet. People usually pay for prepaid bundles of between $100 - $200 Easter Caribbean Dollars (U$37-$74). These bundles are limited, and in the Kalinago territory, your options are either LTE prepaid. A 100GB is about $140EC. I don't know about the higher packages because those were too much for my pocket!"

There is another option with Digicel with unlimited packages using AirFiber radios, but this requires line of sight from the tower. The Kalinago Territory is a really mountainous area. Many people spread out throughout the territory, which means most people can't get this service because they don't have a line of sight to the tower. And for the Kalinago people, it's actually expensive at $176EC (U$66).

So there is practically no residential service in the Territory. The NTRC asked the providers why they have not brought residential services to the Territory. The provider's response was they did a survey and did not make enough money to get fiber to the Territory houses. They said it is not beneficial to them to bring fiber to the home to the area. Yet we still have a fiber line that runs through the Territory and goes up to the tower, which they use to provide these prepaid cellular packages and the AirFiber.

The other problem here in the KT, they don't have jobs. Many people out of high school, out of college, there are no jobs. And we are about 1 or 2 hours away from the capital. After the Hurricane, one of the country's biggest jobs providers, the Medical School, closed. Tourism went down. And now, with the pandemic, even less tourism. Many people have large families. And the government has tried to encourage farming, but there are no markets to sell the produce. There is also the National Employment Program. But the people aren't paid a salary, but instead a stipend. Both these farmers and people who work for the National Employment program don't have any benefits, so it's a challenge here in the KT. So people really can't afford the internet".

"With the network, it has been tough to get support. Digicel and the government had a program where they set up the internet at the school. So for a while, we used the school internet as the backhaul for our community network. We used it for about three months, but after a while, Digicel said that we could not use the connection anymore. We had to stop. They said that the internet was for school, not to give out to people everywhere. The dumb thing is that the school were closed due to the pandemic. So really, the service was not being used at all in the schools, and we were trying to get students to use it at our hotspots.

"Another problem we had was with our volunteers. For a while, we had an excellent network technician. He was really helpful because he knew how to use our Mikrotik router and manage the network. But he also worked for one of the major providers in Dominica, and they said working on the Community Network was a conflict of interest. So we lost his help. It's all kinds of messed up because the network was originally built as a reaction to the Hurricane's devastation. The network volunteer, he was even part of the emergency committee that was created after the Hurricane, but he also does not want to lose his job."

"Right now, we are working with NTRC. It's good that they are working with us. They are providing equipment for 26 hotspots and a server. Sure there have been some challenges. They are slow. This is all new to them working in the Territory with a community network. We would have liked to have had more input; that way, we would have guided them properly. For example, the APs they gave us run on 48V, the point-to-points radios on 24V. From a solar perspective, it is much easier to have one solar system at 24V. And we already knew the right equipment to get that would have matched this voltage. But I don't want to complain, because it is all a big help. Also, they are going to pay for a fiber connection backhaul of 100Mbps, for one year. After the year, we are left to fend for ourselves to keep the network connected to the internet. Which we are told cost $6000EC ($2200) a month for that backhaul connection."

“Our hope with the NTRC is that we can grow our Kalingo Network to something better, bigger. But we need to have a real long-term sustainability plan which will include selling the internet. Be the Internet service provider for the KT.”

“Right now, the application for an ISP is $500EC (U$185), initial fee $20,000EC (U$7,400), +3% tax on the revenues. As an indigenous territory, and because the providers are failing us - and exploiting us - we must build our own network. But we also need to work on changing some of these regulations. A $20,000EC free for a Community Network to sell internet to stay sustainable is too much. We are the original people here, and we must exercise our rights of sovereignty and have rights to services like the internet. Why is it that in the capital and outside the capital, they can get cheaper and better service? Why are we not given those same opportunities? We need them for education, for job potential. It is very important for us. And that is why we are very positive about our partnership with the NTRC.”

Relationships
The Real Routing Map for Internet Traffic

My main initiative with this research was to understand the utilization or underutilization of subsea cable systems in Bluefields Nicaragua and other towns located adjacent to the ARCOS I subsea fiber system.

I believe it is illogical for packets to travel exceptionally far if you have a gateway to the internet at your doorstep. Nonetheless, the internet is a network of networks built over the past 30+ years. It is built-in a Frankenstein disjointed manner that many internet routes don’t make sense from a physical distance perspective.

Imagine a shipment of oranges was going to NYC from Florida. Now imagine that shipment arriving in NYC, but instead of unloading the oranges, they traveled to Chicago, Los Angeles, and then back to NYC. By that time, the oranges may be rotten. This does happen with internet packets as they take unusual long distances paths to reach their final destination. A more sophisticated computer scientist might tell you based on a BGP model, a packet finds the shortest path to its destination via BGP routing tables that tell the packet where to go. The shortest path is evaluated in various situations, including congestion control. In reality, the network of the network model, or more over the ISP to major Tier 1 and Tier 2 carriers, determines packets’ routes.

I ponder to think: are we using our internet efficiently? Our packets may not rot by the time they reach their final destination, but the longer the packet takes, the lower the service quality and the higher the price.

Mapping Internet Routes in Southern Caribbean of Nicaragua

I attempted to map the real routes of packets on the internet highways in Nicaragua’s Southern Caribbean region. Sure, I know the physical routes, you can view these maps at C&W Networks’

and Ufinet's websites, but I wanted to know the real routes packets traveled to and from Bluefields. Additional research and time will be required to realize an accurate routering map. With this research grant, I made a lot of progress, and I will review the undertaken process.

TracerouteSQL

github.com/ereedsanchez/tracerouteSQL

TracerouteSQL is a software tool developed by Daniel German Martinez and me that stores traces in SQL databases, geolocate, and visualizes traffic routes. We saved the traceroute information as both a python object with a randomized hash and within an SQLite database. The program was deployed on various hardware, including 2 Raspberry Pi B+, a Ubuntu Server, and a Kali Linux VMware image, in several Caribbean locations. The documentation for the software is publicly available via the project's GitHub.

I also wanted to set up a traceroute program in Dominica. Due to technical server conflicts and lack of time, I could not install a node in the Kalinago Territory. As I continue the research, I will add this traceroute node to the network.

Location	Host Network	Hardware / OS	Traceroute Destination
Bluefields, Nicaragua	SayCel	Raspberry Pi B+/ Pi O	• Vultr, Miami • Flow - Dominica • Tigo - Little Corn Island • Claro - Bluefields, Nicaragua
Bluefields, Nicaragua	Claro Nicaragua	Raspberry Pi B+/ Pi OS	• Vultr, Miami • Flow - Dominica • Tigo - Little Corn Island • SayCel - Bluefields, Nicaragua
Little Corn Island, Nicaragua	Tigo Nicaragua	Kali Linux VMWare	• Vultr, Miami • Flow - Dominica • Claro - Bluefields, Nicaragua • SayCel - Bluefields, Nicaragua
Miami, USA	Vultr, Hosting Company	Ubuntu Server 18.04	• Tigo - Little Corn Island • Flow - Dominica • Claro - Bluefields, Nicaragua • SayCel - Bluefields, Nicaragua

At each host node, tests were configured to run, traceroutes every hour to the destination's public IP address delineated in the table above. The public IP addresses were collected from the host nodes and used in the other hosts' traceroute parameters. For example, in the Little Corn Island node, we would run the command: `curl ifconfig.co`
This would return that node's public IP address and is equivalent to querying "What is my public IP" in Google. I would configure IP in the automation file that ran every hour in the tracrouteSQL software.

Due to security concerns, I will not include the host's actual IP address or the destinations. These will be delineated and highlighted in the following manner: Vultr, Miami, Flow - Dominica,

Tigo - Little Corn Island, Claro - Bluefields, Nicaragua, SayCel - Bluefields, Nicaragua. I will share the intermediary public IP collected in the traceroute and provide as best I can their geolocation information.

TracerouteSQL Data

The python files collected traceroute information, including hop, IP address, and TTL. Each traceroute test from the above location ran every hour, at intervals spaced by 2 minutes to let the traceroute complete before starting the new traces. I used an ipgeolocation.io API service from the python file to populate an SQLite database with the following details: IP address, City, Country, ISP, Longitude, and Latitude. This information is recorded in an SQLite database at each location, with a file name called *traces.sqlite*. The *traces.sqlite* file is then backed up on a local Apple iMac computer, where I renamed the files to reflect the location and date of the backup.*For example: CornIsland-Feb16-2021-traces.sqlite.* This file would contain all the information from all the tests since the application began running. Subsequent additional backups contain the same information from previous backups plus additional traceroutes from the previous backup date.

The trace files were then converted to a CSV file through SQLite on my iMac computer. With SQLite, I parse the files to only export from one destination. For example, I would parse the Little Corn Island node test to SayCel Bluefields IP. For this section, I will present a few routes and provide a map and analysis of each route.

The automated CSV and database files have several problems. The first is that in the traceroute, you may have more than one IP address, so in the automatic python algorithm, each IP needs to be in its own hop to run the geolocation IP API accurately.

The second problem is that ipgeolocation.io API is not very accurate, which is especially problematic in rural areas of the internet highways.

As seen in the below traceroutes, several hops are exchanged in Europe. I theorize this is likely inaccurate. I do not see a transatlantic cable that would make the shortest path possible to go from a remote Caribbean island to a remote Caribbean mainland city. The IP address with incorrect API location information needs to be further investigated.

Intercity Traffic

Claro Bluefields to SayCel Bluefields

In this section, I will examine how far a packet must travel to go from the Claro Network to the SayCel network within Bluefields' city limits. The location of each node was physically less than 1 mile away from each other. I chose this route because the SayCel public IP address I could verify would trace correctly. I attempted to route from SayCel to Claro, but Claro uses DHCP, and thus the public IP changed daily.

SQL Database of Traceroute

HOP	IP	COUNTRY	CITY	ISP	LATITUDE	LONGITUDE	DATE_CREATED	HOSTNAME
1	192.168.0.1	Nicaragua	Bluefields	Claro	12.006156	-83.771514		
2	190.212.156.1	Nicaragua	Managua	TELEMATIX/ E...	12.1172	-86.24081	2021-02-27 04:12:05.4...	
3	10.38.80.133	unknown	unknown	unknown	unknown	unknown		
4	10.192.108.221	unknown	unknown	unknown	unknown	unknown		
5	10.38.80.146	unknown	unknown	unknown	unknown	unknown		
6	62.115.173.202	Sweden		Telia Company...	57.70862	11.9913	2021-02-27 11:12:07.20...	
7	62.115.125.7	Netherlands	Amsterdam	Telia Company...	52.36757	4.90414	2021-02-27 11:12:08.06...	*mai-b1.ip.twelve99.net
8	195.12.254.86	Germany	Frankfurt	Telia Company...	50.1109	8.68213	2021-02-27 11:12:08.98...	francetelecom-ic152775-mai-b1.ip.twelve99-cust.net
9	193.251.254.124	France	Paris	Orange S.A.	48.86202	2.35896	2021-02-27 11:12:09.46...	unfinetpanama-1.gw.opentransit.net
10	170.80.19.94	Nicaragua	Managua	Ufinet Nicarag...	12.15056	-86.22403	2021-02-27 04:12:07.61...	
11	XXX.XXX.XXX....	Nicaragua	Bluefields	SAYCEL R.P.W....	12.01074	-83.76958	2021-02-27 04:12:09.9...	

Visualization

Based on the traceroute information collected, the packets seemingly go from Bluefields on the Enitel network to Managua, connecting to the Telia network in Europe, returning via Orange network to Managua, and finally back to Bluefields. The geolocated IP locations can not be fully verified, and further investigation will be needed to prove these packets were exchanged in Europe. Some clues point to having the traffic exchange closer to Nicaragua. For example hop 9, has a hostname of “unfinetpanama-1.gw.opentransit.net,” which I can assume means that the traffic is exchanged in Panama. On the other hand, hop 7 - hostname: *mai-b1.ip.twelve99.net, and 8 - hostname: francetelecom-ic152775-mai-b1.ip.twelve99-cust.net, do not generally indicate that these are located in the Americas. Telia, a backhaul carrier, only shows POPs in North America and Europe and no POPs in Latin America.

These tests are inconclusive as to whether the packets are exchanged in Europe. But it is certain these packets travel to Managua but do not exchange in Managua and route outside the country, in the Americas, or Europe returns to Managua and back to Bluefields. **Thus a connection from the SayCel Network to Claro Network in Bluefields theoretically may travel 3000+ miles to go a few blocks away.**

Inter-regional Traffic

Tigo Little Corn Island to SayCel Bluefields

Little Corn Island, Nicaragua, is 50 miles away from Bluefields. There a TracerouteSQL probe was installed on a virtual machine running Kali Linux. The route chosen to visualize was from Little Corn Island to the SayCel Network in Bluefields.

SQL Database of traceroute

HOP	IP	COUNTRY	CITY	ISP	LATITUDE	LONGITUDE	DATE_CREATED
0	152.231.32.202	Nicaragua	Little Corn Isla...	TIGO	12.28463	-82.977534	
1	192.168.43.210	Nicaragua	Little Corn Isla...	TIGO	12.28463	-82.977534	
2	10.218.160.154	Nicaragua	unknown	TIGO	unknown	unknown	
3	176.52.253.42	Spain	Madrid	TELEFONICA.C...	40.51683	-3.66682	
4	94.142.99.223	Spain	Madrid	TELEFONICA G...	40.51683	-3.66682	
5	94.142.98.184	Spain	Madrid	TELEFONICA G...	40.51683	-3.66682	
6	94.142.98.69	Spain	Madrid	TELEFONICA G...	40.51683	-3.66682	
7	193.251.255.29	France	Paris	Orange S.A.	48.86202	2.35896	tengige0-4-0-2.ashtr2.ashburnva.opentransit.net
8	94.142.99.228	Spain	Madrid	TELEFONICA G...	40.51683	-3.66682	
9	81.52.200.173	France	Paris	Orange S.A.	48.86202	2.35896	
10	81.52.200.173	France	Paris	Orange S.A.	48.86202	2.35896	
11	193.251.128.14	France	Paris	Orange S.A.	48.86202	2.35896	hundredgige0-5-0-3.chitr1.chicagoil.opentransit.net
12	193.251.255.249	France	Paris	Orange S.A.	48.86202	2.35896	hundredgige0-5-0-0.miatr2.miamifl.opentransit.net
13	193.251.132.138	France	Paris	Orange S.A.	48.86202	2.35896	hundredgige0-5-0-0.miatr2.miamifl.opentransit.net
14	193.251.254.124	France	Paris	Orange S.A.	48.86202	2.35896	unfinetpanama-1.gw.opentransit.net
15	193.251.254.124	France	Paris	Orange S.A.	48.86202	2.35896	unfinetpanama-1.gw.opentransit.net
16	170.80.19.94	Nicaragua	Managua	Ufinet Nicarag...	12.15056	-86.22403	
27	xxx.xxx.xxx.xxx	Nicaragua	Bluefields	SAYCEL R.P.W....	12.01074	-83.76958	

Visualization

According to the traceroute info, the Tigo Network packets in Little Corn Island immediately leaves Nicaragua on a hop that sends traffic to Spain via the Telefonica network. Then it transverses to the Orange network in France and then to Managua and Bluefields. These geo locations in Europe can not be verified. Nicaragua's exit via Telefonica makes sense because recently, Tigo purchased Telefonica's Movistar operation in Nicaragua. The Orange hops are presumably using the Orange OpenTransit network. Interestingly the hostnames point to making hops in Ashburn VA (tengige0-4-0-2.ashtr2.ashburnva.opentransit.net), Chicago IL (hundredgige0-5-0-3.chitr1.chicagoil.opentransit.net), Miami (hundredgige0-5-0-0.miatr2.miamifl.opentransit.net), and then Panama (unfinetpanama-1.gw.opentransit.net), on route back to Managua, and on to Bluefields. With this traceroute information, there is no sign of using the C&W Network or the ARCOS I cable

system. While I can not prove or disprove exchange of traffic in Europe, the hostnames do indicate that packets travel via an extended United States route leaving Miami, through Panama before getting to Bluefields, as opposed to exchanging in Bluefields where the packet must physically travel to get to the other hops along the traceroute chain.

US Bound Traffic

SayCel Bluefields to Vultr, Miami

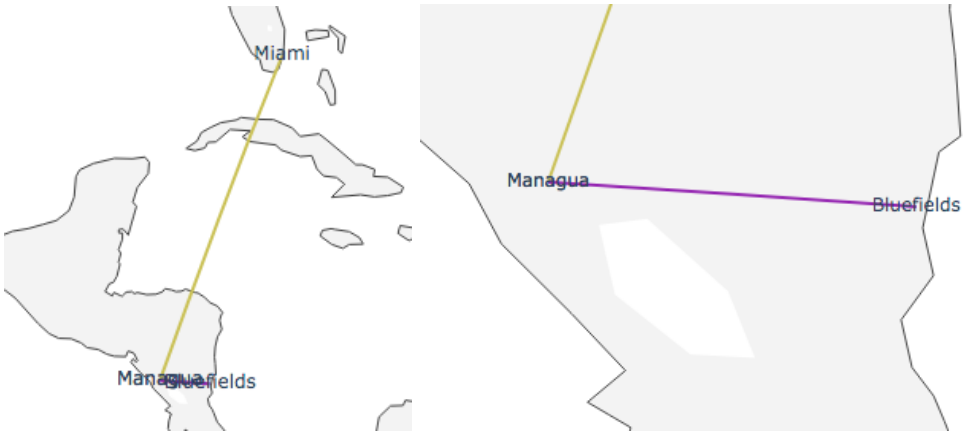
HOP	IP	COUNTRY	CITY	ISP	LATITUDE	LONGITUDE	
1	192.168.88.1	Nicaragua	Bluefields	SayCel	12.01074	-83.76958	
2	192.168.2.1	Nicaragua	Bluefields	SayCel	12.01074	-83.76958	
3	190.107.210.236	Nicaragua	Ciudad Sandino	Enatrel	12.15919	-86.36413	
4	63.245.6.38	United States	North Miami Beach	Columbus Networks IP TRANSIT	25.9229	-80.15635	
5	69.79.104.28	Puerto Rico	Luquillo	Liberty Cablevision of Puerto Rico, Inc.	18.37267	-65.72165	ae9.nmi-mx2020-1.north-miami.fl.usa.cwc.com
6	216.66.15.253	United States	Fremont	Hurricane Electric LLC	37.49103	-121.93088	100ge7-1.core1.mia1.he.net
7	206.41.108.73	United States	Miami	FL-IX INC	25.77583	-80.19295	
8	45.32.169.74	United States	Miami	Vultr Holdings, LLC	25.79751	-80.23006	

This traceroute shows packets going from Bluefields to Ciudad Sandino, located right outside the capital Managua and going on the ENATREL Network. The packet goes on the Columbus Networks, which is C&W Networks via exchange point in North Miami Beach, FL. It is unclear if this is via ARCOS I or the MAYA subsea cable network, both of which have C&W Network affiliations. From here, the geolocation points to exchanges in hop 5 - Luquillo, Puerto Rico and; hop 6 - Fremont, California with Hurricane Electric. The hostnames indicate that the packets stay in Florida with hop 5 (ae9.nmi-mx2020-1.north-miami.fl.usa.cwc.com ae9.nmi-mx2020-1.north-miami.fl.usa.cwc.com) and hop 6 (100ge7-1.core1.mia1.he.net). This route to Miami was significantly quicker and fewer hops than inter-regional or intercity traffic. It is somewhat illogical that packets travel faster to other countries than traffic within the same country.

Bluefields Bound Traffic From USA

Vultr, Miami to SayCel Bluefields

HOP	IP	COUNTRY	CITY	ISP	LATITUDE	LONGITUDE
1	206.41.108.150	United States	Miami	FL-IX INC	25.77583	-80.19295
2	170.80.19.94	Nicaragua	Managua	Ufinet Nicarag...	12.15056	-86.22403
3	xxx.xxx.xxx.xxx	Nicaragua	Bluefields	SAYCEL R.P.W....	12.01074	-83.76958



The route from Miami to Bluefields is direct. It exemplifies the relationship of the UFINET submarine partnership with the Maya subsea system. This provides a direct route from Miami to Managua and then onto Bluefields via UFINETs backbone. This represents the quickest route of all traceroutes presented in the above examples.

Traceroute Patterns

All the traceroutes represent just the beginning of a real in-depth analysis of traffic to and from Nicaragua's Caribbean Coast region. More needs to be investigated and explored. Recurrent IP addresses need to be validated. The biggest mystery is whether traffic is exchanging in Europe. Furthermore, traffic bound for other networks, including Tigo and Claro to and from the United States, also need further examination to see how much the ARCOS I subsea system in Bluefields is being used. The traceroutes ran from Jan 15, 2021, and continued through March 2021. I will continue to collect the traceroute information for later examination.

The major takeaway from this initial subset of traceroute information is the lack of C&W Networks in the traceroute IPs. This is the initial proof that the subsea system in Nicaragua is vastly underutilized, and by the evidence above, most - if not all - traffic exchanges in Managua. Furthermore, intercity traffic and inter-regional data traffic travel significantly further than traffic with destinations in the United States. The local traffic almost always travels internationally to service a local route.

As currently constructed, the internet on the Caribbean Coast of Nicaragua is of lower quality and results in high prices for local operators. There is an increasing demand for bandwidth, and the pandemic has exacerbated this. Local ISPs like SayCel have no choice but to purchase expensive backhaul to service a growing sector of users in the region who require broadband services. These increasing costs limit the ability for a smaller company to expand and reinvest in

scaling their operations, as they are keeping up with the cost of backhaul. The problem is even more acute in rural regions of Nicaragua's Caribbean Coast, where traffic does not immediately connect to the C&W subsea system but instead routes to Managua before exchanging in the US or Europe. Creating a knock-on effect of an even more considerable amount of bandwidth required to service the same customer needs.

Conclusion
So what now?

Let's be clear the current economic model has not solved the rural connectivity problem. It could even be argued it has contributed to the problem by encouraging high pricing in areas with limited bandwidth demands. That is not to say that there are no market or market growth opportunities in underserved indigenous, urban or rural communities - especially ones located adjacent to the subsea system. Major ISPs look at these regions as profit margins. They do not consider the overall value of the internet and its ability to increase education, job, and economic growth. The social goals of improving the internet are integral parts of Micro ISPs and Community Networks. In my experience, these entities try to solve a personal problem that affects the communities they live in. In other words, it is not just about the bottom line but also about the overall positive effect of improving connectivity.

Let's once again take a look at the music industry as an example. It was not too long ago where major label artists could go platinum and end up broke or in debt. Major labels owned the music they created, and they had little power over the monetization of the music outside of live concerts. It was pioneers like Jay-Z and Wu-Tang Clan that were able to flip this model on their head, retain ownership of their material, and grow their market. There have been tumbles along the way. Jay-Z's Tidal company never fully realized exponential growth and was sold to Square. Wu-Tang Clan was shunned by many of the major radio stations and faded into the background for several years until recently with a re-emergence of popularity exemplified by their recent documentaries and shows on Showtime and Hulu. Other artists, including Taylor Swift, have been able to use the new music economy to become huge industry players.

To quote Jay-Z, **"I'm not a businessman, I'M A BUSINESS ... MAN!"**

Even smaller artists today now have more control than ever. A viral hit on Youtube or TikTok could create an overnight sensation. Smaller bands through the internet and using sites like Spotify, Youtube, Apple Music, and Facebook give them access to a community and provide a support system for those artists to retain their product and monetize their music. The industry, which was once dominated by major labels picking the winners and losers in the music world, is now controlled by the people who listen to the music on the internet. The major players are now the distribution companies, the Apples, and Spotify of the world. The economics have changed and have changed for the better—both for the musicians and those who appreciate their music.

A change is also ripe in the world of internet infrastructure. Prices of communications equipment have gone down to the point where Micro ISPs and Community Networks are a real alternative

to the existing Major ISP model. But there are still several challenges, and there is a need to create a level playing field for them to operate. The economics of Internet distribution is not going to change overnight. There needs to be a reexamination of backhaul pricing as solely a supply and demand framework because currently, that framework continues to keep prices high and fail rural communities. Also, regulators of the IP addressing system should work on providing more information regarding traffic exchanges and update geolocation data. This would give a better understanding of the real traffic patterns and where there are bottlenecks in speed and quality, and overall connectivity indicators. IXPs could also potentially benefit rural communities, but that would assume the location of IXPs to be in the rural areas, which in many ways is illogical to the larger providers.

Nonetheless, the challenges for rural connectivity are not impossible. Focusing on the smaller players in these communities could go a long way in creating an equitable internet. Diversity and competition could increase connectivity and increase the potential for education and jobs in rural and impoverished regions. **Funding that has traditionally gone to large Internet Service Providers and MNOs to foster free internet programs should be reallocated to Micro ISPs and Community Networks as grants to build out local infrastructure and create sustainable business models**. Large-scale backhaul providers should consider lowering their prices to increase the local demand and thus increase overall profits.

Personally, SayCel's goal is to service the entire coast of Central America and communities lacking connectivity in the Caribbean; and do it with the best internet possible. SayCel can not do it alone. That's why I write research papers like this, which will hopefully provide insight to large decision-makers at the World Bank, United Nations, UNICEF, and other multilateral funding agencies. I also am committed to connecting with fellow entrepreneurs, indigenous communities, and community providers. It is also imperative to cultivate good relationships - business and otherwise - with the backhaul providers, the UFINETs, the C&W Networks; the regulators; the Internet registries like LACNIC; the non-profits like the Internet Society; and the multilateral institutions like the Caribbean Telecommunications Union, the International Telecommunications Union. Together we can create a more equitable internet, but let's not forget that the last mile - the hardest mile - will be on the backs and hard work of the Micro ISPs and Community Networks.

Acknowledgements

I want to thank my interview subjects, Eduardo Gandarilla (C&W Networks), Silvia Diaz Ulloa (UFINET), Samoza Wilberforce John (Kalinago Network); Daniel German Martinez and his

contributions as the technical advisor, and software developer; Nigel Cassimire (Caribbean Telecommunications Union); Alejandro Acosta (LACNIC) who gave me insight on traceroute data; and of course LACNIC for awarding me this grant. I would also like to acknowledge the SayCel staff and the tremendous free materials available from Telegeography. A special shout out to Alexander Scott and Thomas Pruett for allowing me to deploy a TracerouteSQL probe on their network, as well as my wife and partner Sania Woods. And a final shout out to Jay-Z and Wu-Tang Clan, the RZA, my mother Minerva A. Sanchez, and my father William T. Reed, and all my childhood heroes who made me dream big!