BSP
Technical Advisors

Technical Assessment

of

123 Telecom

for

456 Capital Partners

Phase 1

Red Flags Assessment +
Network Upgrade Options & Costs

Table of Contents

BSP

I. Introduction

456 Capital Partners is considering an investment in 123 Telecommunications, Inc. (123 Telecom). 123 Telecom provides data, Internet, video, voice and managed services to consumer, commercial and carrier customers in XX states over XX,XXX of fiber route miles. They are a Top 20 fiber provider in the U.S. 456 Capital Partners has requested this proposal from BSP to conduct a dual phased evaluation of 123 Telecom's network.

Phase 1 of this evaluation includes a thorough review of the information provided by 123 Telecom and comparison with industry norms and observed features. Drawing on our experience, we will identify any "red flags" that could adversely affect the outcome of the proposed investment.

This inquiry will include particular scrutiny on cost items indicated by 123 Telecom and the vetting of each of those figures against industry norms and practices. This phase was performed by BSP remotely from BSP's own offices via internet and phone.

II. Summary

123 Telecom does not have a large number of customers compared to most ILECs, however the geographical area covered and the rural areas that make up the footprint make it necessary to manage as a very large company.

Like many smaller telcos, 123 Telecom has deployed FTTH successfully. The FTTH networks, however, only represent a fraction of 123 Telecom's network. A significant amount of work lies ahead to replace the aging copper infrastructure.

123 Telecom has decided wisely that upgrading to FTTH will provide the competitive products it will require to expand its customer base, whether in the face of MSO or wireless competition. It has demonstrated that it can build these networks efficiently.

While we identified "Red Flag" items in the areas of incomplete network design estimates, delayed transition from analog HFC, and certain customer service metrics, as well as some incomplete or inconsistent responses, our outlook on 123 Telecom is favorable for considering investment.

III.Methodology

Per our Statement of Work, Phase 1 will be accomplished by completing these actions:

1. Review and validate network information provided by 456 Capital Partners and 123 Telecom
2. Interview 123 Telecom CTO and his team
    - Request any necessary documents not already provided
3. Identify items of significant interest for examination in Phase 2
4. Review specific cost information provided by 123 Telecom for their network upgrade plans
    - Capital budgets
    - Operating budgets
    - Labor costs
    - Material costs
5. Compare cost information provided with reasonable and accepted figures on a line item by line item basis
6. Initial base case forecast including cost per passing, success-based capital, drop cost (CPE), maintenance capex and any material cost
   (BSP will be assisted by 456 Capital Partners provide cost to develop base case forecast)
7. Review operations organization structure and ensure optimized cost structure
8. Review OSS/BSS and cost savings/risks
9. Highlight any major "red flags" and recommend next steps

IV. Network Information Validation

123 Telecom has provided a network information via an online "data room". The information includes plant mileage and routes, examples of central office rack layouts, network diagrams and maps, cost information for certain deployments, network utilization, etc. Let us examine each of these, and grade the material as "Expected, Unusual, Incomplete, or Red Flag"

A. Plant Type Mileage

This list of copper, fiber, and coax mileage by state shows us:

1. There is very little FTTH in the network, several states have none
2. The only coaxial network is in ABC Metro

This data has been validated by examination of the KMZ files to the extent possible, given the lack of house count and footage information. We have not received a national fiber map.

Expected

B. Fiber Route Miles

As would be expected, fiber is used extensively inter-office throughout the network and must be validated by examination of the inter-office network diagrams.

Expected.

C. Office Rack Examples

The supplied rack elevation diagrams are very sparse. They do show that there are such records, and that there is not standardization from region to region in terms of rack numbering. A more comprehensive look at CO design and layout would be a part of Phase 2 of the Due Diligence investigation. Because investigation of specific equipment is out of scope for Phase 1, this is not considered to be a "Red Flag" item. We also have no reason to believe that any equipment is sub-standard.
Incomplete.

D. Optical Network Diagrams

Basic diagrams include connections to a 100G customer, the JKL network used for VOIP business customers, an inter-office DWDM network in Region Z, the national Core network, DWDM interoffice connections in Region X on Acme and Brand X DWDM networks, and DWDM interoffice connections in Region Y using XYZ equipment.

The two interconnect networks use modern technology and the coverage of the networks appears to be complete in terms of hitting all of the central office areas.
Expected.

E. KMZ Files (maps)

The KMZ files provided in 1.1.5.x include existing networks throughout the 123 Telecom footprint. Coverage and routing are reasonable. By using Google Street View, we were able to get an idea of how some of the Central Office and Cabinet facilities look from the outside.

1. ABC Metro Network

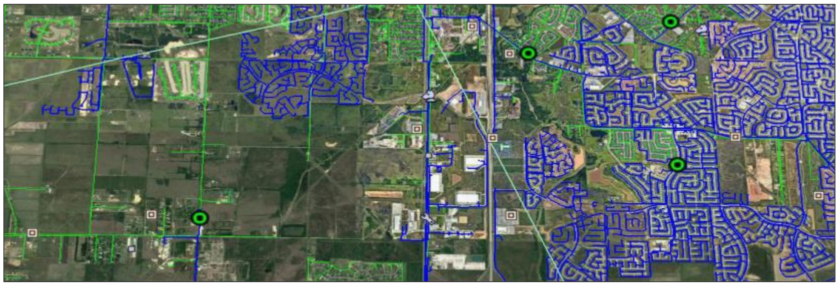
ABC Metro is mostly built with HFC. Yet, there are FTTH areas, as shown here:

HFC areas are shown in green, while FTTH is in red.

2. DEF Muni Network

The KMZ file contains details of DEF Muni. About half of DEF Muni has FTTH available. The file does not break down aerial versus underground.

The FTTH project appears to be in-progress, with several communities having both copper and fiber routes shown.



DEF Muni network with fiber in blue, copper in yellow

F. GPON Per Sub Cost

This is one of the most important network files provided. This spreadsheet shows the itemized cost of everything involved in provision of GPON service to customers as part of an upgrade from BPON to GPON. While the costs are valid to consider for an upgrade from copper to GPON, as will be our primary case, the file does not include drop installation, which must be obtained from other sources. Looking at the information provided in the spreadsheet, we can validate that the prices are reasonable for these items, including:

1. OLT and ONT combined cost

Costs for various OLTs and ONTs from Acme and Zebra are detailed for both indoor and outdoor use. Acme prices range from $XXX per subscriber for a very large XXX PON unit to $XXX for a 40-PON shelf fully loaded with cards. Zone prices range from $XXX per subscriber to $XXX per subscriber.

These are large ranges to consider. When evaluating a new FTTH build, we should limit our concern to INDOOR ONTs, which are considered to be easier to install and maintain than outdoor units. Further, we should limit our discussion to NEW SHELF deployments, because most of the areas we are considering have no existing FTTH. With those limitations, the range shrinks to $XXX to $XXX across both vendors.

2. Other Costs

The CTO team explained that the entire success-based cost for a new FTTH home turnup is $XXX.

Expected.

G. ABC Metro CMTS upgrade February 2020

A PowerPoint presentation showing the HFC upgrade plans for ABC Metro's coax customers. The ABC Metro HFC system, and reasons for its Red Flag indication, will be covered in depth in the Red Flags sections below.

Red Flag.

H. Market Build Sample

We are presented with details on the fiber upgrade plans in a segment of this geography. These folders contain material which is the main focus of our cost validation exercise. We have requested similar detail on additional areas to better understand the variation in cost from area to area in the Residential Wire Center Detail – Capex Build file.

1. Fiber Design Coverage

The KMZ file seems to have extraneous conduit paths (under airport runways and wooded fields) and isolated copper and fiber segments (not connected to anything). In order to determine if this is significant, we would require validation by 123 Telecom. Is the plant really there, or was this an error in creation of the KMZ? The total footage of these mysterious segments is not very significant compared to the overall map.

The KMZ file for “Market Build Design” may have entire neighborhoods omitted from consideration. For example, the area around this area on the east side has at least XX homes has no design. The area on the west side also has no design. We must determine if these areas are included in the home count and then decide if this indicates an incomplete build of the town or an incorrect design. Either would affect the budget. A review of the spreadsheet shows that two areas do correspond – the streets and facilities agree in terms of name and fiber count/type – however the fiber length does not match. This could be due to how the lengths were input into the KML.
Red Flag.

2. Per-Foot Fiber Cost Estimate Inconsistency

An examination of the budget files provides detail on how these project costs are made up. These files contain very few itemized material costs, and a large amount of cost allocations. The CTO explained that miscellaneous materials are listed as “Exempt Material”. By totaling the Exempt Materials and the listed fiber cable and poles, we can calculate the material cost, and by totaling all of the allocations and hourly labor items we may determine the labor cost. With this information, we can fix the actual per-foot costs:

Fiber Build Actual Cost Summary				
	Model	Cost per Foot		
Model	Footage	Material	Labor	Total
1	2892	$ 0.62	$ 6.52	$ 7.14
2	3546	$ 1.30	$ 1.86	$ 3.16
3	17542	$ 0.95	$ 2.02	$ 2.97

4	2160	$ 0.90	$ 5.93	$ 6.83
5	2100	$ 0.77	$ 3.98	$ 4.75
6	18506	$ 0.64	$ 1.89	$ 2.53
Global Average				
Project Average				

These are reasonable numbers.
The Overbuild Costs file **seem to tell a different story**. Those builds ended up costing between $X.XX and $XX.XX per foot. Here we summarize those spreadsheets:

Exchange - Work Required	FDH Cost	Aerial Fiber (ft)	Aerial Fiber Cost/ft	Aerial Fiber Cost	Underground Fiber (ft)	UG Fiber Cost @	Total Fiber Required (ft)	Average Fiber Cost/ft	Totals
A									
B									
C									
D									
Totals:									

It is unknown why the "Aerial Fiber Cost/ft" varies so greatly between these four markets. In order to better understand, we will require the same level of detail provided for the XXX areas.

File XX states, and the CTO team confirmed, that $X.XX is the per-foot number used for the Fiber Construction budget. **If the information in file XX reflects true costs, it may be better to use the $X.XX to $XX.XX range when budgeting for FTTH.**
Red Flag.

I. Utilization

1. Core Network Usage Report

The first section, Internet Uplink Usage, uses the term "xx% used at max" for each item. If this is meaning that the utilization maximum is a xx% of the link capacity, all of the numbers are reasonable. KS and NNE are at 70% should be considered for augmentation this year.

The second section showing the National Core links usage shows no numbers above xx%, which is quite acceptable and shows no need for near-term augmentation.

In-region MPLS Core usage is described in a narrative. The philosophy is sound. The chart in file XX may be detailing this for Region X, but no other areas are so detailed.
Expected.

2. Core Top 20 Link Usage Report
The “top 20” list shows several links operating very near 100% maximum utilization. If so, these links should be upgraded as soon as possible. We asked 456 Capital to relay the concerns to 123 Telecom.
Unusual.

J. FTTH Samples

1. DEF Muni FTTH Example 1,2,3
These drawings detail FTTH design in residential neighborhoods. They show a good detail to proper workmanship in design. No problems found.
Expected.

2. GPON Deployment Legacy 123
This block diagram shows how legacy voice, data, and video networks connect to a fiber access network. Note that the unit labelled as a DSLAM is actually functioning as an ONT (though it may be both). It shows a PON feeding 32 homes, which is normal however it disagrees with the 16-homes per PON described in our first technical call.
Expected.

K. Planning Initiatives

1. Development flow Tech Dev NAT
The process flow diagram shows how a tech dev project progresses through various decision stages. It is reasonable for an organization as large as 123 Telecom.
Expected.

2. Network Architecture Initiatives 2020
These are reasonable items for the CTO team to be looking at strategically, but some should be well underway – particularly IPv6 and SD-WAN. IPv6 was deployed by major MSOs over ten years ago, and address shortages were anticipated then. SD-WAN has been deployed by others for several years. Also note that XGSPON might be a stepping stone beyond GPON ahead of NGPON2.
Expected.

L. Fixed Wireless

1. Wireless Network Drawing

The diagram shows roaming connections from X to wireless carriers, WISPs, IoT providers, and content providers as well as peering between CCI/WPN and wireless carriers. We are not sure how this relates to the 123 Telecom network or its architecture.

Expected.

2. Detail Drawing – CAF-II

A series of diagrams show specifically how the 123 Telecom COs are connected to wireless tower partners. Good detail. Page 4 shows that the firewall equipment is part of the network. That is a good choice.

Expected.

M. DEF Muni Highest Port Grades

The spreadsheet shows the type of ports available for data access services in several COs in DEF Muni. It is quite a mix of various DSL and fiber port capabilities. I put a count in for each port type.

Ports	ADSL-3	ADSL-6	ADSL-8	ADSL-15	SHDSL-1	VDSL-01	VDSL-02	GPON-2
Max Mbps								
Video								
Total								
Percentage								

While this tells us that DEF Muni does not offer many of its customers GPON service, it does not necessarily imply anything anywhere else. I am surprised that such a wide range of DSL capabilities are available in the same central office in many cases. The max speed for GPON should be indicated but is marked “Future Use” in the legend sheet.

Is it important to consider particular DSL port speeds for possible upgrade to faster speeds, and is this information required for other areas?

Incomplete.

N. MPLS Core Design

This diagram shows a very detailed view of the MPLS Core Network. It shows nodes throughout the state. If this is representative of the entire 123 Telecom MPLS network, we can say it is more than adequate.

Expected.

O. Fiber Copper Information

Refer to KMZ file 4.1.5.3. This file shows the total amount of fiber and copper plant included in this network, itemizing individual cables and summarizing aerial and underground portions:

BSP

Fiber Cable	Length
Area 1	
AER FIBER DROP	
AERIAL FIBER	
AERIAL FTTP	
UNDERGROUND FIBER	
UNDERGROUND FTTP	
Area 2	
AER FIBER DROP	
AERIAL FIBER	
UG FIBER DROP	
UNDERGROUND FIBER	
Grand Total	

These totals are reasonable. Having the costs for each of the items would be helpful to determine if this played a role in the per-foot estimate discrepancies noted above.

P. 2020 Q1 CapEx Success Based Breakdown

Detail in this xxx,xxx-line spreadsheet shows the different costs required to connect residential and commercial customers. Although the spreadsheet is very detailed and breaks down every itemized expense, labor information is coded with undefined 123 Telecom references. We sorted and filtered for material.

Unit prices for material such as fiber jumpers, panels, T1 mapper cards, pluggable optical modules, optical attenuators, and various hardware items picked at random seem to be reasonable. A comprehensive review of this list would necessitate a project of its own.

If all CapEx including Maintenance CapEx is based on the material costs in this list, we can say that those material costs should be considered reasonable.
Expected.

Q. DWDM 10yr list- IP overview

This document lists current DWDM platforms in use at 123 Telecom and counts each DWDM network element. Platforms selected are all well-regarded and commonly used in the service provider space. We have direct experience with several of them.

The document also describes the routers and how they are used and are being migrated to other routers in most instances. This is good practice.

Carrier grade NAT (Network Address Translation) is planned. This is acceptable, however if 123 Telecom were further along with IPv6 it might not be necessary.

The SLA monitoring platform is described. This is acceptable.

Routers as Broadband Network Gateway in major markets are being migrated to geo-redundancy. This is good practice.
Expected.

R. Market Matrix

This spreadsheet lists all of the rural markets acquired from X, and which offer IPTV, Cable, and FTTH products. Other tabs list the IPTV and Cable markets among them. This is nice to know, however home and subscriber counts, plant mileage, etc. are not shown.
Incomplete.

V. CTO team Interview

We interviewed 123 Telecom CTO and several of her staff and peers. Information from this meeting is used throughout this report. The team is well versed in operating a broadband network; however, they have wide-reaching responsibilities running a national network made up of disparate pieces. They would benefit from more high-level engineering capability at the regional systems.

VI. Review of Specific Cost Information

A. Capital Budgets

This document details the Consumer Build Capital Methodology. In that document, the reasons behind the budget for the SSW FTTH upgrade are described. The document lists construction costs at $X.XX per foot aerial and $XX.XX per foot underground. This contrasts with the standard mile costs of $X.XX per foot aerial and $XX.XX underground described during the CTO team interview. The reasons for the higher Region X costs are sound, and we believe the numbers in the standard model are low.

It is sound judgement to use higher figures in Region X, and this is borne out by the actual costs in the files as explained above.

This spreadsheet estimates cost by wire center and arrives at an average per-passing cost of $XXX per home. This is reasonable, noting that this does not include any of the success-based costs of actually turning up a FTTH home. Those costs are estimated by 123 Telecom to be $XXX per subscriber location, which we also find as reasonable. The Cost Per Connection in this document shows $XXX equipment + $XXX labor which agrees with the $XXX total.

The detail in this file as explained above shows much higher per-foot construction costs even than is budgeted in the spreadsheet, ranging from $X.XX per foot to

$XX.XX per foot. This is based on a much higher aerial fiber cost per foot in that model. We are trying to determine the cause of this higher cost. I do not think that $X.XX is unreasonable, however $XX.XX is very high.

B. Operating Budgets

Only high-level operating budget expenses are listed in the P&L sheets.

It is important to check the regular costs for facilities, supplies, repairs, salaries, office expenses, travel, vehicle maintenance, etc. While the file does not itemize these specifics for business as usual, documentation for the initial base case growth seems reasonable.

Examination of proper operating budgets will tell, among other things, what proportion of 123 Telecom's network locations (buildings, hub sites, wire centers) are in owned versus leased facilities. It is risky for a service provider to use facilities owned by others. Also, the "COGS" line I assume includes all programming costs for the video business. These should be examined to determine the impact of ever-increasing carriage charges from programmers and local TV stations, and annual adjustments to budget should be checked to match these increases.

VII. Operations Organization Structure

123 Telecom has provided a 250-page organization chart showing all of their employees and how the reporting is structured. For a large organization, we feel that these structures are logical and do not, on their surface, reveal any structural problems or "Red Flags".

The organization chart has provided us with information detailing where NOC facilities are located, and we can also derive which CO locations are under which region's control.

We can also determine that provisioning is performed on a local basis rather than regionally. This could be an opportunity for future consolidation.

VIII. Review of Operational KPIs

Document 14.2.4 contains a presentation of Operations Overview KPIs. We compare these figures to industry norms:

A. Consumer Care

1. Calls Offered and Service Level (there are different ways to calculate Service Level)

   XXXK calls offered with just below xx% Service Level in Jan of 2018. (What is the 123 Telecom definition of Service Level? Does this indicate calls answered within one minute/calls offered?) April of 2020 shows XXK calls and xx% Service Level. Graph on Page 2 shows for most of 2019, Service Level was xx% to xx% - but big drop off in March & April - red flag but could be Covid-Related.

2. ASA (Average Speed of Answer) and Abandon %

   xx% abandoned calls in Jun 2018 to xx% calls abandoned in April 2020. ASA ranges from under one minute to almost X minutes over the same period.

   Calls abandoned should correlate with ASA – longer time on hold, more people hang up. Also, can be considered a good measure of customer satisfaction – faster call is picked up, happier customer is. Most Call Centers target x% or less abandoned calls – but often depends how measured. Red Flag for March/April 2020 – but again could be COVID related. They should be offering call back if not doing today.

   March of 2020 and Nov of 2018 were outliers for abandoned calls – usually network/operations issue causes high level of calls and associated Hold Times and Abandonment rate. Good to find out what caused the spikes.

3. AHT (Average Handle Time) and Cost per call

   Average Handle Time ranges from X.X Minutes to X minutes. Cost per call ranges from $XX to $XX.

   .

   Many KPIs, including Average Handle Time, have been impacted by the introduction of digital channels. Since customers are more likely to address simple issues via digital self-help service options, the voice channel is being used more often to address complex issues – increasing average handle time.

   Cost per call here is a red flag. A mid-sized MSO has approx. $X cost per call – including overhead and allocations for telecom switch and lines.

4. Productivity

   Occupancy rate is a way to measure call center agent productivity across all their call-related duties. It's the measure of how much time your agents are on live calls and/or finishing up work related to those calls.

   The graph on page X shows productivity increasing from XX% to XX% over a one-year period. While going in the right direction, XX% would be more acceptable. Might consider skills-based routing – sales, tech support, billing – to improve average handle time and productivity.

   Install Duration – was X weeks; now down to XX days. Still seems pretty high. Cable guys were working toward same day install. I get number porting can add days to install – but still high.

B. Call Center Rep

1. Calls offered and Service Levels
   xx% Service Level is good.
2. ASA and Call Abandon
   Looks good
3. Cost Per Call
   Starts at $XX (terrible) and drops to approximately $XX. Still high but more reasonable.
4. Productivity
   Improving from xx% to approx. xx%. Better – but north of xx% would be good.

C. Repair/Tech Support

1. Calls Offered and Service Levels
   Looks good – around xx%.
2. ASA and Abandonment %
   Abandonment rate generally looks good – less than x%. Big spike in May 2019 – assume network issue?
3. AHT and Cost per call
   Okay – X.X minutes in February 2020 with approx. $XX per call. Tech Support agents have higher pay scale than traditional call center rep, so even better.
4. Productivity
   Looks low – xx% in April 2020. Might be overstaffed on Tech support side?

D. Broadband Tech Support

1. Service Level
   Big drop in Feb, March and April 2020 – Red Flag. Could be Covid-Related?
2. ASA and Abandonment Rates
   Abandonment rates were high in 2019 – Red Flag.
3. Cost per call
   Seems good - $X in Apr 2020. Best of group.

E. Automated Order Flow Thru

We are assuming this is the percent of orders that can be handled without human intervention. Reports appear steady at around xx-xx%. We cannot comment without knowing what is expected.

F. Technician Productivity

1. Jobs Per Day
   Legacy – X jobs per day is pretty good
   Region X – under X is Red Flag

2. Customer Appointment On Time %
   Legacy OK at around xx%
   Region X Red Flag at xx% or lower

G. Trouble Trends

Region X looks poor – Red Flag

IX. OSS/BSS and Cost Savings/Risks

A review of OSS/BSS tools used for network monitoring shows well accepted products that are current state of the art, however we are not certain how they are integrated with one another and how personnel are using them.

In the organization chart examination, it seemed that certain functions were performed on a per-state rather than per-region basis. Reorganization of these functions to a regional control could lead to cost savings. Because the scope of NOC facilities is so widespread, consolidation to one or two national NOCs is probably not advised.

X. ROW Costs

ROW costs are described as "minimal". However, we were informed that there is a hidden cost: time. The permit process in Smith County is reported to take 60 days, while Jones County takes 45 days. The city itself can take 3 to 6 months.

These delays make it difficult to provide quick service to any customer where lateral construction is required, however all competitors would be subject to the same challenge.

XI. Colocation Costs

123 Telecom does not provide colocation services to others. Below we have listed the reported costs that 123 Telecom pays others for colocation facilities.

XII. IRU Review

We were provided with over 1,600 documents reflecting IRU, Lease, and Swap agreements between 123 Telecom and other parties. While we will examine each company's folder, we will review only the most important of these, in terms of significant cost or critical need as network infrastructure.

A. ABC Duct (Lease)

The ABC Duct folder includes a boilerplate agreement for CLECs, one appendix specific to duct rental, a second appendix which is a non-disclosure agreement, and a signed Letter of Authorization indicating who at 123 Telecom can place orders with ABC Duct. The generic costs for rental of these facilities are:

- Pole Rental $X.XX/year
- Duct Rental $X.XX/foot/year
- Innerduct Rental $X.XX/foot/year

We are also provided with a transaction report spreadsheet as well as two dispute report spreadsheets. These detail the costs for each rented duct and the amount paid.

The total distance of XXX,XXX feet was charged at the “Half-Duct” rate equal to the innerduct price listed above. There is also rental for XX poles.

The ABC Lease UG layer of the KML file totals XXX miles, which is consistent with growth from the XXX miles in the bill. ABC recently added a fee of $XXX for access to a manhole which is a significant cost.

We are concerned that the most recent date for any of this material is 2014. Otherwise, this is reasonable and expected. The rate charged for half-duct by ABC is quite reasonable.

B. DEF (Sale)

Two sale routes are provided:

1. DEF ROUTE 123

A bill of sale and maps are provided indicating sale of X miles of fiber cable route. There is no financial information provided.

2. DEF ROUTE 456

This folder contains several agreements dated between 2000 and 2001 for various lengths and fiber counts. There is an invoice for $XX,XXX for X,XXX pole attachments at $XX.XX each. A bill of sale for $XXX,XXX for the IRU is in the file. Another document confirms that 123 Telecom is responsible for acceptance testing. Because this appears to be an outright sale, we can assume that 123 Telecom is responsible for maintenance.

Reasonable and expected.

C. GHI (Swap)

The agreement involves about XXX route miles of fiber originally placed by GHI, development of system segments for both GHI and 123 Telecom, and provision of fibers from 123 Telecom to GHI in other routes. We would consider this a “Fiber Swap”. This route system provides extensive access in downtown and immediately surrounding areas.

Documents in the folder include NOC escalation policy, construction schedules, colocation agreements, etc. Also included were map files in formats we could not decode. The main agreement indicates that in exchange for these routes 123 Telecom will provide other routes to GHI.

Reasonable and expected.

We are concerned with the absence of lack of an executed, dated, and financially complete agreement.

In summary, the IRU/Lease/Swap arrangements made by 123 Telecom are all reasonable and expected. However, we are concerned that these arrangements constitute infrastructure critical to 123 Telecom's business, and more care should be paid toward maintenance of these agreements such that they are in good, legal order. Many of the documents presented are unsigned by one or both parties and are presented in a haphazard manner.

XIII. Upgrade Options & Considerations

A major difference between FTTH and most DOCSIS networks is that the latter delivers asymmetrical service with download speeds greater than upload speeds. This is due to a small portion of network bandwidth being allocated to the upstream direction. However, current upload speeds over DOCSIS are sufficient for today's needs. In the future, both upload and download speeds will need to be increased.

The main purpose of DOCSIS 4.0 (over DOCSIS 3.1) is to provide operators with additional data bandwidth, both upstream and downstream, by specifying equipment that can use additional spectrum in an efficient manner.

The DOCSIS 4.0 specifications are "feature complete and stable" according to principal architect on the DOCSIS 4.0 standards. He also confirmed that "DOCSIS 4.0 pretty much implies changing the return split. The most talked about options include 204 MHz, 300 MHz and 396 MHz in the return…and with a higher return split will come new amplifiers with a new top end of 1.2 GHz or 1.8 GHz. 2 GHz Passives are available now from at least 3 suppliers. 1.8 GHz amplifiers will likely show up next year. For this big a change, things are progressing nicely. The issue now is preparing the plant for a new split."

Here are the upgrade options, each with different capabilities:

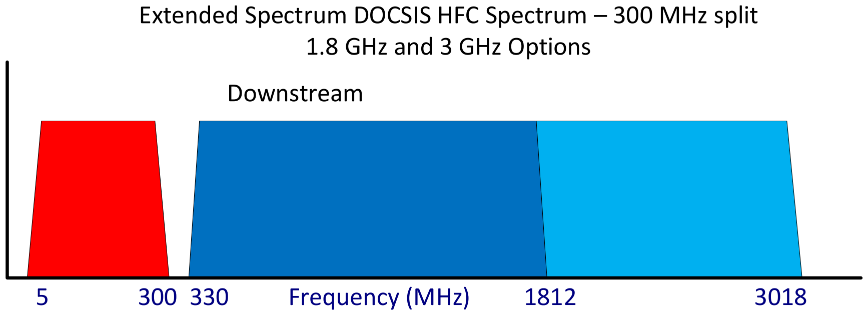
Description	Capability Mbps

The physical layout of the different architectures is shown below. Note that the "DOCSIS 4.0 Full Spectrum" graphic applies to both Node+0 options: Full Duplex DOCSIS (FDX) and Extended Spectrum DOCSIS (ESD).

A. Extended Spectrum DOCSIS (ESD)

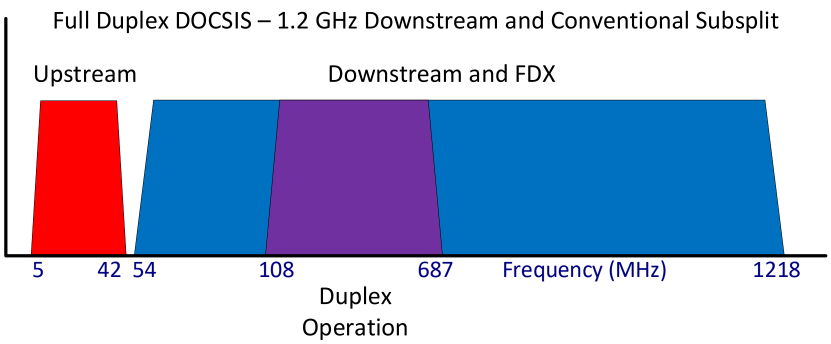
For Extended Spectrum DOCSIS, the highest plant frequency is increased first to 1.8 GHz and later to 3.0 GHz. Along with extending the highest frequency, the upstream/downstream split may be changed not just to 85 MHz, but to 204, 300, or 396 MHz. Some DOCSIS 4.0 equipment will allow the split to be adjusted to one of several choices remotely, allowing operators maximum flexibility.

With an 85 MHz split, 300 Mbps upload speed is possible with DOCSIS 3.1 or 4.0, 204 MHz would allow 1 Gbps upload speeds, and 300 MHz should make 2 Gbps possible.



B. Full Duplex DOCSIS (FDX)

With Full Duplex DOCSIS, a portion of the spectrum is set aside for transmission in both upstream and downstream directions by FDX-capable equipment. In order to make this equipment reasonably affordable and easier to design, the lower range of formerly downstream frequencies are selected, using the range 108-687 MHz. Because this range is no longer available for strictly downstream services, the technique is sometimes combined with ESD to make up the difference.



The main advantage of FDX over ESD is that improved upstream bandwidth is achieved without changing taps, as long as the legacy top frequency available is adequate for all requirements. FDX has a major disadvantage, however. It only works with Node + 0 (Fiber Deep) architectures. No active devices may exist in the network beyond the node, and the node must be a Distributed Access Architecture device. In the case of AB, this would require replacement of all nodes and CMTSs.

While both Full Duplex DOCSIS and Extended Spectrum DOCSIS rely upon Distributed Access Architecture to achieve their full potential, ESD may be used with limited capabilities with conventional analog fiber transmitters and nodes.

Analog bandwidth, typically limited to about 1.2 GHz, is adequate to provide Gigabit Symmetrical service coupled with a high-split plant. Whether or not taps in the network would require replacement depends upon their specifications and actual capabilities.

Although the above diagram shows 3 GHz as the highest plant frequency, that is not achievable with today's available technology. 1.8 GHz is about the commercially available limit now, however some tap housings may be "3-GHz Ready".

Of the two HFC Upgrade options, we believe that Extended Spectrum DOCSIS provides the most capability with least risk, as the viability of FDX has yet to be proven in an actual operating network, and conversion of the network to Node + 0 architecture portends extensive fiber construction not required for ESD with an existing Node + 1 network.

C. Fiber to the Home

The most capability of all is provided by a FTTH upgrade. Here, because the existing plant is overlaid with new FTTH plant, there is no mass disruption of existing customers. Each customer that takes the new FTTH service can be moved to the new facilities one at a time. CPE replacement cost takes place at a gradual pace.

FTTH is an expensive option in terms of capex, but perhaps surprisingly is no more expensive than a DOCSIS 4.0 upgrade including Distributed Access Architecture. The fact is that fiber's almost zero maintenance cost will make it substantially less costly overall (CapEx plus OpEx) over time.

D. Pre-Upgrade Strategy: DOCSIS 3.1 with Extended Upstream Bandwidth

By far, the least expensive path to permit transmission of 100 - 300 Mbps speeds in the upstream direction would be to **change the split** in the plant and add OFDMA DOCSIS 3.1 upstream channels. The cost to do this would involve:

1. Upgrade CMTS hardware to support additional upstream channels
    a. Replace nodes - existing nodes would be replaced with Mid-Split, High-Split, or Adjustable Split nodes
2. Replace amplifiers
    a. Replace Distribution Amps/Trunk Amps (if any) with Mid-Split, High-Split, or Adjustable Split units

   b. Replace Line Extenders with High-Split units
3. Replace taps or reduce cascades – in limited areas
   a. We are assuming that all of the taps are already rated at 1 GHz. As such, it can be expected that these taps will pass somewhat beyond 1 GHz for OFDM (DOCSIS 3.1) data streams and will not need to be replaced.
   b. Older systems, in the North territory, will need to be rebuilt if they are to achieve enhanced capabilities. Some legacy areas are currently Node + 5 or even Node + 10 and would require additional node locations to reduce to Node + 2.

There are other steps involved as well. Any current downstream channels in the range 54 – 238 MHz range must be removed before any of the equipment is changed. This could involve a reduction of available channels on the system.

XIV. Upgrade Costs

We have built models to determine the expected cost for various upgrade options. The projections are made using inputs from provided figures such as homes passed, miles of plant, number of nodes and number of CMTSs. The methodology is explained in Appendix X, and the model spreadsheet is provided in Appendix Y.

The 123 Telecom plant is modern and can easily be upgraded. Our initial recommendation is that 123 Telecom increase upload speeds to 300 Mbps and download speeds to 1 Gbps using DOCSIS 3.1 equipment with mid-split upgrades and adjustable split equipment at a plant cost of $XX.Xmm. If that is completed, a 2022 or later upgrade to DOCSIS 4.0 to deliver symmetrical Gigabit speeds at an incremental cost of $XX.Xmm for a total plant investment $XXX.Xmm.

Upgrades beyond the basic DOCSIS 4.0, to extend spectrum beyond 1.2 GHz to in order to achieve more than 2 Gbps downstream will require extensive plant changes including a change to Distributed Access Architecture. DAA is required to both achieve improved data transmission performance in the plant and to use a minimum amount of headend space.

The real requirement for bandwidth expansion depends on market needs. If 1 Gbps speeds will suffice for the next few years, there may be no need to go beyond the basic DOCSIS 4.0 upgrade for the total plant cost of $XXX.Xmm. Later, FTTH may cost less than it does today and would provide much greater capabilities.

A. Summary

Changing to a mid-split and expanding DOCSIS 3.1 capabilities is the simplest and least expensive option (option 1). However, not enough bandwidth to provide 1 Gbps upstream is available.

If Gigabit upstream speed is a must, DOCSIS 4.0 ESD (option 2) offers significant performance improvements and the most reasonable cost. But replacement of taps in particular comes with significant disruption of service to existing customers on the network. Changing taps and passives is required when a high split is deployed, in order to accommodate the shifted channels.

If expansion of both downstream and upstream capabilities is required beyond 1 Gbps, the FTTH overlay (option 5) will cost less than a DAA DOCSIS 4.0 Node + 1 upgrade (option 3) in some areas.

Going for a full DOCSIS 4.0 ESD or FDX upgrade (option 4) involving conversion to Distributed Access Architecture and converting to Node + 0 while extending the plant bandwidth to at least 1.8 GHz is very costly.

FTTH should be considered. Not only will FTTH cost less initially, in most cases, FTTH has nearly zero plant operating cost and will save considerable OpEx over time.

XV. Red Flags

A. Incomplete Design Estimates

A review of the four-city designs show that the streets scoped for these design estimates did not include all of the residential homes that are part of the community. This could result in a budget under-estimate should coverage of all of the homes be required for the project.

The significance of this red flag depends upon the desired build plan. If all areas in the metropolitan area are to be upgraded to FTTH, then the impact of these isolated sections not being included in the presented budget should be carefully studied.

B. Cost Per Foot Discrepancies

There are several cost-per-foot numbers provided by 123 Telecom and gleaned by review of the documents provided by 123 Telecom. It is important to make sure that the number used in the budget for FTTH builds is conservative enough to account for all of the possible actual costs. It appears that the $X.XX figure used in the Region X budgets is low compared to the costs in the Region X designs in Areas A and B but high compared to Areas C and D.

C. HFC DOCSIS low speeds due to Analog Reclamation not completed

The basic architecture of the HFC network in ABC Metro is sound – the current design reported as "Node + 1" with 125 home nodes combined to 250 home service groups means that the system can be re-segmented to 125 home groups easily. There might be a line extender amplifier after the trunk amplifier, making this actually a Node + 2 network, which is still good. Because of the small service group sizes, this system has avoided the requirement to "split nodes" due to congestion, a problem frequently encountered by HFC network operators.

In an HFC system, analog video channels consume a vast amount of spectrum from the plant compared to QAM video. A single six-MHz channel could transmit one channel of analog HD or SD video, while that same six MHz could instead transmit 2-6 HD channels or well over a dozen SD channels. Alternately, the channel could carry about 34 Mb/s of DOCSIS 3.0 downstream data. Nearly every cable system we have encountered completed their analog to digital transition at least five years ago.

During the CTO team Interview, John Smith explained that continuation of the analog service was a conscious decision, designed to provide a feature (service to analog TVs) not available from video competitors. This decision, in my opinion, cost the company years of progress in increasing internet speeds due to the unavailability of spectrum for bonding more than X DOCSIS 3.0 channels or providing any DOCSIS 3.1 downstream spectrum. RF spectrum for gigabit downstream service will not be available until the transition is completed. In the interim, XXX Mbps and XX Mbps are the highest speed available.

Worse is the upstream plan. 5-42 MHz is available and there is no plan to change the split until a possible Distributed Access Architecture conversion is completed, however that DAA plan has not yet been formulated. Until then, there is no spectrum available for DOCSIS 3.1 OFDMA upstream use and upstream speeds are limited to XX or XX Mbps now. When Gigabit downstream is available, the plan is to offer XX Mbps upstream. This upstream limitation could limit the desirability of Gigabit downstream service.

Because ABC Metro is the only large HFC system in the 123 Telecom portfolio, the impact of this concern is limited to that one market. The major item (lack of Gigabit downstream service) will be resolved as planned later (2020-2021) upon completion of analog reclamation. I recommend that competitors in the ABC Metro area be carefully scrutinized to see if an acceleration of the DAA plan is warranted.

We have not received any information on the small cable systems in the TG footprint.

D. Customer Service Metrics, particularly in Region X

The following reported items were flagged and explained above:

1. ASA and Abandoned numbers for March/April 2020

   Could be Covid-19 related

2. Cost Per Call

   Very high compared to Cable MSO. $XX-$XX versus $X.

3. Technician Productivity

   Compared to the rest of the 123 Telecom network, the Region X systems have considerably poorer performance in many KPIs. Note that these figures are only broken out for Region X Technician Productivity – we do not know if customer service call center productivity numbers are similarly skewed against Region X. Technician drive-time in Region X would not explain the difference, especially when compared against many of the extremely rural areas in the 123 Telecom footprint.

   a. *Much lower productivity*
   b. *Cost per call high*
   c. *Appointment on-time is poor*
   d. *Service trends not looking good, particularly Consumer*

   Region X practices should be adjusted to more closely align with the rest of 123 Telecom's regions, and overall cost reductions to better compare with MSO competitors could be examined.

XVI. Items for Phase 2 consideration

A. KMZ Design Validation

We should visit some of the locations identified as lacking design in the model example and ascertain if there is any reason for this. Photos would be taken to show these areas in more detail.

B. Operational Concerns

1. Call Centers

   The red flag report shows unusually poor call center performance compared to cable MSOs. We should determine if this is due to inadequate training, understaffing, or other causes.

2. Region X Repair Technicians

   Productivity is low compared to other regions, while missed appointments are high. We should try to find out why.

C. OSS/BSS Demonstrations

Since we were unable to view these demonstrations in Phase 1, they should be presented in Phase 2.