Brownfield broadband access network planning in a rapidly changing environment

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Executive Summary

Broadband Access networks are constantly evolving to keep pace with ever growing subscriber demand. This comes at a significant cost for network operators. At the same time, network planners are faced with an increasingly complex set of factors that drive these changes from changing subscriber needs, emerging new technologies, challenging competitive landscape, and shifting regulatory requirements to name a few. In addition, long-term planning comes with additional challenges including numerous unknowns and assumptions which need to be evaluated. Many operators also maintain different networks as independent lines-of-business that are planned separately. Traditional planning tools and methods can no longer keep up with the complexity and pace of this change. Consequently, operators are often forced to take quick short-term tactical decisions that are not optimal in the long-term.

In this whitepaper we discuss these challenges and introduce a new tool called Jibe™ which is specifically designed to enable network planners to model the evolution of their access network over an extended period, and quickly analyze the resource requirement and other impacts of these changes. It is designed to facilitate integrated planning of multiple networks. This will enable operators to quickly evaluate long-term impacts of network changes in a timely manner to make effective long-term strategic decisions.

WHAT IS THE PROBLEM?

Broadband access networks need to evolve to keep pace with ever increasing subscriber demand. Network planners are faced with the challenging task of planning network upgrades in an optimum manner in a fast-changing, complex environment driven by new technology options and changing competitive and regulatory pressures.

Key Words: Brownfield, Broadband Access Network, Bandwidth Growth, Planning Tools, Jibe, Transformation

Access Network Planning Challenges

Broadband access networks [1] have come a long way since the early days of dial-up internet. The networks have seen tremendous growth in size, scope, and complexity. Access planners are facing tremendous challenges due to:

- Exponential growth in the subscriber demand for bandwidth
- Increasing competition to gain market share
- Significant operational challenges due to complex deployments, and
- Myriad of coax, copper, fiber and wireless access technology options

These challenges are explained in the next few sections and we provide a solution on how we can assist the industry during this access transformation turmoil.

KEY TAKEAWAYS

- ✓ Access networks are being upgraded frequently now due to exponential demand growth
- ✓ Access network changes have significant cost and operational impacts
- ✓ Current planning tools and processes are unable to keep up with this pace of change
- ✓ Planners are often making short-term decisions that are suboptimal in the long-run
  - 10 one-year plans ≠ one 10-year plan!

⇨ The industry needs new access planning tools (such as Jibe™) to enable planners to effectively evaluate various optimal long-term decisions

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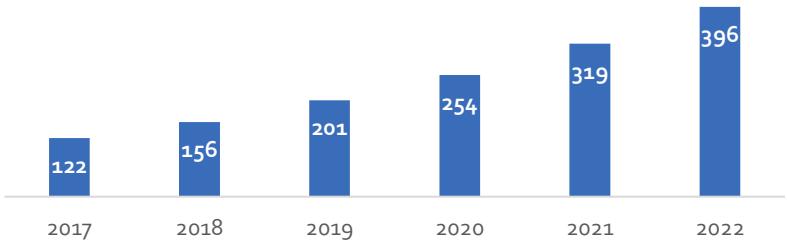
Demand Growth Related Challenges

The main driver for the evolution of access networks has been the growing subscriber demand. Constantly evolving applications and services require more-and-more bandwidth. The chart on the right from Cisco VNI report [2] shows that Internet consumption traffic is predicted to grow at 26% per year over next few years. This graph shows the projected traffic growth at a macro level. However, network operators must plan their networks for the peak time traffic demand. Typically, peak time demand is 1.5 to 1.7 times more than consumption. Refer to the difference in the peak time demand versus consumption in our white paper (Forecasting Bandwidth Utilization Growth, [3]).

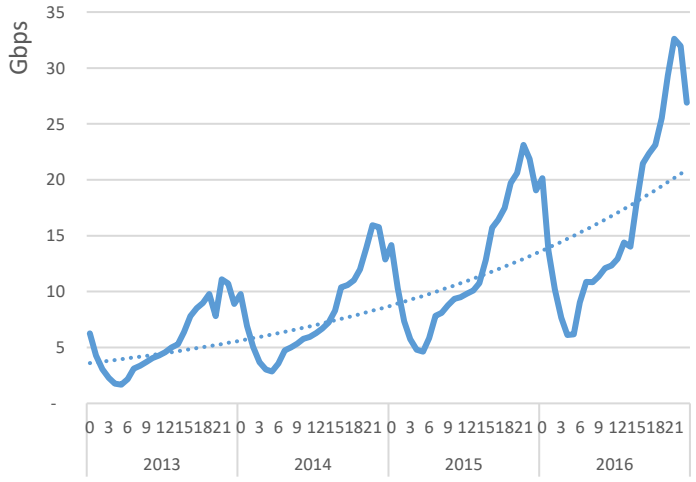
Global IP Traffic Forecst from Cisco VNI Report

Exabytes per Month (26% CAGR 2017 - 2022)



The chart below shows a typical intraday traffic demand growth at a node level over a four-year period. Although, this growth is node composition dependent, it is well understood that the node level peak time traffic is growing between 35 – 50%.

Intraday traffic of a node in a typical day



There are many factors that influence traffic demand growth. Some examples include the subscriber mix (e.g., residential vs business), neighborhood characteristics such as dorms around a college campus versus a quiet residential neighborhood, or different subscriber demographics such as average age, income, or family size (see [3] for a detailed discussion on this).

Getting the growth profile right is essential for planning.

Why is growth profiling so important?

Let's take a simple example from the intraday traffic growth as shown in the chart on the left.

Absolute peak demand growth (not the rate) from 2013 – 2014 is approximately 5 Gbps. The same from 2015 – 2016 is 10 Gbps. You may ask – so what? Because of this "hockey stick" growth that the operators are experiencing, the linear capacity addition levers such as carrier additions and node splits will no longer be enough to address the future demand growth. Hence, the operators are increasingly forced to look at other non-linear upgrade levers such as Fiber Deep, Fiber to the Home. Of course, these levers are a lot more expensive than simple node splits. The question is which path to take – linear or non-linear? Here is where your access planning team is challenged.

Growth Related Challenges faced by Network Planners

- Should the growth profile be at a node, facility, or market level?
- Should a node growth profile be based on the type of subscribers (e.g. SFU, MDU, business, demographics etc.)?
- How to plan for a new node for a community that is building in phases?
- How to create different growth profiles for integrated networks (e.g. business, fixed wireless, backhaul, residential etc.)?

And finally, how can planning be done by applying such growth profiles to your networks? Planning tools, such as Jibe, provide growth profiles and constructs to apply them at different granularities to better project the impact of growth on network evolution.

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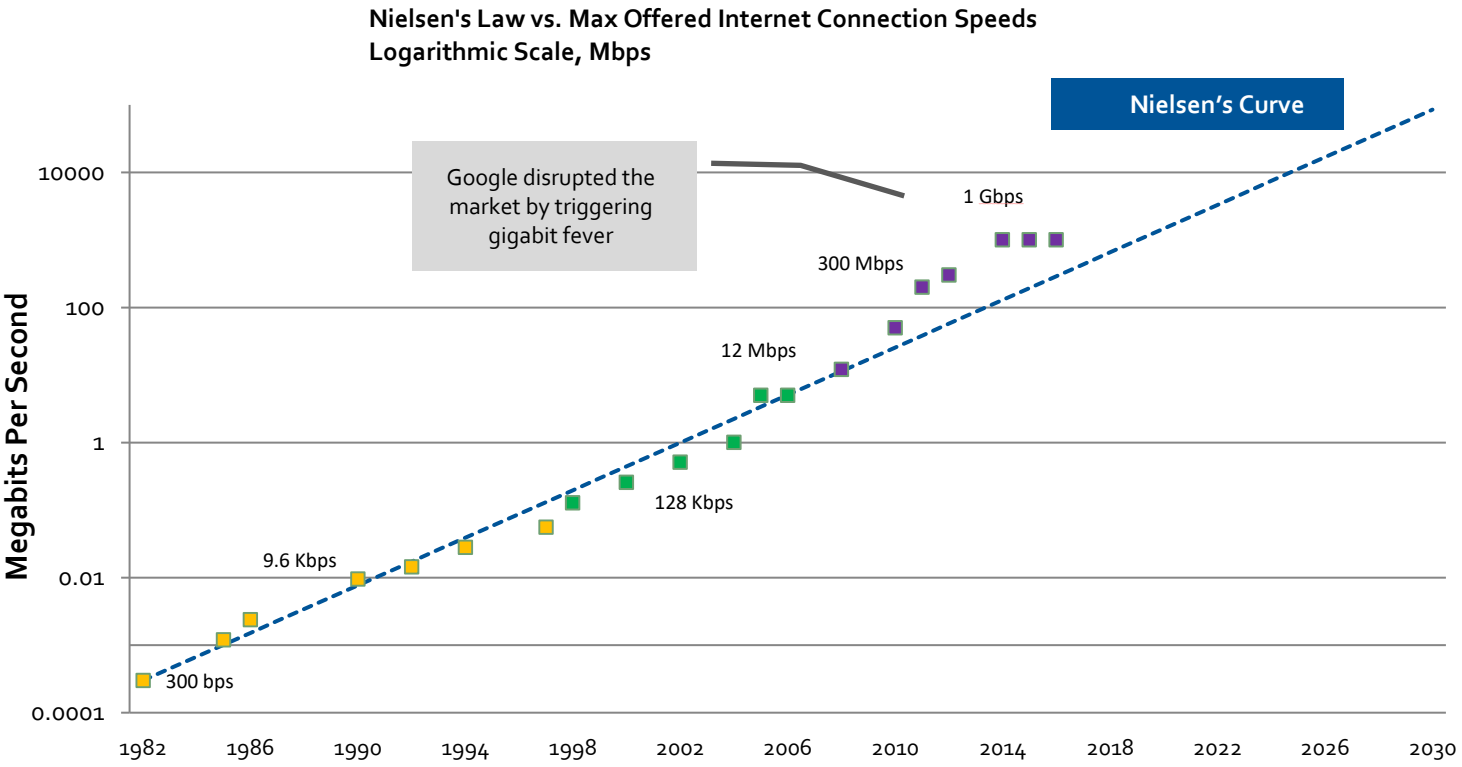
Different Business Challenges

In this section, we talk though different business situations that a planning team faces. Our goal is to motivate different rules (or strategies) that the leadership must take while planning for their network upgrades.

Scenario 1: Incumbents and new entrants constantly changing the service game

Although Neilson's law [4] (refer to the chart below) predicted the bandwidth demand is growing at 50% for the last four decades, the services offered by your competition is what matters when it come to the operator revenue recognition.



There is no shortage of competition in the telecom business. While the incumbents are going head on, new entrants such as google have created enough disruption.

As shown in the chart above, the gigabit fever created by Google disrupted the market dynamics and fueled significant upgrades all over US. Now that all the incumbents are excited, the speed wars are on.

So, what does this mean for the planners?

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Competition triggered planning challenges

- How to plan for a technology for different product and marketing needs?
- How to take into consideration the micro and macro level competitive threats during planning?
- How to "timely" incorporate the game theory behind these competitive pressures – knowing the dynamics involved here?

Scenario 2: Mixed residential and business deployment

Let's say we have a residential community built around a business park, as shown in the picture on the right. The demands of a business and residential customers grow at different rates. Their bandwidth consumption patterns are different, and their service offerings are different. As a planner or as a product strategist – how do you devise a deployment strategy that meets subscriber's current and future needs in such a mixed environment?

Mixed deployment planning challenges

- How will a planner incorporate the varied bandwidth and service needs of mixed deployment?
- How can a planner have different deployment paths for the business customers and residential customers?
  - For example, Fiber to the Business for business customers and Fiber Deep for residential customers

Scenario 3: Old and new Multi Dwelling Unit (MDU) deployments

MDUs are treasure chests. The deals sales folks make with them and the take rates operators can experience, once there is an existing agreement with the property owners can be extremely lucrative. This calls for handling MDUs with kid gloves. Every operator has its own strategies on how to win and keep these properties for a long time. This is typically done by offering the best internet connectivity, good service and bulk pricing deals.

So, what is the challenge here? The drop! Connecting and upgrading individual units is very expensive. While connecting an MDU during its construction time (Greenfield MDUs), the operator has a lot of flexibility. However, connecting an MDU after it is built (Brownfield MDU) can be very expensive or even impossible. These challenges force operators to consider different technological and deployment options which impact network planning.

MDU connection and upgrading planning challenges

- How to apply planning constraints to the greenfield MDUs and the brownfield MDUs?
- What is the strategy for the brownfield MDUs? What is the timing of the investments?
- Which technology to use for the planned service tier offering over the planning cycle?

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Other macro business challenges such as regulation

Changing regulatory environments also has significant impact on network upgrade planning. Take for example the recent changes in FCC's position regarding network neutrality. After FCC enacted strong network neutrality regulations in 2015, many operators seem to have reduced network investments [5]. Then, when FCC reversed its position in 2018, several operators expressed their desire to increase investment [6]. Such regulations change makes the operators re-evaluate their network plans.

Operational Challenges

Due to the introduction of construction-intensive non-linear (such as Fiber Deep and FTTH) levers, the operational organizations are stretched to the limit. To have a viable network transformation plan, operators must deal with the following key challenges:

- **Capability of the organization:** Is the current structure of the organization suitable for the transformation?
- **Availability of the resources and material:** Are the necessary resources and material available at the required time?
- **Efficiency of the team and the operations:** Are we using the team and operating at the right efficiency levels?

Organizational challenges

The non-linear deployments such as FTTH, Fiber Deep are going to challenge the organization structures. The days of organically increasing the workload for the teams are gone. Imagine an operator who is used to doing 100 node splits in a market per year have to grow the team to perform 5 – 10x in couple of years! Back to the white board right. Moreover, this is not just happening in one market – but all the markets at the same time. And – yes, it is not just impacting the construction teams, but planning, designing, permitting, customer support, material management and on and on. All of this is going to increase by 5 to 10-fold. What is the answer? In addition, the level of upgrades is not going to stay the same. These activities come in waves. How are the operators going to organize themselves? Is the organization going to be centralized, distributed or hybrid?

Planning challenges to solve organizational issues

- When do you need what level of resources for a given plan?
- What kind of organizational structure is suitable for the projected volume of activities?
- Should the operator ramp up the in-house resources or contract labor to meet some of the transitional activities?

Material forecasting

Introduction of next generation technologies and the increased volume of activities (due to non-linear levers), will mean that the volume of material required will increase significantly. Operators need to forecast this need accurately, work with vendors to gain access to the material, secure them at the right time, ramp up their storage capacity, implement effective delivery mechanisms, and create a viable sparing strategy. All this excitement begins with proper planning.

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Planning challenges to forecast material

- What are the different material needs for a given plan?
- When do the operators need these materials? Where do they need them?
- How much storage is required? What are the sparing needs?

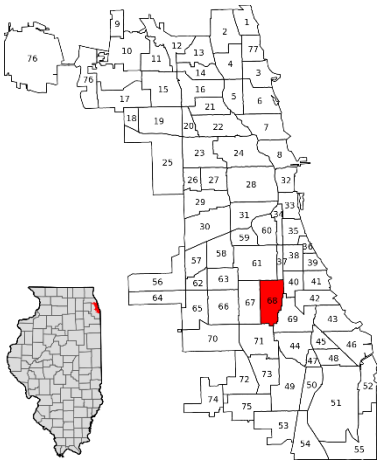
Macro level labor challenges

Operators who are during transformational upgrades are well aware that they are not the only ones doing this. There are labor shortages and execution risks – both at individual market and at the enterprise level. A key resource in short supply is coax splicers. Most of the trained coax splicers moved to the more lucrative fiber splitting business.

What does this mean for planning? Well, for one – the planners need to forecast different construction crews by market by period. This is essential for the execution of their plan.

Planning challenges in forecasting macro level labor needs

- How many crews of different types are needed when for a given strategy?
- How many fleets are required for these crews (if you are souring them internally)?
- More importantly, from the operational point of view, can such levels of crew be secured?



Micro level labor challenges

OK – we have planned for the macro level issues. Now how to make micro-level decisions? Why are they important? Let's say there is a construction crew working in a market that is shuttling between a group of network elements in different areas that are 20 – 30 miles away from each other. How much of their efficiency is lost driving around every day? Where is the material stored to be effective? What alternatives do operators have to solve these micro-level inefficiencies? Can the operator group some of the future activities in order to efficiently use the resources in the same area? Can the operator plan in such a way that the resources are not dispersed? Such micro-level planning will help operators greatly reduce challenges during the operational phase of their network transformation. Note that these issues are exacerbated by the non-linear levers.

The question is - how can planning help with such challenges?

Planning challenges in forecasting micro level labor needs

- Are current macro level considerations creating micro level inefficiencies that are going to derail the transformation?
- How to create a micro level plan that is efficient from the operations point of view? Not just financial.
- How does such micro level levers influence the overall long-range planning?

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Integrated coordination challenges

Many service providers operate multiple access networks to support different subscribers or services. For example, residential vs business subscribers, or retail vs backhaul services. Quite often these networks are operated as independent lines-of-businesses with little coordination. However, when it is time to make any upgrades, it is essential to coordinate actions between the various networks. This can lead to frequent planning changes. If not done in a coordinate way, it leads to significant inefficiencies. As an example, a permitting group – if not coordinated – will have residential, business, backhaul etc. lines of businesses all reaching out to the permitting entities for same/similar and overlapping requests. Imagine the mess they can create internally and externally!

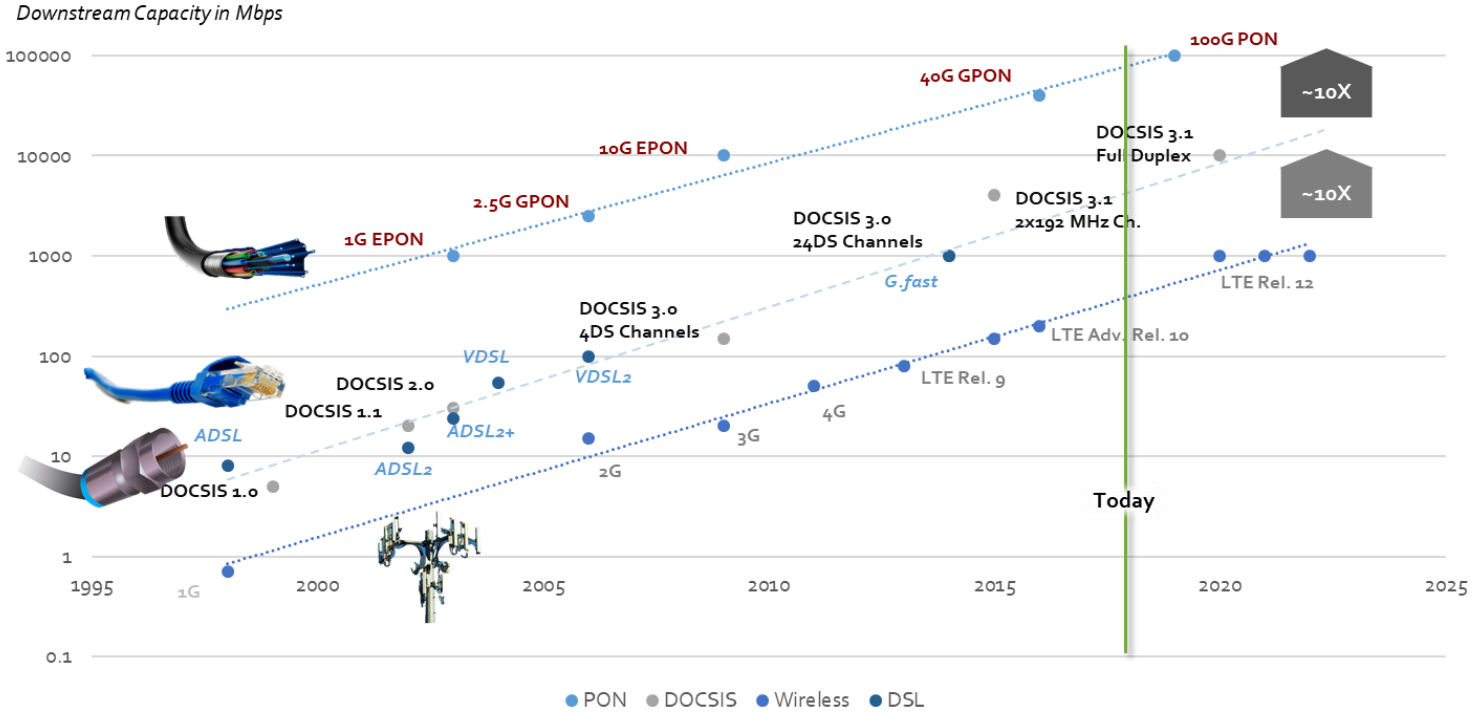
Planning challenges with the integrated operational scenarios

- How to plan for resource and material needs across multiple organizations/service offerings?
- How to synergize the plans for different organizations?
- How to design an organization and engage contract labor vendors that meet the demands of combined offerings?

Technology to the rescue - well, partly…

To keep up with the growing subscriber demand, the capacity of the access networks needs to be constantly upgraded. Fortunately, there is a broad range of wireless and wireline (PON, DSL, DOCSIS) architectural and subscriber reduction per shared medium (node splits, fiber deep, FTTH split reduction etc.) options are available to network operators to upgrade their networks, with new options ([7], [1])being developed from different forums.

FTTH, DSL, DOCSIS and Wireless Technology Evolution
Downstream Capacity in Mbps



Cable operators can optimize their spectrum utilization by upgrading from from DOCSIS 3.0 to DOCSIS 3.1 to Full Duplex; or deploy construction upgrades such as Node Splits, Mid Split, High Split, Fiber Deep (R-Phy, R-Mac-Phy); or move to new access technologies

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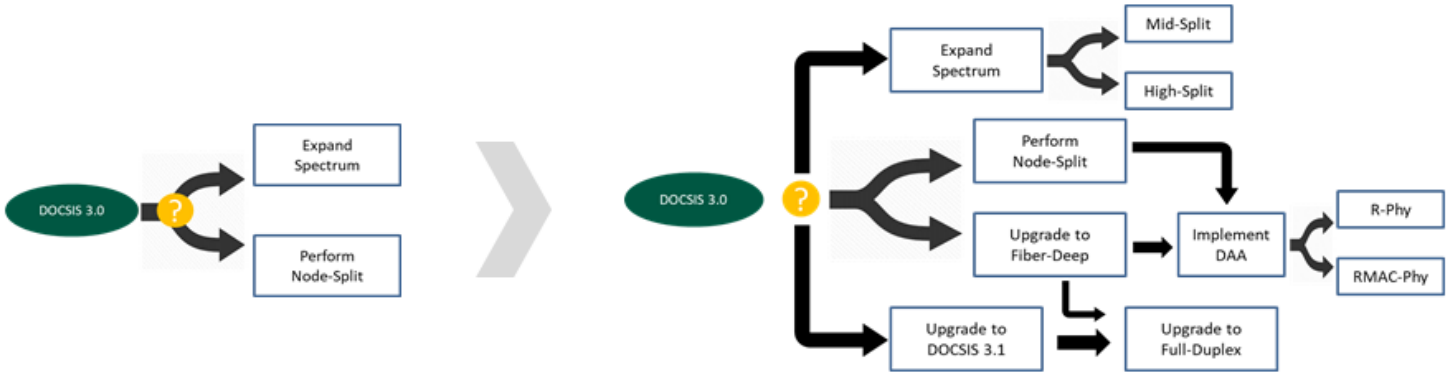
such as millimeter wave, FTTH etc. It is good that there are multiple options ([1]) to counter growth based and competition-based needs. Each of these technologies in turn have their own evolution path as shown in the above graph.

Telco operators can upgrade their networks from ADSL to VDSL, VDSL2, or G.fast. Ultimately, they can also upgrade to an all-fiber network. Fiber-to-the-home (FTTH) networks can upgrade from GPON/EPON to XG-PON/10G-EPON or NG-PON2/NG-EPON to deliver up to 100 Gigabits per second capacity.

Each of these technologies come with a range of implementation options with different cost-benefit tradeoffs. While all these options help address the need for greater capacity, they also make the job of planners increasingly complicated.

Let's take the example of a cable operator with a network of predominantly DOCSIS 3.0 nodes. In the past the typical upgrade options for increasing capacity were adding additional carriers or node-splits where a congested node is split into multiple child nodes. Planners had to decide which option to choose. Unlike node-splits (where construction is involved), adding carriers to service group is alot cheaper. To evaluate cost-benefit tradeoffs operators had to do a market wide exercise. Until now the planners had these two simple options to balance.

Now that even more technology options are available – e.g. upgrading to DOCSIS 3.1, performing mid or high-split, moving to a fiber-deep architecture, changing to a Digital Access Architecture (DAA) using Remote-Phy or Remote-MAC-Phy nodes, or upgrade to a full-duplex DOCSIS technology – the planning task gets significantly more challenging as illustrated in the figure below.



To select the optimum upgrade path, the operator needs to analyze cost-benefit tradeoffs between all the various options not just as a single step, but as a series of steps over a period. In addition, the operator must decide whether to apply the upgrade strategy across the network, or customize it by region, market, facility or even node level. Whichever way it is done, this can be a fairly daunting task for planners.

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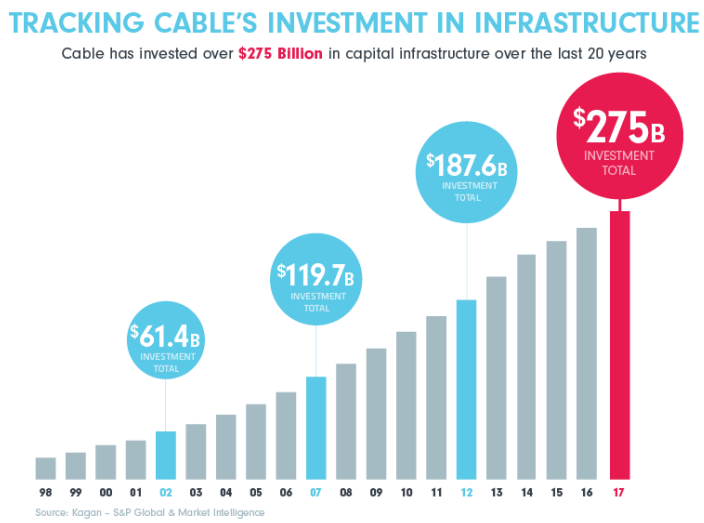


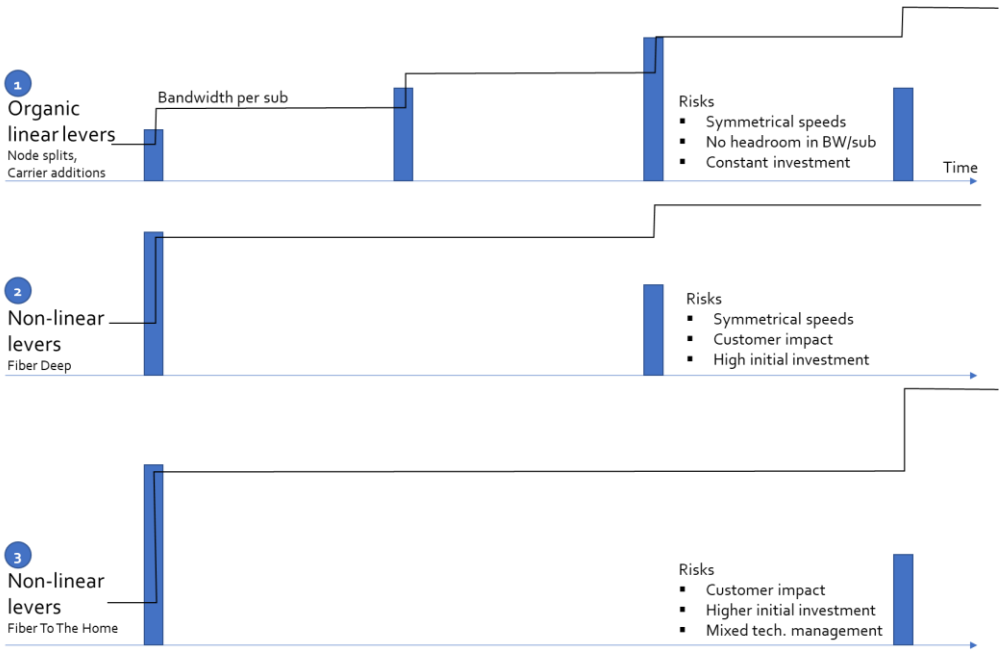
… but, you must pay the piper

As we discussed above, several technology options are available for operators to upgrade their networks to deliver higher capacity in this competitive environment. Unfortunately, upgrading access networks is not easy. It usually comes with a hefty price tag.

The access network constitutes the bulk of the network infrastructure owned by the service provider. Any change here has large-scale implications.

Network operators are spending a large portion of their capital investment on network upgrades [8]. A significant portion of that (up to 80 - 90%) is spent on the access network itself.

It is therefore critical that any changes to the access network be carefully evaluated over a long enough horizon to ensure optimal use of their investment in the long term.



Financial planning brings its own set of challenges for network planners. Quite often, network upgrade planning is limited by the available budget. Network planners must balance the cost associated with the upgrades, competitive pressure and the customer demands with the available budget.

As shown in the figure, the planning exercise is a balancing act of risks and investment profiles with metrics as the measure of success. For example, we can use bandwidth per sub as a metric. The investment profile of three different strategies are shown in the figure. Linear levers add incremental bandwidth per sub with investment at regular intervals (as in the case 1 from the figure). Example for such investment strategy include node splits, carrier additions etc. They come with some of the risks in the product capabilities and the investment profiles. Non-linear levers such as Fiber Deep (case 2) and Fiber To the Home (case 3) advocates higher initial investments (and hence some increase in customer impact) with reduced product risk in terms of higher bandwidth per sub. We are not advocating one strategy is better than the other. Our goal is to show that the planning exercise is a balancing act of different dimensions. How are you doing this now?

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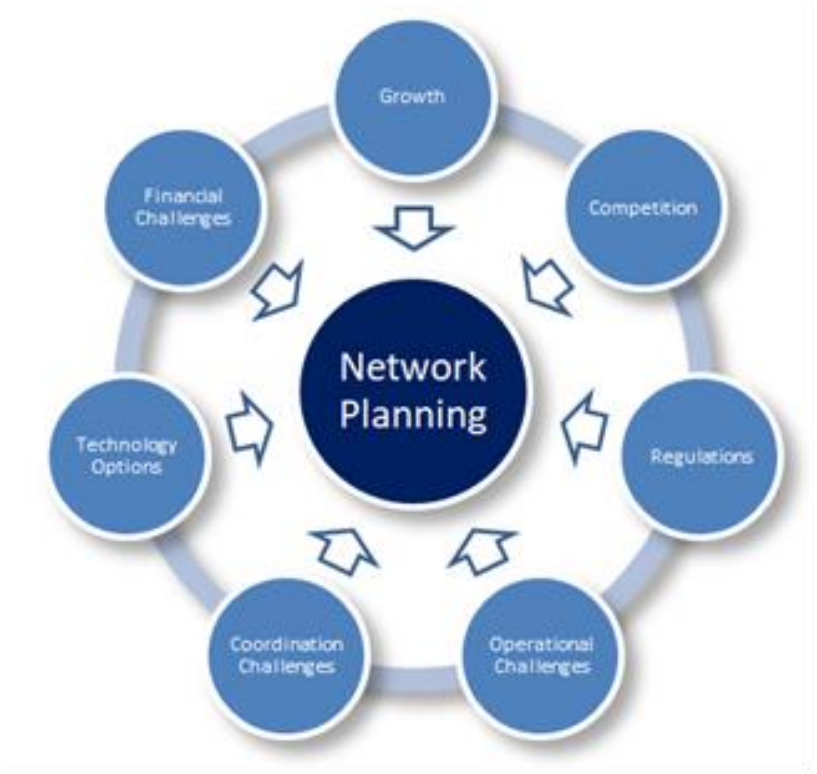
Network planning in a challenging environment

As outlined above, numerous factors affect network upgrade planning as summarized in the chart on the left. Frequent changes driven by all these factors makes the task of network planners extremely challenging.

In the past network operators had plenty of time to analyze their networks, collect various statistics, conduct various studies and compile necessary data models to evaluate impacts of any new technology introduction. In most cases this involved compiling pieces of information from various teams which could take many months if not years.

Now that the pace of change is so rapid, traditional planning tools and techniques used by network planners are unable to keep up.



Enter Jibe - the next generation network planning tool

To help address the challenges faced by network planners as outlined above, a new breed of planning tools is being developed. The access part of a network is fundamentally different from any other network area and requires a unique planning approach. One such tool focused on the access network is Jibe™ from First Principles Innovations [9]. Jibe is a tool specifically designed to address the predictive planning of access network deployment and transformation.

To cope with all the planning complexities discussed in this paper, planners are spending most of their time on creating tools to gain insights into a chosen solution rather than focusing on creating and comparing different strategies for network deployment and transformation. Jibe is a comprehensive tool that allows you to create a validated enterprise level long term access network transformation plan in minutes giving you immediate macro level insights while allowing you to zoom in as deep as individual access network elements. Using Jibe will enable you to focus entirely on deployment and transformation strategy creation and only be limited by your imagination as to how many alternative approaches or what-if's you want to evaluate. Many of the input parameters used to build a network transformation plan such as demand growth, competition and others have a high degree of uncertainty, making it essential to include sensitivity analysis as part of your plan validation strategy and putting even more pressure on plan creation turn-around time.

Let's see how Jibe can handle your access network transformation use cases with your specific parameters, and input network architectures. And at the same time, keep configuration simple enough for you to build a use case in minutes. This was only possible by exploiting access network characteristics in the creation of Jibe internal algorithms and input/output modelling. The following illustrates some of the key differentiating characteristics of the Jibe tool:

- **Simplified configuration**: Simplified configuration is realized by understanding what input parameters are constant across use cases and what input parameters are use case specific. Configurations can be further simplified by using service provider specific defaults. The section below will go in more detail on Jibe configuration.
- **Hidden algorithm complexity**: As discussed in [1], the operators have choice of different types of access architectures and technologies. But they all evolve using similar transformation actions. The Jibe algorithms "understand" how to correctly

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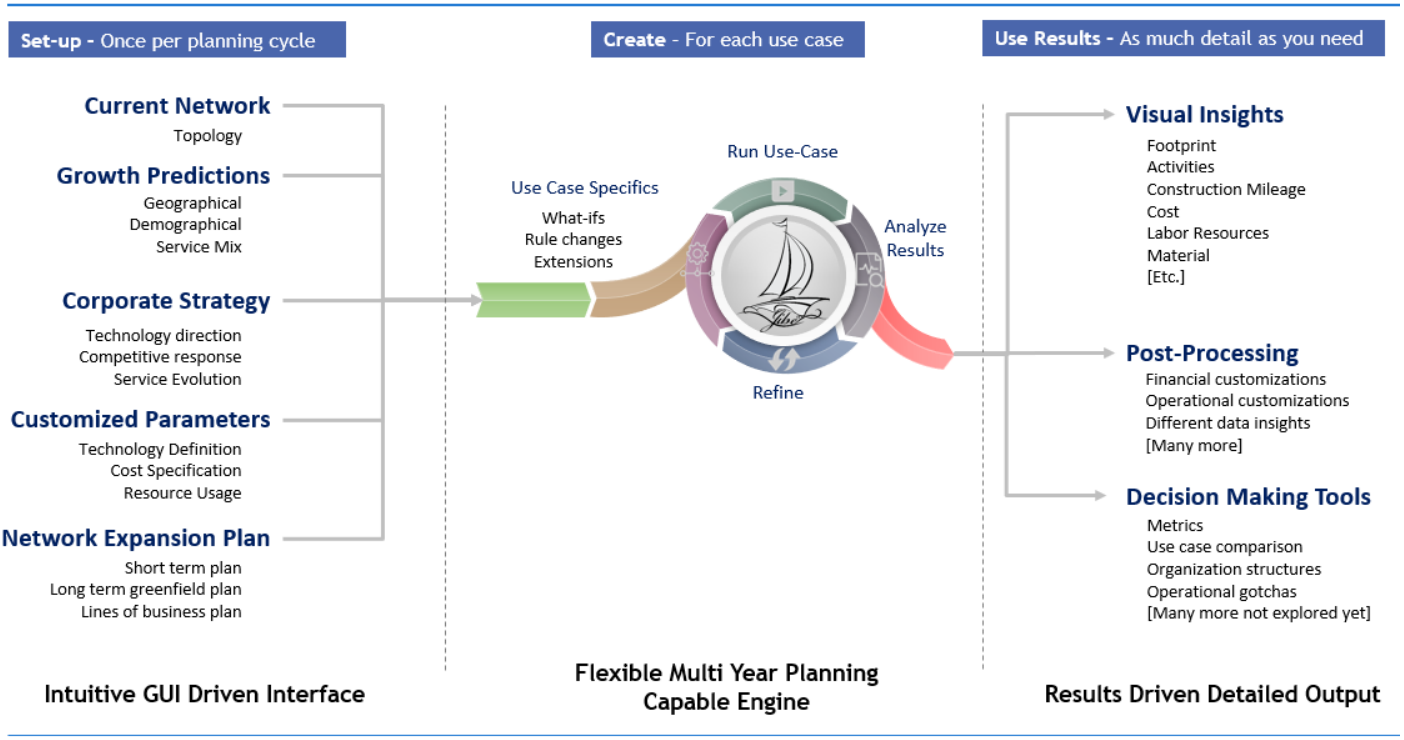
execute a transformation action for all common access architectures. With this complexity hidden, the user can focus on configuring the what instead of the how.

- **Granular calculation**: Building a network transformation plan comes down to calculating what actions need to be taken to the lowest network component level. Jibe always calculates these actions at the lowest level of granularity of the access network element that directly serves the subscriber. Calculating and saving all actions, and related information (cost, resources needed, material etc.) at the lowest level of granularity, guarantees that no information will ever be lost due to aggregation. This allows the user to drill down to the individual network element if he chooses to do so.
- **Detailed reporting**: All results calculated by Jibe are reported for each individual access network element at each calculation cycle. Visualization templates customized for the Jibe results format give the user access to network wide aggregated views with the option to drill down at any level of granularity. In addition, with all details available in open documented format the user can further evaluate or adapt results with other visualization or post processing tools.

The figure below illustrates how Jibe works in a nutshell.



Configuring Jibe

To ensure full flexibility and applicability of Jibe, all input parameters are fully configurable in an intuitive GUI or using open, documented configuration files. While making everything configurable is great for flexibility, it can easily reduce usability if not carefully designed. As mentioned in the introduction some input parameters will be adjusted for each use case while others only once per planning cycle or even less. Let us look at different groups of input parameters to better understand frequency, complexity and effort required to update the parameters for each planning scenario. A scenario is the term used in Jibe for denoting a single run of a use case.

Current Network Configuration

If Jibe is to be used to calculate network transformation for a brownfield network, the current state of that brownfield network needs to be imported. The current state required by Jibe includes a detailed list of access network elements ordered in a hierarchy of

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geographical Regions, Markets, and Facilities. The minimum network element details including the node technology, homes-passed, bandwidth demand levels, and associated plant status (such as, fiber/coax miles, aerial/underground miles etc.).

Network Configuration Details

- **Frequency**: Once per planning cycle
- **Data type**: Your network status
- **Input**: XML
- **Defaults**: Not applicable

Onboarding the network data into Jibe is obviously a big task, but luckily only needs to be done once at the beginning of every planning cycle and can be re-used for all scenarios. Moreover, Jibe loads the date from an xml file in a well-documented open format. Once the effort is done to interface with the operator's tool(s) containing the required information, a tool could be easily written to convert the information automatically into the Jibe xml format and make the onboarding process very simple.

Growth Predictions

Demand growth is obviously one of the main drivers for network transformation and changes not only over time but can also significantly change from one network element to the next based on location, subscriber types – e.g. residential vs business etc.

Growth Profile Configuration Details

- **Frequency**: Once per planning cycle
- **Data type**: Network element level
- **Input**: XML
- **Defaults**: Profiles for types of nodes

That is why Jibe introduces the concept of growth profiles and to achieve ultimate flexibility expects assignment of growth profiles at the individual access network element level. There is no real limit on the number of growth profiles a user can define allowing for any type of demand growth identification strategy.

Obviously, it would be impractical to ask the user to assign growth profiles to each individual access network element manually in a large network. That is why assignment is part of the xml input file and can be fully automated as part of the network data onboarding process.

Customized Parameters

Customized parameters are mostly static and are rarely updated for specific use cases. For most customized parameters Jibe comes with a predefined set of default values based on industry knowledge. These default values are loaded into the use case every time the user starts a new use case. Like everything else in Jibe, the default values are in open configuration files and will typically be overwritten at Jibe installation time to reflect customer specific values.

Custom Configuration Details

- **Frequency**: Static – Same for all scenarios
- **Data type**: Dependent on the config type
- **Input**: CSV or GUI config
- **Defaults**: Predefined for industry

Some example of parameters in this class:

- **Technology definitions**: These defines the characteristics of technologies used in the access network. Most standard access technologies will come as part of Jibe defaults and will not require to be changed by the customer.
- **Cost and cost component definitions**: While defaults are provided by Jibe, cost and cost components are typically operator specific and the defaults for this area are typically overwritten but need to stay consistent across all scenarios to be able to effectively compare multiple scenarios against each other. As they have no bearing on upgrade activity calculation, operators can start off with rudimentary definitions of cost and cost components that can be included at a very granular level or very coarse level depending on the operator's preference.
- **Other parameters**: This class include material and labor, basic transformation actions, and definitions of network elements types the network can migrate to.

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Scenario Specific Parameters

Scenario Specific Configuration Details

- **Frequency**: Specific to a scenario
- **Data type**: Upgrade paths, business rules
- **Input**: GUI based configuration
- **Defaults**: Not applicable

These are a group of parameters that steer calculation algorithms and really define the unique characteristics of a scenario. As is to be expected these are the set of parameters a planner will update for every scenario. Input of these parameters is normally done directly through the intuitive GUI screens.

These parameters specify potential upgrade paths for all technologies used in the network as well as upgrade triggers and constraints the planner can specify to implement business rules on top of basic growth driven transformation.

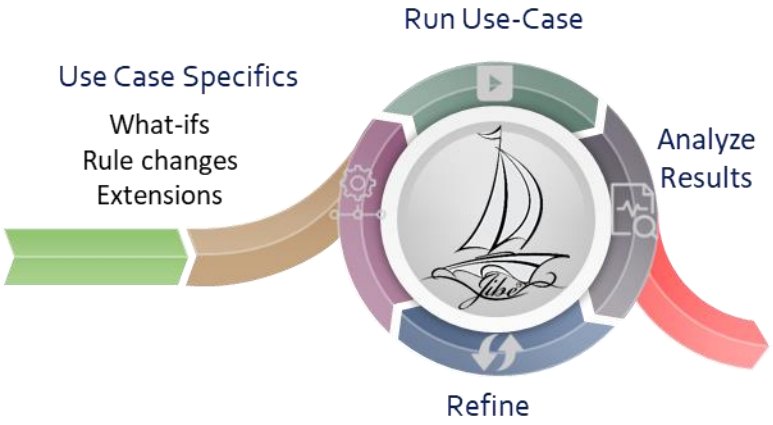
The simplicity of the behavior steering parameters is what allows an experienced Jibe user to input scenario rules in a very short amount of time.

Building Planning Scenarios

After the necessary planning information has been compiled, the operator can define a set of network evolution use cases called Scenarios. Scenarios capture the evolution of the network over a defined period of time with a specified planning interval. Scenarios can be developed for short or long term as well as for specific lines-of-business or for integrated lines of business. A variety of scenarios can be compiled with different planning assumptions to understand their impact.

Executing a Planning Scenario

In this step Jibe takes all the input parameters of the scenario and calculates a network transformation plan for the complete network footprint that was onboarded. The time-scope of the transformation plan is fully configurable for as many years as the planner wants with up to 12 periods per year.



The true power of Jibe is that it does not take any shortcuts or performs any aggregation during calculation. Every period in the entire time scope (referred as Calculation Instance in Jibe), Jibe starts with the entire resulting network of the previous calculation instance and calculates the required upgrade actions for every individual network element in that network. The current detailed state of every network for that calculations instance is saved by Jibe as well as all detailed information on all network actions that were taken (what triggered the action, what upgrade options were blocked, detailed cost of the action, detailed resource requirements for the action etc.). It is this level of detail in the output that allows for the creation of very insightful visualization templates as well powerful post processing tools.

The task of compiling network planning data for a large network typically used to take operators many weeks if not months. With Jibe this is completed in a matter of a few minutes.

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What about network expansion

New subscribers or service endpoints are added to existing networks all the time be it for expansion into new greenfield area or onboarding end-points for new lines of business such as small cell backhaul.

Today planning for brownfield network transformation and future network expansion are completely distinct efforts often executed by different teams in the organization. There are many benefits to combine all these planning efforts in a single integrated long-term plan as explained in detail in the white paper *Solving the Access Network Footprint Expansion Enigma* **Error! Reference source not found.**.

Jibe is extended to support network expansion as part of a network transformation scenario. A separate set of input parameters (both XML and GUI) allow the user to onboard the network expansion plan and provide some network expansion specific inputs such as network expansion specific costs. During calculation Jibe will automatically apply the same transformation rules to network expansion network elements unless the user specifically specifies differently. The output generated by Jibe will include a complete integrated view. Network element attributes will allow for easy filtering of brownfield and network expansion network elements and activity in visualization and post processing tools.

Analyzing Scenario Output

A tool, such as Jibe, has no value if there is no way to present the results for users to analyze and understand, that is why a lot of effort was put into the creation of a rich set of insightful reports.

Rather than providing a closed set of reports directly in Jibe, it was decided to opt for a much more open approach. Jibe exports the output in an open documented format that can be used by a variety of standardized tools like Power BI, Tableau, Excel etc. for visualization, reporting, or further analysis. This approach fits well with the full flexibility mindset baked into Jibe and created the option to further enhance Jibe's value with custom built post-processing tools. Out of the box Jibe comes with a PowerBI template that includes a rich set of reports and allows for PowerBI reporting to be launched directly form the Jibe GUI.

In the remainder of this section some of the standardized reporting screens will be showcased and explained. Most captured images will be shown for the entire network footprint. Note that with the templates provided by Jibe information can be easily displayed for any aggregation level with the click of a button.

Network Footprint Evolution Report(s)

These reports (see below) show how technology deployment for your footprint will evolve over time with this network transformation plan. The top-most view shows the evolution of technology per house hold passed (HHP). The fact that HHP goes up over time is due to the network expansion included in this scenario. For a pure brownfield scenario, HHP will be constant for the full-time scope.

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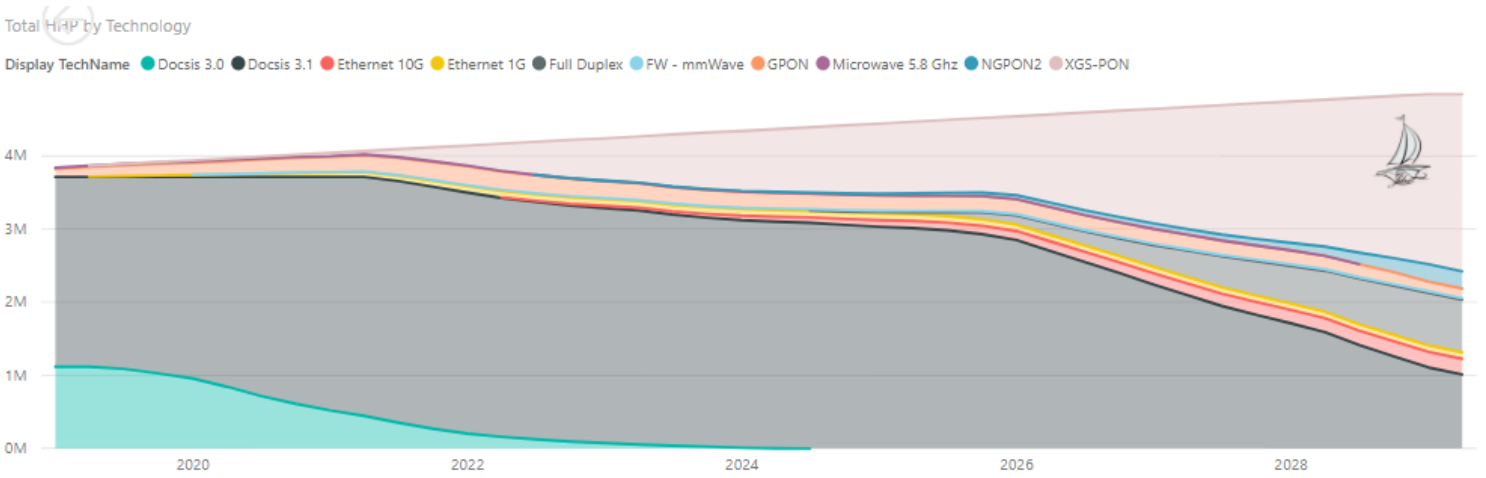
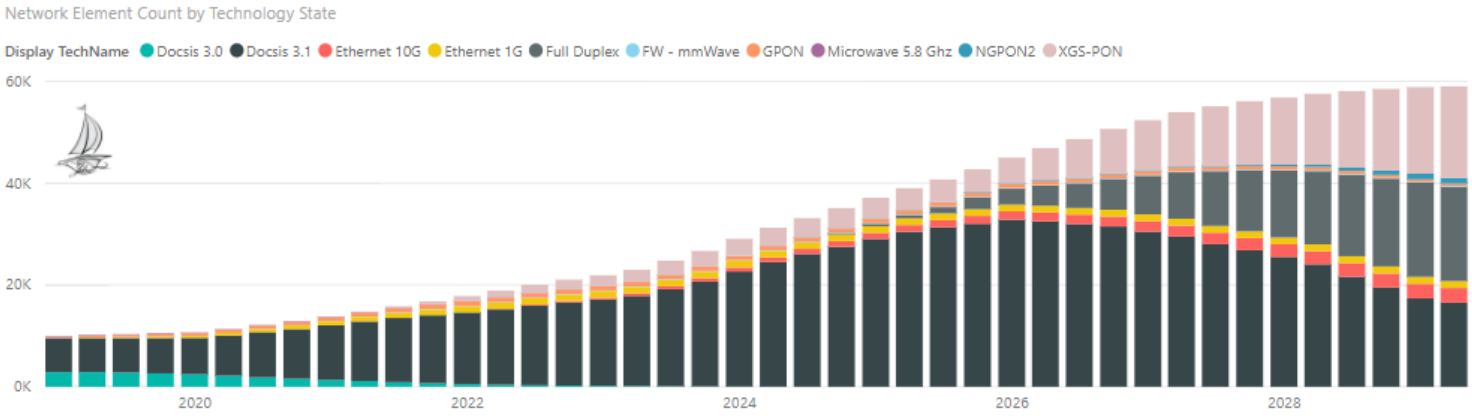
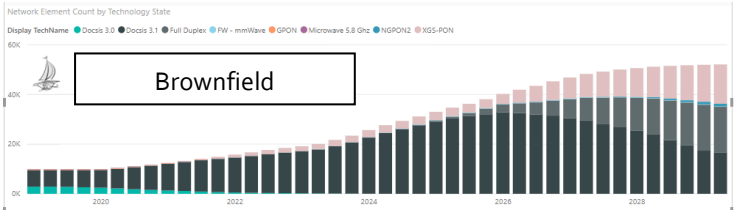
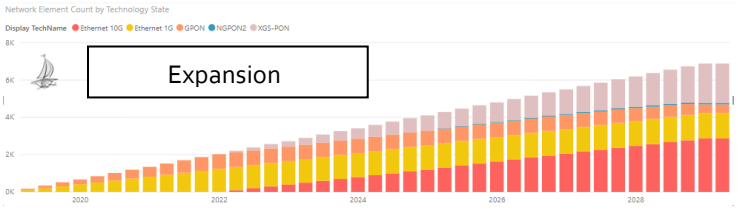




The bottom graph shows the evolution in technology across the footprint by access network element. In addition to giving an understanding of technology evolution it also shows how, over time, your network is growing in terms of the total count of active network elements. The growth in network elements is mainly due to the fiber deep strategy chosen in this scenario and due to network expansion. With some basic filtering one can immediately see the exact details behind this observation.





Network Construction Activity Report(s)

One of the key indicators to assess the operational feasibility of a scenario is the amount of outside plant construction. The Jibe template therefore includes multiple views on outside plant construction. The first view shows the total miles of coaxial and fiber cable that need to be constructed every calculation instance (period). Additionally, the main graph is further broken down for greenfield and network expansion.

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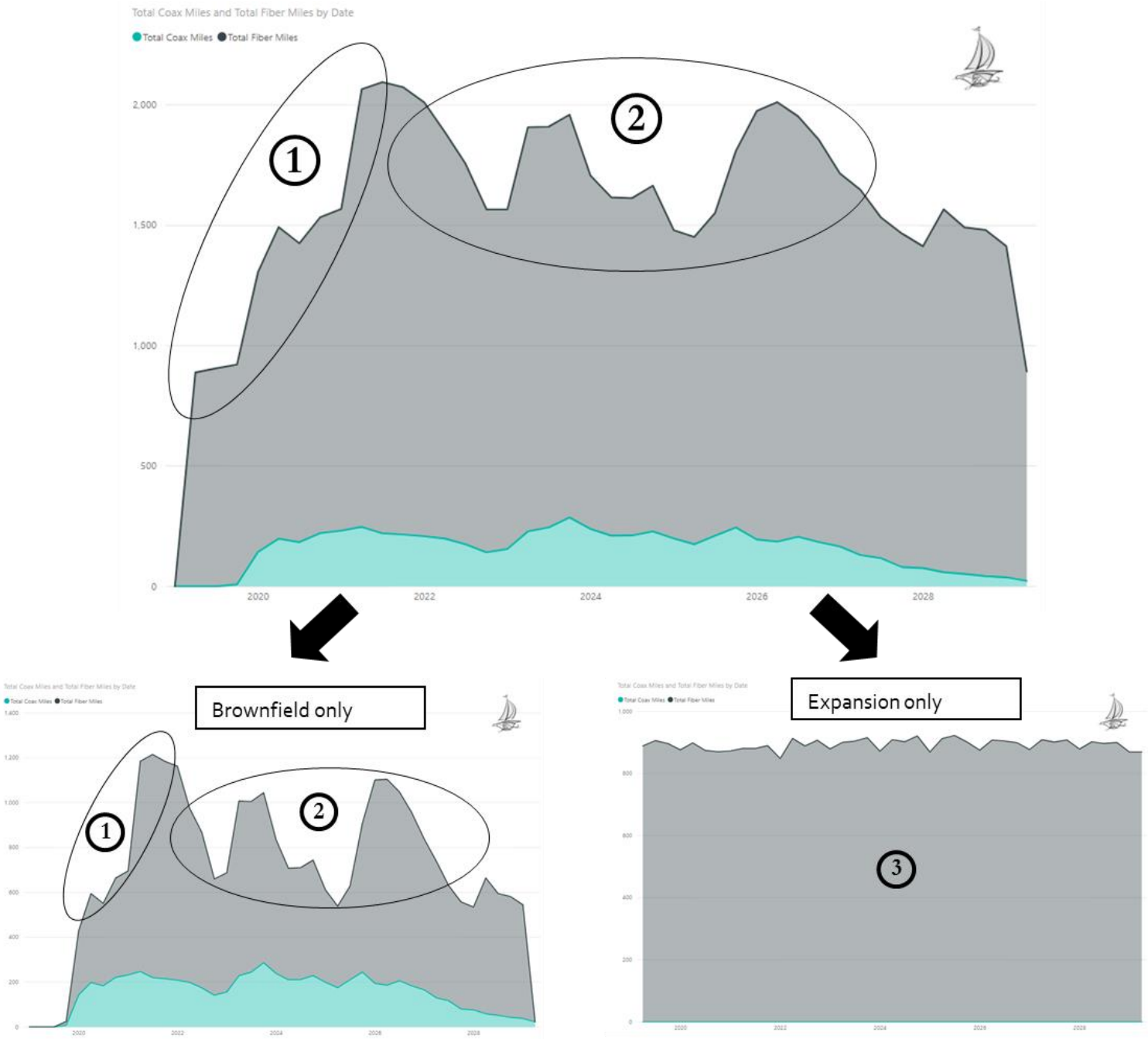

Looking at these diagrams it is immediately obvious that this scenario as it stands is very difficult to operationalize. Zooming in a little bit on the problem areas identified on the picture:

1. During the year 2020 there is a significant ramp up of fiber construction activity. Comparing the overall picture with the breakdown the ramp-up is entirely due to the transformation of brownfield node. Looking back at the scenario definition would reveal an aggressive strategy to convert coax customers to fiber to the home customers. If this aggressive ramp-up is deemed impractical by the operations team, the planner would adjust the scenario definition to result is a slower ramp up maybe by spreading out FTTH conversion by network element priority.
2. During further years, too much fluctuation in construction levels is observed due to brownfield node conversions. Before selling this scenario as a viable approach the planner should adjust some of the Jibe input parameters to smooth out the construction level curve. Smoothing out a curve comes down, in most cases, to tweaking when network elements can upgrade and does generally not require a rethinking of the transformation strategy.

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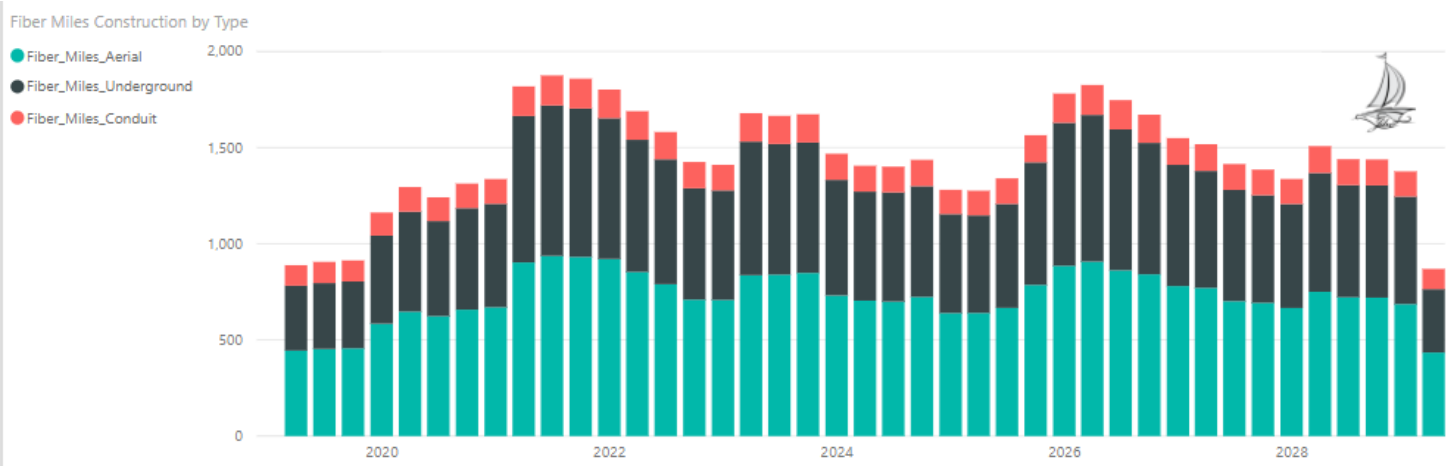
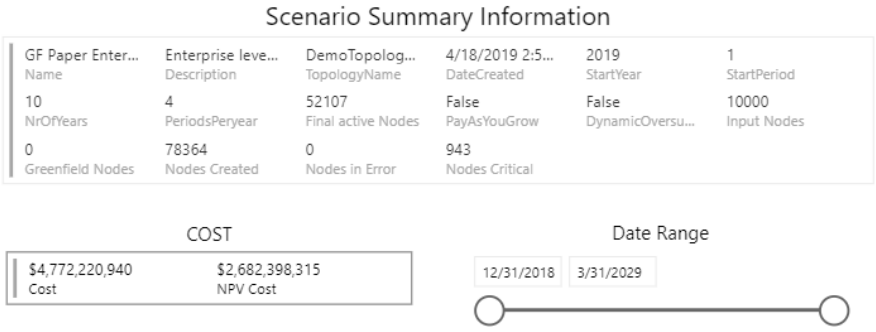
3. Even though it is not a problem, but it is worth to point out that, even though new network elements for network expansion represent only a small percentage of the network - they represent a large percentage of the outside plant construction activity. But this activity is potentially constant.

Sometimes more details are required to understand the feasibility of construction levels. For instance, the screen below breaks down the miles of fiber construction in aerial construction, underground construction and construction in available conduit.



Projected Cost Reports

Another make or break area for any plan is obviously the total cost and cost breakdown over time. Cost details are used for immediate scenario validation against the budget or have a tangible comparison between scenarios. Also, the detailed cost outputs from Jibe can be used as input for a plethora of financial tools.



Every scenario output template starts with a summary view that includes total cost for the entire time-scope and footprint. The scenario visualization template includes multiple financial views give both the planners and financial wizards a comprehensive cost assessment of the scenario. In the figure below, the stacked bar graph shows the total cost per calculation instance and a further breakdown of that cost per component. The accuracy of cost breakdown view is a direct outcome of the level of details provided in the cost input screens, there is no limitation on the details or complexity Jibe cannot handle. Refer to the graph below for a glimpse of Jibe's cost breakdown potential.

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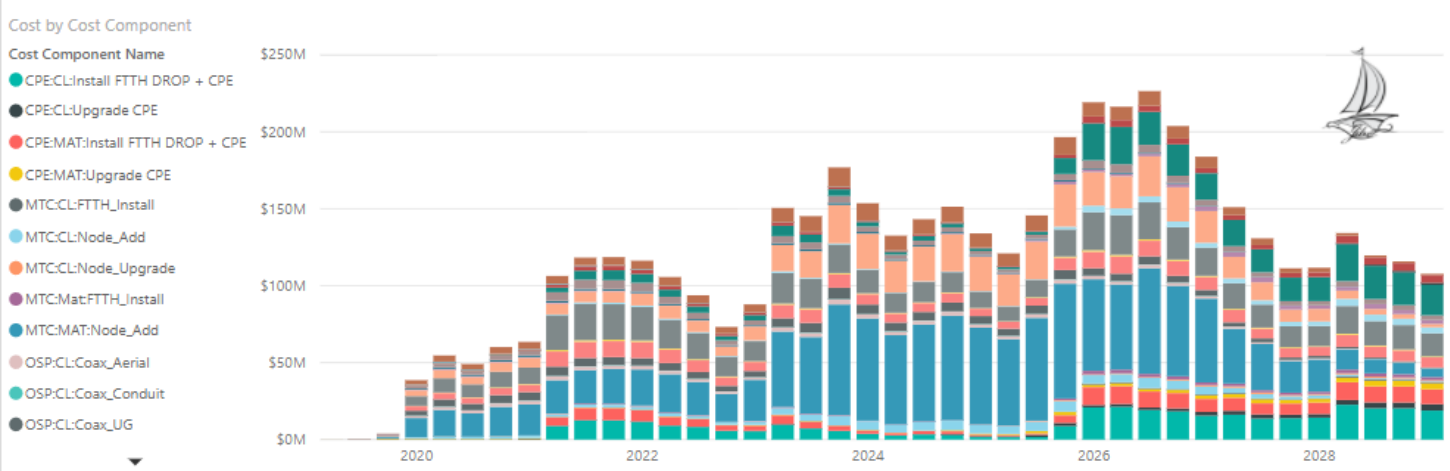
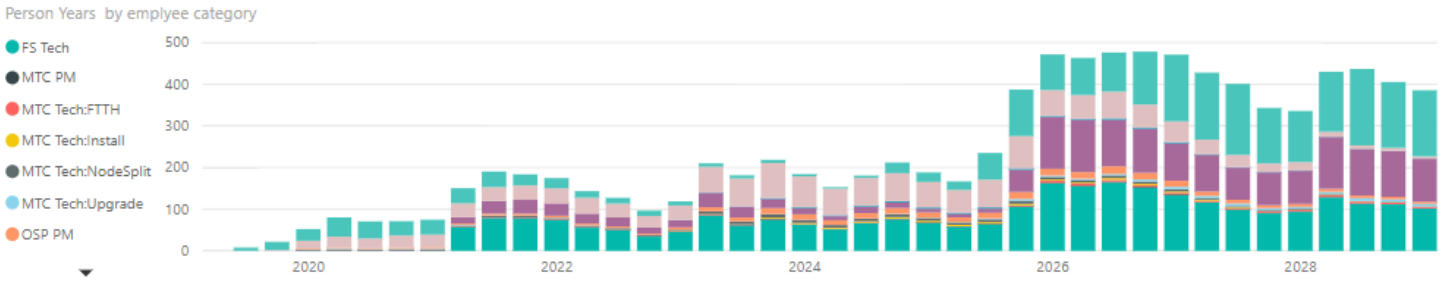


Projected Resource Requirement Reports

Like the cost structure, Jibe can calculate the required labor and material needed for every single action and bring them together in a single view broken down per component. The graph below is an example of labor needs calculated in person year and broken down per employee type. The calculation units for labor and material are, as everything else in Jibe, completely configurable.



Activity View

The activity view assists the planner in understanding the network transformation actions included in the scenario. It gives the planner, the level of activity in the network for every calculation instance and the total broken down by per activity type. The latter will answer, in the blink of eye, how the network will be transformed over time.

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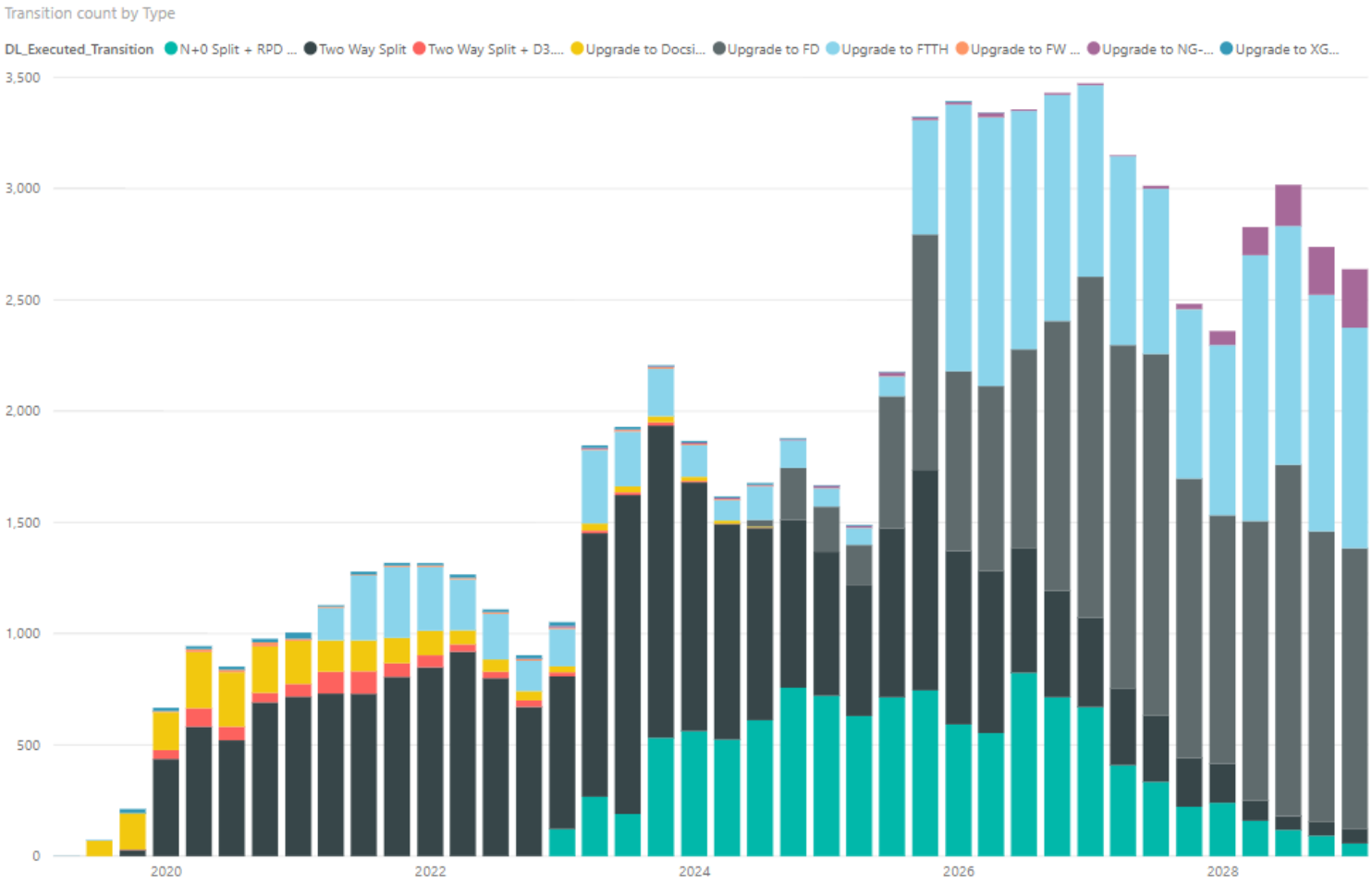

Detailed Node-Level Reports

All the summary views are ideal to evaluate the feasibility of a scenario and compare different scenarios against each other. To really understand the transformation behavior resulting from scenarios nothing beats going down to the network element level and investigating what is going on with the subscribers that start of on a single network element. In the Jibe template, *life of a node* tab provides such a view. Information in this view includes:

- Evolution of technology on the user facing side
- Distribution of subscribers over new (smaller) network elements
- Action on the subscriber facing side of the network element
- Technology evolution on the network facing side of the original of newly created network elements.
- Activity on the network facing sides.
- Details on activity cost and resources.

The graph below includes a snapshot of the "single" network element view.

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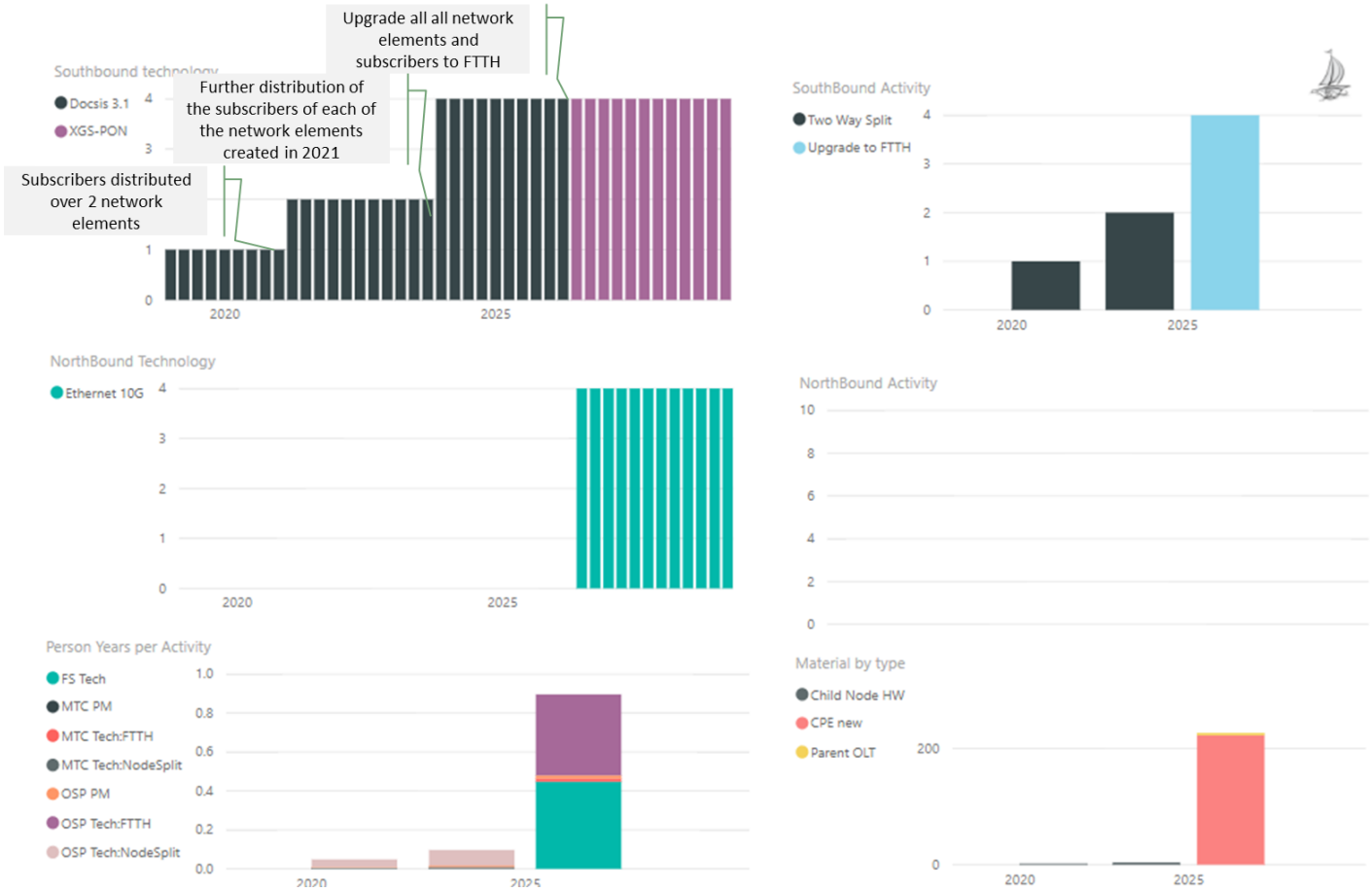

Conclusions

Broadband access networks are having to upgrade frequently due to a multitude of factors including growing user demand, competitive pressures, and regulatory changes to name a few. Network planners often have little time to properly plan their upgrades using their traditional tools and processes. They are often forced to make quick short-term decisions that are not optimal in the long term.

In this paper we introduced a new planning tool called Jibe which is specifically designed to address this challenge for broadband access network planners. Jibe enables planners to rapidly model and assess impacts of various planning options, and thereby determine the optimal upgrade path for their network in the long term.

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-Fiber Deep?
-FTTH?
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