Fault Management and Service Provisioning Process Model of Next Generation Access Networks

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Abstract—**Network operators are nowadays upgrading their access networks to cope with the increasing number of users and the increasing bandwidth required by services. However, cost plays a crucial factor. In order to decide which next generation access network will be implemented, an accurate cost evaluation should be performed. This evaluation requires a total cost of ownership model including a detailed model of the most costly operational processes: fault management and customer provisioning. These models help identifying the most costly subprocesses, where network providers should improve their cost efficiency. This paper presents detailed models for these operational processes and gives an approach to use them for estimating future operational costs.**

Keywords-operational cost; process modeling, savings

I. INTRODUCTION

Telecommunication networks are evolving continuously not only driven by technological innovation but also by cost factors such as the required network maintenance and operation. Particular attention has been paid to aggregation and access networks which have been shown to be the most expensive per transmitted bit [1]. The OASE (Optical Access Seamless Evolution) project takes a closer look into the evolution, 2020 and onwards, of next generation optical access networks (NGOA networks), their costs and business models targeting more than 1000 customers per fiber feed over a transmission distance up to 100 km and in which each customer is getting more than 1Gbps [2].

The costs that have to be taken into account in the cost assessment of NGOA networks cover equipment, infrastructure and operational aspects of the network. In research typically the main focus goes to the upfront investment costs and not into the operational costs. The evaluation of operational costs focuses on the main cost driving network related processes such as service provisioning, fault management and maintenance as well as costs for real estate and energy consumption. Beside the impact of different architecture designs on operational expenditures, also the impact of node consolidation through long reach and high sharing capabilities should be investigated. This paper focuses on the detailed modeling of the two most important operational processes: fault management and service provisioning [3]. The proposed models, which describe the process much deeply than other proposals [4], use the Business Process Modeling and Notation (BPMN), which provides a standard graphical notation for business procedures [5]. In comparison to other approaches such as the business process framework (eTOM) [6] issued by the TMF or the Information Technology Infrastructure Library (ITIL) [7] issued by the Office of Government Commerce (OGC) BPMN processes present real processes indicating in much more detail the flow, choices and actions in the processes, where others typically give classification of processes to be taken care of and give best practices within such processes. The advantage of BPMN is that it is intuitive to business users but still able to represent complex process semantics.

The remainder of this paper is organized as follows. Section II describes the considered Total Cost of Ownership model and the cost classification. In Sections III and IV, we zoom into the operational expenditures of fault management and service provisioning processes, which are described in detail. Section V presents the process of cost evaluation and Section VI concludes the paper.

II. COST MODEL

Total Cost of Ownership (TCO) embraces all costs associated to the network including equipment, infrastructure, real state as well as operational costs such as fault management, customer provisioning, energy, network planning, network maintenance, etc. A lifecycle approach is proposed, as this ensures that every step of the production cycle will be covered. A typical lifecycle of an access network has the following processes [6]:

- Network planning and design: This phase follows the strategy of the network operator based on business studies. It consists of network design and dimensioning depending on the geographical areas, network topology and constraints as well as on the whole market and service demand forecast

- Network implementation involves the initial roll-out including the installation of any required infrastructure as well as the installation and initial configuration of the new

equipment. The network implementation can follow more closely the demand.

- Network Operation includes any activity required during the operation of the network such as the repairing of failures, the maintenance of the infrastructure and equipment, the consumed power, etc.

- Decommissioning: At the end of the network operational time, the network operator transfers any running service to the new network and dismantles the equipment of the redundant platform.

Clearly the initial rollout of an optical access network will be the most costly part of the aforementioned costs since it requires the purchase and installation of most of the required equipment and infrastructure. However, other costs will also have a high impact on the total costs. This is the case of the required and consecutive upgrades of equipment and services as well as the continuous network operation. The operational costs are strongly influenced by the network components characteristics (power consumption, reliability etc.), the network architecture design as well as any special network automation functions which reduce the actions on control and management. All these factors will be an important cost and pose tradeoffs in the choice of equipment and provide important opportunities for increasing the cost efficiency of running the network.

In the following sections we will focus on the modelling and calculation of those operational processes and pay special attention to the fault management and service provisioning process. It extends previous work on modelling [9] and is the first step in estimating operational expenditures [10] correctly.

III. FAULT MANAGEMENT PROCESS

The Fault management process, depicted in Figure 3, is triggered either by alarms received by the Network Management System (NMS) or by the contact of the customer service line by customer(s). In the first case, a Trouble Ticket (TT) is created and a *Fault Diagnosis and isolation* is performed. If the failure is not identified, an extended failure

diagnosis is performed until the failure is identified. Then, *fault isolation and traffic recovery*, shown in Figure 1 is performed to minimize the service interruption times. This sub-process consists of isolating the failure and, in case no automatic protection is implemented, the protected lines are re-routed via the back-up lines. Depending on the nature of the failure, whether it is a configuration or a physical failure, different sub-processes are executed.

- If it is a configuration failure, then the *configuration fault repair* is performed, and a test is executed to verify that normal functioning has been correctly restored. If it has been repaired, the TT is closed and the process ends. Otherwise, the *fault diagnosis and isolation* is performed once again.

- If it is a physical fault, a *physical fault repair* sub-process is executed, which is shown in Figure 4. This sub-process first distinguishes whether the repair is outsourced or not. If it is outsourced, a failure report is submitted to the outsourcing company. This company processes the report and repairs the failure within the agreed time and quality. If the repair is not outsourced, the operator has to distinguish whether it is a cable or an equipment failure. If it is a cable cut (CC) failure, the sub-process *CC failure repair* is performed for which a detailed description is shown in Figure 5. If it is an equipment failure, the operator has to check whether the required manpower, material, spare components and mobility means for the failure repair are available. Furthermore, if digging is required, it is subcontracted and the repair has to wait until the pavement is open. When all the prerequisites are accomplished, the technicians travel to the failure location and they repair or replace the failed component. Once the failure has been repaired, a *line test* is performed (shown in Figure 2) to check whether there is connectivity and the signal quality is above the required value. If the quality is good, the TT can be closed. Otherwise, the components and lines are checked again. If the problem continues to be unsolved, the *fault diagnosis and isolation* is performed once again.
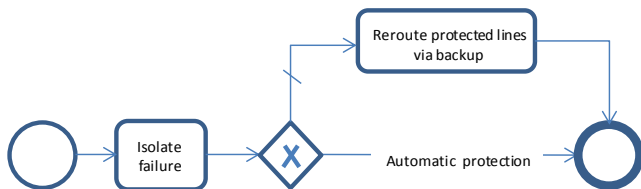

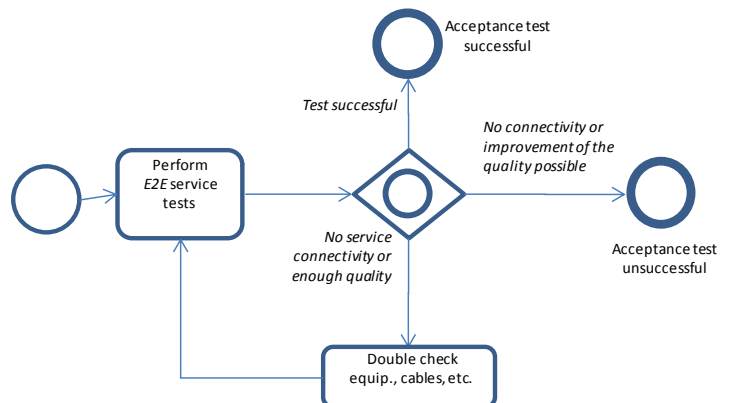Figure 1 Fault isolation and traffic recovery sub-process
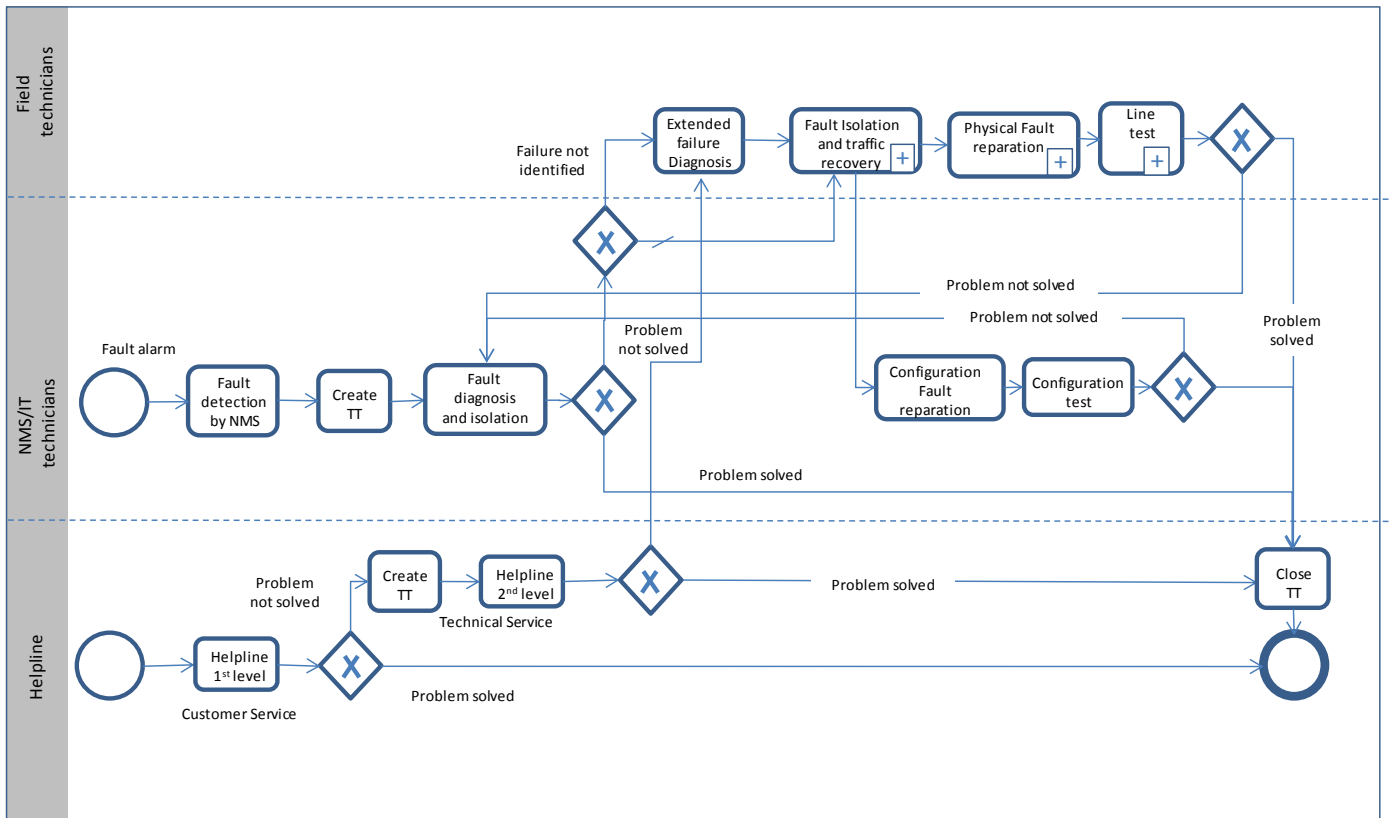
Figure 2 Line test sub-process
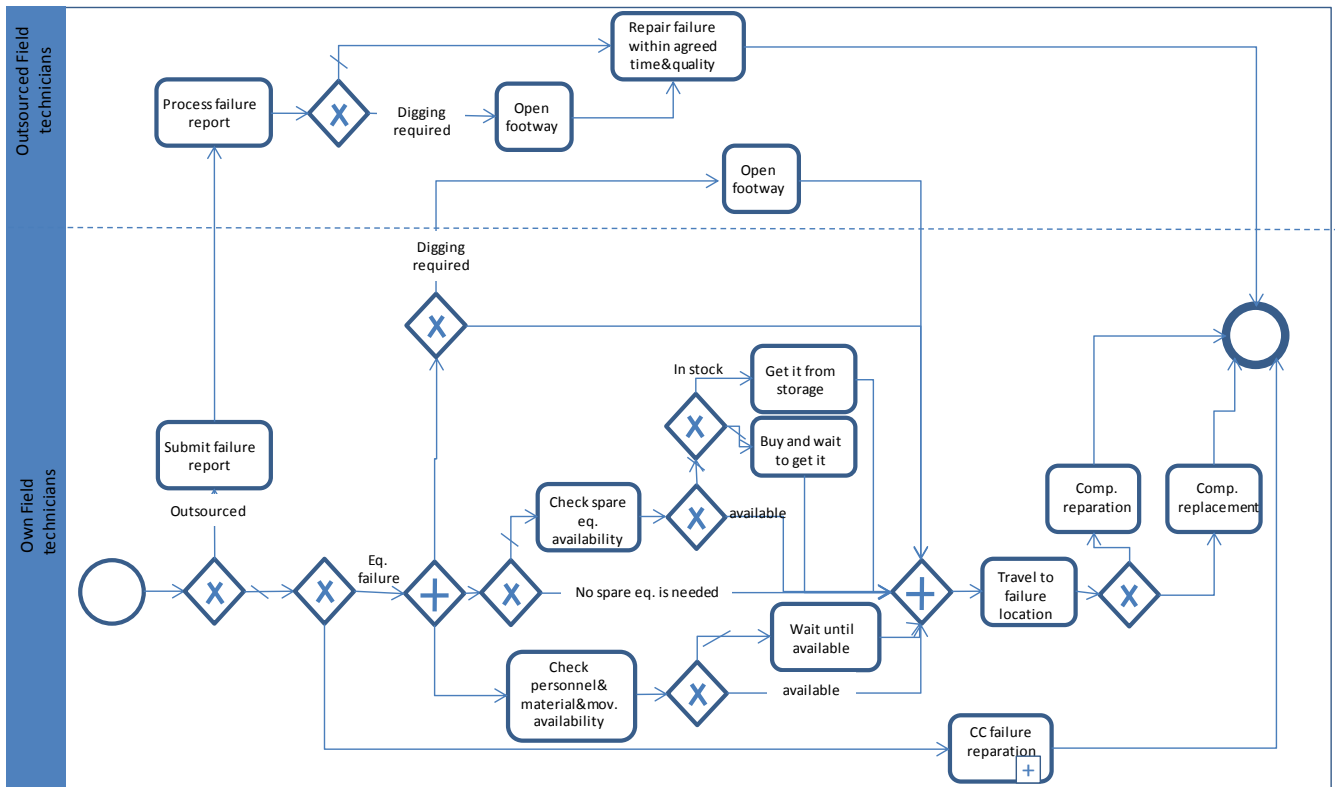
Figure 3 Failure management process

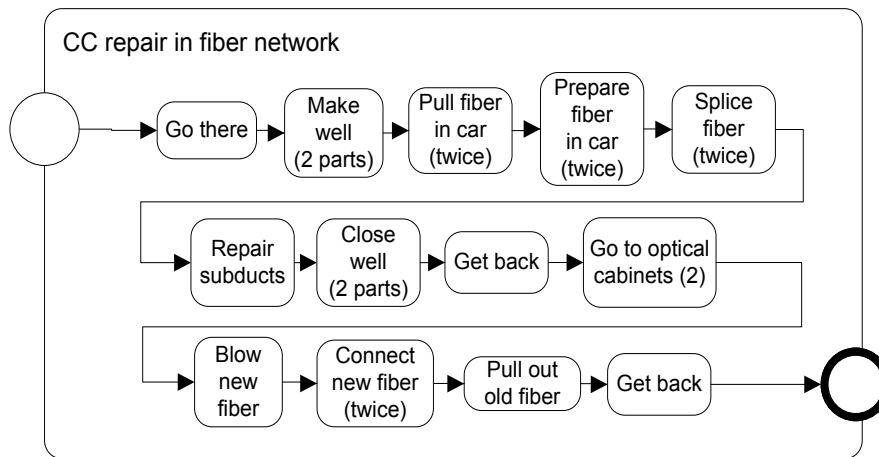Figure 4 Physical Fault Reparation sub-process

Figure 5 CC Failure Reparation sub-process

IV. SERVICE PROVISIONING PROCESS

The service provisioning process deals with the procedure of adding, changing or canceling services of a given customer. The process model is shown in Figure 6.

- Add service: In order to add a new service, two activities are triggered in parallel: the first one deals with the physical connectivity, and the second one is related to the configuration of the customer service profile and service path through the network. The service will to be released to the customer until both activities are successfully completed. In particular, the first activity checks whether there is physical connection and available capacity or not. If there is not enough capacity, a new physical connection has to be added (called *physical connection* sub-process). The detailed model of this sub-process is shown in Figure 7. It can be observed that the connection can be outsourced or done by the own technical personnel. In that case, the connection will be done once the personnel and resources are available at the connection location. Once the connection is done, tests to guarantee a good signal quality are performed before this activity is successfully completed. The second activity configures the service from a central NMS desk.

- Change service: A customer may request a change of a service because of his/her new location or because the customer wants an upgrade of the service (e.g. more bandwidth). If there is a new location, the operator has to check whether there is physical connection with enough available capacity or not. If there is capacity, the service has to be re-configured to the new customer's location. Otherwise, new physical connection has to be added before configuring the service.

- Cancel service: A customer may request a cancellation of his/her service because he/she wants to change provider. In this case, the operator has to check whether there is a bit-stream access. If so, the service can be re-configured through the NMS. Otherwise, the service is switched over to the new provider and removed from the current one.

V. COST EVALUATION

BPMN models, and more in general annotated flowchart diagrams, can easily be accommodated to be used in cost calculations. It suffices to associate an *execution cost* to each activity and associate information on the *statistical occurrence* to each branch at a gateway.

The execution cost of an activity in the process is typically calculated from the amount of resources on average consumed in this activity multiplied by the cost of each of those resources. Typically this contains the details of the type of personnel that is required and the time it (statistically) will take to execute the activity. This approach is suggested in activity based costing (ABC) [8]. Next to working hours, also other resources could be used in the execution of a process. This is for instance necessary when modeling parts of the CapEx using operational processes, e.g. an activity that involves the insertion of new linecards.

The statistical occurrence of a branch at a gateway is reflecting the number of times this path will be taken for one execution coming into the gateway. Very often this reflects in a chance of executing one path or another and as such is very often restricted in the following way: the sum of all paths is often 1 (or 100%) and all paths have occurrence < 1 (100%). For instance in the case of a network failure, the process can make a distinction according to the cause of the failure, either being hardware or software. However, while these restrictions will be often used, they are not mandatory for the calculations nor for the modeling. In this way the process can for instance model an outgoing occurrence different than 1 (100%). For instance a small part of the failures could include both hardware and software failure (e.g. 80% and 30%). The same approach is used in translating loops into a multiplier after the gateway, shown later in this section.

Figure 6 Service provisioning process

Figure 7 Add Physical Connection sub-process

The cost of executing the process once is then calculated by summing up the weighted cost of each of the activities. The weight is the total statistical occurrence of the activity, as shown in (1) In case a process contains a loop, this can be analytically removed from the process by altering the entrance probability (or occurrence) of the first and consecutive activities in this loop and beyond. The entrance probability is multiplied by a factor as shown in Figure 8. This approach is able to remove a loop from the process in case this loop completely covers a separate part of the process with no paths running to parts outside this loop and a full probability at the exit (here $x + y = 1$). This has always been sufficient for the analysis of processes in our research.

Finally the total cost of executing the process once is multiplied by the number of occurrences of this process, leading to cost estimation over a given planning horizon (e.g. 1 year).
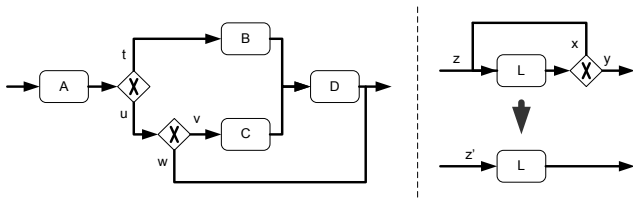

Figure 8: Simplified processes used in examples for the cost calculation

The total cost associated to the left process of Figure 8 can be expressed as:

$$Cost_{tot} = Cost_A + Cost_B + t \cdot Cost_C + (t + v) \cdot Cost_D \quad (1)$$

With: $Cost_i$ = The cost of executing a precise activity i or the total process from Figure 8 (left). Note how the statistical occurrences t and $u.v$ are summed for the calculation of the cost of executing activity D.

Regarding the cost of the right process of Figure 8, it can be found using the following expression:

$$z' = z \cdot (1 + x + x^2 + ...) = z \cdot \sum_{i=0}^{\infty} = \frac{z}{1 - x}$$

With: z' = The new entrance statistical occurrence (i.e. replacement for z) when removing the loop link from the process. This will alter the statistical occurrence of all consecutive activities and gateways in the process.

Within the OASE project we will complement the process models for fault management and service provisioning. As we have the knowledge to construct a full TCO model based on existing research results. The comparison of equipment investments to the costs for the operational processes over several years, allows assessing correctly which next generation optical access technology to choose to be cost-efficient in the long run. As mentioned before, this question will become very important once the Fiber To The Home (FTTH) network is rolled out and the equipment should be upgraded in the future.

Since the communications arena is open, there are more complex business scenarios than years ago. In these business scenarios, costs associated to physical infrastructure providers, network providers and service providers should be split among the different providers, each one being responsible for the installation, maintenance, reparation, etc. of their own equipment.

VI. CONCLUSION

The deployment of future-proof FTTH networks is mainly driven by technological innovation, the increasing market competition with the obligation to offer the best services on a low price level, and by new service evolutions which require ever higher access bandwidths but also operational cost factors. Next generation optical access networks aim to bring high bandwidths to the customers in a cost-efficient way by minimizing the network investments (€/bit) and by reducing the operational expenditures. The thesis is that evolving capabilities of future optical architectures will allow higher utilization of fiber infrastructure and longer transmission distances with less operational effort and new opportunities as for example new cuttings of access areas with larger area sizes and fewer network locations. In order to test this thesis, the research community requires detailed operational models and this study provides a sound basis of these operational processes and indicates how to use these to estimate the costs.

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