On the costs of operating a next-generation access network

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***Abstract*—Most telecom operators today are reluctant to deploy Fibre to the Home (FTTH) in the access networks as this is a very cost intensive operation. Typical figures mention in the range of 750 up to 1000 Euro per home passed and up to 2000 Euro per home connected. It is thus for a network operator of utmost importance to get and keep a clear and balanced view on the deployment costs of FTTH and the most important trade-offs.**

In this paper we present results from a realistic case study considering a full, GPON based, FTTH deployment in a city of about 10000 residents of Belgium. After discussing the overall cost breakdown, we focus on the costs of operating the network which typically get less attention. We give template process descriptions for typical repair and provisioning processes and indicate typical times and occurrences for the activities involved.

***Index Terms*—Operations research, Communication system operations and management, Communication system planning, Optical fiber communication**

I. Introduction

SOME FTTH deployment projects attracted a lot of attention recently. FTTH networks were successfully deployed in different cities such as Amsterdam [1], Vienna [2], Paris [3], Vasteras [4] and other. However, the overall number of FTTH customers throughout Europe is still very limited and most of the deployments fit within community initiatives.

Traditional network operators are reluctant to any FTTH deployments. Both the unclear legal situation [5] and the expected high costs are cause to this. To make any profound decisions on FTTH deployment, an accurate cost model is to be used, given enough detail on differences between deployments in different regions.

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Several references describe typical infrastructure costs. Also fiber deployment costs (outside plant: trenching) are rather well known [6]. In this paper we provide a model for estimating the costs of network operations. We sketch the framework of business process modeling in telecom in which our models fit and provide template process descriptions for repair and provisioning processes. We indicate reference times for the activities involved which can be used as an input for an activity-based cost calculation of these processes.

II. Typical FTTH Deployment Cost Breakdown

A. Case study for a Belgian mid-sized town

As an exemplary case we calculated the FTTH deployment costs for a greenfield scenario for Zele (Fig. 1). Zele is a Belgian town of about (potential) 10000 customers, meaning 10000 homes, including currently empty parcels. We considered a passive optical network (PON) with a 1:32 split factor. Four main cost categories have been considered for an expected lifetime of 10 years:

- Outside plant includes both trenching and equipment cost (splitters and flexibility points) and adds up to 65 % of all costs. We assumed an all buried scenario (no aerial fiber deployment).
- Inside plant is basically the cost of one central office (for the 10000 customers under consideration) and represents 7% of the costs.
- Service provisioning for connecting the customers to the new FTTH network means 27% of the costs (assuming a take rate of 100% and all customers connected up front)..
- Up and running costs represent around 1% of the cost. This is the expected costs for cable cut repair and energy consumption over 10 years.

Overall, this leads to a cost per home passed of about 1050 Euro and a cost per home connected of about 1450 Euro for a 100% take rate. Drastically lower take rates can have a major impact on the expected cost per home connected (as volume independent costs like outside plant deployment costs contribute to the majority of the overall cost). In the considered case the cost per home connected grows to 2900 euro in case of only a 50% take rate.

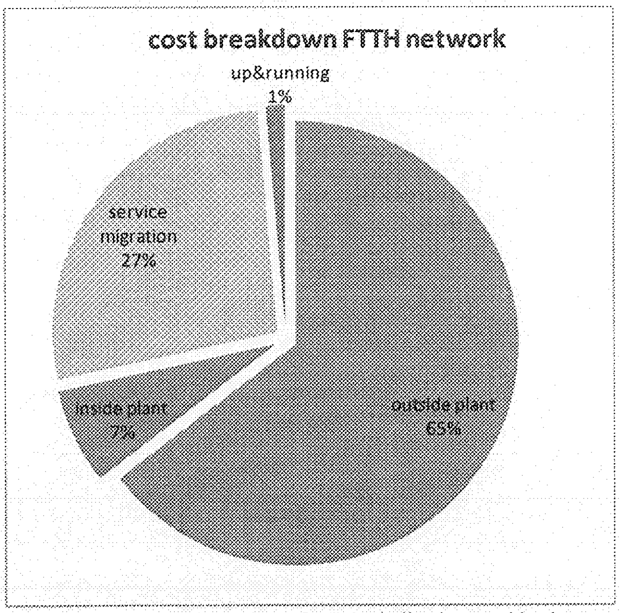

Fig. 1 FTTH cost breakdown for Zele, indicating outside plant as the major cost contributor.

B. Deployment cost

The cost for network deployment can be split in the cost for the physical infrastructure itself (fiber, splitters, flexibility points, etc.) and the labor cost for deploying this equipment. They represent capital expenditures (subject to depreciation) and are sometimes called 'first time installation cost'. Outside plant contributes to about 90% of the deployment cost, inside plant to only 10%.

- Considering outside plant, the main cost contributor in the considered case for Zele is clearly trenching with 94% of outside plant cost, splitters account for nearly 1.5% and flexibility points (both the physical equipment and installation) for the remaining 4.5%. Note that the trenching costs could be reduced in case also aerial or façade deployment is taken into account (taking advantage of the physical proximity in some neighborhoods).
- The inside plant costs can be split in a part proportional to the number of fibers, a part proportional to the number of customers and a part proportional to the number of central offices (CO). For the considered case in Zele, we neglected the CO-driven costs for airco and backup generator. 54% of the inside plant cost is fiber-driven (optical main distribution frame (MDF), optical line termination (OLT) cards, optical jumpering, internal cabling), 46% is customer-driven (chassis, rack, shelf, control).

C. Operational costs

Operational expenditures for a network which is up and running typically consist of two parts.

First, there is the continuous cost of infrastructure which is proportional to the amount of equipment and includes costs for energy consumption (for powering and cooling) and floor space. In the Zele case described here only the energy for powering is counted, which represent a low cost. We based the calculation of these costs on the figures found in [7]. It should be noted that this study as well as our study assume only the power consumption of the access network in the central office (thus excluding all network infrastructure at client side or beyond the OLT-cards) for a PON network.

Second, there are the operational costs driven by labor cost. This part contains different operational processes for network operators, like maintenance, repair, service provisioning, operational planning and marketing. The cost of a single occurrence of the repair process is estimated by multiplying its duration with the hourly cost of the person involved. It is useful to consider different costs for administrative versus technical personnel for example or to distinguish based on the required skills of the technical people, as well as on the typical size of the technical intervention team (number of people working together). Hourly wages should account for the full cost towards the operator, and thus include taxes, overhead for training, tooling, etc. This way, the experienced hourly wage can easily increase up to 2 times the actual hourly wage paid.

Within the case we considered, we focused on repair and service provisioning.

- The repair process cost is taken together with the energy cost in Fig. 1 and account in the exemplary case for 1% of the total cost. In the first place this means that operating a fibre network could be less costly than operating a copper network. However, it should be noted that the exemplary case uses a PON architecture with a split factor of 1:32, where an active architecture would thus contain up to 32 times more fibres in the feeder cables.
- The service provisioning accounts for 27% of the overall cost. Within this category we can again distinguish three parts. The physical installation (cable) accounts for 15% of the service provisioning cost, the technical installation for 74% and the administrative work for 11%.

The processes behind FTTH network operation have attracted only limited attention in literature. As they also represent at least somewhere around 30% (exactly 28%) of the total cost they form the focus of this paper. Additionally we try, where possible to indicate the important differences to operating the existing infrastructures, such as copper access networks.

III. Modeling Network Operations

In order to calculate the expenses for operating a network, there are two prerequisites. In the first place we need a clear model of the processes, preferably in a standardized and easily understandable notation. Here it is also important to find out where those processes are situated and whether we are not overlooking other important processes. In the second place we need information on the occurrences and costs for each action in such operational process model.

In the following subsections we build a model for the provisioning and repair process and complement this with information on the time-consumption of the actions and occurrences of those processes.

A. Enhanced Telecom Operations Map

In order to calculate and optimize operational expenditures, it is definitely necessary to get a better view on the operational processes behind these expenditures. Business Process Modelling (BPM) can be used for describing the existing situation "as-is" as well as the future situation "to-be". Processes are typically considered hierarchically and are composed of sub-processes, which can in their turn be decomposed in smaller sub-processes, etc. The required level of detail in a certain modeling exercise depends on the goal of the exercise. The typical process levels distinguished are listed below:

- Level 0: business activities
- Level 1: process groupings
- Level 2: core processes
- Level 3: business process flows
- Level 4: operational process flows
- Level 5: detailed process flows

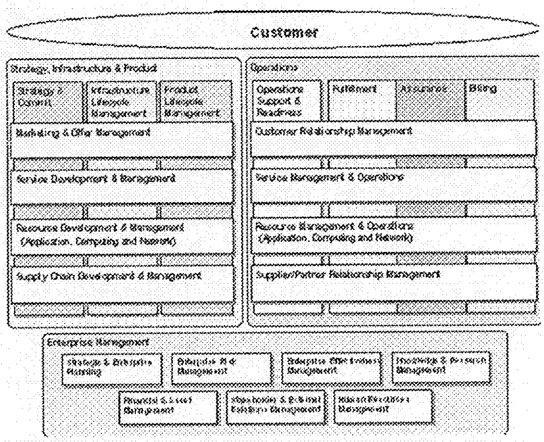

Fig. 2: eTOM level 0 and level 1 processes

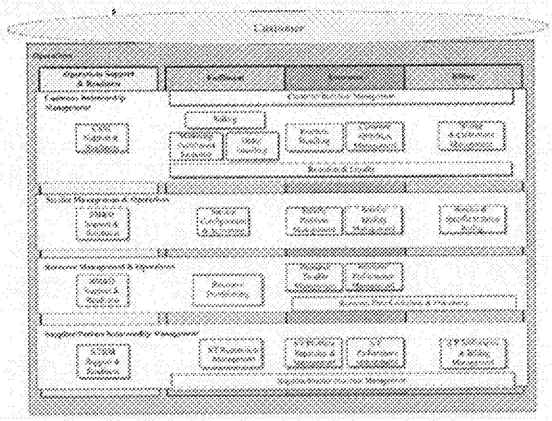

Fig. 3: eTOM level 1 and 2 processes within level 0 process Operations

The processes on levels 0-3 (see also Fig. 2 and Fig. 3) for a telecom enterprise are described in the enhanced Telecom Operations Map (eTOM, standardized by TMF: ITU-T M.3050). eTOM is an activity-based process decomposition model, grouping typical processes according to their purpose or where they are taking place. It is not within the goal of eTOM to address detailed processes and procedures of an enterprise. Moreover, rainy day scenarios and dynamic aspects are out of scope.

The considered processes for repair and service provisioning will be modeled at level 4. They both span different level 3 blocks as indicated in eTOM. For instance the repair process will involve partly each of the building blocks within L1 – Operations and within L2 – Assurance (see also Fig. 3). Service provisioning will involve the L3 blocks within L1 – Operations, L2 – Fulfillment and L1 – Strategy, Infrastructure & Product, L2 – Infrastructure Lifecycle Management considering the installation of equipment.

B. *More detailed (L4) modeling*

The aim of the processes that fit within eTOM level 4 is to describe a typical process flow, indicating typical actions performed by the operational teams of the network operator (e.g. replacing equipment or rebooting software).

Using L4 processes and additional information on the actions it is possible to estimate the costs of executing a specific process a given number of times. It is thus perfectly suited for bottom-up calculation of operational costs. A typical activity based costing (ABC) approach, as described in [8] and [9], can then be used for these calculations.

The processes are described using the Business Process Modeling Notation (BPMN) [10]. BPMN was developed by the Business Process Management Initiative and provides a standardized graphical notation for drawing business processes in a workflow. In order to construct a detailed model it is often necessary to get in touch with the people actually performing the actions. Therefore it makes sense to use a readily understandable model (such as flowcharts) and adapt this to include all necessary details. BPMN combines both an intuitive flowchart based model and a sufficient level of detail. Finally it can also be used on the different process levels.

Not a lot of literature on such level 4 processes exists and it all focuses on processes in core network [11][12].

In this paper, we focus on the operational processes for repair and service provisioning for a future FTTH access network. For both processes, we will start by giving an activity-based process description and we will indicate reference times for the action involved. We will also indicate how to estimate the number of occurrences of these processes in order to be able to calculate the associated costs.

IV. Provisioning Process

The provisioning process is this process in which the clients are connected to the new network and the services offered over this network. It is clear that the FTTH subscriptions will cannibalize on the other subscriptions. In the end this will be a deliberate side-effect, which will even be actively intensified, as this allows the operator to phase out the existing network (copper based digital subscriber line (DSL) or hybrid fibre coax (HFC)) and thus reduce maintenance for this network.

It is a costly process, which was estimated to consume 27% of the expenses of the full rollout. Considering this large cost, it makes sense to model this process in more detail.

A. *Activity-based description*

A high level overview of the process for connecting a customer to the FTTH network and providing him with all services over the network is shown in Fig. 12 using the aforementioned BPMN notation. It consists of four large building blocks.

A first block contains all administrative tasks which are necessary in advance to the physical installation of the customer. This sub process will check if the customer can be connected to the network, if there are existing subscriptions which should be removed in advance and finally detail the specifications for the physical installation. In the meantime, all administrative tasks necessary for subscribing the customer to the different services and registering him into the databases, for instance for pricing and billing purposes, is also taken care of. A more detailed view on this sub process is given in Fig. 4.

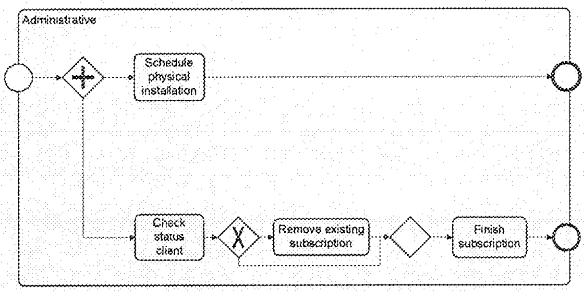

Fig. 4: administrative provisioning sub-process

All other processes will execute the work which was scheduled in the administrative process.

In the first place this means connecting the customer to the newly deployed FTTH network. This sub process will be almost fully conditioned by the decisions taken during the planning phase. At first a decision has to be made on the type of deployment, being either aerial, façade or buried. Secondly an operator might decide to pre-connect the customers to the network (in which he might be using a restrictive subset of customers for instance based on previous subscriptions). This pre-connected administrative only connection might be used for modelling this reconnection as well, as customers, which are already connected, might switch to other providers and back. Finally it should be noted that both decisions are not independent of each other, as the savings made possible by either pre-connecting or later installation will not be the same for aerial, façade or buried. It is also important to use this operational process in the planning phase as it represents a large cost and is not straightforward. For instance it might in some cases be easier (and less costly) to postpone installation for an aerial installation. In this case an increase of later installation will probably reduce upfront costs and reduce the discounted value of the overall expenses. On the other hand, due to the trenching, postponing a buried installation will most probably result in a much higher installation cost (especially in urban environments) and postponing all installation might lead to much higher overall expenses (even after discounting). To make things worse, the decision of postponing installation will undoubtedly have an impact on the market share and create opportunities for competing operators to aggressively seize market share. The sub-process for the physical installation contains different gateways resembling these decisions and all actions from going to the location to the actual installation at the drop-box up and at the customer premises. Fig. 5 shows the graphical representation of this sub-process.

Finally it should be noted that the pre-connection of customers will most probably include additional administrative work (for instance for upfront appointments, customer visits concentrated in time etc.) which were not included in this process.

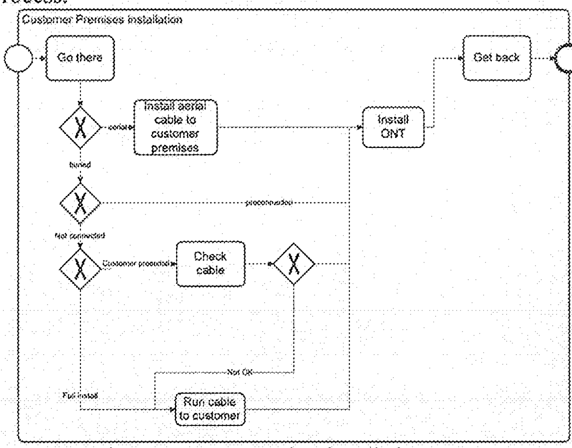

Fig. 5: customer premises installation process

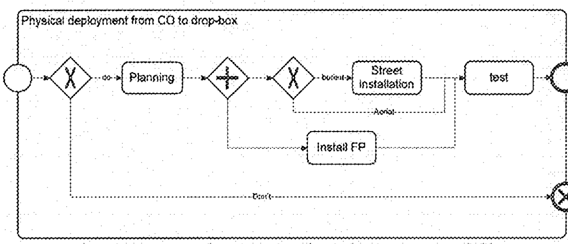

Fig. 6: process for the physical deployment of fibre from CO to drop box

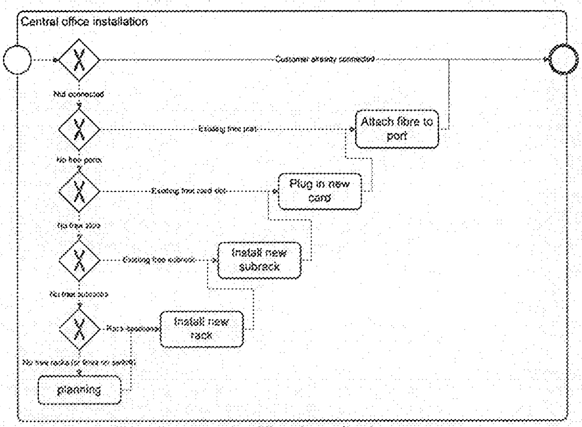

Fig. 7: central office installation process

The two remaining sub-processes detail the actions to be taken for providing connection from the CO up to the drop-box. The amount of up front installation and later installation in terms of residential areas and equipment is a decision taken by the operator during the planning phase. The sub-processes shown in Fig. 6 and Fig. 7 contain all details and will work with whatever granularity of installation envisaged by the operator. In the considered exemplary case we used a full up-front installation of the network, which means that this process is straightforward and required no additional focus. The calculation of the actual cost for the outside plant made use of a heuristic approach for calculating a near optimal trenching structure which is described in more detail in [13].

B. Reference times

Physically connecting the customer to the network is the most costly process, especially in the initial phase of the network.
Given the historical use of the copper wires for telephone services, almost all houses are already connected to the copper network. Newly built houses will typically have a connection to one or more fixed broadband access networks, which in the case of Belgium is either the copper network or the HFC network. It is thus hardly possible to relate the times for the different actions to the actions taken in the copper process.
In the absence of such information we base the timings on experience of field experts. The execution times are not based on any measurement or time registration.

process	Activity	Time (h)	Other
	Validate request	0.17	
	Close request	0.08	
Administrative installation	Schedule physical installation	0.17	
	Check status client	0.41	
	Remove existing subscription	0.17	
	Finish subscription	0.5	
Customer premises installation	go there	0.3	-
	Install aerial cable to customer premises	0.25	15m cable
	Check cable	0.1	
	Run cable to customer	2	10m cable
	Install ONT	2	ONT
	Get back	0.3	
CO → dropbox	planning	X	
	Street installation	X	
	Install FP	6-12	FP
Central office installation	Attach fibre to port	0.17	Fibre connector
	Plug in new card	1	OLT card
	Install sub rack	X	OLT
	Install rack	X	rack

Table 1. Estimated duration of activities in provisioning process in FTTH network (in hours)

The other sub-processes can more easily be related either to the same (or comparable) processes for copper (or HFC) based broadband access networks, or more in general to other administrative, equipment or deployment processes.
An estimation of the execution times based on the various inputs as mentioned before for the different actions is aggregated in Table 1. Some execution times are very hard to quantify and/or very dependent on the specific situation at hand (for instance on the type of hardware used). We marked those cases with an X.

C. Occurrences and associated costs

The provisioning process is executed any time a new customer should be connected.
In the exemplary calculation in the second section, there is no notion of timing and thus the figures found do not show the net present value (NPV) of such installation. Such calculation resembles the case in which all costs are paid up front.
In reality the customers will gradually subscribe to the FTTH network and not all customers should be connected at the same point in time. Anyhow, due to manpower limitations, connecting all customers to the network at the same point in time will most probably be impossible as well. This means that a more realistic calculation requires time-based adoption of the customers. As FTTH is both providing broadband access, voice and video services, the adoption model can be based on the adoption of either of these services. Information on this is found in annual reports of the telecom operators. The paper [14] contains fitted parameters for a Bass adoption model of broadband access and IPTV in Belgium.

V. Repair Process

Repairing a fiber network is fundamentally different from repairing a copper network. Whereas copper welding can happen on site, in the well, in a dirty environment, fiber splicing is far more delicate and requires a cleaner environment. Therefore it is done in a dedicated car which is put close to the location of the cable cut. This leads to higher repair times and therefore higher costs of fiber repair versus copper repair. On the other hand, a copper network is more vulnerable to outside plant conditions like rain, so that we can expect a higher number of interventions needed in the copper network.

A. Activity-based description

The repair process typically consists of several steps (Fig. 13). After fault detection, a trouble ticket (TT) is created. Then the cause of the problem is searched for (fault diagnosis), the fault is isolated and the traffic is recovered. Depending on the specific fault type, the necessary repair actions are taken (fault repair) and some tests are performed. Finally, the TT is closed. We can zoom into all sub processes depicted within this high-level overview in order to find out more details about the activities involved.

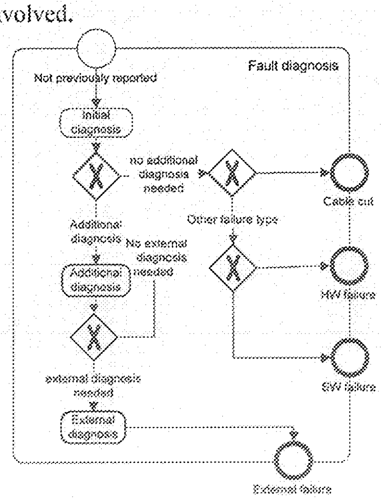

Fig. 8: fault diagnosis process

The fault diagnosis sub processes (Fig. 8) includes different sequential diagnosis steps in order to decide between a cable cut (CC), hardware (HW), software (SW) or external failure. Once the failure has been categorized, according actions for failure isolation and traffic recovery are taken (Fig. 9).

The repair actions (Fig. 10) for software failure and hardware failure and for external repair are pretty straightforward; they consist of rebooting the software, replacing the failing equipment part (on site), or contacting the external team for the repair.

For the cable cut repair (Fig. 11), on the other hand, the sub process is rather elaborate. It typical consists of two steps on two different sites. First there is a temporary repair on the location of the cut, a well is made (big enough to generate some cable overlength which is required in order to be able to pull the cable in the car), then a new cable part is inserted at the location of the cut, which means making two pairs of splices (both sides). The damaged sub-ducts are also repaired. Second, the entire cable part between the two closest optical cabinets is replaced. New fiber is blown, connections to this new fiber are made and the old fiber is taken out (freeing the sub-duct).

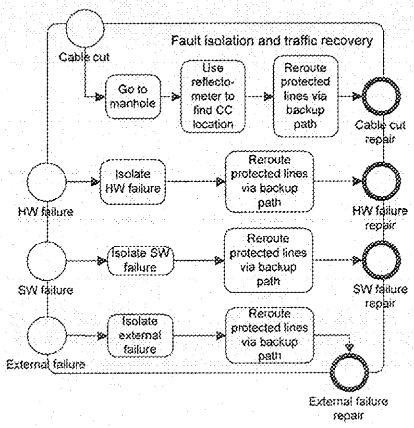

Fig. 9: Fault isolation and traffic recovery process

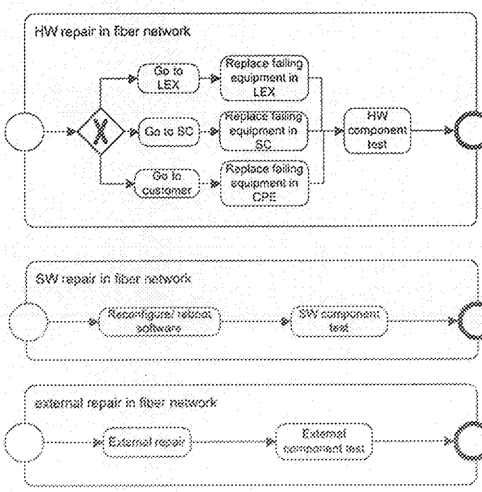

Fig. 10: HW, SW and external repair processes

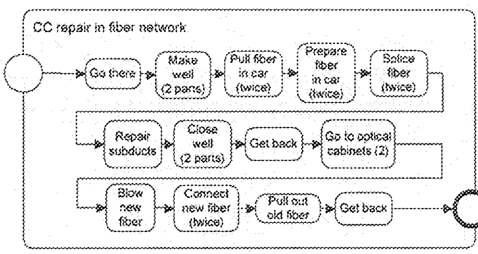

Fig. 11: CC repair process

B. Reference times

We distinguish between a CC repair in a handhole (splicing box) and a CC repair in the field. The former typically corresponds to a mistake in a previous splicing activity in the considered handhole and is assumed to boil down to splicing a single fiber. A CC in the field typically means a cut in the entire cable and we assumed it to correspond to 8 fibers in the distribution part and 72 fibers in the feeding part of the network.

Sub process	Activity	Time (h)		
		handhole	in the field	
			distribution	feeding
fault isolation	go to handhole	0.50	0.50	0.50
	use reflectometer to find CC location	0.25	1.00	1.00
repair	go there	0.00	0.50	0.50
	make well (2 parts)	0.00	0.50	0.50
	pull fiber in car (twice)	0.50	0.50	0.50
	prepare fiber (twice)	1.00	1.00	1.00
	splice fiber (twice)	0.03	0.27	4.80
	repair subducts	0.00	0.16	0.50
	close well (2 parts)	0.00	0.50	0.50
	get back	0.50	0.50	0.50
	go to optical cabinets (2)	0.00	0.50	0.50
	blow new fiber	0.00	0.25	0.25
	connect new fiber (twice)	0.00	0.27	4.80
	pull out old fiber	0.00	0.25	0.25
	get back	0.00	0.50	0.50
testing	measure lines for testing	0.16	0.16	0.16
logging	log	0.33	0.33	0.33
total		*3.27*	*7.88*	*17.09*

Table 2. Estimated duration of activities in cable cut repair process in FTTH network (in hours)

Table 2 indicates the reference times we gathered through comparison with copper processes and experience from experts. Again the execution times are not based on any measurement or time registration. It is interesting to note that it takes a lot of time to prepare the environment for the actual splicing. Before the splicing of the fiber can start, the fibers

need to be unrolled, disentangled, the appropriate fiber needs to be identified and the cladding removed. The splicing time itself is proportional to the number of fibers to be spliced and is estimated at about 2 minutes per fiber.
The higher cost for a failure in the feeding part of the network (with a typical duration of 7 hours and 41 minutes) compared to a failure in the feeding (17 hours and 5 minutes) is due to the actual splicing time of 8 versus 72 fibers. Note that this time is counted twice as splicing is required both for the temporary (step 1) and the permanent repair (step 2).

C. Occurrences and associated costs

The number of occurrences of the repair process will depend on the failure rate of the equipment or cable involved. In [15] a typical failure rate of 3 cable cuts per year per 1000 miles (1609 km) for long haul and 13 cable cuts per year per 1000 miles for a metro network is mentioned.

Apart from the explicit cable cut in most cases caused by human intervention (civil work, accident, etc.), also cable degradation can lead to failure. This is especially important in copper networks, where water intrusion both corrodes the copper and leads to loss of the electrical signal. Given the non-electrical nature of fibre, such loss is non-existing in fibre network. This expectation of a lower number of failure occurrences could be the main factor to the low operational costs of a fibre network (1%) of the exemplary case.

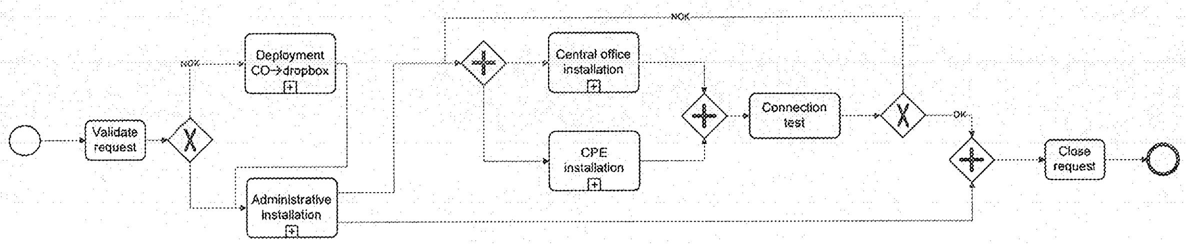

Fig. 12 - High level overview of the provisioning process

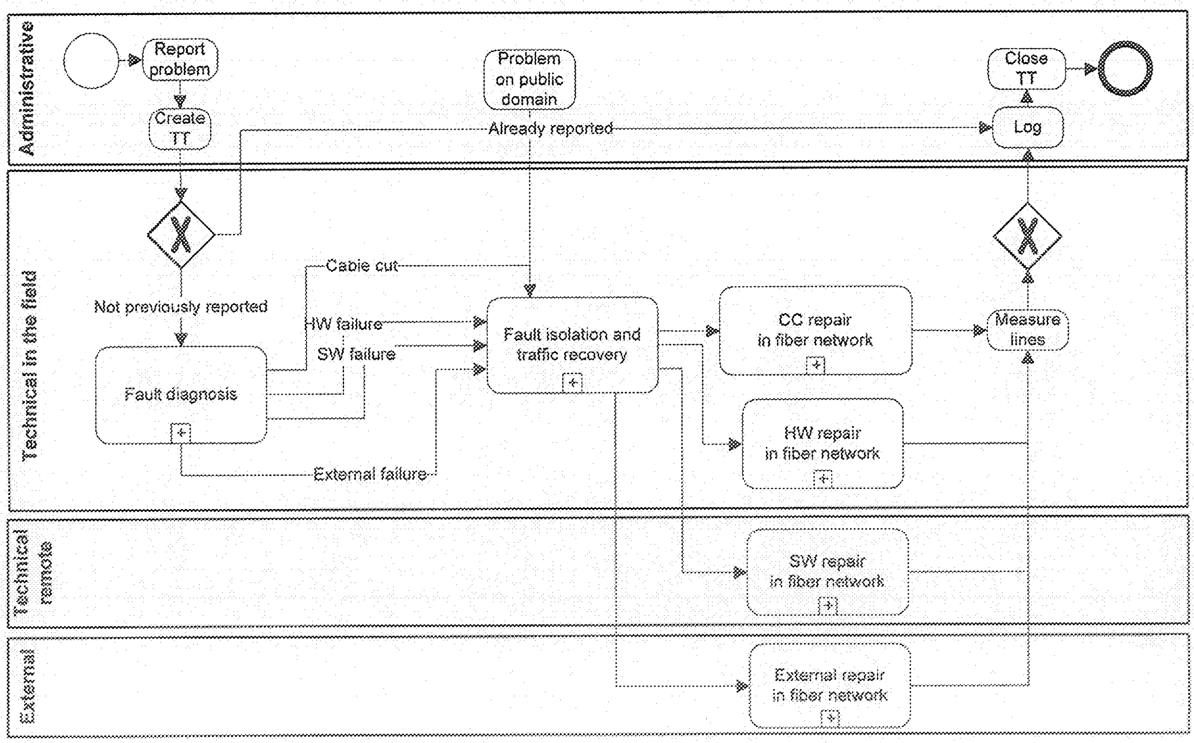

Fig. 13: high level overview of the repair process

VI. Summary

Within the planning of the deployment of a FTTH access network, it is clear that the highest part of the expenses is found in the physical installation of the outdoor plant (typically in the order of 60-70%). This important part has already received a lot of attention in the research. The remaining part, based on operational processes, is often neglected or at most modeled in much less detail. As this counts up to 30% of the expenses though, it is important to calculate these expenses in more detail.

It is important to start from a clear process model for the calculation of these operational expenses. Such processes can be completed with figures for time-consumption of the different actions and occurrences. When all this information is available, a detailed calculation of operational expenses and the impact of decisions (for instance PON vs. Pt2Pt) can be made.

In this paper we proposed detailed operational models for the provisioning process (how customers are subscribed to the services offered in the network) and the repair process. These process models are complemented with realistic figures for time-consumption and some trade-offs. Furthermore the paper contains an indication of where to find data and how to calculate the occurrences of both processes.

Future research will focus on using the proposed operational process models and complementary information for detailed analysis, for instance for estimating the impact of a technology choice on the operational expenditures.

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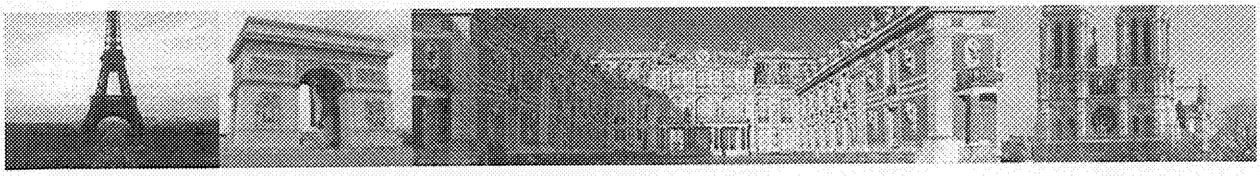

CTTE 2008

7th Conference on Telecom, internet & media Techno-Economics 18 June 2008, Paris, France

Program

(Final Program)

Opening Session

Hour	Paper / Topic	Author(s) / Presenter	Notes
09:00-09:30	Registration		
09:30-10:30	Keynote	Keynote Speaker: Gilles Le Blanc, director of CERNA, Ecole des Mines de Paris	

Coffee break (10:30-11:00)

Session 1: Next Generation Networks (11:00-12:00)

Hour	Paper / Topic	Author(s) / Presenter	Notes
	Techno-Economic Considerations for Development of NGN	Supavadee Aramvith, Chulalongkorn University, Supatrasit Suansook, NTC, Thailand and Prasit Prapinmongkolkarn, NTC, Thailand	
	On the costs of operating a next-generation access network	Koen Casier, Ghent University - IMEC - IBBT, Sofie Verbrugge, Raf Meersman, Didier Colle, Piet Demeester	
	Business case evolution across technology and services	Robin Bailey, Analysys Mason	

Lunch (12:00-14:00)

Session 2: Inequalities, territories and telecom infrastructures (14:00-15:00)

Hour	Paper / Topic	Author(s) / Presenter	Notes
	A digital divide convergence rate estimation methodology	Vagia Kyriakidou, Christos Michalakelis and Thomas Sphicopoulos, University of Athens	
	Telecommunications in South-East Europe: operators, reforms and outcomes	Ewan Sutherland, Cullen International	
	Techno-Economic Comparison of Urban and Rural Broadband Access Network Deployment	Blaz Peternel, Andrej Kos, University of Ljubljana	

Coffee Break (15:00-15:30)

Session 3: Technoeconomic methodologies and modelling – OPEX & CAPEX models for networks and services(15:30-17:00)

Hour	Paper / Topic	Author(s) / Presenter	Notes

	Applicability of Target Costing to ICT Services and Service Platforms	Denis Becker, NTNU Trondheim Josip Zoric, Telenor Research and Innovation, Trondheim
	Telecommunications Software Industry Evolution	Lauri Frank and Eetu Luoma, University of Jyväskylä
	Analysis of Network Cooperation in Terms of Operator and User Satisfaction	Petteri Pöyhönen, Nokia Semens Networks, Jan Markendahl, KTH, Ove Strandberg, NSN
	Trust in Internet: Issues and Incentives	Mikko Sarela and Pekka Nikander, Nomadiclab, Ericsson
17:00-18:00	Closing session	

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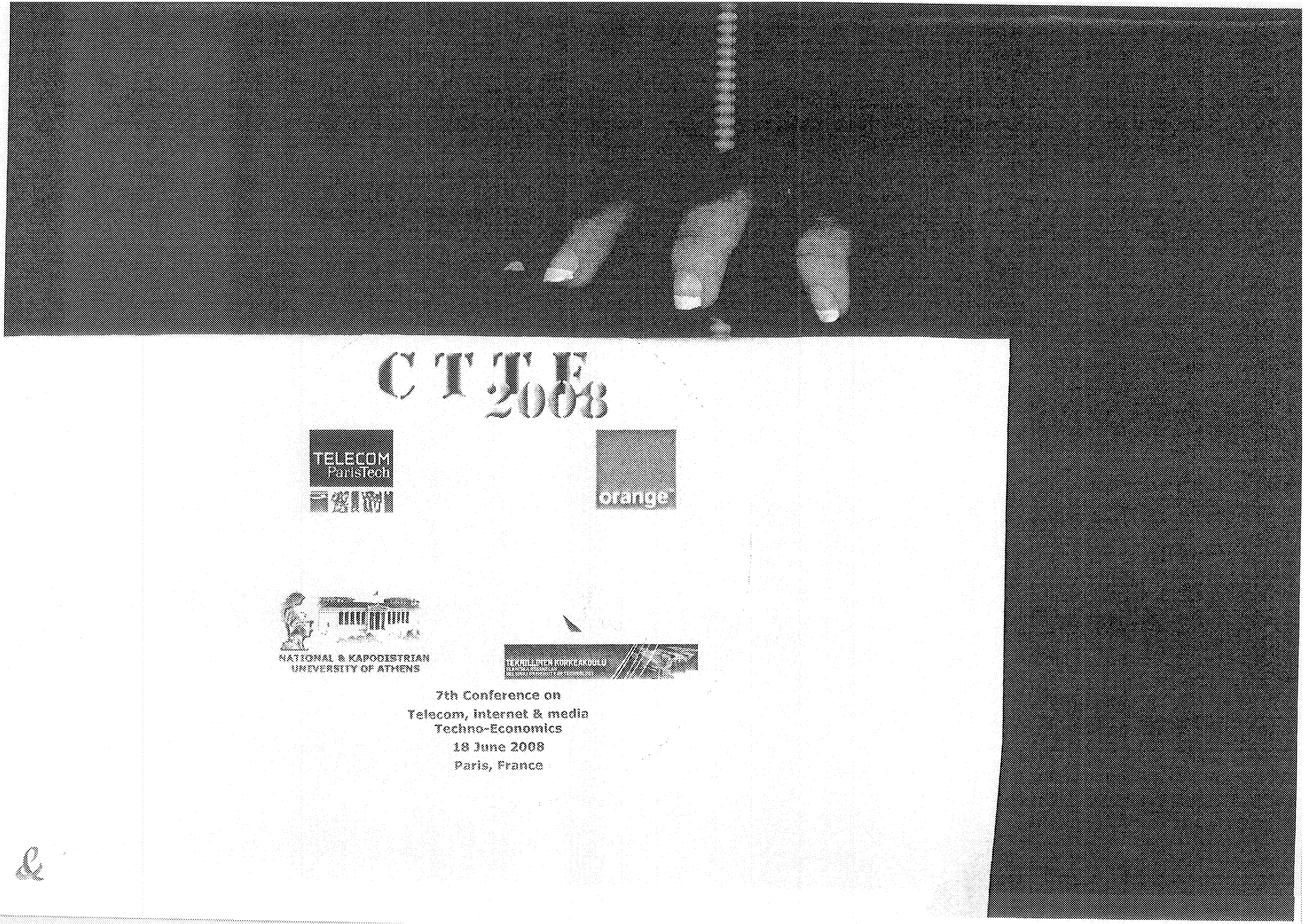
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