FTTH home investment and customer experience

White paper

This white paper discusses techno-economical aspects involving the residential customer domain as Fiber-to-the-Home (FTTH) network and service providers roll out and operate their network. It is demonstrated that technological innovation, sound investments and customer experience improvements can go hand-in-hand in FTTH. By selecting an up-to-date and future-oriented home devices feature set and by streamlining and automating the home connection processes, an FTTH operator maintains or expands competitive advantages and can even achieve significant savings. Investment case calculation examples with sensitivity analysis are shown, and practical overviews and assessments are provided for technical aspects.

Contents

1 Introduction

Deploying FTTH is a crucial goal for network operators, but also a huge CAPEX challenge, further complicated by end-user satisfaction and logistics concerns. This white paper aims to help with solutions focused on the FTTH residential end-user environment.

Deploying Fiber-to-the-Home (FTTH) networks is a strategic goal for many network operators as it provides high capacity and robustness combined with low OPEX. However, deploying FTTH poses a huge challenge in terms of capital expenditure (CAPEX). Moreover, concerns of end-user premises logistics and customer satisfaction further complicate the challenge. This white paper aims to help address these challenges with up-to-date guidance and solutions for the FTTH residential end-user environment.

A residential home or so-called SFU (Single Family Unit) environment in FTTH is depicted in Figure 1, and the Multi-Dwelling Unit (MDU) environment of e.g. an apartment building will also be discussed.

Figure 1. ONT and RGW in SFU environment
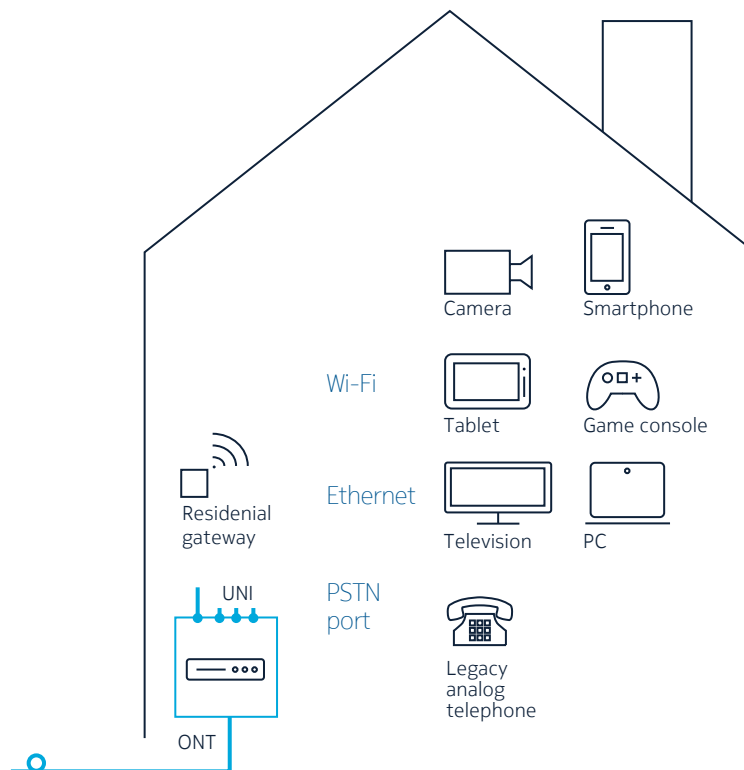
The Optical Network Termination (ONT) terminates the operator's fiber network at the home and provides the user endpoint at L2 (Layer 2 in the OSI network model). It offers downstream and upstream connectivity to the end user via User to Network Interface ports (UNIs). When focusing on FTTH networks of the GPON family, applicable standards are ITU-T G.984, G.988, G.9807 [1], and Broadband Forum TR-156 for ONT OAM and network management [2]. A GPON survey article is [3].

The Residential Gateway (RGW) forms the user endpoint at L3 (OSI Layer 3 or the Internet Protocol layer). The RGW is connected to the ONT with one of the UNI ports via Ethernet. The RGW provides the in-premises fixed and wireless local area networks (LANs), typically Ethernet and Wi-Fi, to which most of the end user devices are connected. Functional requirements for the RGW are in Broadband Forum TR-124 [2] and further references can be found via e.g. [4].

When deploying FTTH, it is in the last hundreds and tens of meters closest to the premises that civil works and cabling tend to be very costly per end user. For Brownfield situations, i.e. for pre-existing premises, in a medium-density urban environment (1500 households per km^2), a study by Bell Labs Consulting (BLC) found that civil works and cabling form approximately 67% of FTTH CAPEX, i.e. they form the largest CAPEX factor by far.

Figure 2. Breakdown of CAPEX for FTTH Brownfield deployment in medium-density urban environment
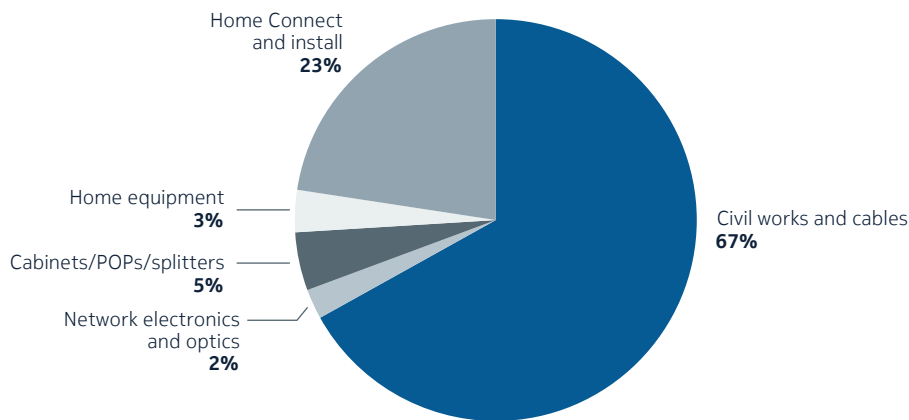
(Source: Bell Labs Consulting proprietary study)

Directly following civil works and cabling, the second largest Brownfield FTTH CAPEX factor at 23% is the "Home Connect and Install" cost. The latter includes the installation cost of drop fiber and ONT. The cost of the "Home Equipment" itself, i.e. ONT and RGW is 3%. These two factors combined add up to more than a quarter of Brownfield FTTH CAPEX. They are from now on referred to as "Home Connect and Devices" for short, and are the focus of this white paper

In a Greenfield situation, i.e. when new premises are constructed, civil works are done for general utilities and FTTH together. Much of these costs can be distributed over several premises. Thus Greenfield FTTH has a lower average CAPEX per end user than Brownfield FTTH, and Home Connect and Devices contribute an even higher CAPEX percentage.

Improving cost in Home Connect and Devices, while targeting customer experience improvement at the same time, is therefore relevant for FTTH network and service providers.

Network providers, for example, Brazil, Canada, China, Spain, the UK and the USA are deploying several hundred thousand up to millions of new FTTP home devices per year. In the calculation examples throughout this white paper, a medium-low volume of 100,000 devices per year will be used.

2 ONT technical assessment

ONT selection criteria must cover aspects of technical performance, connectivity, operations and maintenance, upgradeability, network security, dimensions, etc.

2.1 FTTH/GPON throughput

The FTTH service must be capable of meeting ever-increasing end-user expectations on throughput over the next years. In 2018, Ookla measured global average fixed internet speeds across all technologies of 46 Mb/s download and 22 Mb/s upload. However, similar Ookla numbers from December 2019 were already 74 Mb/s down and 40 Mb/s up, while 800 Mb/s downlinks appeared in ~3% of Singapore's 2019 FTTH subscriptions. An FTTH connectivity at 100 Mb/s download and 50 Mb/s upload may still seem state-of-the-art today, but may soon be outdated.

The chosen FTTH technology will determine the maximum end user speed that the FTTH operator can configure. With GPON technology, each set of ONTs connected through the same feeder fiber with a port on the OLT (i.e. each PON), has a shared bandwidth of 2.488 Gb/s downstream and 1.244 Gb/s upstream. For XGS-PON the per-PON bandwidth is 9.95328 Gb/s in both downstream and upstream. For example, with 64 active GPON ONTs on a PON, the average guaranteed bandwidth per ONT would be 39 Mb/s down and 19 Mb/s up. However, the bandwidth temporarily available per individual ONT can be much higher because OLTs and ONTs adapt as end-user traffic occurs in bursts and packet rates fluctuate. For example, a network provider can provision to all 64 GPON ONTs on a PON a symmetric service of up to 1 Gb/s, which implies an over-subscription factor of 26 in downstream and 51 in upstream. End-user traffic and usage patterns limit the over-subscription options. Because of these technical as well as competitive reasons, upgrades from GPON to XGS-PON will soon become a global trend, requiring replacement of the ONT.

2.2 UNI Ethernet ports

The UNI interfaces in GPON ONTs are usually 1 Gigabit Ethernet (GE) ports. Similarly, XGS-PON ONTs typically have 10 GE UNIs. These UNI speeds are well above the average guaranteed speed per ONT as discussed in the previous paragraph, i.e. the UNIs are not the throughput limiting factor. Sections 3 and 4 discuss the Wi-Fi connection as another potential LAN-side constraint.

2.3 Legacy analog telephony (PSTN) support

With the earliest FTTH deployments of nearly two decades ago, support for analog voice service was often a requirement. An ONT or RGW can indeed support legacy analog Public Switched Telephone Network (PSTN) services by means of integrated Analog Telephone Adaptors (ATA) and typically RJ-11 ports. In upstream, the ATA converts the analog signal to digital (Voice-over-IP [VoIP]), which is then transported over GPON and handed over to e.g. media gateway servers deeper in the network. The reverse happens in downstream.

While the digitized PSTN throughput is low (64 kb/s for basic quality up to 320 kb/s for premium audio), PSTN support may be complex and costly, as e.g. TR-069-based VoIP provisioning, interoperability with specific Session Initiation Protocol (SIP) servers, etc. is often needed, and a sizeable in-home backup battery pack may be required because of PSTN regulation.

Hence when selecting ONT or RGW features for a new investment cycle, analog PSTN service support is worth reconsidering.

2.4 Operations, maintenance, test and troubleshooting features

As focus on service level agreements and customer satisfaction continues to increase, extensive monitoring and troubleshooting support features must be a key goal when selecting new ONTs. Because the ONT is basically an L2 device, these features are situated at networking Layers 1 and 2.

- DDM (Digital Diagnostics Monitoring) is an ONT L1 feature, whereby an ONT supports monitoring of its transceiver's optical power level. Customer dissatisfaction with FTTH services is typically rare, but when it occurs, the root cause is often that the optical power level is out of the proper min-max range. DDM support is therefore an essential feature, that is available on most new ONTs.

- Another valuable and well available ONT feature is L2 OAM functionality, including link trace (LT), loopback (LB), Delay and Loss measurement (DM and SLM), according to ITU-T standard Y.1731, which is a superset of IEEE 802.1ag Connectivity Fault Management (CFM).

- Beyond the ONT itself, fiber networkwide analysis is also useful. Realized as a centralized, permanently running software tool, it provides network wide L1 optical link quality monitoring and troubleshooting and L2 traffic analysis.

In Operations and Maintenance (OAM), upgradeability is an important aspect. As software upgrades tend to lead to increasing software image sizes, it is important that the non-volatile memory designated for the firmware image, i.e. the ONT flash memory, is dimensioned large enough.

2.5 Network security aspects: ONT software image verification and security roadmap

An ONT faces security threats, such as Spoofing, Tampering, Repudiation, Information disclosure, Denial of Service, and Elevation of privilege (STRIDE). Apart from countermeasures that can be applied to any old or new ONT model (banning default account and password, disabling unsecure and unnecessary features, etc.), several threats can be addressed only by up-to-date ONT models.

Security features therefore rank high on the selection criteria for new ONTs. For example, to counter the specific threat of ONT software tampering, ONT software image protection with a digital signature is vital for a new ONT. Generally, there is a need to coordinate new ONT features with the organization's network security roadmap.

2.6 ONT dimensioning

Regarding physical dimensions and shape of the ONT, one specific solution is a complete single-UNI ONT in a standard Small Form Pluggable (SFP) package, i.e. a so-called SFP ONT. An SFP ONT requires the RGW to have an SFP cage into which the SFP ONT can be plugged, resulting in a natural 1-box deployment. Among the drawbacks are the constrained ONT onboard processing and memory which limits advanced functionalities, and the absence of an ONT's typical LED indicators.

Another dimensioning element is the ONT's volatile (RAM) memory, determining the number of individually manageable and configurable traffic streams, QoS queues etc. Sufficient internal queuing capacity (buffer size) is important to better cope with the ONT's waiting time for upstream time slots and with upstream traffic burstiness.

2.7 Other ONT aspects

Other ONT selection aspects include electrical power consumption, environmental conditions (temperature and humidity ranges, suitability for indoor and/or outdoor usage). As fiber cable needs to be somewhat more carefully handled than copper wire cable, ONT wall mounting with presence of an optical fiber lock on the ONT may be preferred over movable desktop mounting.

3 RGW technical assessment

> For the residential gateway, features for latency reduction, Wi-Fi interference avoidance and glitch-free roaming are highlighted. Wi-Fi 6 (802.11ax) is a must-have for the upcoming years.

Nearly all RGWs enable the connectivity from any device anywhere in the home through Wi-Fi. Many operators struggle with underperforming or unstable in-home Wi-Fi in the resolution of customer complaints. Wi-Fi is therefore the main topic of this section.

3.1 Wi-Fi radiofrequency interference

Intermittent or non-stop interference detection on the Wi-Fi signal, combined with automatic and possibly adaptive learning of frequency band or channel adaptation, is highly effective to counter radio frequency interference and greatly improves the end user's perceived Wi-Fi quality.

3.2 Wi-Fi roaming and meshing

In case an end user moves ("roams") between several Wi-Fi access points in the same premises, a smooth, ideally glitch-free end-user experience can be obtained by a mesh of Wi-Fi devices all identifying with the same SSID with automatic management of the handoff from one access point to the other.

3.3 Wi-Fi 6

The latest Wi-Fi version, introduced in 2019, is 802.11ax and is commercially branded as Wi-Fi 6. The benefits of Wi-Fi 6 over previous Wi-Fi generations are summarized in Table 1. Wi-Fi 6 is today's must-have RGW feature. More details can be found in [5], and a comparison between Wi-Fi 6 and 5G cellular networks from a consumer perspective can be found in [6].

Table 1. Summary of Wi-Fi 6

Frequency band	Maximal data rate	Other Wi-Fi 6 benefits summary
2.4 GHz + 5 GHz + 6 GHz concurrently	9.6 Gb/s (probably increasing further)	• Improved throughput, peak data rate and latency via OFDMA (orthogonal frequency division multiple access) • Interference reduction and dense network features, also somewhat improving range vs. 802.11ac • Lower client device power consumption, security improvements

3.4 Latency and other RGW technical features

Low latency communication is especially important for cloud gaming, tactile, AR, and similar applications. The very latest RGWs therefore have features to support such low-latency end-to-end communication. The innovations underlying these features are called L4S and DualPI2 and are now included in IETF drafts [7].

Other features of specific RGW importance include ACL, DDNS, parental control, support for public Wi-Fi, etc. Support for L3 service activation and troubleshooting tests following BBF TR-143 [2] is also an important feature. Further technical features, such as throughput, dimensioning, security, PSTN support, etc. were already discussed in the ONT section and apply to the RGW as well.

4 Separate versus integrated ONT and RGW

While a "1-box" solution with integrated ONT and RGW has some clear advantages and is very popular, especially in China and APAC markets, the inherently different lifecycles of ONT and RGW remain a drawback for ONT and RGW integration. In case two separate organizations need to manage ONT resp. RGW, the issue of remotely managing an integrated ONT – RGW device will gradually vanish because of the emerging TR-369 ecosystem.

4.1 Lifecycle of ONT and RGW

While an operational lifecycle of 10 years or longer can be expected for an ONT, a Wi-Fi generation on an RGW is outdated after 5 years at most. RGW security vulnerabilities will arise every few months, although during the support period these can often be patched through firmware updates. The inherent lifecycle difference implies a drawback for ONT and RGW integration.

4.2 ONT and RGW remote management

In both the separated and the integrated ONT-RGW cases, the ONT function is remotely managed over OMCI, a GPON standard embedded OLT-ONT communication channel.

With separated ONT and RGW, the RGW can be managed via TR-069. With integrated ONT and RGW, the emerging TR-369 User Services Platform (USP) [2], which was defined in 2018, allows for a virtual software-defined ONT and RGW partitioning without requiring a physical separation. When ONT and RGW are operated by different companies or separated entities in the same company, TR-369 will eliminate an obstacle to ONT-RGW integration. TR-369 is backwards compatible with TR-069, and also facilitates IoT device management and user interaction with devices and services via the users' own smart devices.

5 ONT investment assessment

By picking an up-to-date and future-oriented ONT feature set, a provider deploying 100,000 devices per year can achieve cumulative saving of more than 14 M€ over 5 years.

5.1 Situation

This section illustrates how an ONT financial investment case for a network provider can be calculated. The example situation here is that of a wholesale network provider fulfilling a volume of new FTTH connection subscriptions per year by deploying ONTs of a given current type, and now considering deployment of an optimized ONT type for new subscriptions instead (not included in this scenario is a swap-out of already deployed ONTs). ONT unit cost savings should help recover the new ONT introduction investment.

Figure 3 illustrates a model that calculates the net yearly and cumulative savings and the Payback Period (PBP), i.e. the period after which the new ONT starts delivering more saved money than it has cost as upfront introduction cost. The next section clarifies the inputs in more detail.

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Figure 3. ONT investment case calculation model
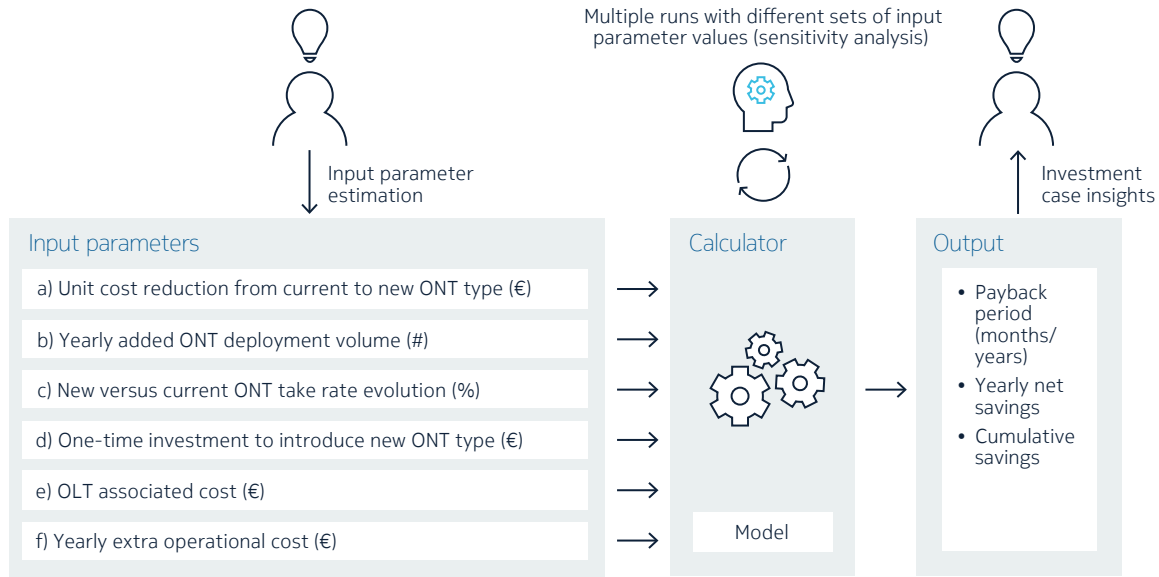
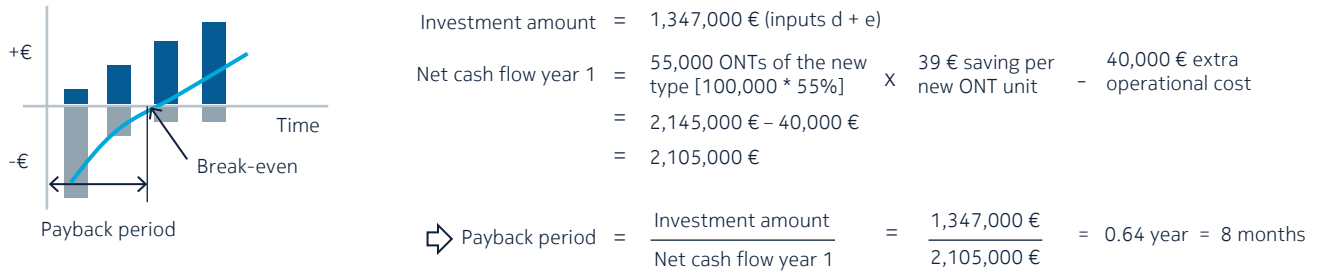**5.2 Payback period calculation with base assumptions set**

The calculations are done first for the following set of input parameter values, called the base assumptions.

Input	Parameter	Value in base assumptions set
a	Unit cost reduction from current to new ONT type	39 €
b	Yearly additional ONT deployment volume	100,000
c	New vs current ONT take rate evolution, year 1-5 (%)	55%, 75%, 95%, 97%, 100%
d	One-time investment to introduce new ONT type	1,300,000 €
e	OLT associated cost	40,000 €
f	Yearly extra operational cost	47,000 €

The input **a** value corresponds to introducing a simplified ONT instead of a more expensive and complex ONT, because legacy analog telephony support (see section 2.3) is no longer needed. Input **c** means that in year 1 only 55% of the yearly ONT volume is deployed with the new ONT type (and 45% still with the old ONT type), i.e. the take-rate of the new ONT type in year 1 is 55%. That take-rate increases over the following years to reach 100% in year 5. Input **d**, the one-time new ONT introduction investment cost, is in this case a significant sum of roughly 20 individually estimated factors, including a large OSS system integration cost for the new ONT type, service testing or interoperability testing with service providers (as applicable), various design updates and tests, etc. However, in many situations a lower value will apply. Input **e** concerns the one-time cost for OLT software upgrade if needed, and OLT-OSS interoperability test.

With these base assumptions, the payback period is calculated as 8 months in Figure 4.

Figure 4. ONT investment payback period calculation with base assumptions

Investment amount = 1,347,000 € (inputs d + e)

Net cash flow year 1 = 55,000 ONTs of the new type [100,000 * 55%]   X   39 € saving per new ONT unit   –   40,000 € extra operational cost

= 2,145,000 € – 40,000 €

= 2,105,000 €

Payback period = $\frac{\text{Investment amount}}{\text{Net cash flow year 1}}$ = $\frac{1,347,000\ €}{2,105,000\ €}$ = 0.64 year = 8 months

It is calculated similarly that the cumulative net savings would already be almost 800 k€ after 1 year, over 7 M€ after the 3 years, nearly 15 M€ after 5 years, and so on.

5.3 Sensitivity analysis

A sensitivity analysis is done by modifying the base assumptions one by one for the following input parameters that by experimentation were found to have significant influence. For each parameter, values are determined so that the PBP becomes 6 resp. 12 months instead of 8 months, and for those values the cumulative net savings after 1, 3 and 5 years are calculated too.

		PBP (months)	Cumulative net savings M€		
			Year 1	Year 3	Year 5
Unit cost reduction with new ONT type (input a)	56.00 € (high, +44%)	6	1.7	11	22
	39.00 € (base)	8	0.8	7	15
	26.00 € (low, -33%)	12	0.06	4	9
Year-1 percentage new ONT (input c)	81% (high, +26%)	6	1.8	8.6	16
	55% (base)	8	0.8	7	15
	36% (low, -19%)	12	0.03	7	14
New ONT introduction cost (inputs d+ e)	0.84 M€ (low, -37%)	6	1.2	8	15
	1.34 M€ (base)	8	0.8	7	15
	2.04 M€ (high, +52%)	12	0.09	6	14

The confidence of recovering the upfront investment within 1 year is clearly high: even with an ONT unit cost saving of only 26€, or a new ONT take-rate in year 1 only 36%, or the total introduction cost increased to 2.04 M€, pay-back within year 1 still stays feasible.

Also, the cumulative net savings are not excessively sensitive to any of the examined parameters.

6 ONT Connect Automation (OCA)

Automating and streamlining the Home Connect and Install processes results in cost savings, because it shortens the field technician time to activate the ONT connectivity and reduces the risk of errors. This can be further augmented by end user self-service activities.

Figure 5 describes how an ONT Connect Automation (OCA) solution such as [8] can streamline the Home Connect process. When an OCA solution is deployed, it automates the manual interactions that were previously required, such as contacts between field technician and service center to activate the service, actions in OSS and BSS systems, FTTH provisioning and OLT element management actions and the various interactions between those systems.

Figure 5. Process streamlining via ONT Connect Automation
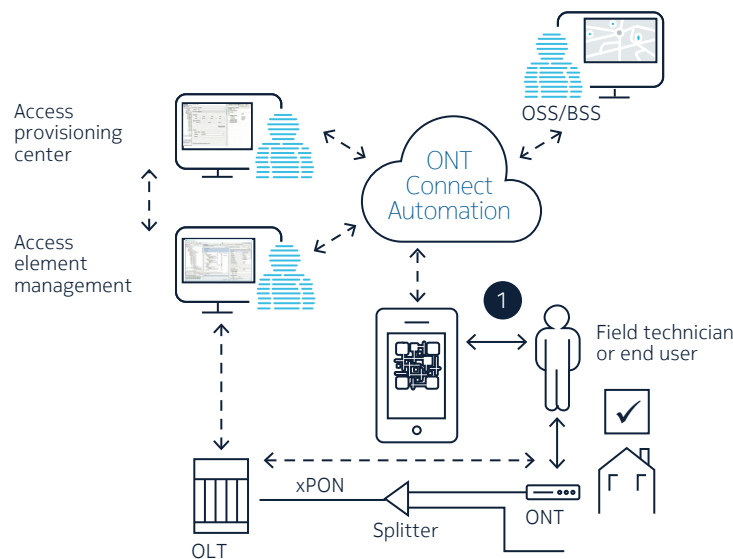
By using the OCA smartphone app (or by browsing to the OCA server), the field technician now scans the QR code that is present on the ONT and in which the ONT serial number is encoded, which triggers the OCA software system. The OCA then automatically interacts with OSS and BSS systems, and coordinates these with the access provisioning and element management systems. The operators at the different OSS/BSS/EMS workstations still monitor what is now being executed automatically. Because the actions are automated, they are executed fast and with reduced risk of errors. Therefore, OCA shortens the time that the field technician must stay in the premises.

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Using the OCA smartphone app and scanning the QR code are actions which can easily be performed by end users as well. If this would be the only action for a field technician, that remaining field technician time can vanish completely, if the end user accepts doing these activities. E.g., in an advanced self-service approach, the end user also installs the ONT i.e. unboxes it, mounts it, and connects the drop fiber. In the latter case, consumer instructions about the very low Class 1 laser safety hazard and about fiber damage prevention are required.

In one example OCA-supported scenario, a field technician installs an ONT in a Brownfield SFU and activates the ONT via the OCA solution. In another example, the end user in a Greenfield MDU with preinstalled ONTs does the self-service ONT activation using OCA (after receiving a letter with the credentials from the network operator). In case the end user encounters difficulties, a field technician intervention can still be requested via the same smartphone app.

Several other scenarios can be supported, e.g. also ONT swaps without technician intervention can be enabled, and the enhanced control and traceability provided by OCA still delivers benefits in the ONT de-commissioning process.

7 ONT Connect Automation investment assessment

If an ONT Connect Automation is well executed, 5-year cumulative net savings can range from 0.7 to 5 M€ depending on the selected scenario, with greatly improved customer experience as bonus.
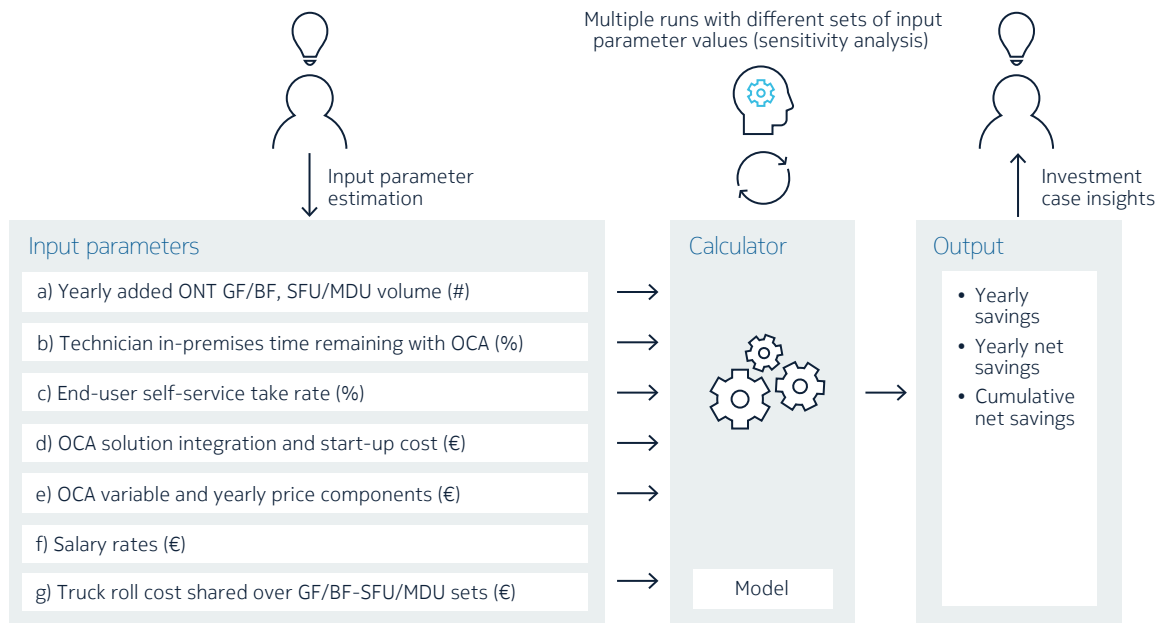
7.1 Situation

As in section 5, this section discusses an example investment case for an ONT Connect Automation solution. The considered situation is that in the current fulfilment process for new FTTH connections, a field technician installs and activates the ONT in the end-user premises, and the provider now considers introducing an OCA solution. Cost savings on technician time and truck rolls should help recover the investment cost of introducing the OCA solution as well as license costs associated with it. If the wider network management and OSS will evolve, for instance to SDN/NFV, then it is important to optimize the OCA investment through an OCA solution that fits in old and new environment.

Figure 6 illustrates a calculation model that allows to calculate the savings due to the OCA solution. The shown list of inputs is not exhaustive: parameters for field technician and back-office time prior to OCA, "redo" situations, ONT shipment cost, etc. are also included in the calculation model.

Following results are calculated:

• Yearly gross saving = Cost difference between case without OCA and case with OCA

• Yearly net saving = yearly gross saving – OCA yearly cost (incl. start-up cost in year 1)

• Cumulative net saving.

Figure 6. OCA investment calculation model

Multiple runs with different sets of input parameter values (sensitivity analysis)

Input parameter estimation

Investment case insights

Input parameters	Calculator	Output
a) Yearly added ONT GF/BF, SFU/MDU volume (#)		• Yearly savings
b) Technician in-premises time remaining with OCA (%)		• Yearly net savings
c) End-user self-service take rate (%)		• Cumulative net savings
d) OCA solution integration and start-up cost (€)		
e) OCA variable and yearly price components (€)		
f) Salary rates (€)		
g) Truck roll cost shared over GF/BF-SFU/MDU sets (€)	Model	

7.2 Savings calculations for base assumptions

It would be too exhaustive to list all the numbers, but the following is a summary of the base assumptions:

- A large network operator deploying 100,000 ONTs per year, of which 65% Greenfield SDU and 35% Greenfield MDU, at an average hourly wage rate of 35 €

- An OCA solution with as price components: 7 € per successful ONT activation and 50,000 € yearly license fee

- With OCA, the technician time in-premises is reduced to 50% of what it was without OCA

- The self-service take-rate, i.e. the percentage of end users willing to do self-service activities, is 50%

- Integration and start-up cost of 600,000 € (see also remarks in section 7.3).

The savings calculations are then done for the following scenarios.

Scenario 1: No pre-installed ONTs, only saving from OCA is due to the reduced in-premises time of the field technician. In this case, the OCA investment breaks even from the second year, then continues saving money year after year, with 5-year cumulative net savings of nearly 0.7 M€.

Scenario 2: Pre-installed ONTs only for Greenfield MDUs, i.e. normally no field technician time is required, resulting in a large additional savings on 35% of the new activations. The pre-installed ONT investment is not discounted for, as a large and rapid FTTH service subscription take-rate is assumed. As a result, the OCA investment starts paying back late in the 1st year, and the 5-year cumulative net savings exceed 1 M€.

Scenario 3: Pre-installed ONTs for Greenfield MDUs and SDUs, i.e. normally no field technician time for any new activations. The OCA investment starts paying back early in the first year, and the 5-year cumulative net savings exceed 5 M€.

Scenarios including Brownfield ONT deployments or involving end-user self-service show equally favorable results. Particularly attractive OCA investment cases are pre-fiberized MDUs, especially when pre-installed ONTs moreover enable complete and low-risk end-user self-service.

7.3 Sensitivity analysis

A generally higher sensitivity to following parameters can be seen for Scenarios 1 and 2 of the OCA investment case (for Scenario 3 the effect is less significant).

- If the field technician's time with OCA is not reduced to 50% but only to 60% of what it was, the 5-year savings for Scenario 1 and 2 become 0.2 M€, 0.8 M€ and the investment pay-off moment is delayed 3 and 1 years, respectively.

- Similarly, with a wage rate reduced by 15% to 29.75 €, the 5-year savings for Scenarios 1 and 2 become 0.2 M€ and 0.7 M€, with 3 and 1 years pay-back delay, respectively.

- The integration and start-up cost can vary widely in practice. If it is 900,000 € in a complex integration environment, the 5-year savings for Scenarios 1 and 2 become 0.4 and 0.7 M€, with 3 and 1 years pay-back delay, respectively. But if it is 200,000 €, which is realistic in a simple integration environment or a first deployment phase, then the 5-year savings for Scenarios 1 and 2 exceed 1 and 1.4 M€ respectively, with pay-back within the first year.

8 Customer experience of home devices and Home Connect

The customer experience of the FTTH service end user is highly influenced by ONT throughput and performance monitoring, automatic Wi-Fi interference avoidance and meshing, and streamlined Home Connect and install processes including end-user self-service.

In this section, the ONT, RGW and Home Connect processes are assessed through the lens of the end user's customer satisfaction. The **Bring-up** phase, the **Operate** phase, and the **Repair** phase of the FTTH connection are reviewed for each topic.

8.1 ONT

FTTH connection **Bring-up** phase. In a home environment, the end user can appreciate the aesthetics of a simplified and often more compact ONT.

FTTH connection **Operate** phase. A new simplified ONT can also save 15% to 50% electrical power consumption for the end user.

FTTH connection **Repair** phase. The customer perceived reliability of the FTTH connectivity can be improved by enhanced pro-active performance monitoring and test capabilities on the new ONT. Incidents root-caused to out-of-range optical power are among the most common (though rare) customer-impacting FTTH issues (excluding in-home issues). DMM support on a new ONT, along with permanent FTTH network-wide automated L1-L2 testing, is effective to prevent such issues.

8.2 RGW aspects

Bring-up. In a home environment, the end user can appreciate an integrated ONT-RGW solution because of reduced space requirement, tidier cabling, and the need for only a single power adaptor. An SFP ONT solution can incidentally realize similar benefits.

Operate. An integrated ONT-RGW solution may have a slightly lower total power consumption. Even moreso, a state-of-the-art Wi-Fi implementation on the RGW can highly improve customer satisfaction: upgrades from Wi-Fi 4 or 5 to Wi-Fi 6 result in better net throughput and latency, and the implementation of L4S and DualQ features can result in even lower end-to-end latency. Additional Wi-Fi meshing and continuous Wi-Fi interference avoidance can eliminate roaming glitches and annoying connection degradations.

Repair. Customer satisfaction is highest when the advanced Wi-Fi operational features are combined with end-user apps helping with optimal placement of access points, Wi-Fi issue resolution support, and convenient escalation to the operator's help desk.

8.3 Streamlined Home Connect and install processes (OCA)

Bring-up. Many end users will appreciate the reduced technician time in their home when an OCA solution is available. That applies even more when no technician visit is needed at all: there is no need to be at home at the appointed time, and end users may prefer to accomplish this type of activity by themselves [9], with stronger preference among younger generations. This can be particularly relevant in post-COVID-19 times, when social distancing measures apply to help control the spread of diseases.

Repair. In case an ONT defect must be solved by an ONT hardware replacement, OCA delivers similar customer satisfaction benefits for the ONT swap process.

Table 2. Summarized customer experience benefit assessment

Customer experience benefit across FTTH phases	Bring-up	Operate	Repair
New ONT with associated end-to-end improvements	Low	High	Medium
RGW aspects, e.g. Wi-Fi, ONT-RGW integration	Low	High	Medium
Streamlined Home Connect and install processes (OCA)	High	Medium	High

9 Conclusion

The home environment contributes the second largest part of FTTH deployment cost and hosts unique opportunities to further improve the FTTH customer experience.

The FTTH home devices, ONT and residential gateways must meet a range of requirements, several of which matter directly for customer satisfaction: throughput, stability, state-of-the-art, in-home Wi-Fi, aesthetics and so on. On the other hand, features that once were important can be phased out today. When selecting an up-to-date and future-oriented home devices feature set, an FTTH operator maintains or expands competitive advantages and can even achieve significant savings, while improving customer experience.

The process to install and activate FTTP home devices also represents a large efficiency gain and cost savings opportunity, via automation and self-service for end customers. An operator can also achieve significant financial savings, while greatly improving the customer experience.

This all demonstrates how technological innovation, sound investments and customer experience improvements can go hand-in-hand in FTTH.

About the authors

Maurits Malfait has 25 years' telecommunications R&D experience and has a PhD in Engineering, a Business Economics post-graduate degree, and PMP certification. **Tom Van Caenegem** has 19 years' telecommunications research, CTO, and consulting experience, published numerous papers and patents, and has a PhD in Engineering. Maurits and Tom consult for Bell Labs Consulting with worldwide telecommunication and public service providers.

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