Cost Assessment of FTTdp Networks with G.fast

Juan Rendon Schneir and Yupeng Xiong

The authors analyze the main cost components of FTTdp networks with G.fast and the cost differences that can be achieved in comparison to FTTH networks. The two metrics employed in the article, the cost per home passed and the cost per home connected, were applied to six different geotypes that range from dense urban to rural scenarios. The results show that the cost per home passed of an FTTdp network with the distribution point located in the street is lower than the cost of FTTH.

Abstract

FTTdp networks using G.fast can complement the rollout of FTTH, especially in regions where the deployment of fiber inside the building is difficult. This article analyzes the main cost components of FTTdp networks with G.fast and the cost differences that can be achieved in comparison to FTTH networks. The two metrics employed in the article, the cost per home passed and the cost per home connected, were applied to six different geotypes that range from dense urban to rural scenarios. The results show that the cost per home passed of an FTTdp network with the distribution point located in the street is lower than the cost of FTTH. The cost per home connected for FTTdp is lower than that of FTTH for all of the scenarios studied. The cost reduction rates achieved by FTTdp networks are higher when employing a brownfield deployment scheme than when employing a greenfield deployment scheme.

Introduction

Different telecommunications operators are examining the features of various access networks to provide a high-speed fixed broadband service. In terms of transmission capacity over long distances, fiber to the home (FTTH) networks outperform cable- and copper-based networks. However, one of the drawbacks of FTTH networks is the cost of deploying fiber to each home, which can be quite high for some network scenarios. Moreover, from the viewpoint of implementation, in some cases it can be problematic to roll out fiber in the last segments of the network because of the necessary approvals that are required, especially inside buildings and in customers' apartments. One possibility to overcome this limitation consists of reuse of the copper cable in the last segments of the end-to-end network. This can be achieved by employing a fiber to the distribution point (FTTdp) network, which is a hybrid fiber- and copper-based network that requires a distribution point located close to the end user's premises. The distribution point is connected to the end user's premises through the existing copper cable and to the central office by means of a fiber cable. The distribution point can be located in different places; for example, it can be placed by the door of the apartment of the end user, on the floor, in the cellar of the building, or on the street.

The following network technologies can be employed for transmission over unshielded twisted pair (UTP) cabling: extended bandwidth asymmetric digital subscriber line 2 (ADSL2+), very-high-speed digital subscriber line 2 (VDSL2), VDSL2-vectoring variants, or G.fast — fast stands for *fast access to subscriber terminals*. In this article we use the terms copper cable and copper line to refer to UTP cabling. In almost all cases, there is existing ADSL2+ or VDSL2 equipment already deployed to provide up to several dozen megabits per second. In theory, with G.fast it is possible to achieve a combined upstream and downstream bandwidth of up to 1 Gb/s over a category 3 (CAT3) cable shorter than 100 m [1]. Based on this high-speed transmission capacity, a few operators are pondering whether G.fast could be employed as an alternative to FTTH in regions where the rollout of the fiber infrastructure to the in-building segment is complicated. Fiber to the basement or building (FTTB) networks have a network architecture similar to an FTTdp network that has the distribution point in the cellar of the building.

Some studies have addressed technical and strategic aspects of FTTdp and G.fast. The concept of hybrid fiber-copper network architectures is described in [2]. The way in which hybrid FTTH-copper networks can be employed to provide a transmission capacity of several hundred megabits per second is explained in [3]. Technical aspects of G.fast, such as medium access, coding, channel characterization, reverse powering, and crosstalk cancellation, are addressed in [4]. Different studies analyze several aspects of the cost of FTTH networks [5–8]. However, according to the authors' knowledge, little research has been published so far on the cost of hybrid networks with G.fast. The penetration rate that can be achieved by hybrid fiber- and copper-based networks that work with G.fast for some network deployments is explained in [9]. The cost of deploying an FTTdp network with G.fast for a few geotypes is explained in [10], and it is shown that for certain network deployment scenarios FTTdp networks with G.fast can have lower costs than FTTH networks.

Telecommunications operators are keen to know the cost implications of FTTdp networks

The views expressed in this article are those of the authors and do not reflect the opinions of the authors' employers.

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with G.fast and how they might fit into their broadband strategy. The goal of this article is to examine the cost implications of the rollout of FTTdp networks with G.fast. The research questions addressed are: *What are the main cost drivers of rolling out an FTTdp network with G.fast? What are the cost differences in comparison with FTTH access networks?*

These questions were addressed by means of a cost model that was employed to obtain the cost of FTTdp and FTTH networks. The cost comparison was made with FTTH, because it is expected that in several regions FTTdp and FTTH networks will have a broadband transmission capacity on the same order of magnitude. The following six geotypes, which are based on fixed access networks in various regions in Europe, were employed: dense urban, urban, dense suburban, suburban, dense rural, and rural. There are several differences between the research done for this article and the research presented in [10]. For instance, in this article we consider six different geotypes and different building types.

The rest of the article is organized as follows. In the next section, the concept of FTTdp networks and a few aspects of G.fast are described. We then explain the network architectures used for cost analysis and the features of the cost model. We present the results of the cost analysis by analyzing the following two types of results: the cost of a home passed and the cost of a home connected. Finally, some conclusions of the study are made.

FTTdp Networks and G.fast

Various hybrid fiber-based and copper-based networks can be built up according to the location of the distribution point. For instance, the FTTdp networks that can be constructed include fiber to the street (FTTS), FTTB, fiber to the floor (FTTF), and fiber to the door (FTTD). Operators can face some difficulties when trying to deploy fiber inside buildings or apartments. For example, in some cases the process of attaining permission to deploy fiber in the building can be long and burdensome. In some European countries, for instance, a decision about the possible deployment of fiber inside the building must be approved first by the community of neighbors, who in some cases hold a meeting only once a year. Furthermore, it is not always easy to obtain the approval of the owner or occupant of the apartment to roll out fiber in the household. These inconveniences can result in a long time to market (TTM) for the provisioning of a high-speed fixed broadband service.

VDSL2, VDSL2-vectoring, and G.fast are the possibilities being considered by operators for the copper network section of FTTdp networks. The International Telecommunication Union (ITU) Study Group 15 (SG15) has been working on the standardization of G.fast, which is a high-speed fixed broadband copper-based access technology. The specifications of the power spectral density appear in ITU Telecommunication Standardization Sector (ITU-T) Recommendation G.9700 [11], whereas the physical layer specifications of subscriber terminals are described in ITU-T Recommendation G.9701 [1]. It is possible that enhancements will be standardized in the future in the form of amendments to Recommendation G.9701. The Broadband Forum (BBF) defined the specifications of the distribution point unit (DPU), which is an essential component of the FTTdp network architecture [12]. Theoretically, with G.fast it is feasible to achieve a transmission rate of up to 1 Gb/s for combined uplink and downlink transmission over a length shorter than 100 m [1]. The transmission capacity decreases for distances higher than 100 m.

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Cost Modeling

Network Architectures

Tables 1a and 1b show a few features of the six geotypes employed. The geotypes differ in various aspects. Table 1a shows the values of the following parameters: the feeder, distribution, and drop segment lengths; the number of households per central office and per street cabinet; and the cost of trenching and duct deployment in the feeder and distribution segments. Table 1b shows the building features and the gigabit-capable passive optical network (GPON) splitting ratios. Several of the input parameters employed in the cost model were derived by contacting companies that deploy and maintain fixed access infrastructure in France, Germany, and the United Kingdom. Cost studies of fixed access networks in different regions of Europe were also employed as information sources [13, 14]. Based on the information collected, average values were derived.

We have assumed that for the dense urban, urban, and dense suburban geotypes multiple dwelling units (MDUs) with the number of households per building that appear in Table 1b are employed. Table 1b also shows that single dwelling units (SDUs) are employed for the suburban, dense rural, and rural geotypes. Moreover, we have considered one operator deploying G.fast in the building or house, and that there is no mix of technologies.

The network architectures of the following three types of networks employed for the six geotypes are shown in Fig. 1: FTTH, FTTdp with the distribution point located in the cellar of the building (FTTdp-Building), and FTTdp with the distribution point located in the street (FTTdp-Street). An FTTdp-Building network is in fact an FTTB network, but as this article focuses on FTTdp networks, we employ the term FTTdp-Building. Figures 1a, 1b, and 1c show the network architectures employed for the dense urban, urban, and dense suburban geotypes. These geotypes work with MDUs. Figures 1d, 1e, and 1f show the network architectures employed for the suburban, dense rural, and rural geotypes, which work with SDUs. The cost of the active and passive network components of the following sections of the network, which are depicted in Fig. 1, were considered in the analysis: the central office, the feeder segment, the street cabinet, the distribution segment, the drop segment, the DPU elements, the in-building segment, and the equipment in the customer's premises.

The three networks studied in this article employ GPON. The downstream capacity provided by GPON is 2.5 Gb/s, and the splitting ratio

(a)						
Geotype	Length of the feeder segment	Length of the distribution segment	Length of the drop segment	Number of households per central office	Number of households per street cabinet	Cost of trenching and duct deployment in the feeder and distribution segments
Dense urban	950 m	200 m	4 m	17,000	500	US$110/m
Urban	1100 m	230 m	8 m	15,000	480	US$110/m
Dense suburban	1040 m	300 m	10 m	10,000	420	US$92/m
Suburban	1800 m	980 m	30 m	4000	350	US$92/m
Dense rural	500 m	650 m	18 m	1000	180	US$80/m
Rural	800 m	1300 m	75 m	800	115	US$80/m

(b)					
Geotype	Building type	Households per building	Floors per building	Splitting ratio in the street cabinet	Splitting ratio in the building or in the street
Dense urban	MDU	28	7	4	8
Urban	MDU	8	4	4	8
Dense suburban	MDU	6	3	4	8
Suburban	SDU	1	-	32	(No splitter)
Dense rural	SDU	1	-	32	(No splitter)
Rural	SDU	1	-	32	(No splitter)

Table 1. Input parameters according to the different geotypes: a) access network features; b) building features and GPON splitting ratios.

employed is 1:32, which is typical for certain GPON deployments in Europe. This splitting ratio provides every household with an average transmission capacity of 78 Mb/s. Usually, operators assume that all users who share the same GPON port are not transmitting simultaneously, and, as a consequence, the broadband commercial offer of the operators, based in many cases on the peak bandwidth that can be provided, can be of several hundred megabits per second.

From the central office up to and including the distribution segment, the network elements shown in Fig. 1 are the same for the three network architectures. The central office contains the optical line terminal (OLT) and the optical distribution frame (ODF). The OLT contains upstream Ethernet and downstream GPON ports. The number of GPON ports depends on the geotype employed. The feeder and distribution segments contain ducts, fiber, and manholes. A small street cabinet was employed, because it will need to contain only the splitters. The distribution segment contains at least two fibers per building. The drop segment contains the ducts and fiber for the FTTH and FTTdp-Building networks as well as the copper cable for the FTTdp-Street network.

As shown in Fig. 1b, for FTTdp-Building a DPU cabinet is located in the basement of the building. As shown in Fig. 1c, for FTTdp-Street the DPU cabinet is located on the street between the distribution segment and the drop segment. In our study, the energy of the DPU cabinet is provided from the end user's premises by using reverse powering. The reverse power feeding (RPF) located in the end user's premises sends energy to the DPU. The DPU cabinet includes the following network components: a DPU per FTTdp subscriber, an internal main distribution frame (MDF), 1:8 splitters, and the cabinet. The DPU cabinet considered in the analysis can contain up to eight DPUs, which enables the provisioning of a broadband service for up to eight FTTdp users.

The FTTdp networks work with an existing external MDF, which is placed in the basement of the building and appears in Figs. 1b and 1c. This MDF is not the same as the internal MDF of the DPU cabinet. Figure 1a shows the fiber cable located in the in-building segment of the FTTH network. A twisted pair copper cable is employed in the in-building segment of the FTTdp-Building and FTTdp-Street network architectures, as shown in Figs. 1b and 1c, respectively. A copper cable is also employed in the drop segment of the FTTdp-Street network architecture. It is assumed that the existing CAT3 cable, which has been used for telephony service for decades, is employed for the transmission with G.fast.

Two splitting levels are employed for the three network architectures shown in Figs. 1a, 1b, and 1c: a first splitting level of 1:4 in the street cabinet, and a second splitting level of 1:8, which is located in the basement of the building for FTTH and in the DPU cabinet for the case of FTTdp-Building and FTTdp-Street. In total,

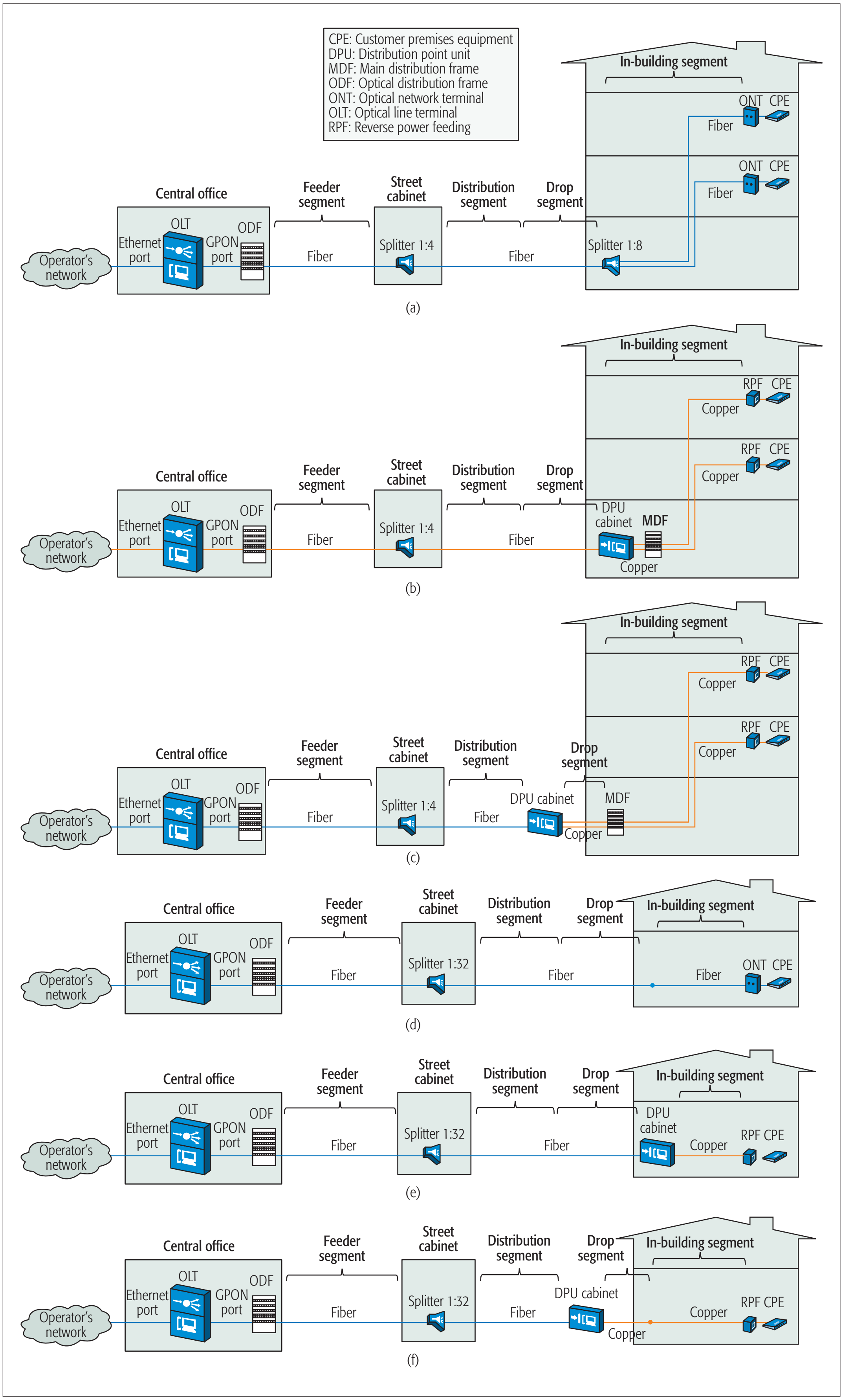

Figure 1. Network architectures for the geotypes dense urban, urban, and dense suburban: a) FTTH; b) FTTdp-Building; c) FTTdp-Street. Network architectures for the geotypes suburban, dense rural, and rural: d) FTTH, e) FTTdp-Building, f) FTTdp-Street.

Usually operators assume that all the users that share the same GPON port are not transmitting simultaneously and, as a consequence, the broadband commercial offer of the operators, based in many cases on the peak bandwidth that can be provided, can be of several hundred Mb/s.

Two metrics were employed for the total cost of ownership analysis: the cost per home passed and the cost per home connected. The main difference between both values is that the cost per home passed does not include all the network components or the effect of the market share value.

both splitting levels yield a total splitting factor of 1:32. The optical network terminal (ONT), the customer premises equipment (CPE), and RPF active equipment can be located in the subscriber's premises.

For the network architectures that work with SDUs, which are shown in Figs. 1d, 1e, and 1f, there is only one splitting level in the street cabinet, which is 1:32. Furthermore, for the FTTdP network architectures, the DPU cabinet does not contain a splitter and supports a single-port DPU.

Cost Methodology

For the cost analysis it was assumed that almost all network components that appear in Fig. 1 should be deployed. The external MDF and the copper cables employed in FTTdp architectures were not considered as capital expenditures (CAPEX) in the cost model because it was assumed that they exist before the FTTdp network deployment takes place.

Two metrics were employed for the total cost of ownership (TCO) analysis: the cost per home passed and the cost per home connected. The main difference between both values is that the cost per home passed does not include all the network components nor the effect of the market share value. For example, frequently the cost of a home passed in a VDSL2 or G.fast deployment does not include the cost of the CPE, any active network equipment located in the subscriber's premises or the cost of the cable in the in-building segment.

For FTTH, the cost of a home passed encompasses the network components located from the central office up to the drop segment. For FTTdp-Building and FTTdp-Street the cost per home passed includes all the network elements from the central office up to the drop segment and distribution segment, respectively. The cost of a home connected includes all the network elements considered in the cost per home passed, but also the additional elements that will permit an end-to-end connection. For FTTH, the cost of a home connected also includes the cost of the splitters in the basement of the building, the in-building fiber cable, and the CPE and ONT. For FTTdp networks, the cost per home connected also includes the cost of the DPU cabinet, the maintenance cost of the copper line, and the cost of the RPF and CPE. It was assumed that every DPU unit would be installed in the DPU cabinet on an on-demand basis. The cost of the DPU and RPF of the FTTdp networks were obtained by taking into account the present cost of the internal network components and assuming that over the next years several network components will have a price reduction due to a rise in sales volume.

The cost per home passed includes the CAPEX values. It was assumed that it takes four years to pass all the households in the deployment area. The rate of households passed was 25, 50, 75, and 100 percent over the first four years. The cost per home connected includes CAPEX and operational expenditures (OPEX) over a timeframe of 15 years. The cumulative present value (CPV) formula with a discount rate of 10 percent was employed to calculate the present value of the CAPEX and OPEX.

The CAPEX involves all the investment needed to roll out the active and passive infrastructure. The cost of digging, the deployment of ducts, and the rollout of fiber and manholes belong to CAPEX for the feeder, distribution, and drop segments. All the fiber installation considered in the study is underground, and there are no aerial components. The OPEX includes the annual cost of maintaining the infrastructure, and the repair and replacement of damaged network components. It was derived by using mark-up values of 1 percent for the passive infrastructure and 7.5 percent for the active infrastructure applied to the CAPEX. In the central office, the OPEX also includes the cost of energy consumption and the rental of floor space. For the calculation of the OPEX associated with the maintenance of the copper cable in the in-building segment and in the drop segment, monthly values of US$1.1 and US$0.4 were employed, respectively.

The values of the asset lifetimes are six years for the active network equipment placed in the subscriber's premises (ONT, RPF, and CPE); eight years for the rest of the active equipment (DPU and OLT); 25 years for the fiber cables; and 45 years for the ducts. To derive the cost per home connected, it is necessary to have the market share value of the operator, which we name the target market share. In the approach adopted in this study, an operator reaches 22.5, 45.0, 67.5, and 90.0 percent of the target market share in years one, two, three, and four, respectively. Subsequently, the annual take-up rate of the operator is 0.9625 percent, which permits the operator to reach 100 percent of the target market share in year 15. Additionally, after year two the cost model assumes a churn rate of 10 percent.

This study considers only the cost of the network components shown in Fig. 1. The cost model does not involve the cost of the systems that help to manage and deliver access to the customers; the cost of video, broadband, or telephony services; the cost of the core, backhaul, and aggregation networks; the marketing and sales costs; the costs of the permits to roll out the infrastructure; the cost of engineering drawings; and the common costs, that is, for management and administration tasks not directly allocated to specific services, such as strategy, regulatory, human resources, and research departments.

Results and Analysis

Cost per Home Passed

The results of the cost per home passed for all the geotypes are shown in Fig. 2a. The results were derived by calculating the CAPEX with a coverage of 100 percent. There are substantial differences between the costs for the six geotypes because of the different feeder and distribution segment lengths and the different household densities. The cost of a home passed for FTTH and FTTdp-Building is similar. This is because all the network components from the central office up to the drop segment are the same. Given that there is no initial investment in the drop segment for FTTdp-Street, the cost of FTTdp-Street is lower than the cost of FTTH and FTTdp-Building. The cost reduction achieved by FTTdp-Street in

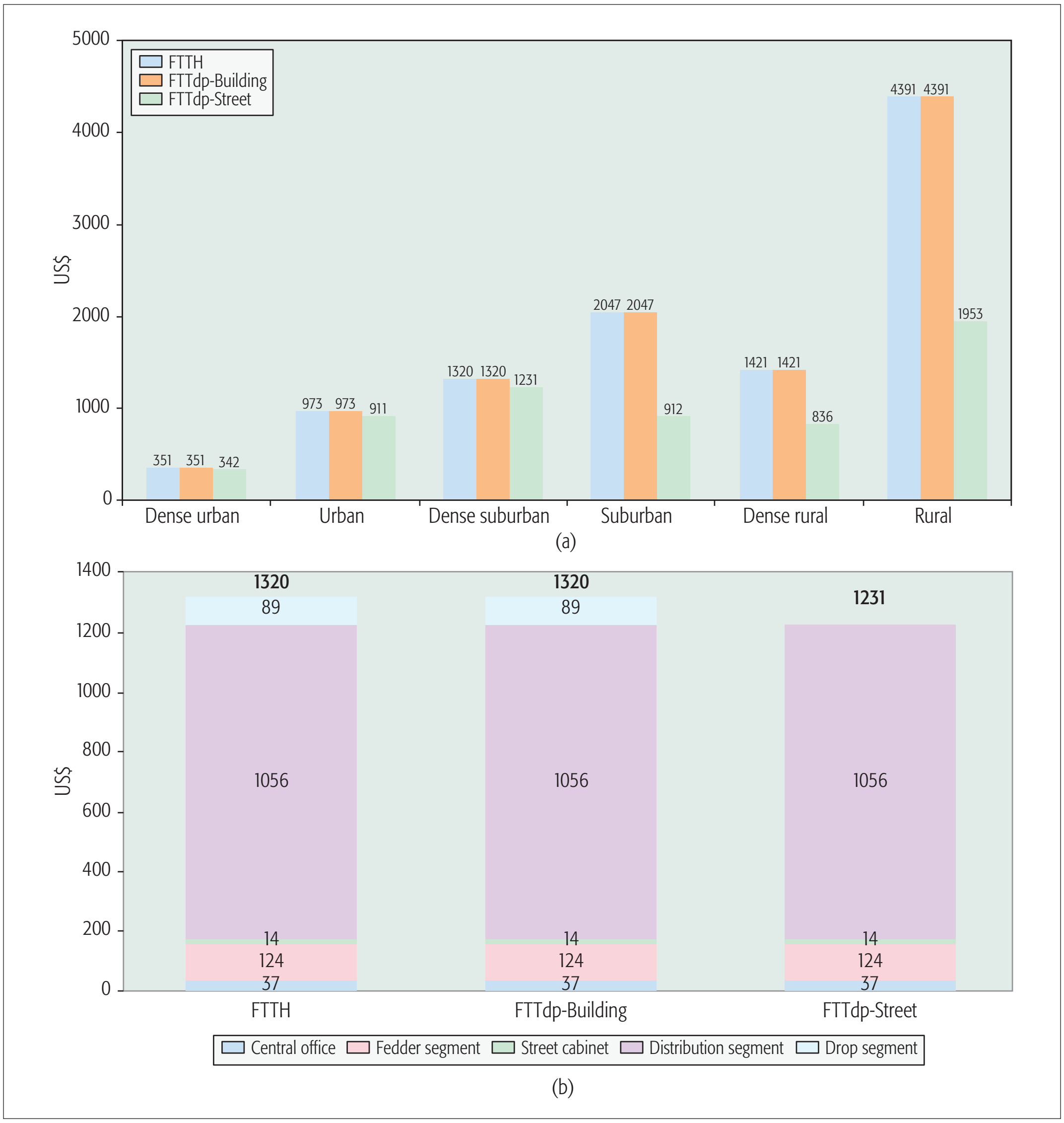

Figure 2. Cost per home passed, CAPEX: a) cost for the six geotypes; b) cost composition of the network elements, dense suburban area.

In the approach adopted in this study, an operator reaches 22.5 percent, 45.0 percent, 67.5 percent, and 90.0 percent of the target market share in years one, two, three, and four, respectively. Subsequently, the annual take-up rate of the operator is 0.9625 percent, which permits the operator to reach 100 percent of the target market share in year 15.

comparison with FTTH and FTTdp-Building for dense urban, urban, dense suburban, suburban, dense rural, and rural areas is 2.4, 6.4, 6.8, 55.4, 41.2, and 55.5 percent, respectively. This gives an average total cost reduction of 28.0 percent.

The cost differences and similarities among the three network architectures are explained by Fig. 2b, which shows the cost composition of the cost per home passed for the dense suburban area. The cost of the central office, feeder segment, street cabinet, and distribution segment is the same for FTTH, FTTdp-Building, and FTTdp-Street, whereas the cost of deploying the fiber in the drop segment is the same for the FTTH and FTTdp-Building architectures. Due to the fact that the DPU cabinet is placed in the street between the distribution and drop segments, there is no CAPEX-related cost of the drop segment for FTTdp-Street. As depicted in Fig. 2b, the largest part of the cost for the three network architectures depends on the feeder and distribution segments. For FTTH and FTTdp-Building networks, the cost percentage of both segments is 89 percent of the cost per home passed, whereas it is 96 percent for the FTTdp-Street network.

Cost per Home Connected

For the analysis of the cost per home connected, we have used the following two approaches for the network deployment, which are explained below: greenfield and brownfield. For both cases, it is assumed that the copper cables and MDF already exist.

Greenfield Deployment: It is assumed that there is no fiber-based infrastructure previously deployed, and almost all network elements located in the access network will be deployed. As mentioned above, some sections of the existing copper-based infrastructure will be reused.

Brownfield Deployment: It is considered that the following components of the fiber-based infrastructure already exist: the network elements located between the central office and the distribution segment. The operator will only need to deploy the following network elements: drop segment, in-building segment, DPU elements for FTTdp networks, and the ONT/RPF and CPE equipment.

Tables 2a and 2b show the cost per home connected and the cost reductions achieved

For the greenfield and brownfield deployment schemes the cost delta or cost difference between the FTTH and FTTdP network architectures for each geotype is the same. However, the cost reduction rates that can be achieved by FTTdp in comparison to FTTH when employing the greenfield and brownfield rollout schemes change.

(a)

	Dense urban (US$)	Urban (US$)	Dense suburban (US$)	Suburban (US$)	Dense rural (US$)	Rural (US$)
FTTH	1613	3027	3808	5317	4031	10480
FTTdp-Building	1570 (2.7 %)	2923 (3.4 %)	3707 (2.6 %)	5275 (0.8 %)	3990 (1.0%)	10439 (0.4 %)
FTTdp-Street	1607 (0.4 %)	2855 (5.7 %)	3596 (5.6 %)	2974 (44.1 %)	2874 (28.7 %)	5322 (49.2 %)

(b)

	Dense urban (US$)	Urban (US$)	Dense suburban (US$)	Suburban (US$)	Dense rural (US$)	Rural (US$)
FTTH	794	981	1064	3257	2071	6072
FTTdp-Building	751 (5.2 %)	877 (10.6 %)	963 (9.4 %)	3215 (1.3 %)	2030 (2.0 %)	6031 (0.7 %)
FTTdp-Street	788 (0.8 %)	809 (17.5 %)	852 (19.9 %)	914 (72.0 %)	914 (55.9 %)	914 (85.0 %)

Table 2. Cost per home connected and cost reduction vs. FTTH, CAPEX, and OPEX, 50 percent market share: a) greenfield deployment; b) brownfield deployment.

for the greenfield and brownfield deployment schemes, respectively. The results were derived by considering CAPEX and OPEX with a market share of 50 percent. For the greenfield and brownfield deployment schemes the cost delta or cost difference between the FTTH and FTTdP network architectures for each geotype is the same. However, the cost reduction rates that can be achieved by FTTdp in comparison to FTTH when employing the greenfield and brownfield rollout schemes change.

As shown in Table 2a, in all cases the cost of FTTH is higher than the cost of FTTdp networks. The average cost reduction rate achieved by FTTdp-Building in comparison to FTTH is 1.8 percent. The average cost reduction rate of FTTdp-Street in comparison to FTTH is 22.3 percent. For the dense urban geotype, the cost of FTTdp-Building is 2.3 percent lower than the cost of FTTdp-Street. This is because of the low cost of the drop segment for this geotype. Moreover, in all cases the total cost of the DPU elements for FTTdp-Building is lower than the total cost of the DPU elements for FTTdp-Street. The DPU equipment deployed outdoors for FTTdp-Street is more expensive than the DPU equipment deployed indoors for FTTdp-Building. For the rest of the geotypes, the cost of FTTdp-Street is lower than the cost of FTTdp-Building. The average cost reduction rate achieved by FTTdp-Street in comparison with FTTdp-Building for the urban, dense suburban, suburban, dense rural, and rural geotypes is 25.2 percent.

For FTTdp-Building, the cost reductions achieved in the geotypes that work with MDUs are higher than the cost reduction achieved in the geotypes that work with SDUs. For FTTdp-Street, the cost reduction rates obtained in the geotypes that work with SDUs are higher than the cost reductions obtained in the geotypes that work with MDUs. This is because of the relatively high cost of the drop segment for FTTH networks in SDU-based geotypes. The average cost proportion of the drop segment in SDU-based geotypes for FTTH and FTTdp-Street networks is 42.5 and 0.7 percent, respectively.

The cost reduction rates achieved by FTTdp networks when using a brownfield deployment scheme, which are shown in Table 2b, are in all cases higher than the cost reduction rates achieved when using a greenfield deployment scheme, which are shown in Table 2a. Whereas the average cost reduction rate achieved by FTTdp-Building when employing the greenfield deployment approach was 1.8 percent, the average cost reduction rate achieved when employing the brownfield rollout scheme was 4.9 percent. Regarding FTTdp-Street, the cost reduction rates achieved when employing the greenfield and brownfield deployment schemes were 22.3 and 41.8 percent, respectively.

Figure 3a shows the cost structure of the cost per home connected in the dense suburban geotype. The values of CAPEX and OPEX for the three networks are the same for the central office, the feeder segment, the street cabinet, and the distribution segment. The cost percentage of the feeder and distribution segments for the FTTH, FTTdp-Building, and FTTdp-Street networks is 67, 69, and 71 percent, respectively. The FTTH and FTTdp-Building networks have the same cost of the drop segment: US$195. The US$25 of the drop segment in the FTTdp-Street network corresponds to the cost of the maintenance of the copper network. The cost percentage of the in-building segment for FTTH is 15 percent of the cost per home connected, whereas the cost percentage of the DPU elements for FTTdp-Building and FTTdp-Street is 13 and 15 percent, respectively. The cost of the active equipment in the end user's premises is higher for FTTH than for the FTTdp network architectures. Even though the cost of the CPE is the same for the three networks, the difference lies in the fact that the cost of the ONT for the FTTH network is higher than the cost of the RPF for the FTTdp networks.

An essential cost difference between the

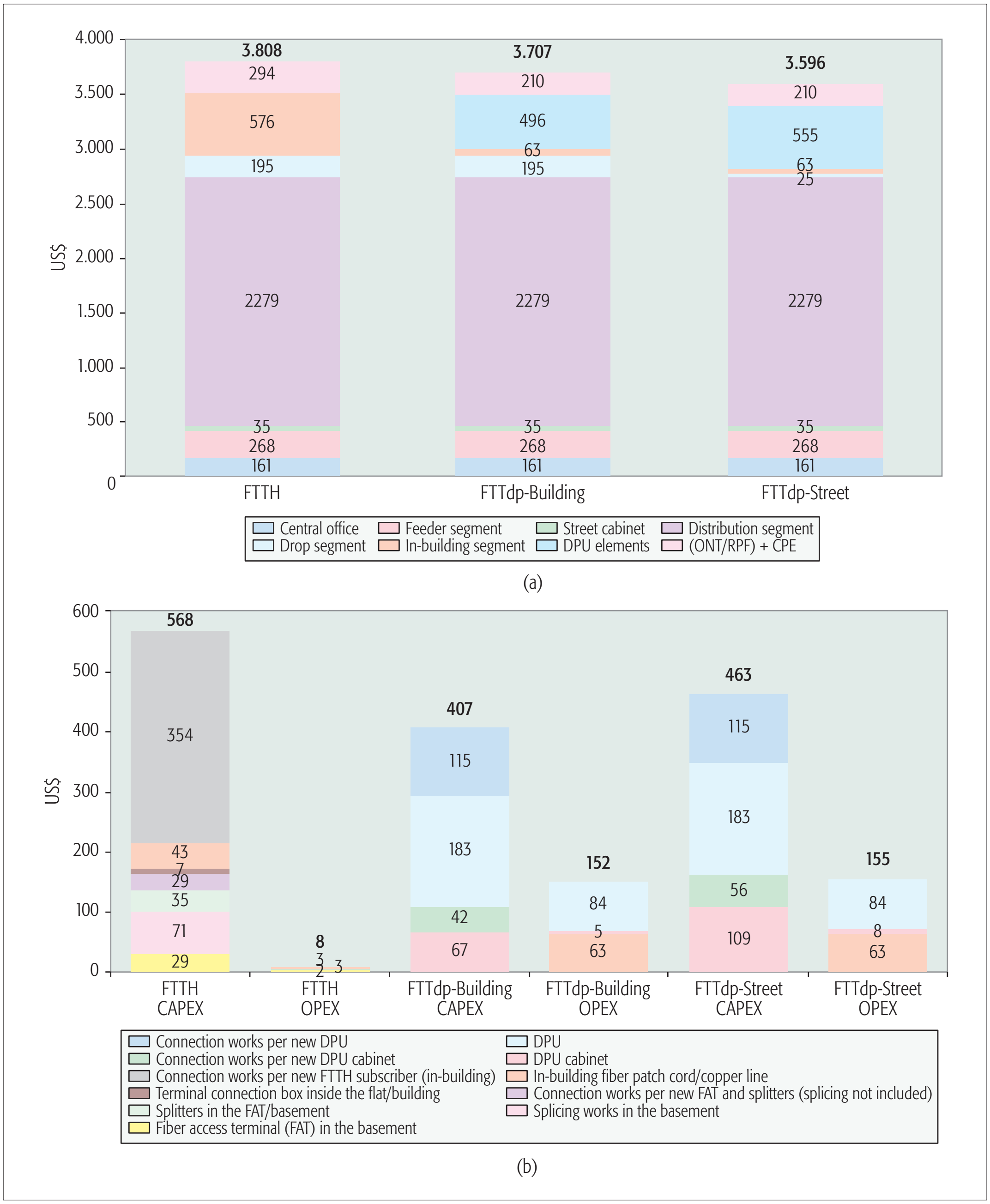

Figure 3. Cost per home connected, CAPEX and OPEX, 50 percent market share, greenfield deployment, dense suburban area: a) cost composition of all the network elements; b) cost composition of network elements in the in-building segment and in the DPU.

The cost percentage of the in-building segment for FTTH is 15 percent of the cost per home connected, whereas the cost percentage of the DPU elements for FTTdp-Building and FTTdp-Street is 13 percent and 15 percent, respectively. The cost of the active equipment in the end-user's premises is higher for FTTH than for the FTTdp network architectures.

FTTH and FTTdp networks is motivated by the costs of the in-building segment and the FTTdp DPU elements. As shown in Fig. 3a, the cost of the in-building segment for the FTTH and FTTdp networks is US$576 and US$63, respectively. For FTTdp-Building and FTTdp-Street, the cost of the DPU elements is US$496 and US$555, respectively. Based on the values of Fig. 3a, Fig. 3b shows in detail the cost components of the CAPEX and OPEX for the in-building segment and the DPU elements.

As is depicted in Fig. 3b, the US$568 CAPEX for FTTH is higher than the US$407 CAPEX for FTTdp-Building and the US$463 CAPEX for FTTdp-Street. Nonetheless, the OPEX for FTTdp-Building, US$152, and the OPEX for FTTdp-Street, US$155, are higher than the US$8 OPEX for FTTH. The required CAPEX for connecting a new FTTH subscriber, which is US$354 and corresponds to the task of deploying the fiber cable in the building, is higher than the CAPEX of a new DPU for FTTdp networks, which is US$183. The OPEX allocated to the maintenance of the DPU elements in FTTdp networks is higher than the OPEX needed to maintain the FTTH network inside the building. Moreover, the cost of maintaining the copper line in the in-building segment for FTTdp networks, US$63, is higher than the cost of maintaining the fiber line for FTTH networks, which is US$3. The maintenance cost of the DPU, which is an active element, is higher than the maintenance cost of the DPU cabinet, which is a passive network element.

The cost reduction achieved by FTTdp networks with G.fast in comparison with FTTH and the lower rollout time of FTTdp networks make FTTdp with G.fast a good candidate for the provision of high-speed fixed broadband services, especially in buildings where the roll-out of fiber inside the building is challenging.

Conclusions

This article has shed light on the main cost components of FTTdp networks with G.fast. Moreover, the cost differences that are achieved in comparison with FTTH networks that provide similar broadband transmission rates have been analyzed. The cost per home passed of FTTH and FTTdp-Building networks is the same, but the cost of FTTdp-Street is lower than the cost of FTTH. The results show that for all the network scenarios studied when analyzing the cost per home connected, the usage of FTTdp-Building and FTTdp-Street leads to cost reductions in comparison to FTTH. With FTTdp-Street, it is possible to obtain for the majority of cases lower costs and therefore higher cost reductions than with FTTdp-Building.

The cost reduction rates achieved by FTTdp networks are higher when employing a brownfield deployment scheme than when employing a greenfield deployment scheme. The cost reduction achieved by FTTdp networks with G.fast in comparison with FTTH and the lower rollout time of FTTdp networks make FTTdp with G.fast a good candidate for the provision of high-speed fixed broadband services, especially in buildings where the rollout of fiber inside the building is challenging.

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