TELECOM Paris

INSTITUT POLYTECHNIQUE DE PARIS

Séminaires du département Comelec

Présentation des technologies de l'accès optique : la connectivité fibre à haut débit

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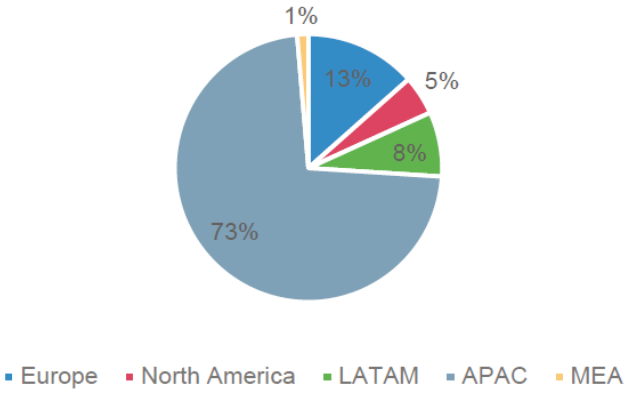
Orange Innovation Networks, WNI/FUN/FAN

The 7th May 2024

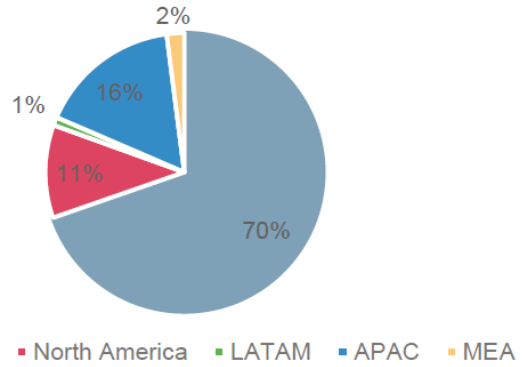
orange™

The different superfast broadband technologies – Dec. 2023

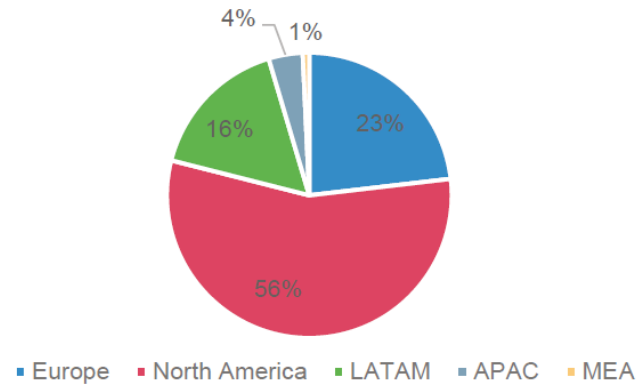
FTTH/B: 897 million subscribers



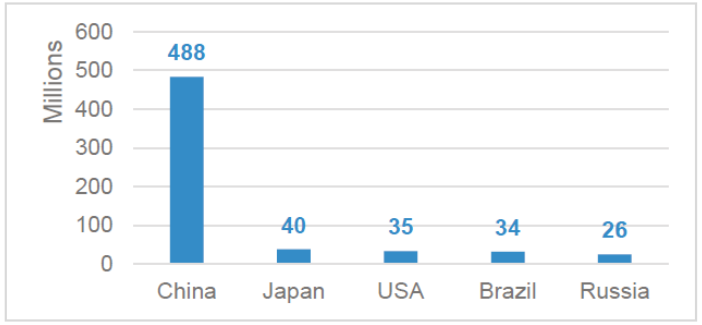
VDSL: 95 million subscribers



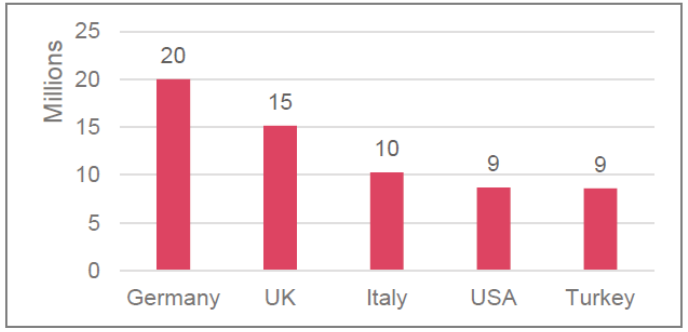
DOCSIS 3.x: 156 million subscribers



Top 5 FTTH/B countries, June 2023
(in terms of subscribers)



Top 5 VDSL countries, June 2023
(in terms of subscribers)



Top 5 DOCSIS 3.x countries, June 2023
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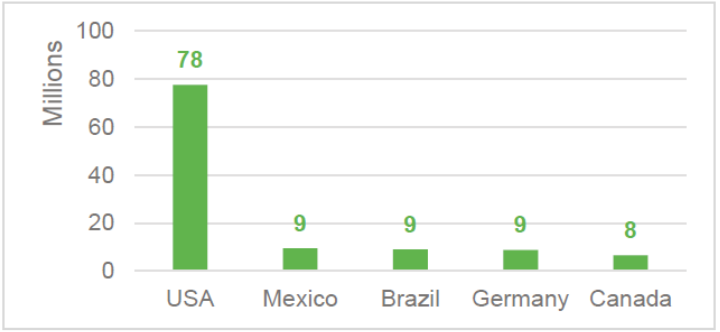


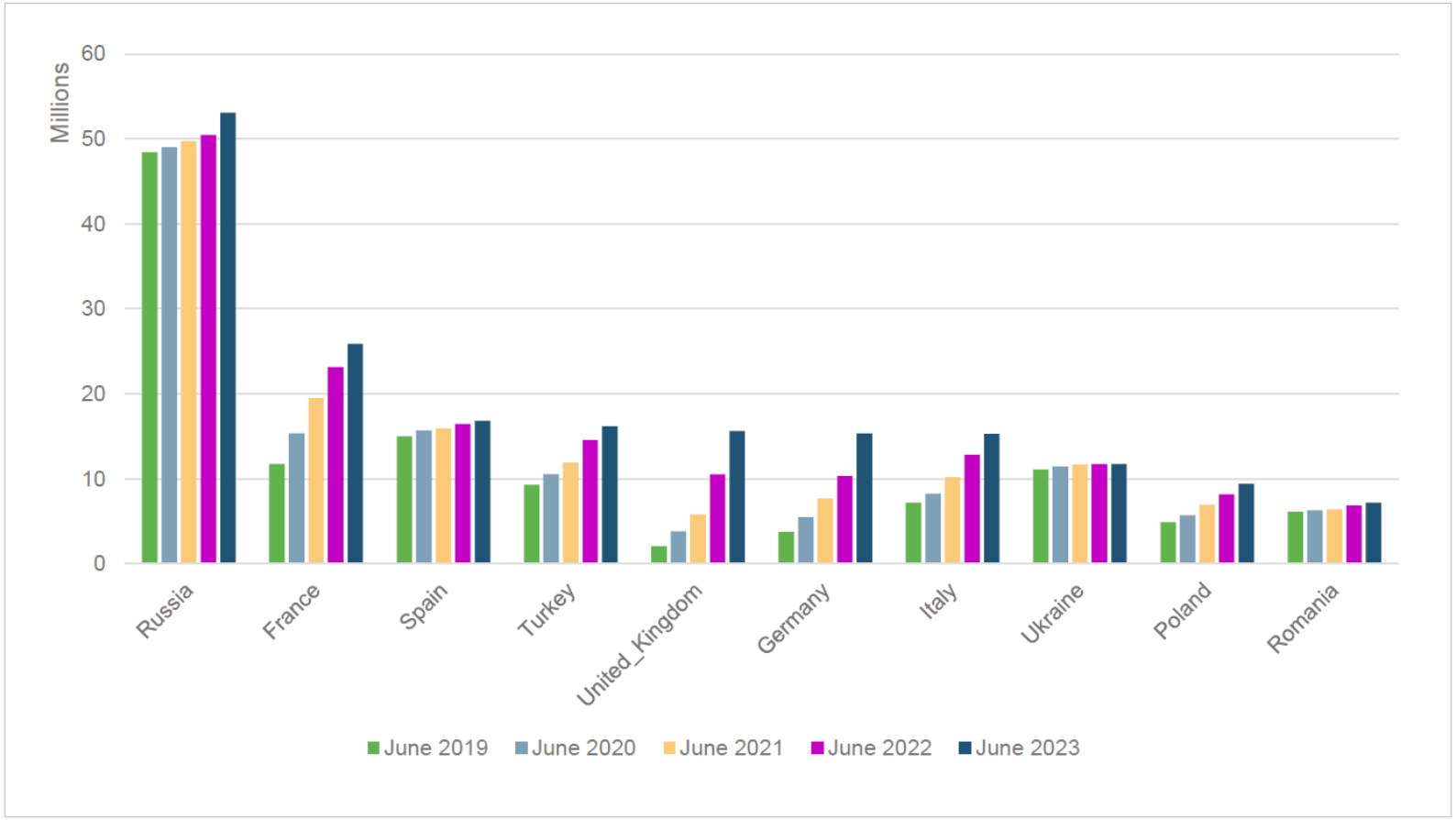
1,148 million FTTx subscribers worldwide by June 2023

Source: IDATE, *World FTTx markets*, December 2023

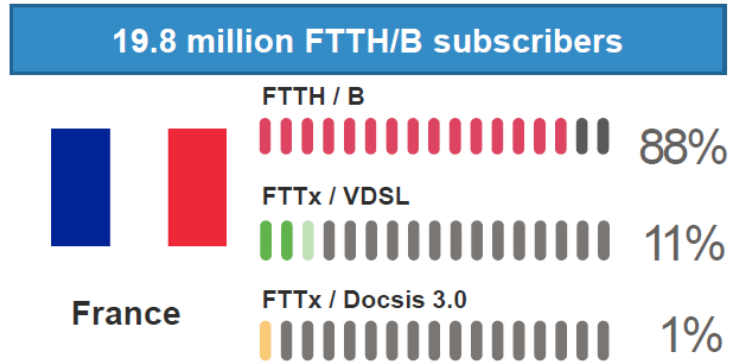
FTTH/B homes passed in Europe

FTTH/B subscribers in France

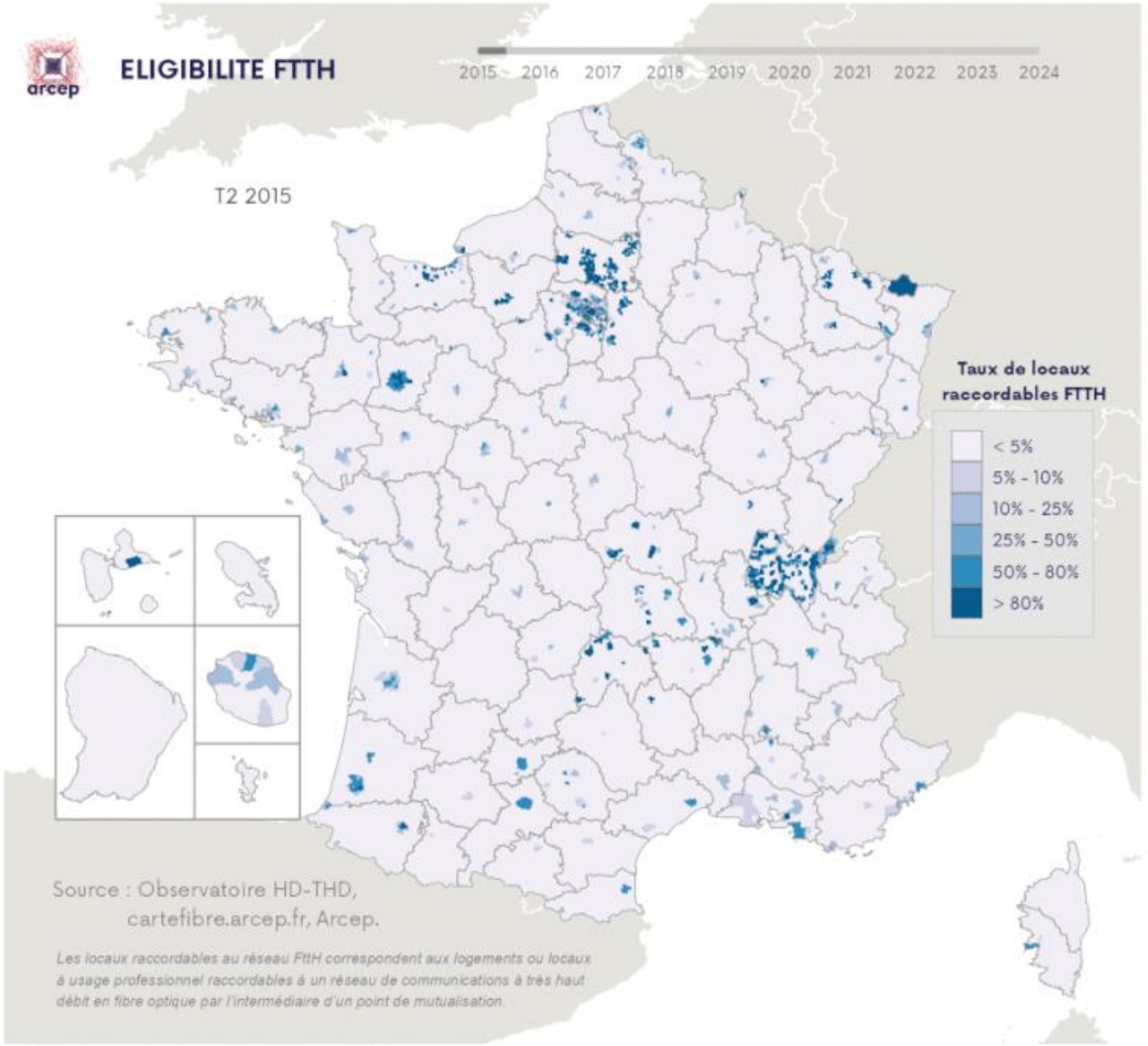
Progress in the top 10 European countries in terms of FTTH/B homes passed
(in million homes), June 2017 to June 2023



Source: IDATE, *World FTTx markets*, December 2023

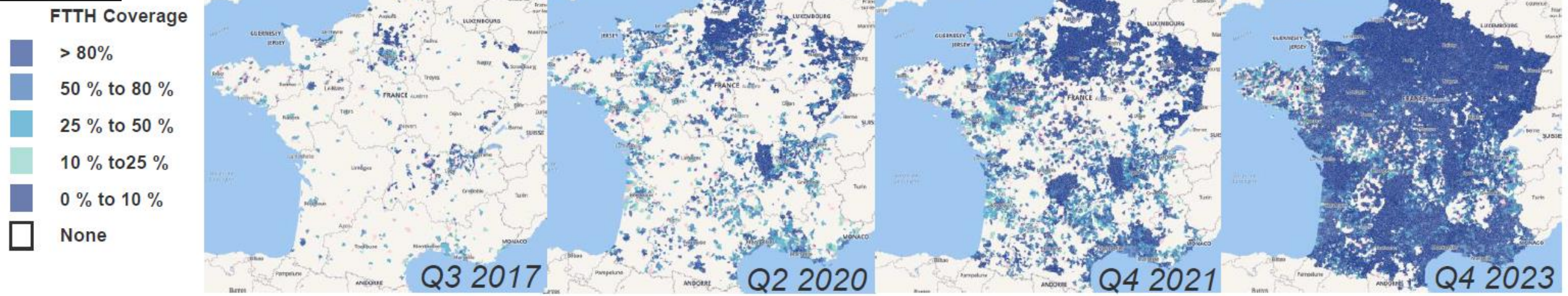


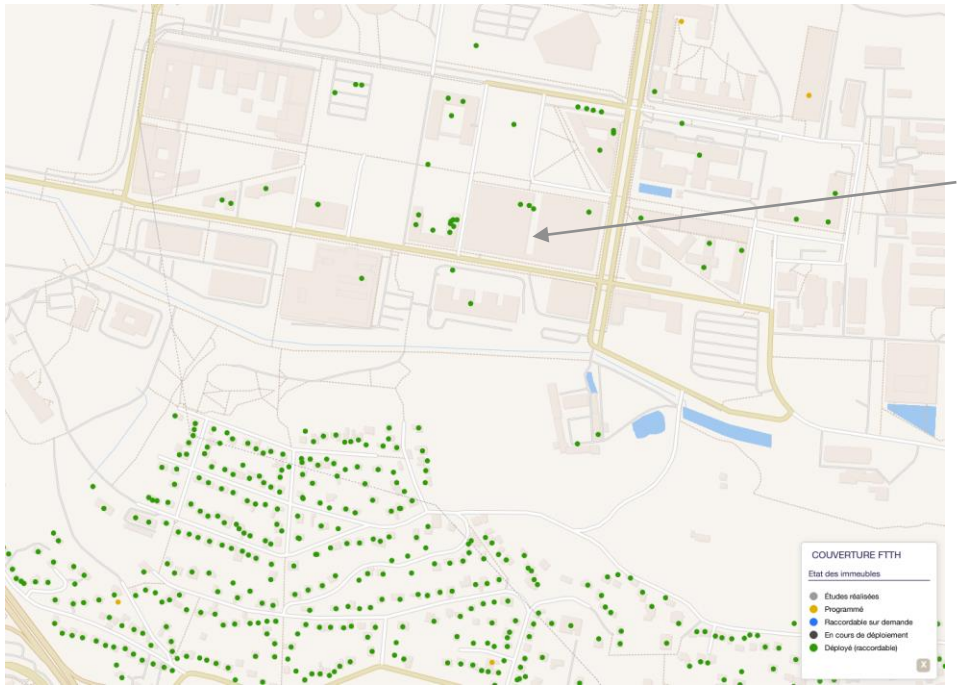
FTTH coverage (France)



FTTH coverage (France)

source : https://cartefibre.arcep.fr





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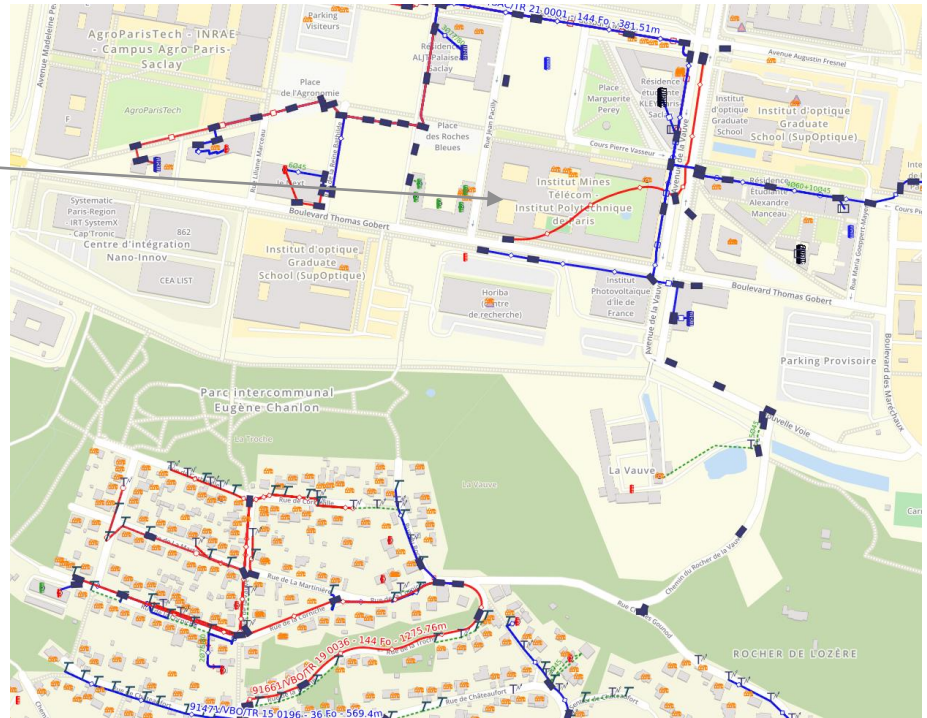
Liberté
Égalité
Fraternité

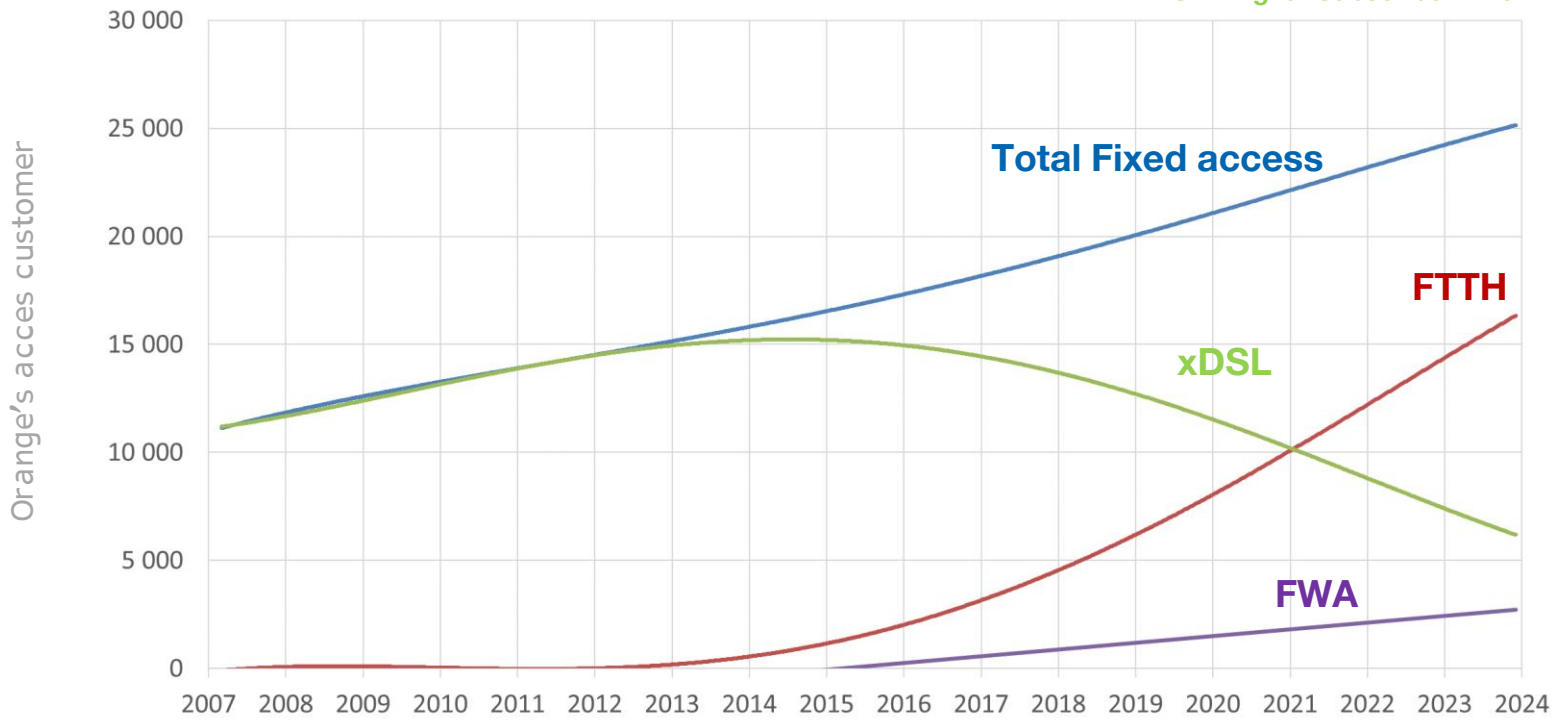
Institut Mines-Télécom



Orange’s Fixed accesses customers

[customer base x 1000]

FWA: Fixed Wireless Access
FTTH: Fiber to The Home
xDSL : Digital Subscriber Line



Orange Fixed operations around the world

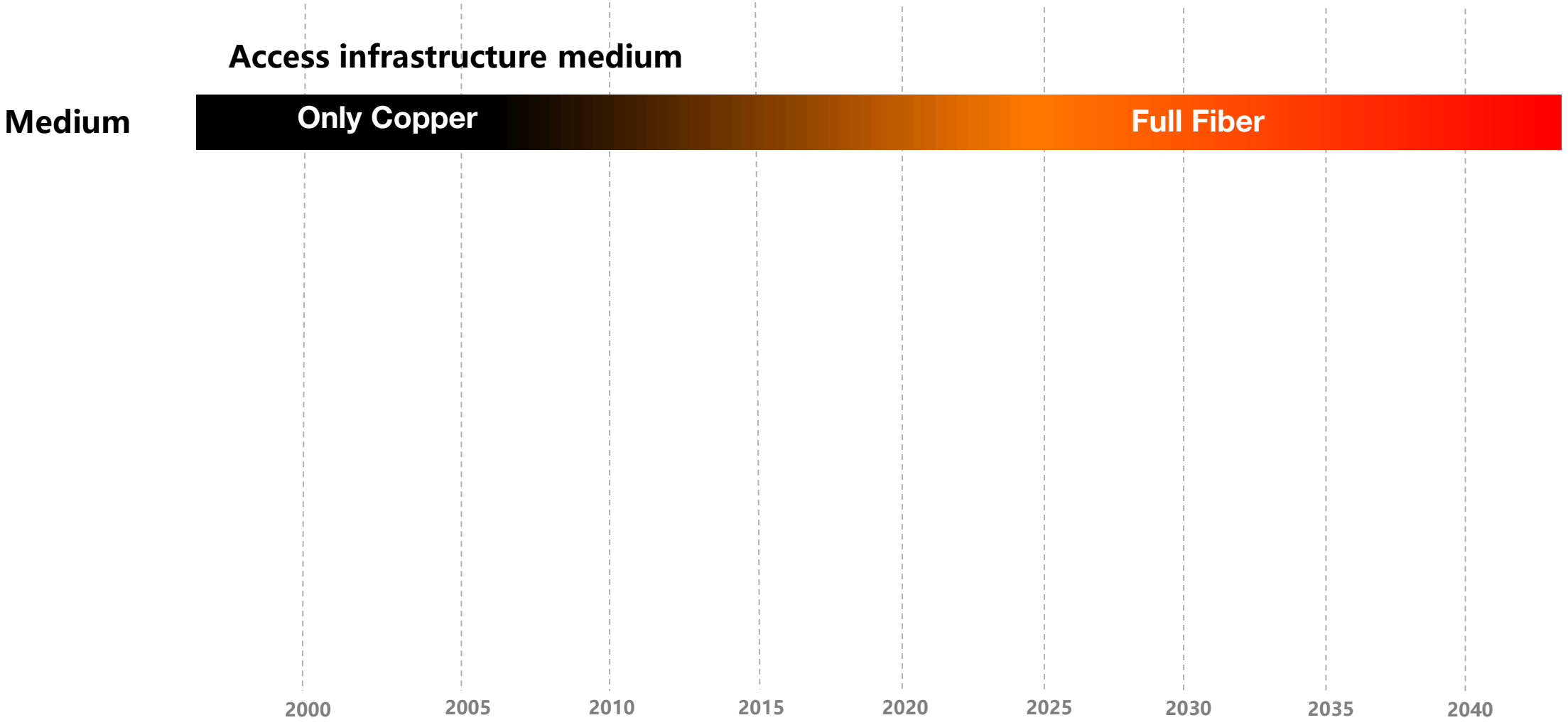
~ 25M
Broadband internet customers

~72M
FTTH Home Passed

~17M
FTTH customers

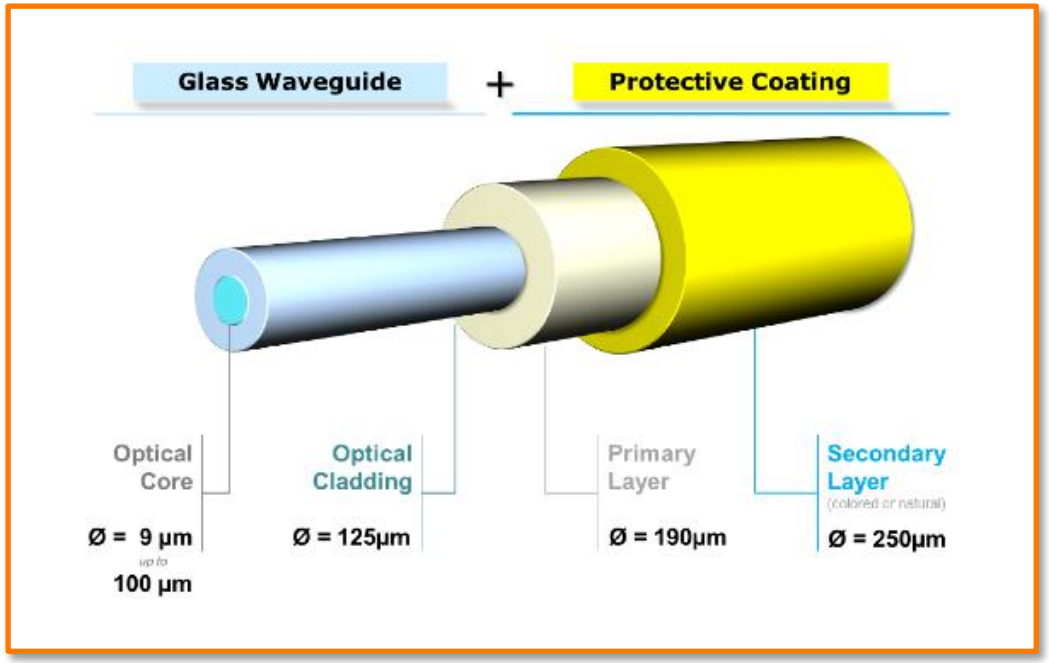
17
FTTH networks in Europe (8) and MEA (9 and counting…)

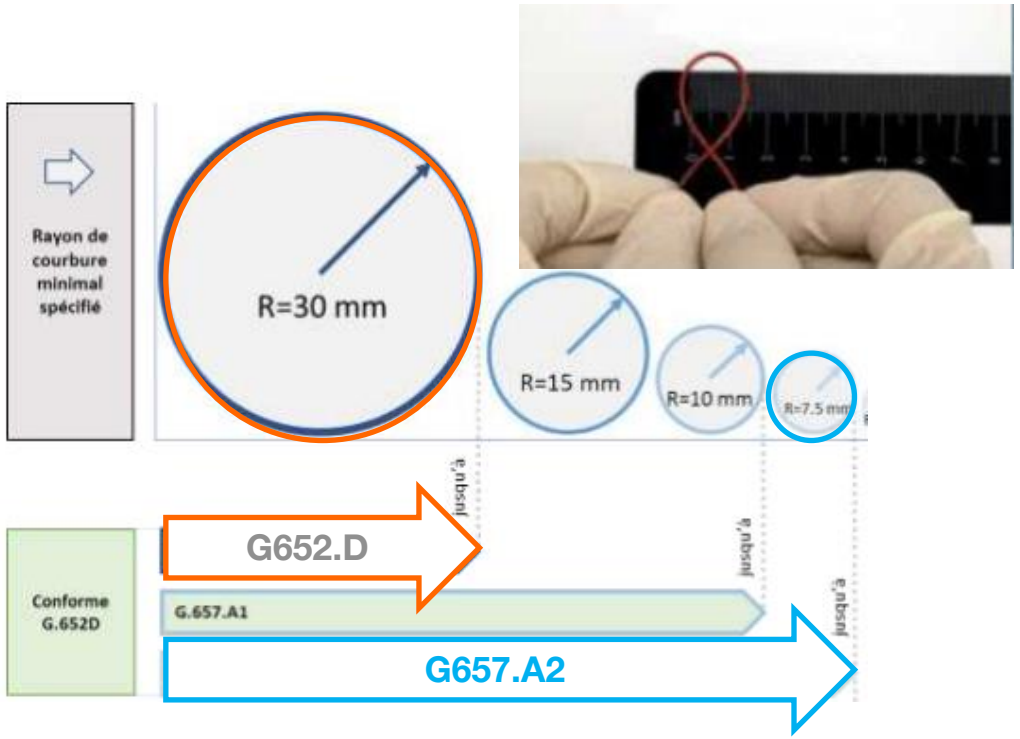
The right medium to maintain high quality fixed access network (FTTx)



La fibre optique chez Orange

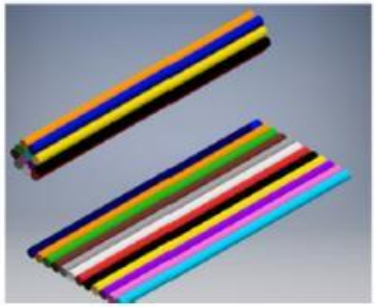
- Fibre de diamètre extérieur 250 microns, constituée d'un cœur en silice dopé Germanium, d'un cladding en silice et de 2 couches de revêtement polymère. Des diamètres extérieurs plus petits (typ. 200 µm) sont envisagés.
- 2 catégories de fibres monomodes déployées sur le réseau Orange : G652.D pour le réseau structurant et G657.A2 (faible sensibilité aux courbures) pour le réseau d'accès FTTH
- Besoin de la protéger dans un câble pour maintenir ses performances mécaniques et optiques





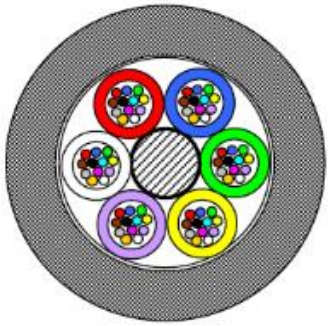
Le câble optique chez Orange

- UN CABLE =
  - Modules à fibres optiques (fonction de transmission)
  - + Eléments additionnels (fonction de renforcement et propriétés particulières)
  - + Enveloppe (fonction de protection)



Ruban

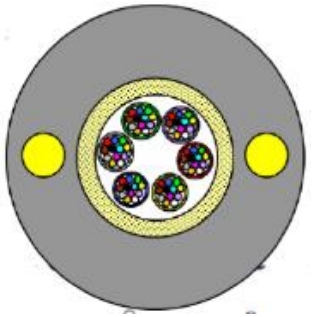
- Différentes technologies de modules:
  - Le micromodule
  - Le loose tube
  - Le ruban



Structure loose tube

- La structure micromodule est majoritairement utilisée par le groupe Orange

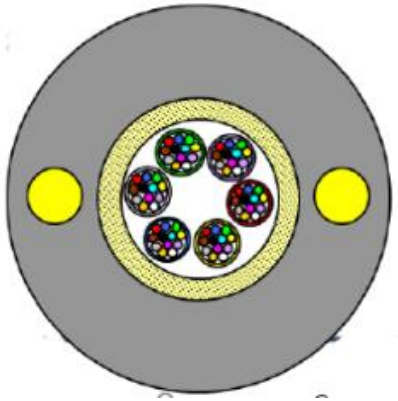
	France	Espagne	Pologne	Slovaquie	Côte d'Ivoire	Roumanie	Jordanie	Maroc	Mali	Burkina Faso	Sénégal
Structure Micromodule	X			X	X	X	X	X	X	X	X
Structure Loose tube		X	X	X							

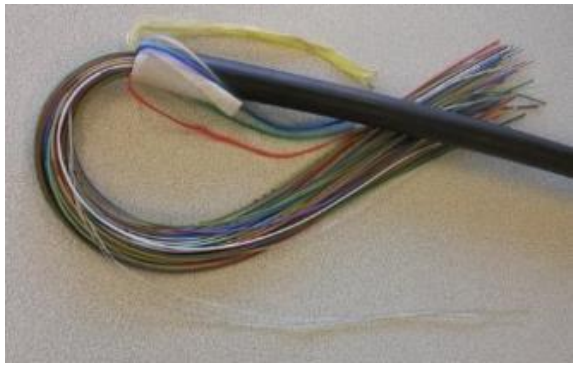


Structure micromodule

Micromodule versus Loose tube

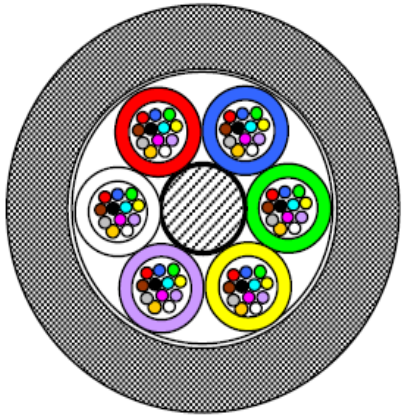
Micromodule: tube de protection souple





- Quantité de graisse limitée ou utilisation de filins gonflants
- Accès rapide sans outil
- Souplesse dans le lovage, donc manipulation aisée dans les boitiers

Loose tube: tube de protection rigide



- Quantité importante de graisse
- Outil nécessaire pour l'ouverture
- Forte sensibilité à la pliure

Vers une miniaturisation du câble…Le micro-câble

Généralités

- Câble de faible diamètre avec une densité importante de fibres
- Pose en micro-conduite par Soufflage/portage ou Flottage

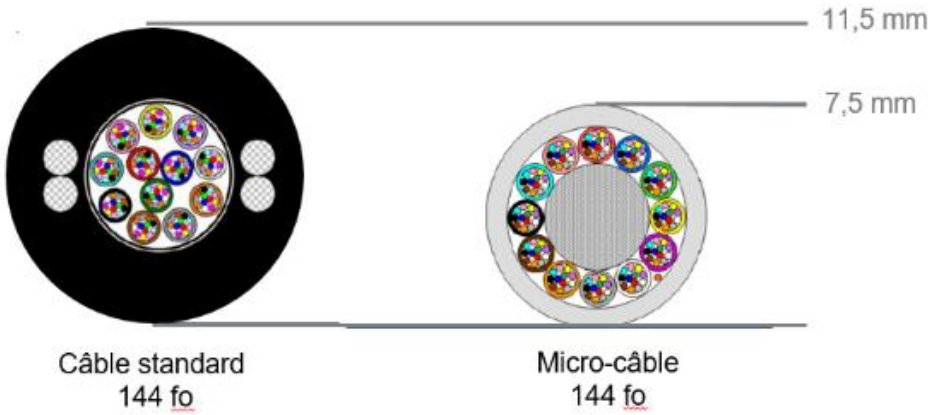
Cas d'usage

- Création de Génie Civil dans des zones sans conduites existantes et pose en aérien impossible
- Réhabilitation de conduites existantes dans des zones à forte occupation

Caractéristiques

- Basées sur la spécification Orange L107X
- Sanctions mécaniques allégées car protection mécanique assurée par la micro-conduite

Fibre G657.A2, d=250 µm	Câble standard L1091-4 (GC)	Micro câble L1072 (Nexans)
Nb de fibres	144	144
Modularité	12	12
Diamètre	11,5 mm	7,5 mm
Effort de traction	220 daN	100 daN
Ecrasement	20 daN/cm	5 daN/cm
Rayon de courbure	R=10D (120 mm)	R=15D (150 mm)
Choc	5J	2J



Câbles conduite extérieur / micro-câbles

Câble conduite standard

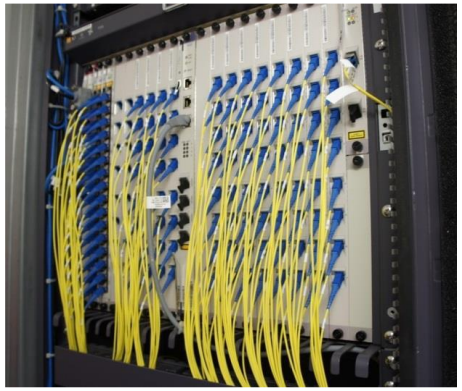
- Conduites en PVC ou PEHD (diamètre intérieur de 45 à 160 mm)
- 1 ou plusieurs câbles par conduite (parfois déjà occupées par câbles cuivre)
- Câbles généralement installés par poussage/tirage ou parfois par flottage pour longue portée

Micro-câble

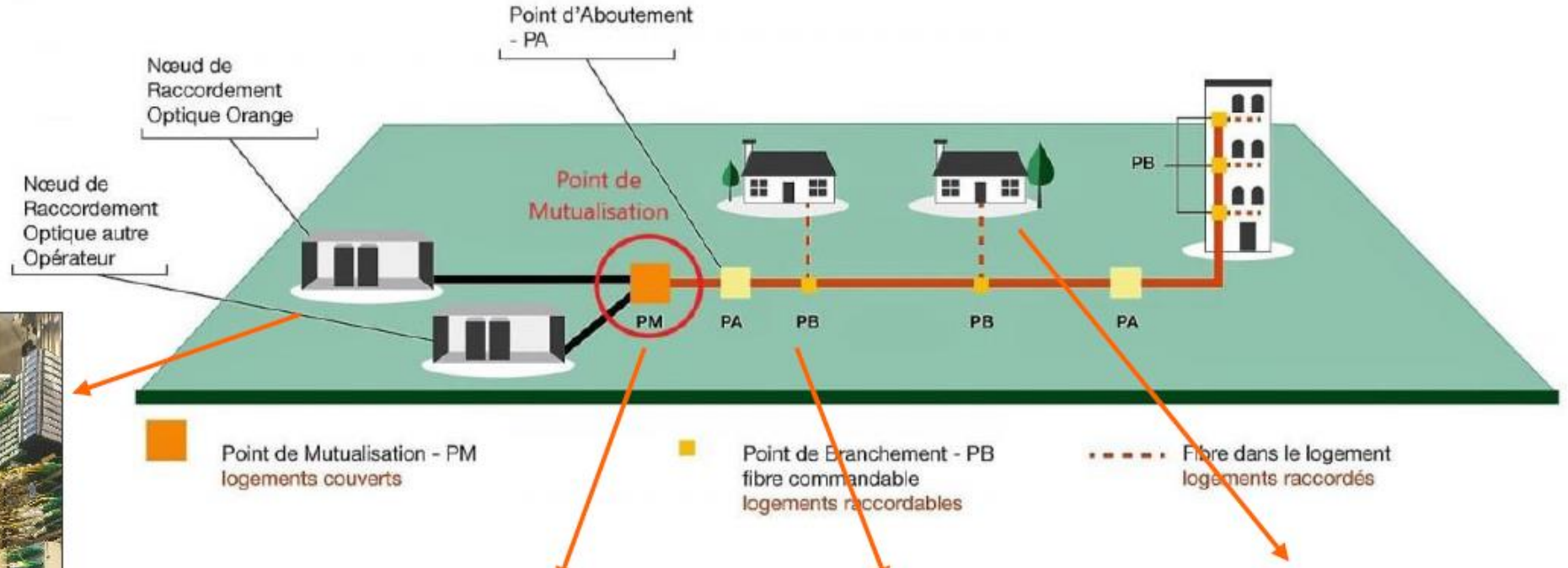
- Micro-conduites en PEHD (diamètre intérieur de de 3,5 à 16 mm)

- Un câble par micro-conduite
- Câble généralement installé par soufflage voire par poussage pour faible portée.
- Micro-conduite ou faisceau de micro-conduites peuvent être installés dans des conduites standards

FTTH : présentation générale de l'infrastructure fibre



Optical Line Terminal (OLT)



Noeud de raccordement Optique (NRO) de Lannion

Point de mutualization (PM)

Point de Branchement Optique (PBO)

Point de Terminaison Optique (PTO)

The right medium to maintain high quality fixed access

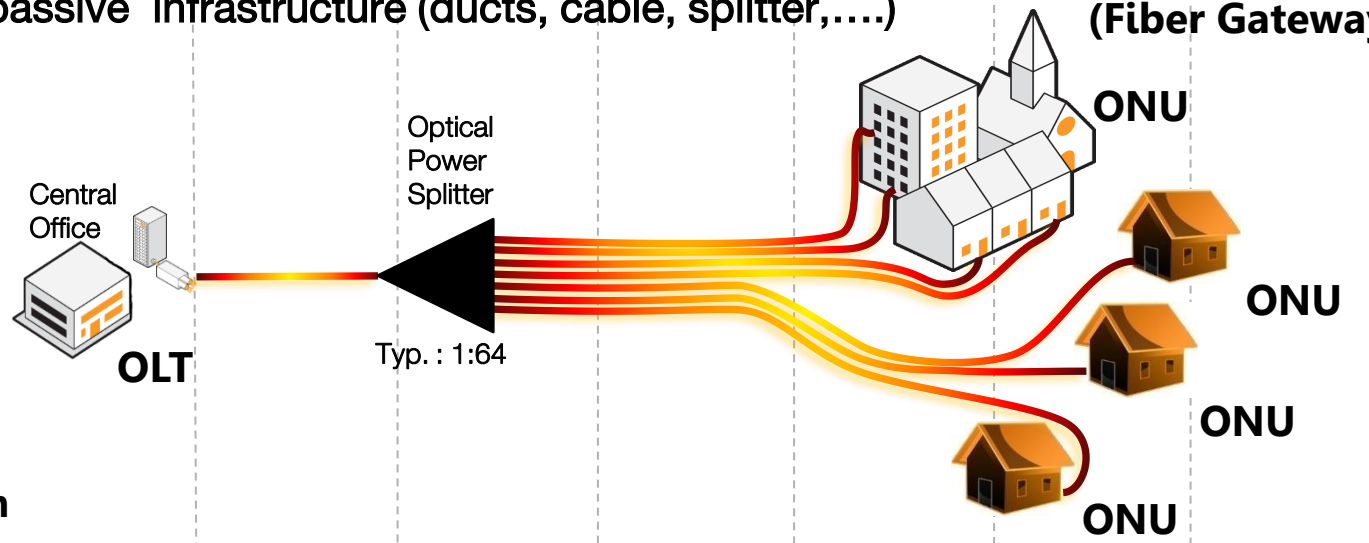
Preserve the passive FTTH plant investments

FTTH CAPEX investment is about

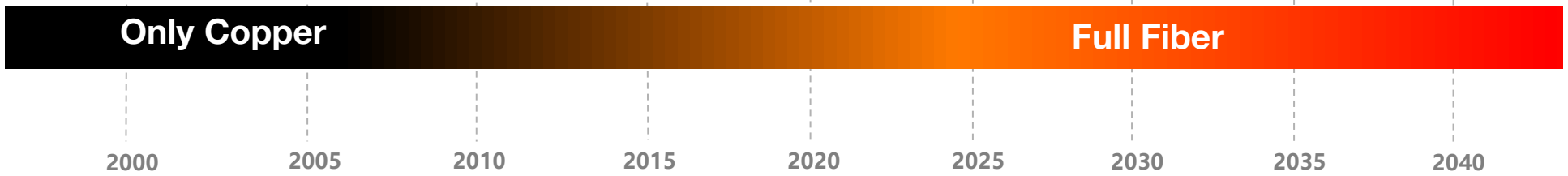
- 10-20% Active network equipment (OLT, ONU/ Fiber gateway)
- 80-90% Passive
  - 40% civil work
  - 60% passive infrastructure (ducts, cable, splitter,….)

ONU: Optical Network Unit (Fiber Gateway)

OLT: Optical Line Terminal



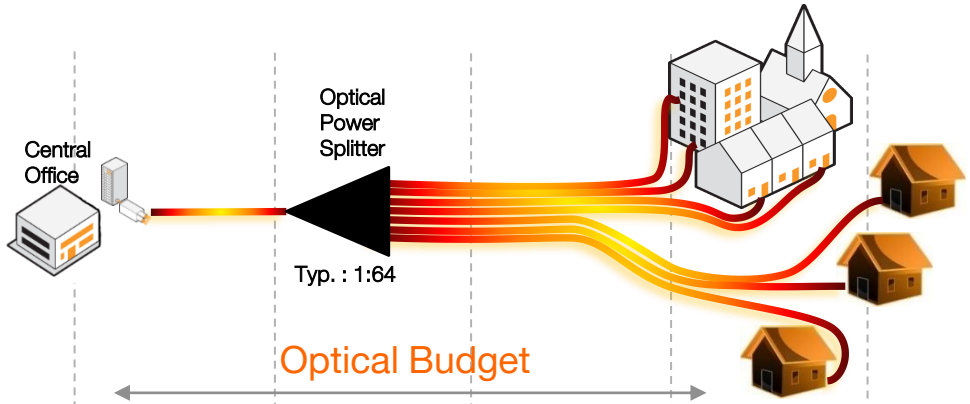
Access infrastructure medium



The right medium to maintain high quality fixed access

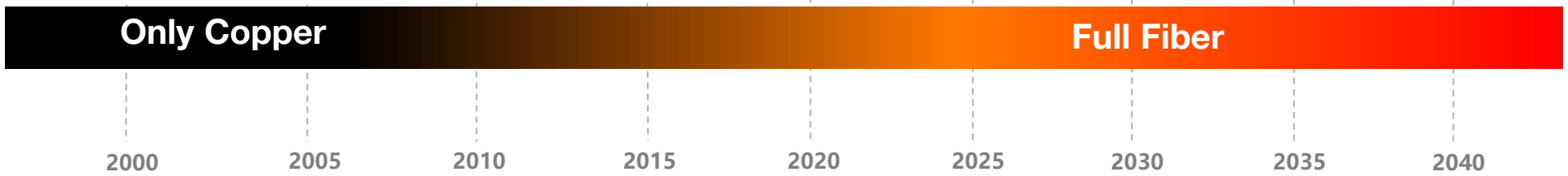
Preserve the passive FTTH plant investments

Standard	Optical Budget class	Maximum attenuation (dB)
G-PON	A	20
	B	25
	B+	28
	C	30
	C+	32
	D (new)	35
XGS-PON	N1	29
	N2	31
	E1	33
	E2	35



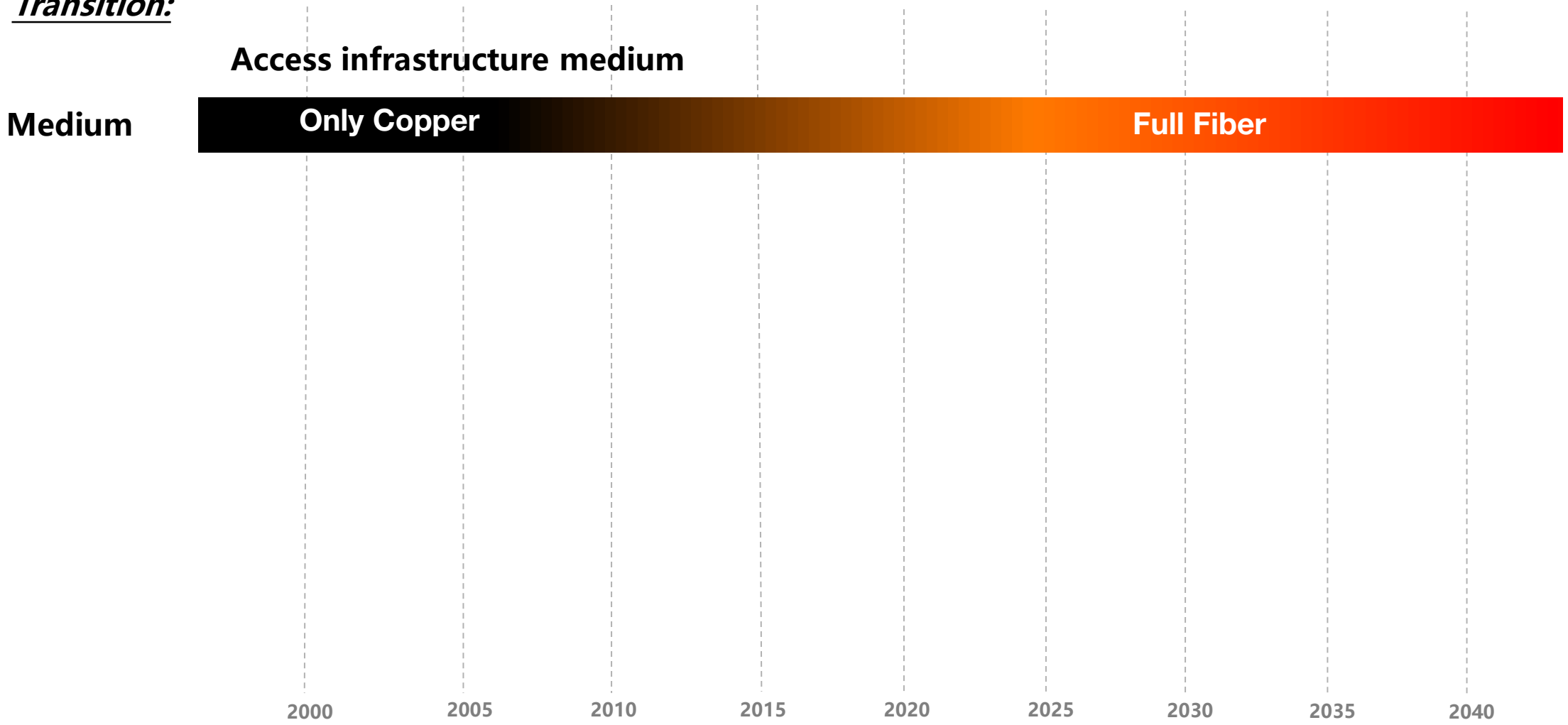
28dB (Class B+) and 32dB (Class C+) are the main classes that need to be preserve

Access infrastructure medium



The right hardware and software to maintain high quality fixed access network (FTTx)

Transition:



Outline :

1. **Hardware** transition : G-PON to G-&XGS-PON

2. **Software** transition : Modernization of Optical Access Network Management (FTTH)

3. **Fibre to Everywhere and Everything** transition: Fiber Optical access is not only for FTTH

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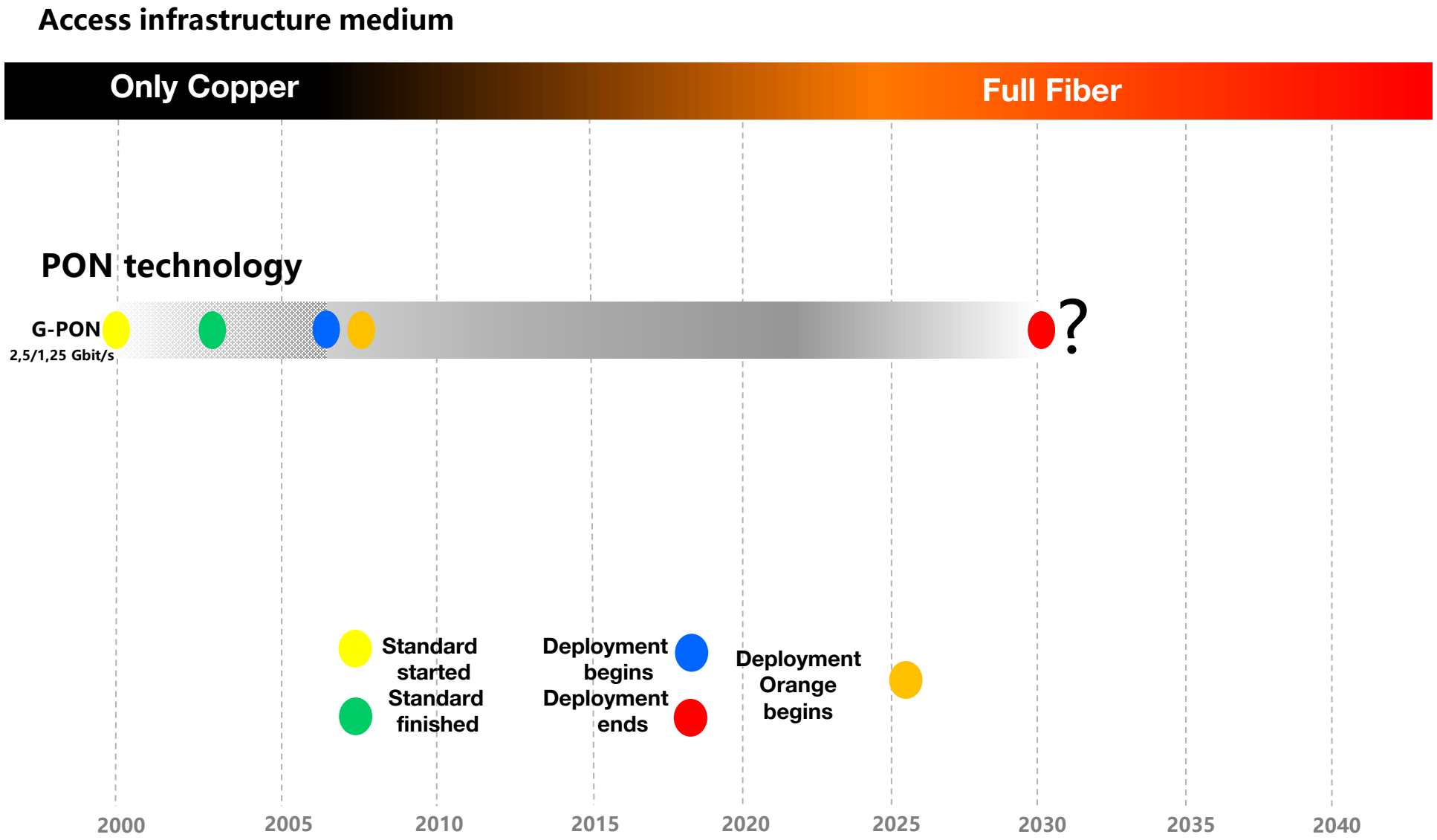
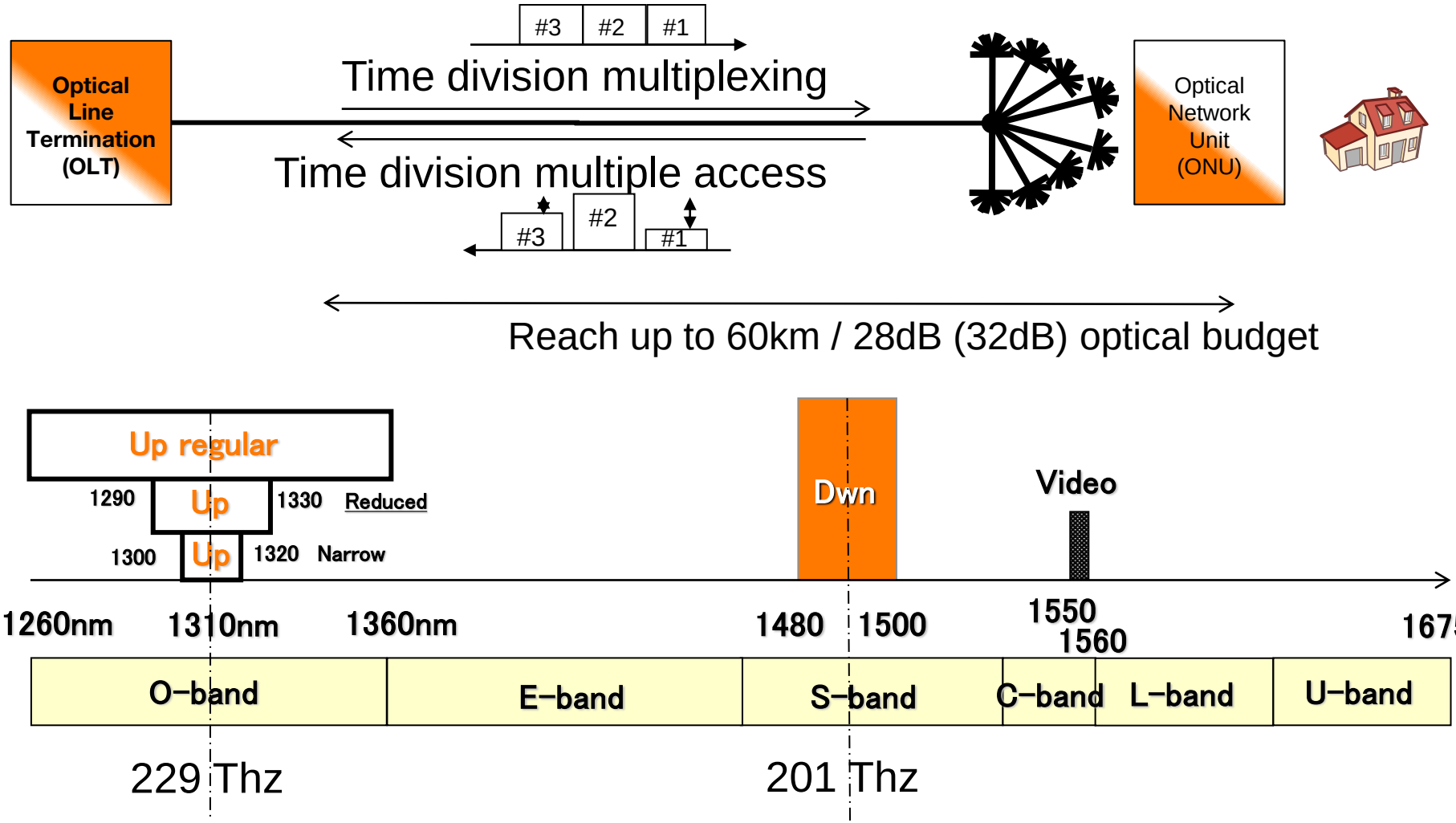
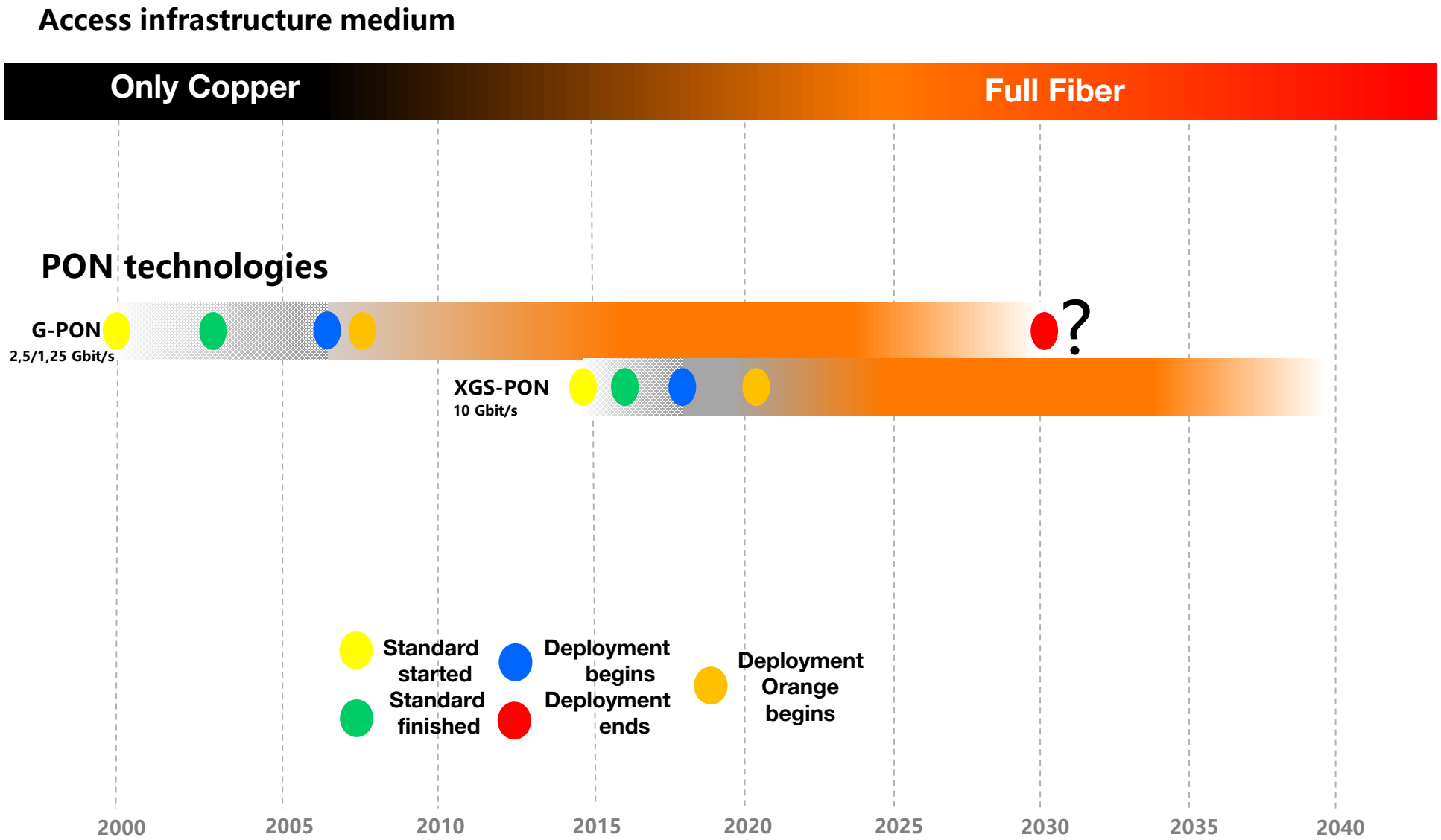
The right technology to maintain high quality fixed access



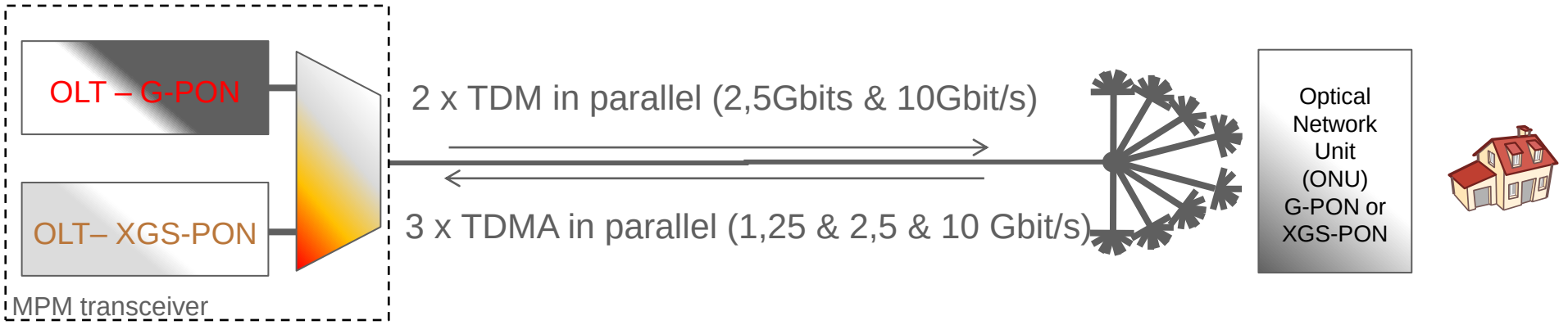
G-PON : Gigabit capable Passive Optical Network

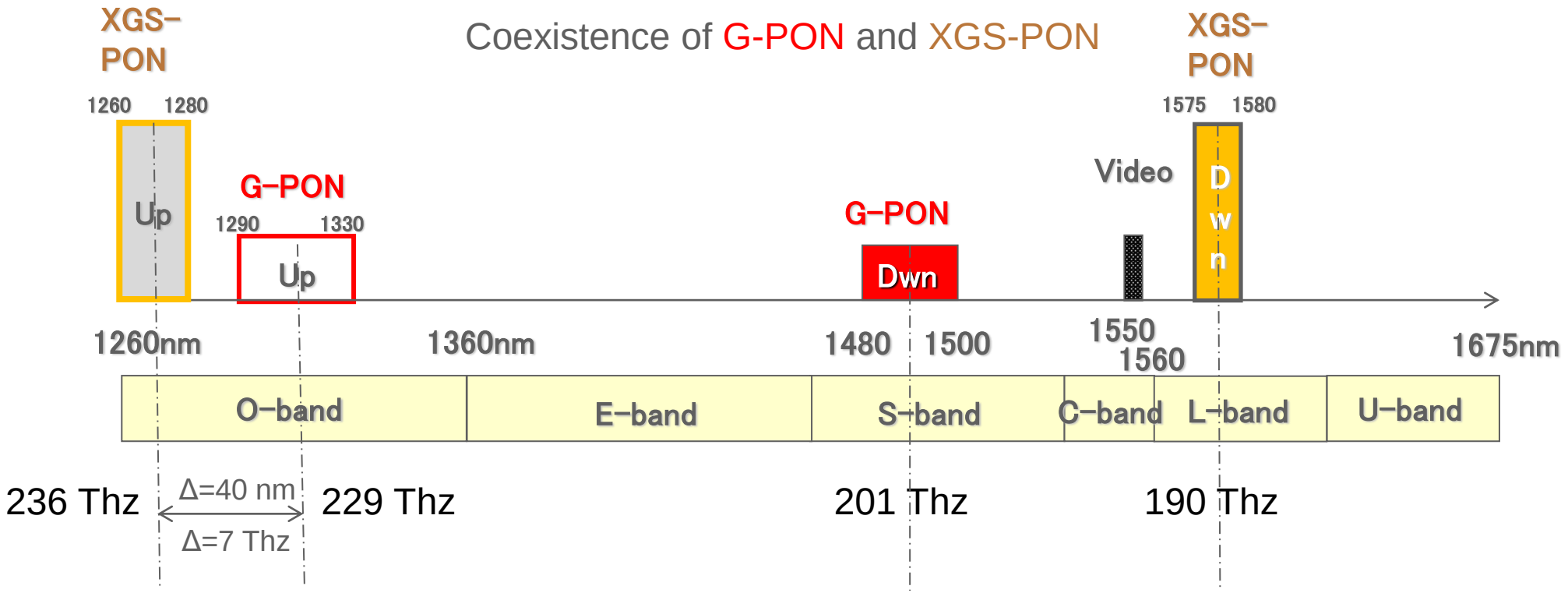


The right technology to maintain high quality fixed access

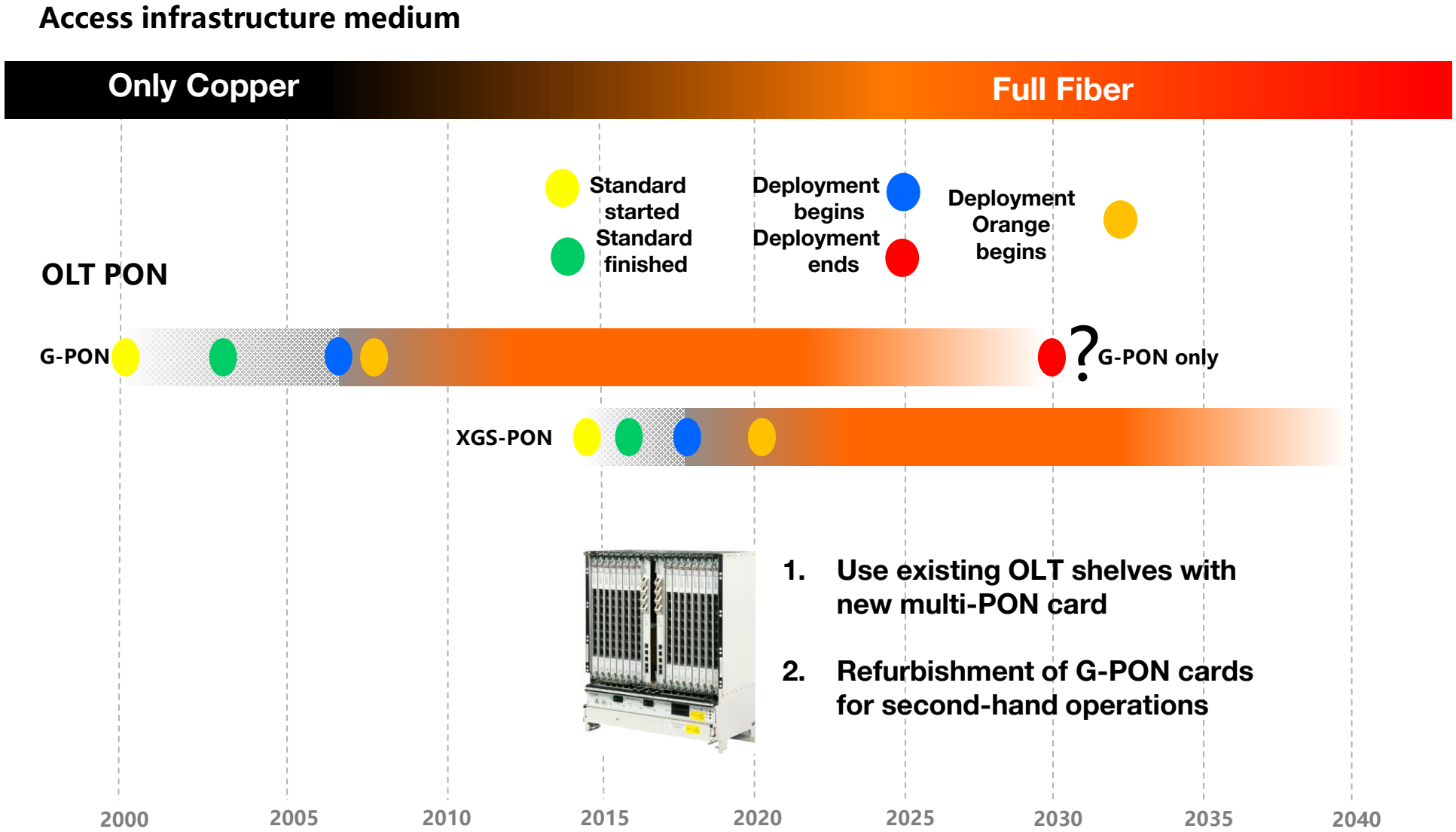


XGS-PON : 10 Gigabit Symetrical capable Passive Optical Network

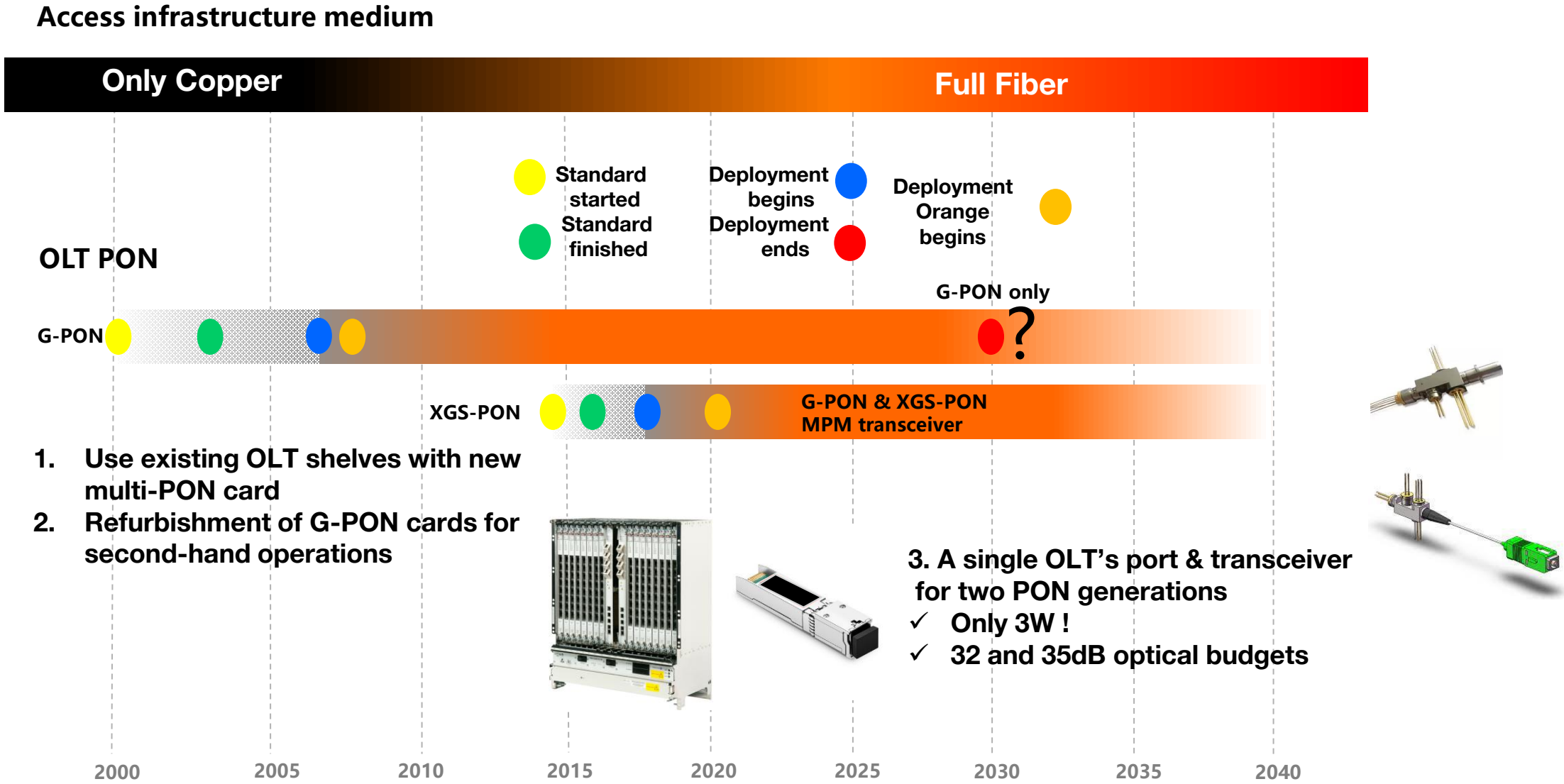




The right technology to maintain high quality fixed access

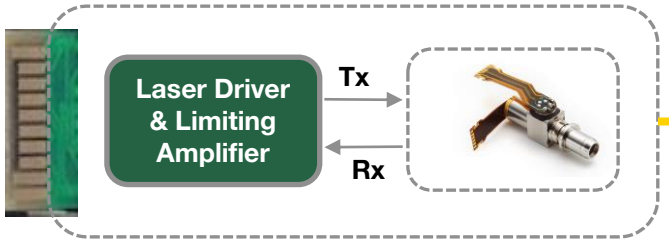


The right technology to maintain high quality fixed access



The role of photonic integration for G-PON and XGS-PON technology (FTTHome)

G-PON



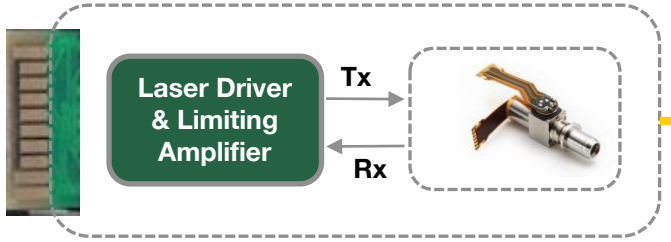
Two wavelengths (1490 / 1310 nm):

Wavelength up

Single fiber

Wavelength down

XGS-PON



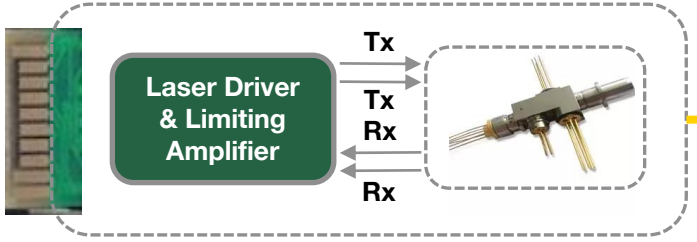
Two wavelengths (1577 / 1270 nm):

Wavelength up

Single fiber

Wavelength down

Combo
G-PON & XGS-PON

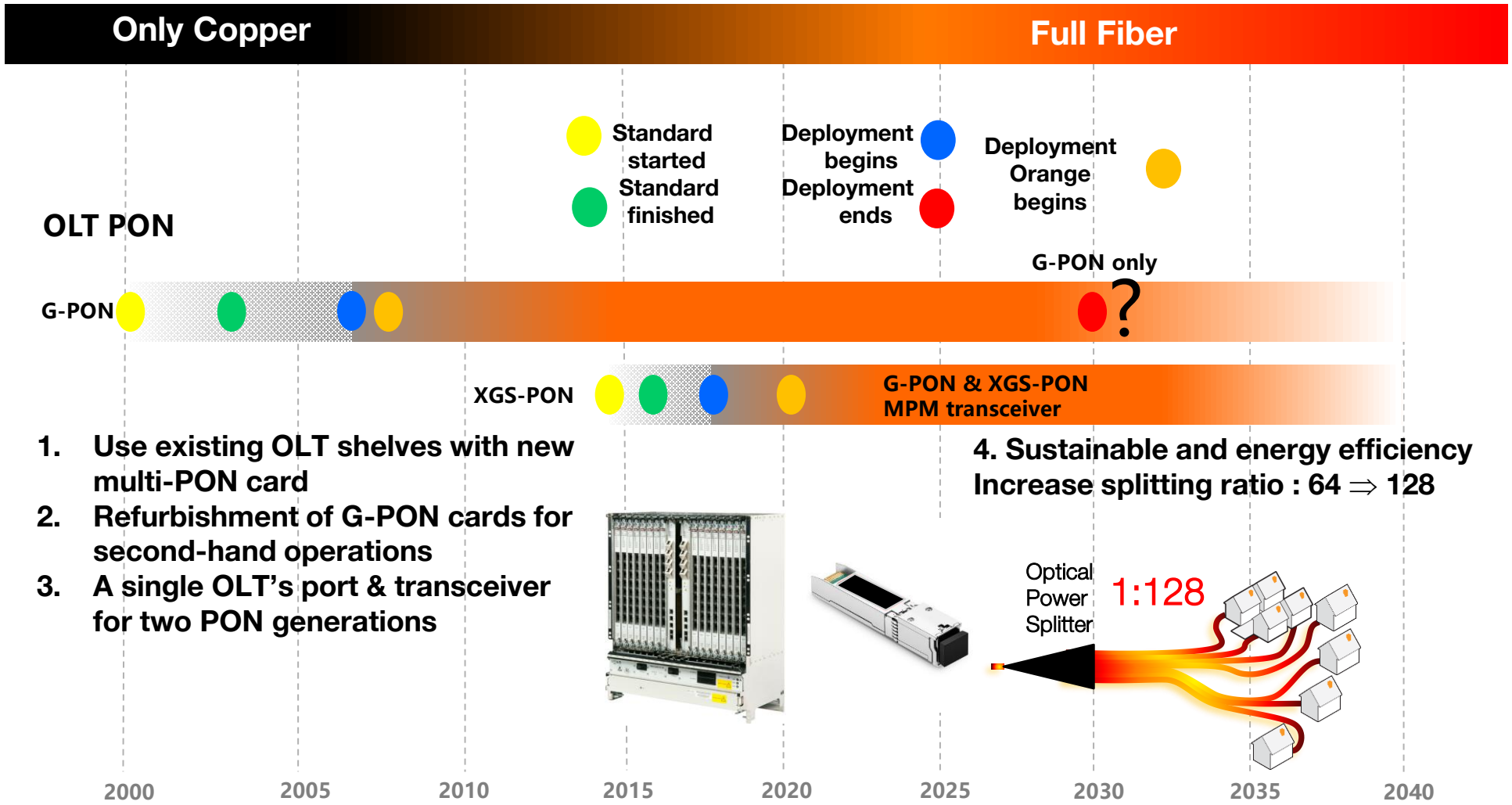


Four wavelengths (1577 / 1270 + 1490 / 1310 nm):

Single fiber

The right technology to maintain high quality fixed access

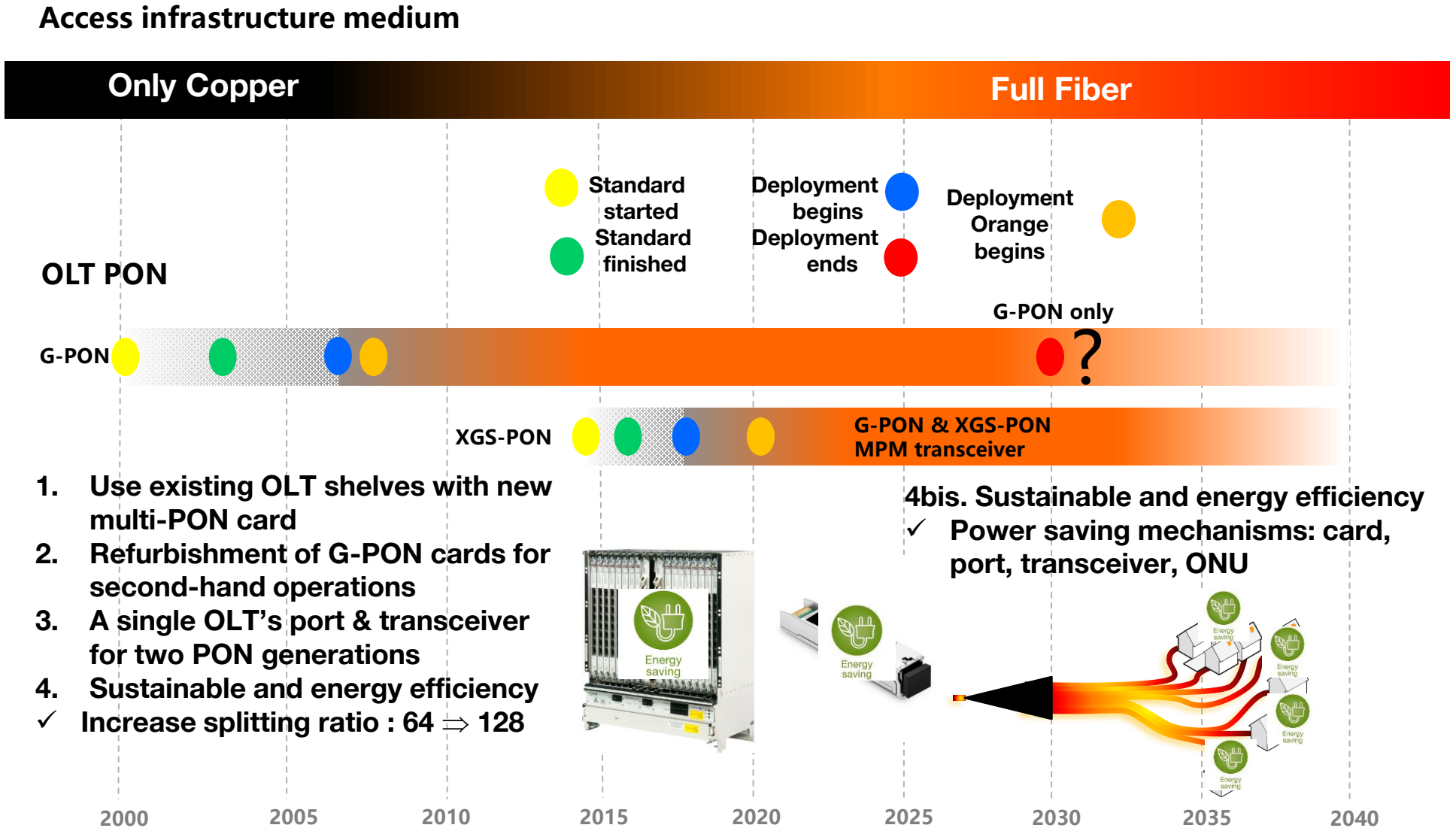
Access infrastructure medium



1. Use existing OLT shelves with new multi-PON card
2. Refurbishment of G-PON cards for second-hand operations
3. A single OLT's port & transceiver for two PON generations

4. Sustainable and energy efficiency
Increase splitting ratio : 64 ⇒ 128

The right technology to maintain high quality fixed access



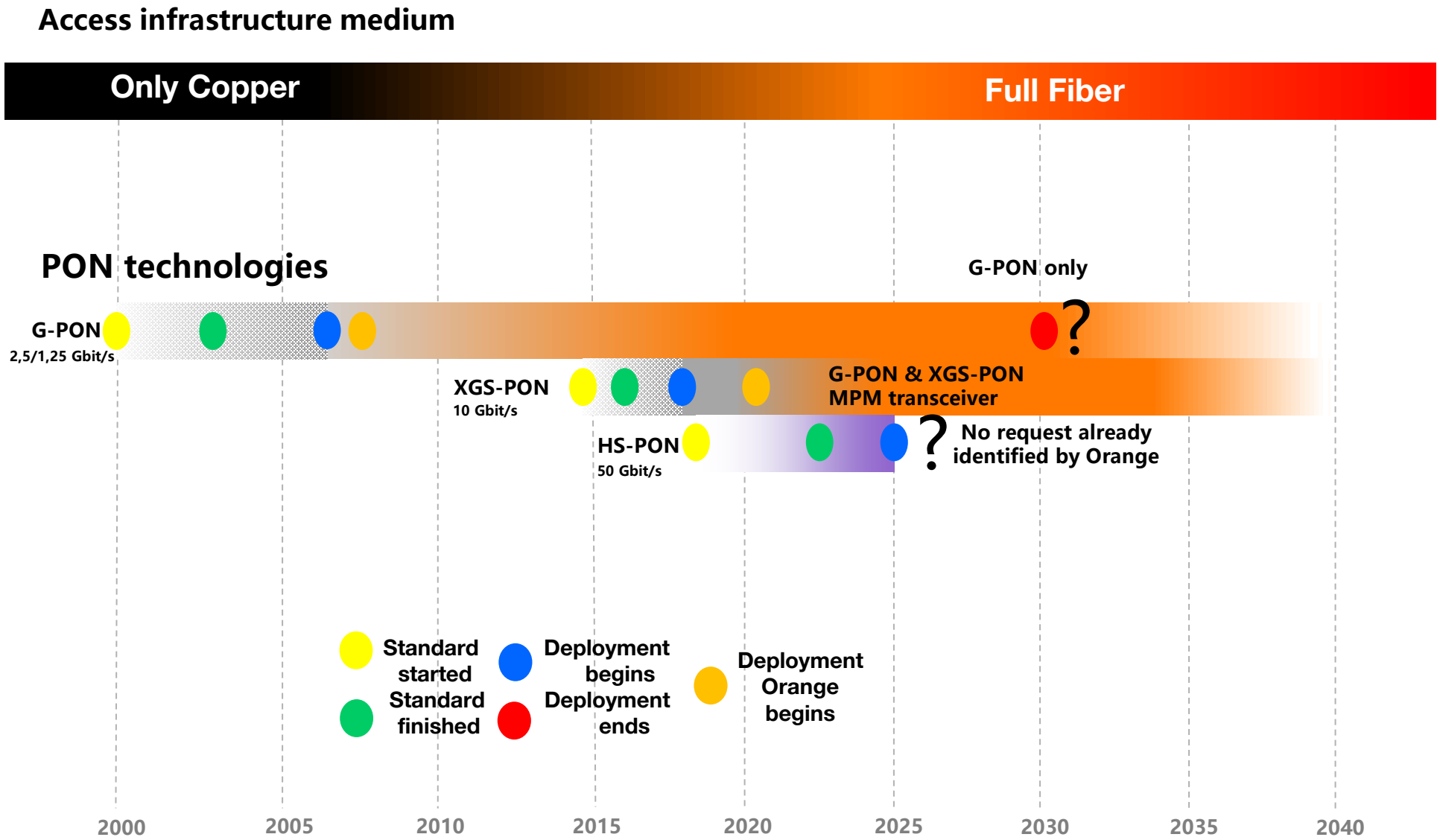
1. Use existing OLT shelves with new multi-PON card
2. Refurbishment of G-PON cards for second-hand operations
3. A single OLT's port & transceiver for two PON generations
4. Sustainable and energy efficiency

✓ Increase splitting ratio : 64 ⇒ 128

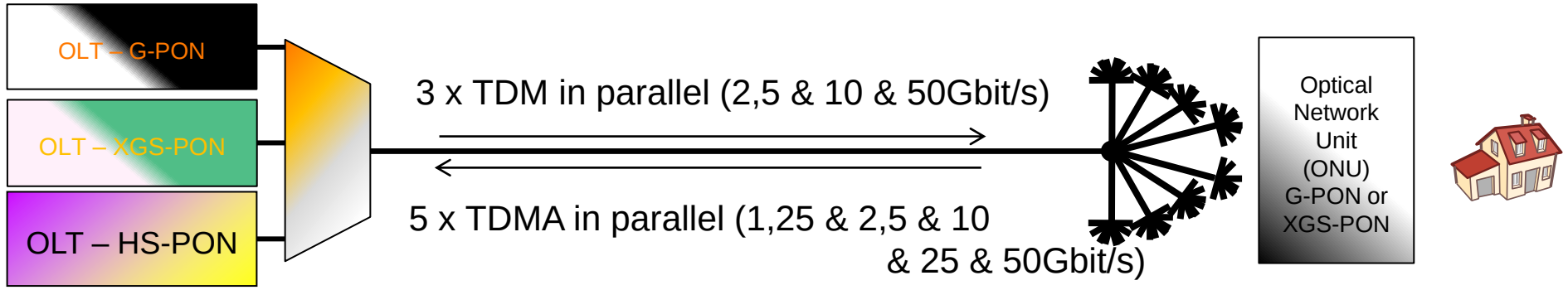
4bis. Sustainable and energy efficiency

✓ Power saving mechanisms: card, port, transceiver, ONU

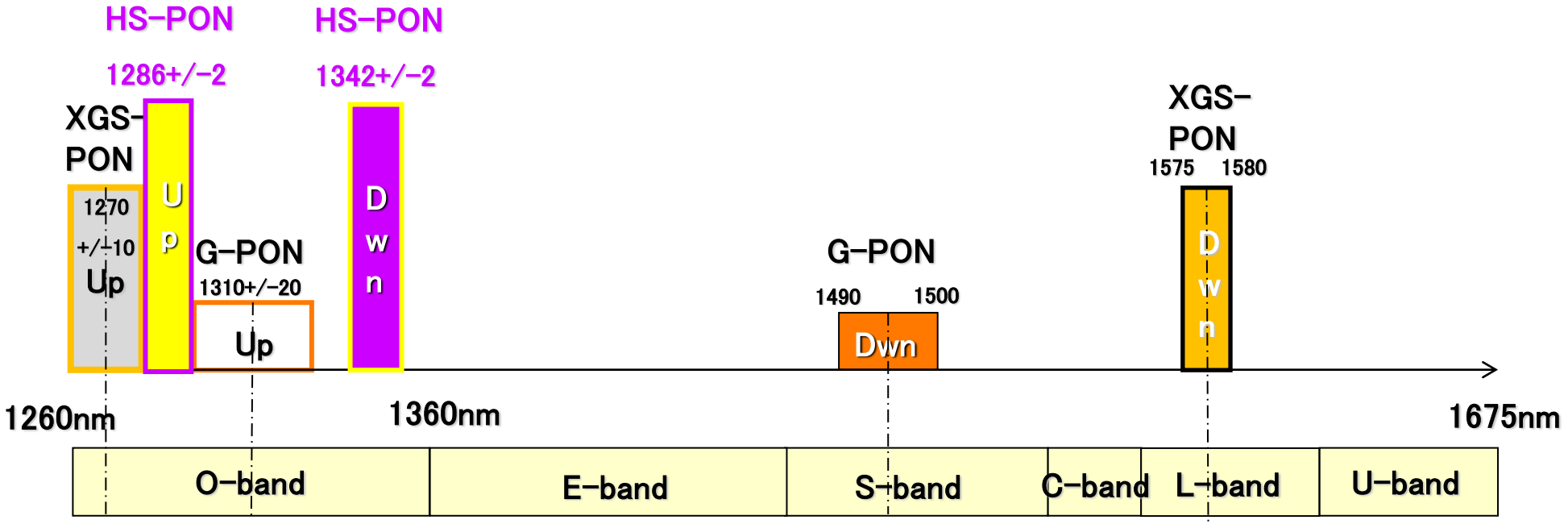
The right technology to maintain high quality fixed access



The right technology to maintain high quality fixed access

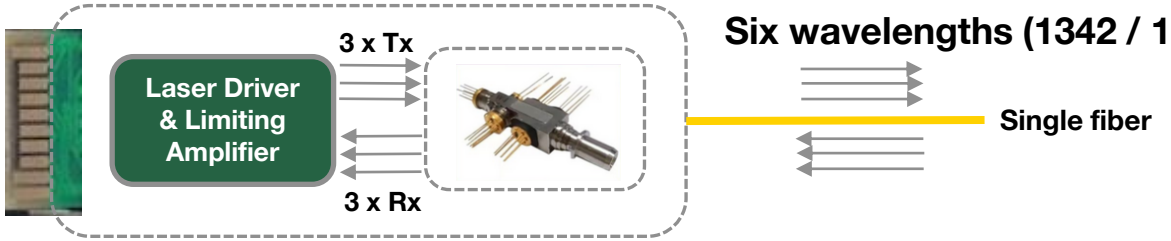


Coexistence of G-PON, XGS-PON, 50G-PON



The role of photonic integration for G-PON, XGS-PON and 50G-PON technology (FTTHome)

Tri-Combo
G-PON & XGS-PON & 50G-PON



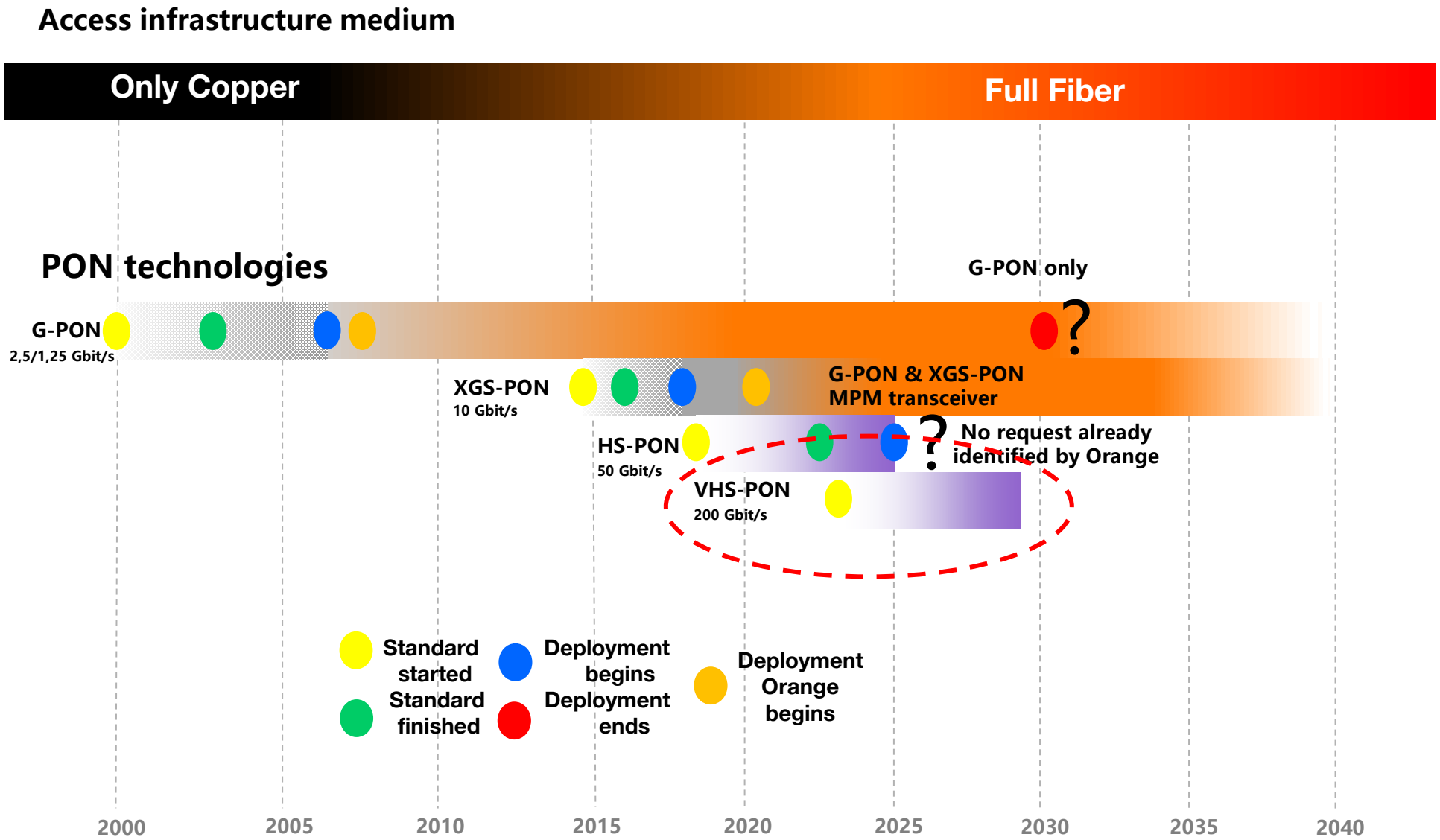
- 50G-PON was initialized with “Combo”. First with either G-PON or XGS-PON and now with the three technologies: G-PON, XGS-PON and 50G-PON.

- 50G-PON : this year, first commercial products are available

- The trend is to maintain the optical budget :
  - New FEC (LDPC) with more gain
  - First time that we use electronic equalizer (FFE 13 symbol taps)
  - Class C+ (32 dB) due to progress on the photonics performance (Tx/Rx) (Tx with EML + SOA)

- Lesson learn : The maturity of photonics allows to maintain optical budget in same time that line rate increase with a “combo” integration (2,5Gbit/s to 10 Gbit/s to 50 Gbit/s)

The right technology to maintain high quality fixed access



Moving from G-PON only to G- & XGS- PON

Standard started
Standard finished
Deployment begins
Deployment ends
Deployment Orange begins

OLT PON

G-PON
G-PON only
?
XGS-PON
G-PON & XGS-PON MPM transceiver
HS-PON
?
Orange considers HS-PON as the next step but no deployment request already identified by Orange

Access infrastructure medium

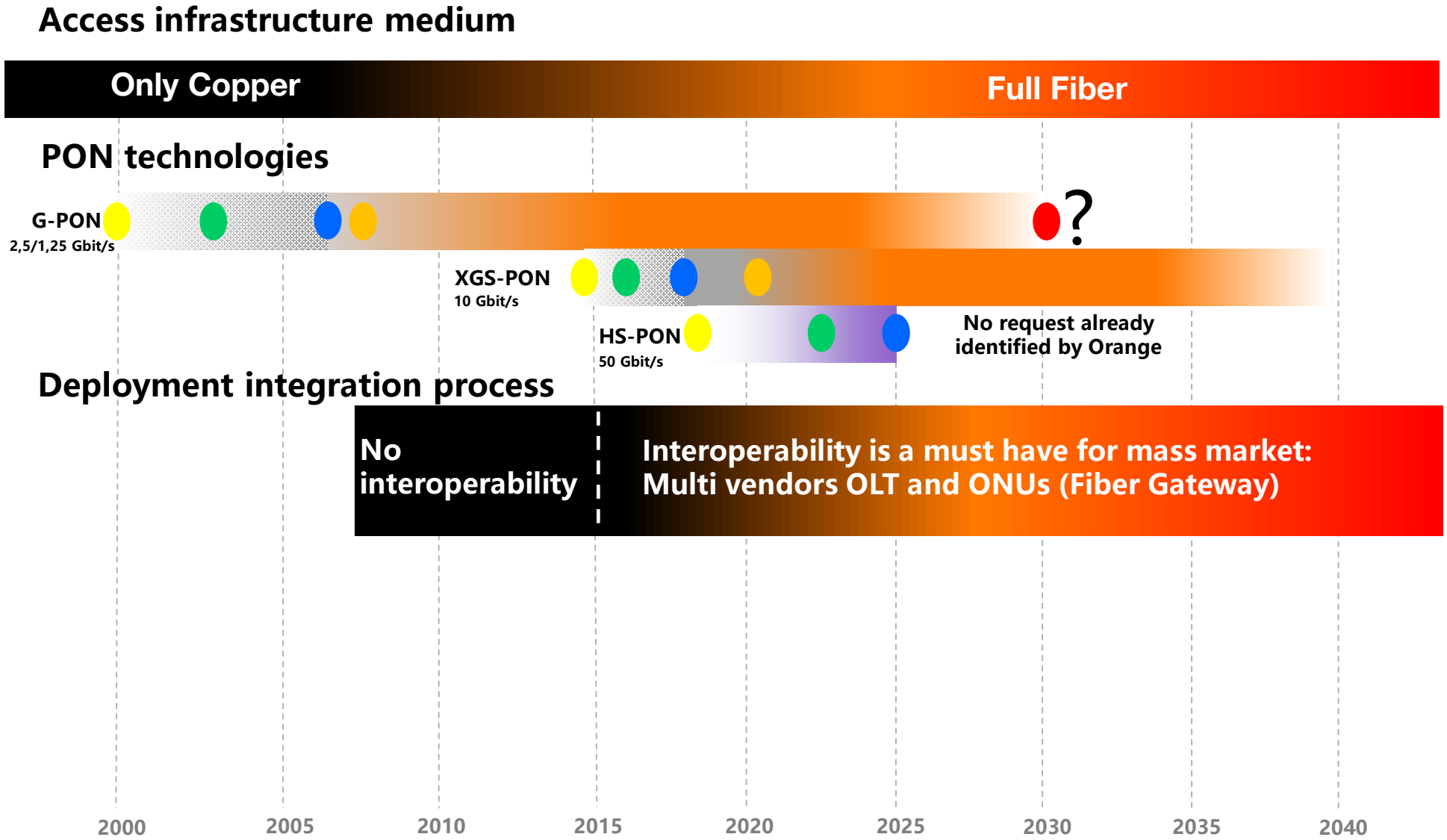
Only Copper
Full Fiber

Deployment integration process

To decrease complexity and enhance sustainability, it is essential to effectively manage the integration of multi-vendor systems and several generations of operations.

2000 2005 2010 2015 2020 2025 2030 2035 2040

The right technology to maintain high quality fixed access



PON interoperability & benefits for Orange group

Firsts G-PON deployments [2006 - 2015]:

- Necessary to install ONU from same vendor as OLT
- No possibility to change the market share allocation, low leverage on vendor features

G-PON ONU RFP in 2015 to decrease prices and reduce vendors dependency:

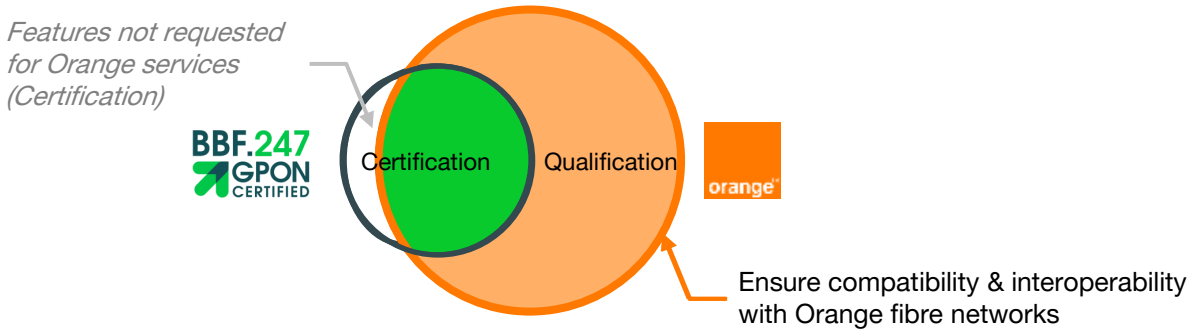
- Interoperability (standards), the key word for sourcing and to respond to increasing volume demands
- Facilitate equipment, network and services evolution: Maintain the existing base with our OLT suppliers and be able to deploy the ONU and optical gateway without any constraint

XGS-PON ONU purchasing is natively based with interoperability features (it is a must)

- Interoperability test plan ready for XGS-PON (BBF 247 issue4) since April 2020 and several plugfest events before
- LANPARK independent testing Lab ready for BBF certification and Orange Qualification

Certification & Qualification benefits for PON ONU at Orange group

- For any PON products selection, the BBF.247 Certification is mandatory and this is a prerequisite to prove the terminal is mature enough
- The objective of the Qualification tests phase is to verify the OLT - ONU interworking according to Orange engineering rules



Two XGS products already certified and qualified:

XGS gateway "Infinity"

Single XGS ONU

BBF.247 XGS-PON CERTIFIED

⇒ Certification and Qualification ensure the system is fully interoperable & compatible with the same OLT as the OLT deployed in Orange fibre networks

⇒ Interoperability can play an important role in reducing eCarbon emissions and sustainability. By promoting compatibility and interconnectivity between different vendors, interoperability enables more efficient use of resources and process optimization (avoid waste and inefficiencies)

⇒ End to End integration in Orange labs on CI/CD chain with OLTs and ONUs/gateways including automated test suites provided by vendors

Certification & Qualification benefits for PON ONU at Orange group: the lastest Fiber gateway Livebox 7

Livebox 7

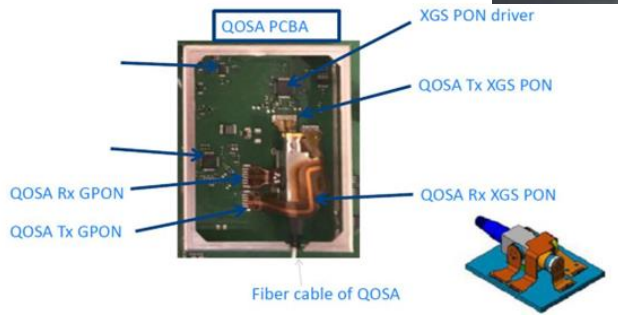
A GPON or XGSPON compatible box, without the need for customer intervention when changing technology.

10G Ethernet port.

BBF.247 GPON CERTIFIED

BBF.247 XGS-PON CERTIFIED

A single « fiber » port for G-PON and XGS-PON

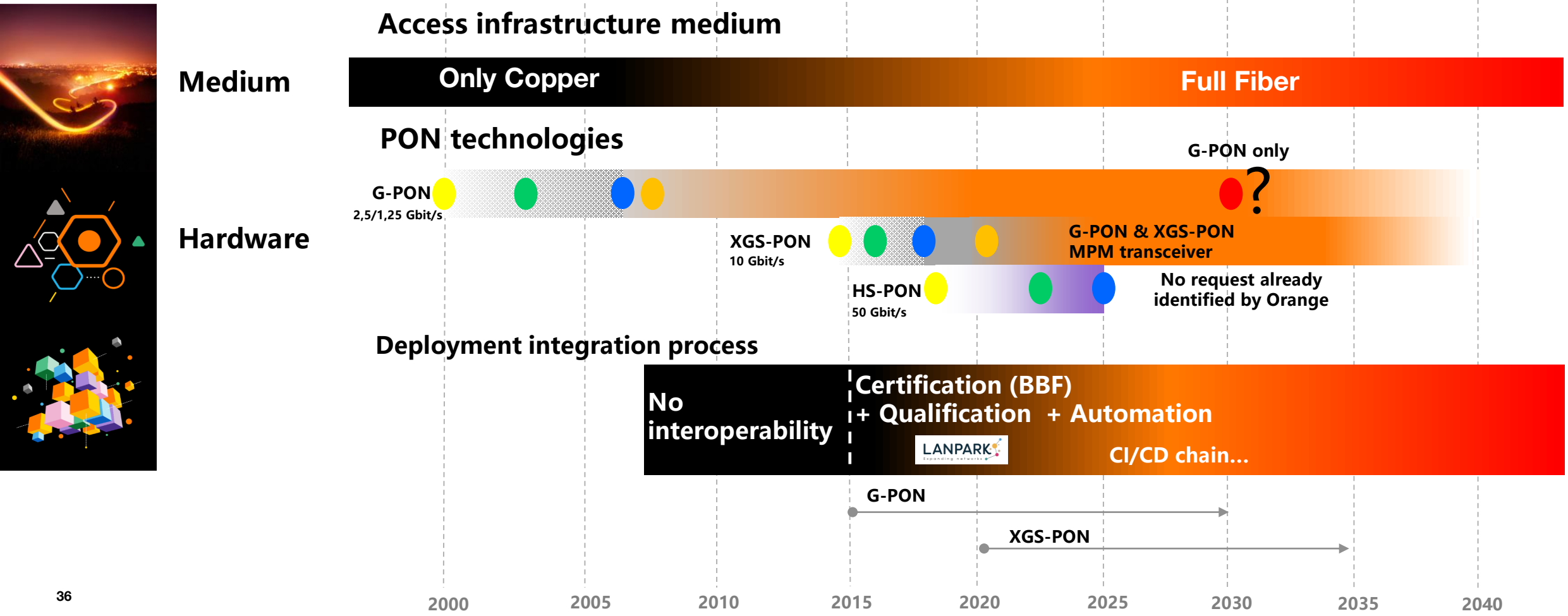


Multiple PON technologies gateway with automatic PON technology selection

Wi Fi 6E CERTIFIED

The right hardware and software to maintain high quality fixed access network (FTTx)

Transition:



Outline :

1. Hardware transition : G-PON to G-&XGS-PON

2. Software transition : Modernization of Optical Access Network Management (FTTH)

3. Fibre to Everywhere and Everything transition: Fiber Optical access is not only for FTTH

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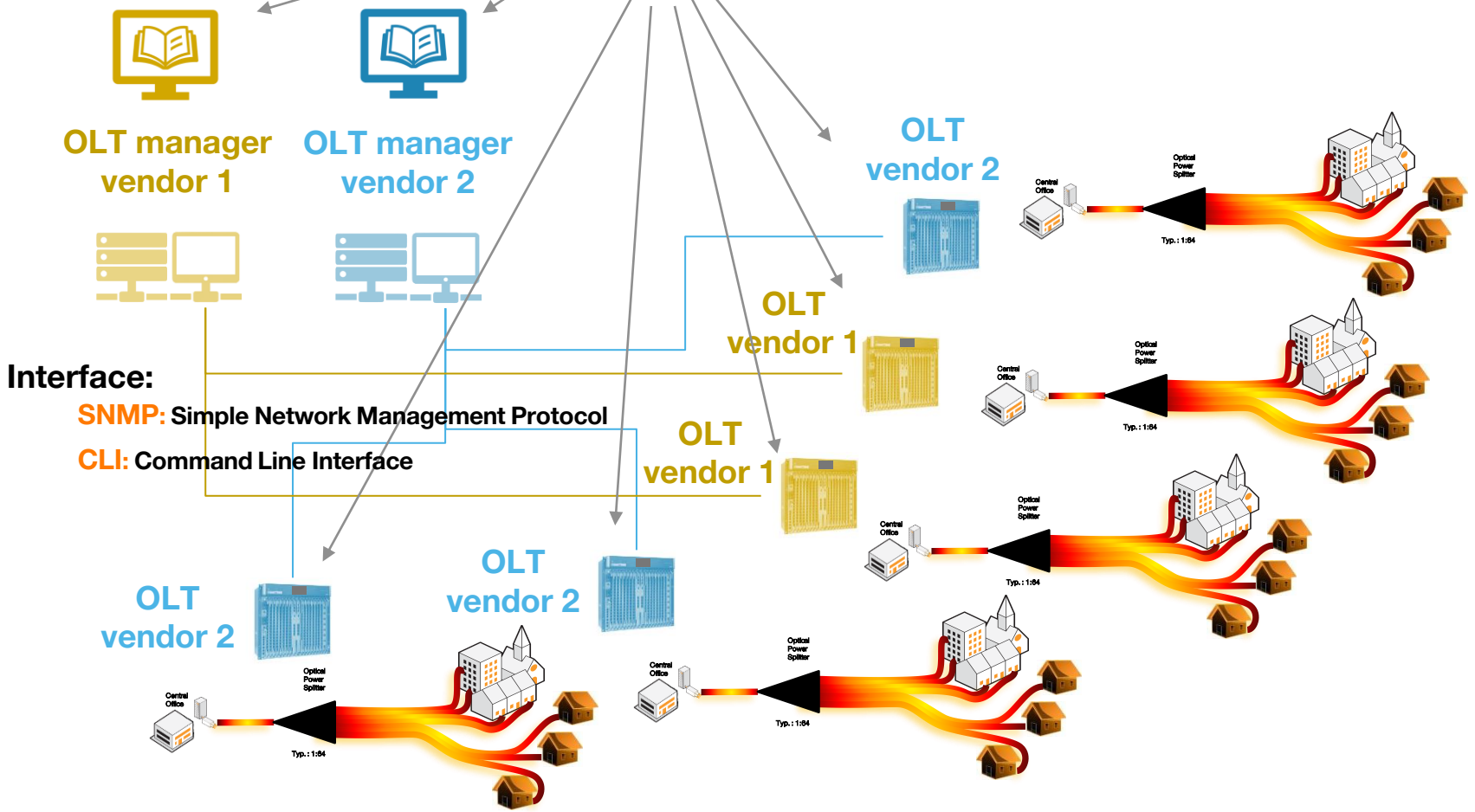
The right “software” to maintain high quality fixed access

Today’s management

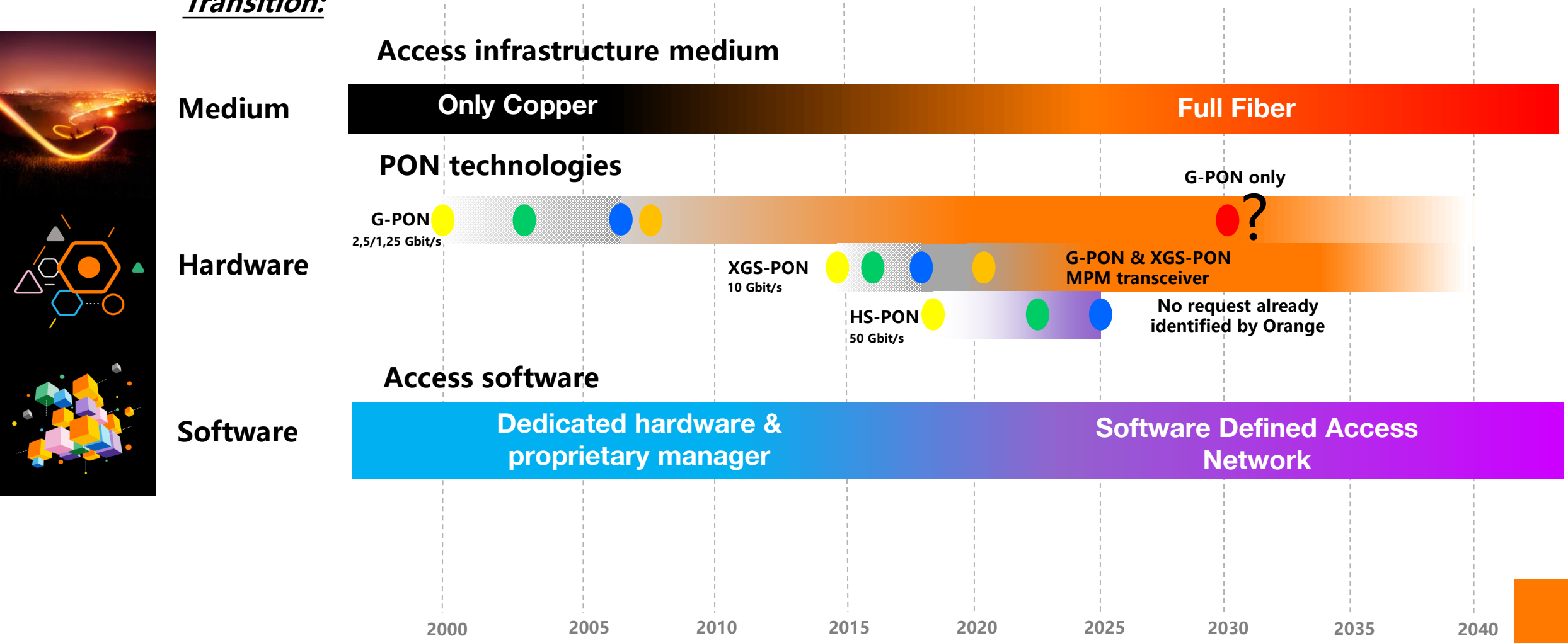
OLT management uses vendor dedicated software

Fixed Access OSS (Operations Support Systems)



The right hardware and software to maintain high quality fixed access network (FTTx)

Transition:



Open Broadband – Broadband Access Abstraction

Tomorrow's potential implementation:

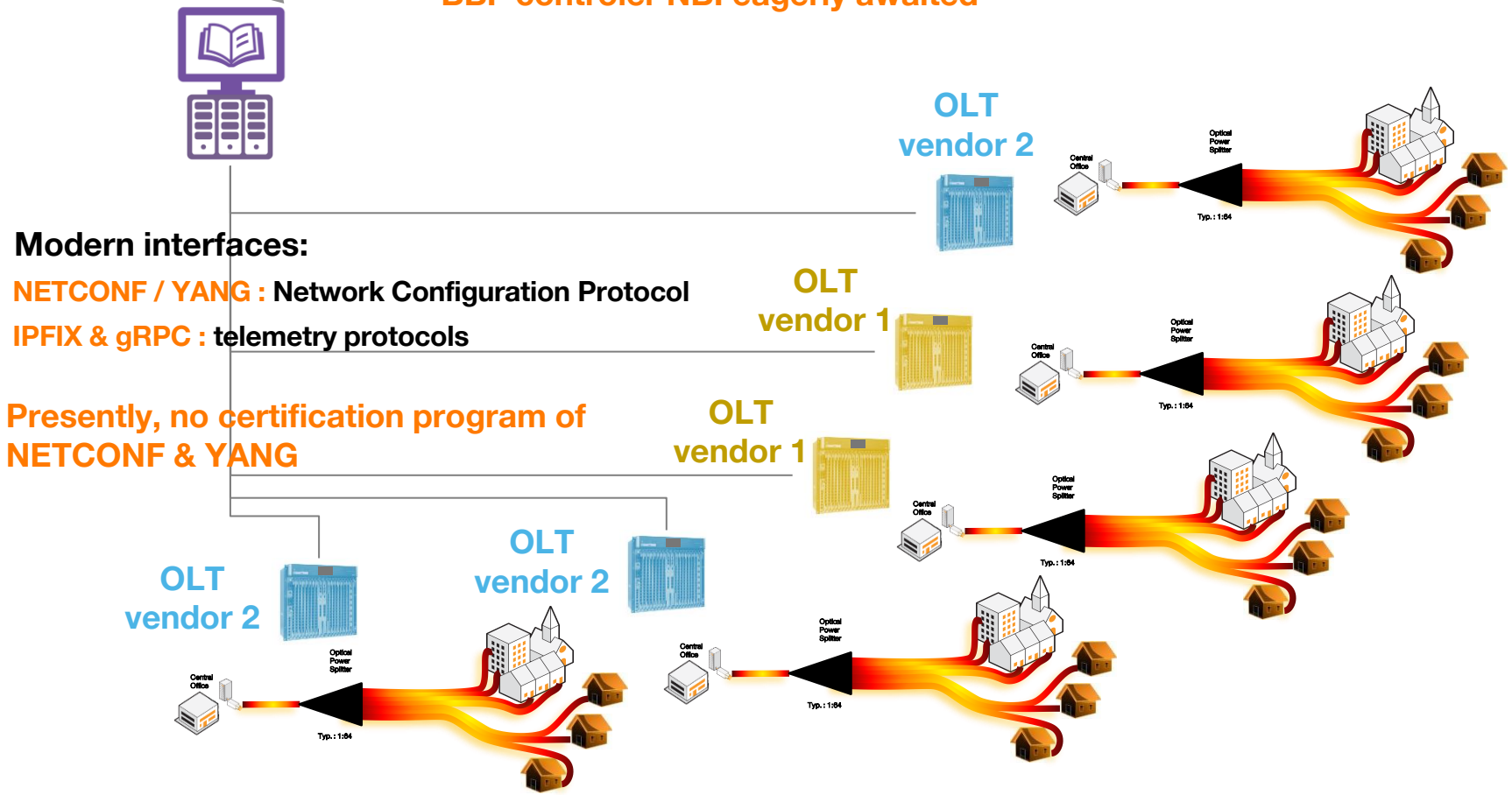
Fixed Access OSS (Operations Support Systems)

OLT controller with the "promise" to be vendor agnostic

BBF controler NBI eagerly awaited

broadband forum

open broadband



Modern interfaces:

NETCONF / YANG : Network Configuration Protocol

IPFIX & gRPC : telemetry protocols

Presently, no certification program of NETCONF & YANG

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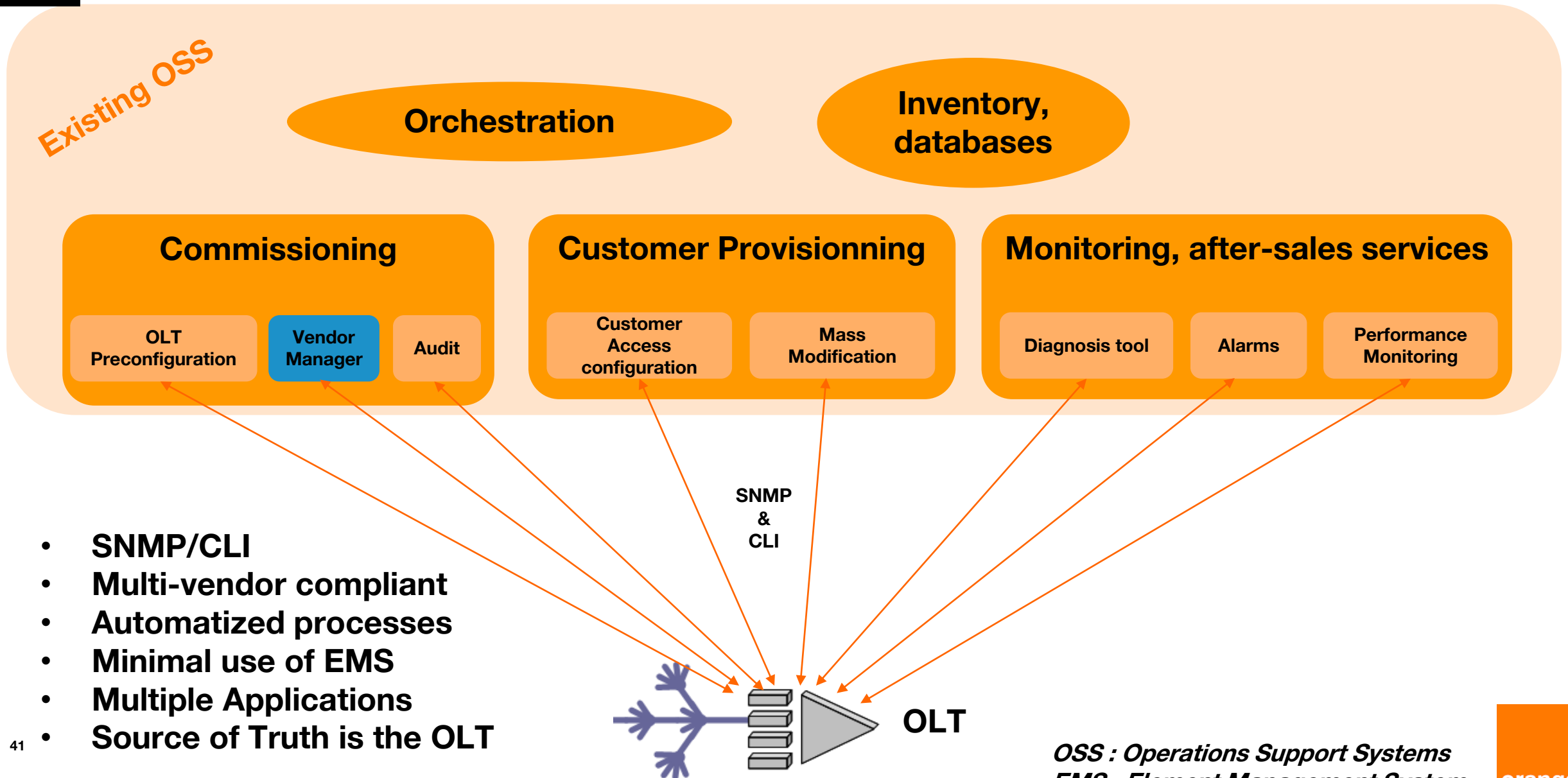
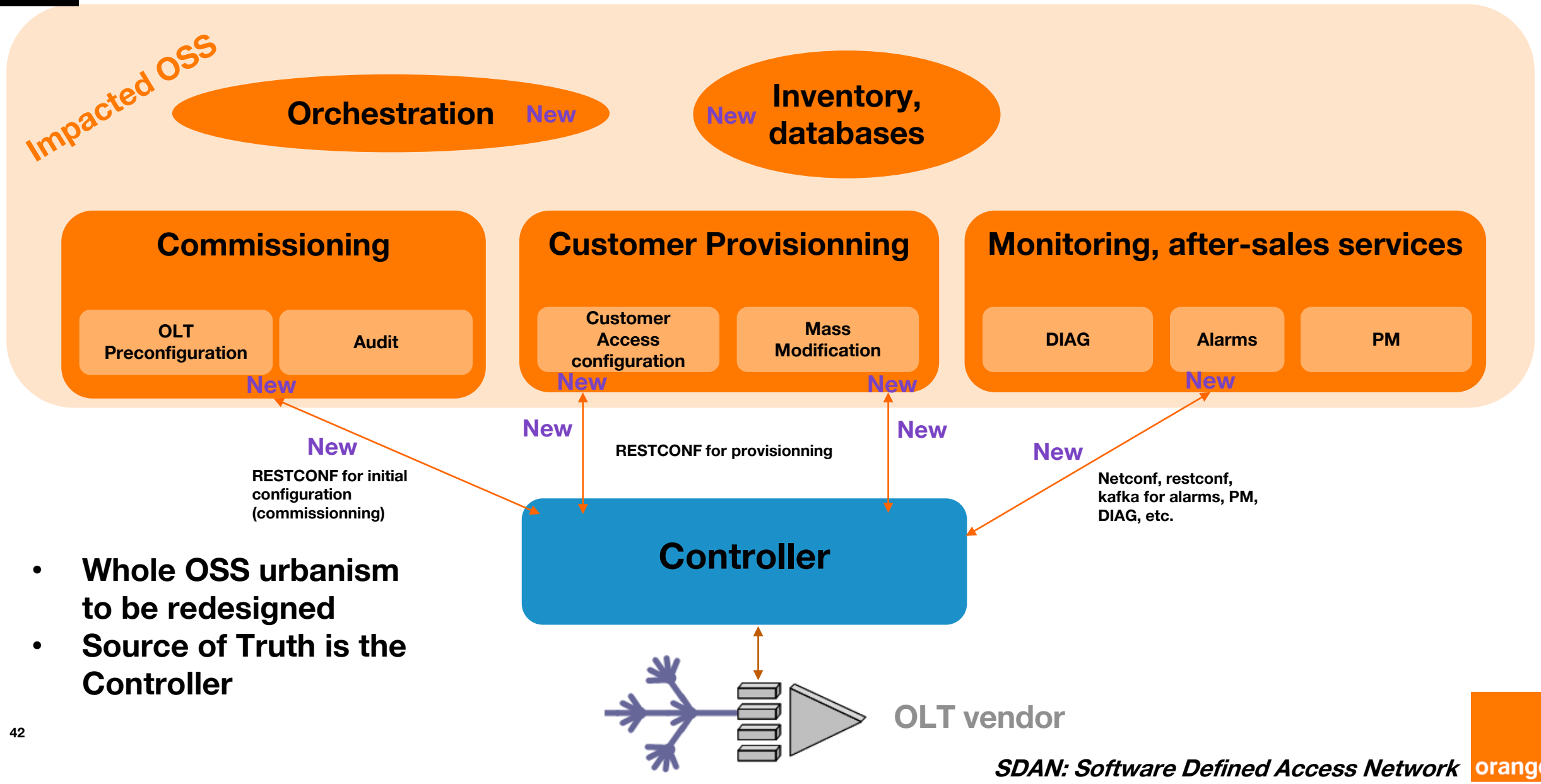
Simplified representation of an OSS today



- SNMP/CLI
- Multi-vendor compliant
- Automatized processes
- Minimal use of EMS
- Multiple Applications
- Source of Truth is the OLT

OSS : Operations Support Systems
EMS : Element Management System

Introduction of an SDAN Controller: severe impacts on OSS



- Whole OSS urbanism to be redesigned
- Source of Truth is the Controller

Outline :

1. Hardware transition : G-PON to G-&XGS-PON

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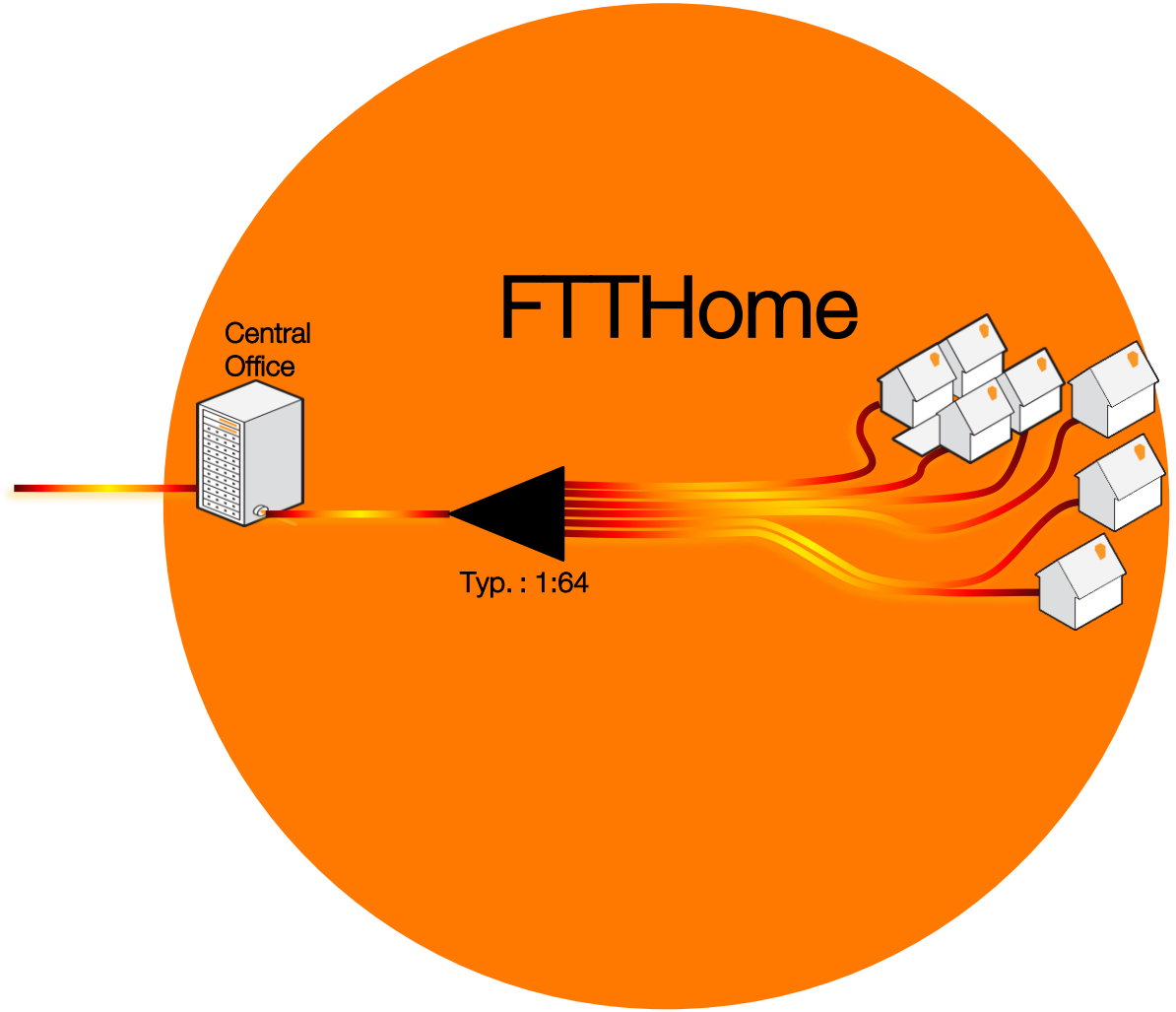
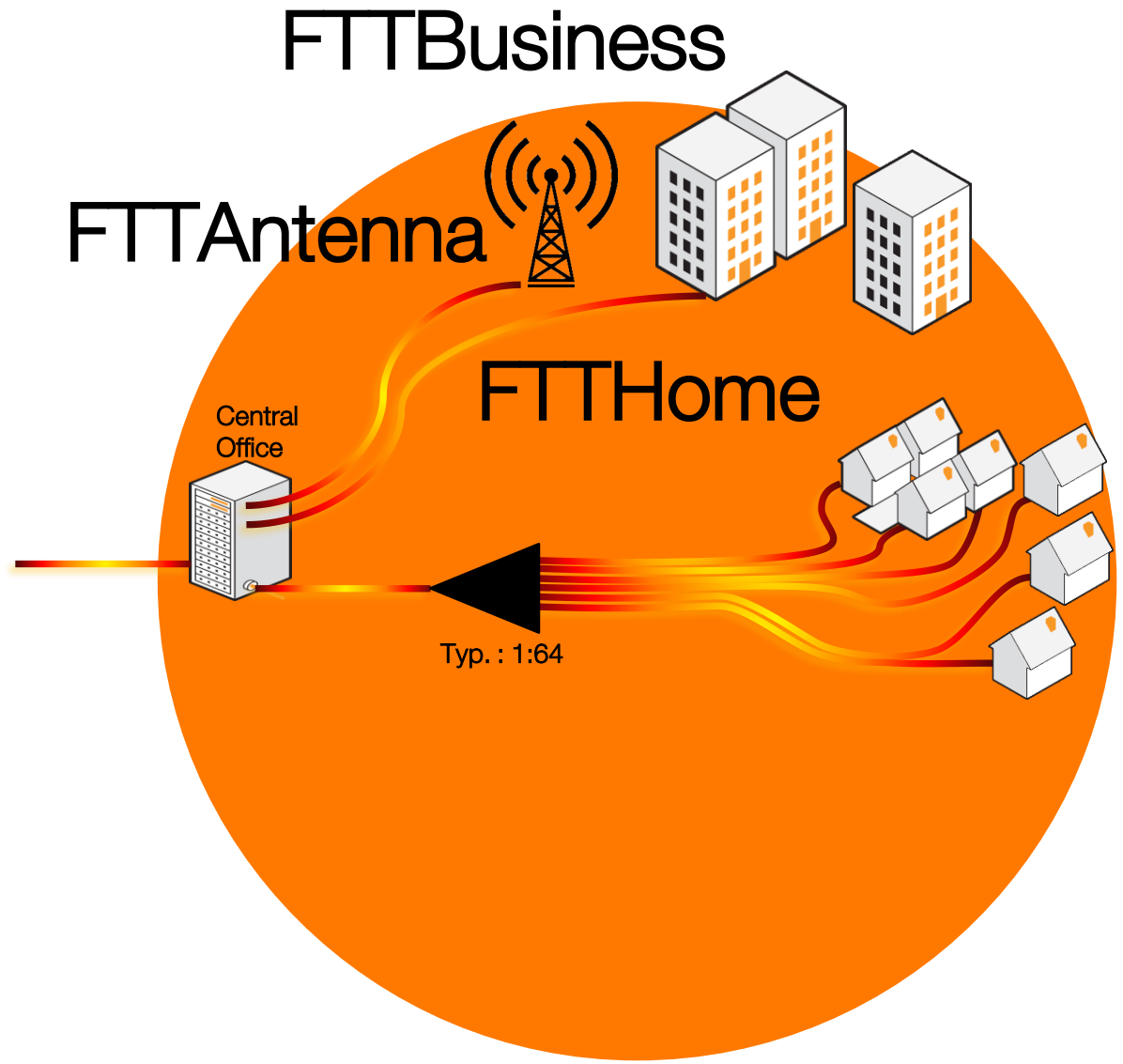
3. Fibre to Everywhere and Everything transition: Fiber Optical access is not only for FTTH

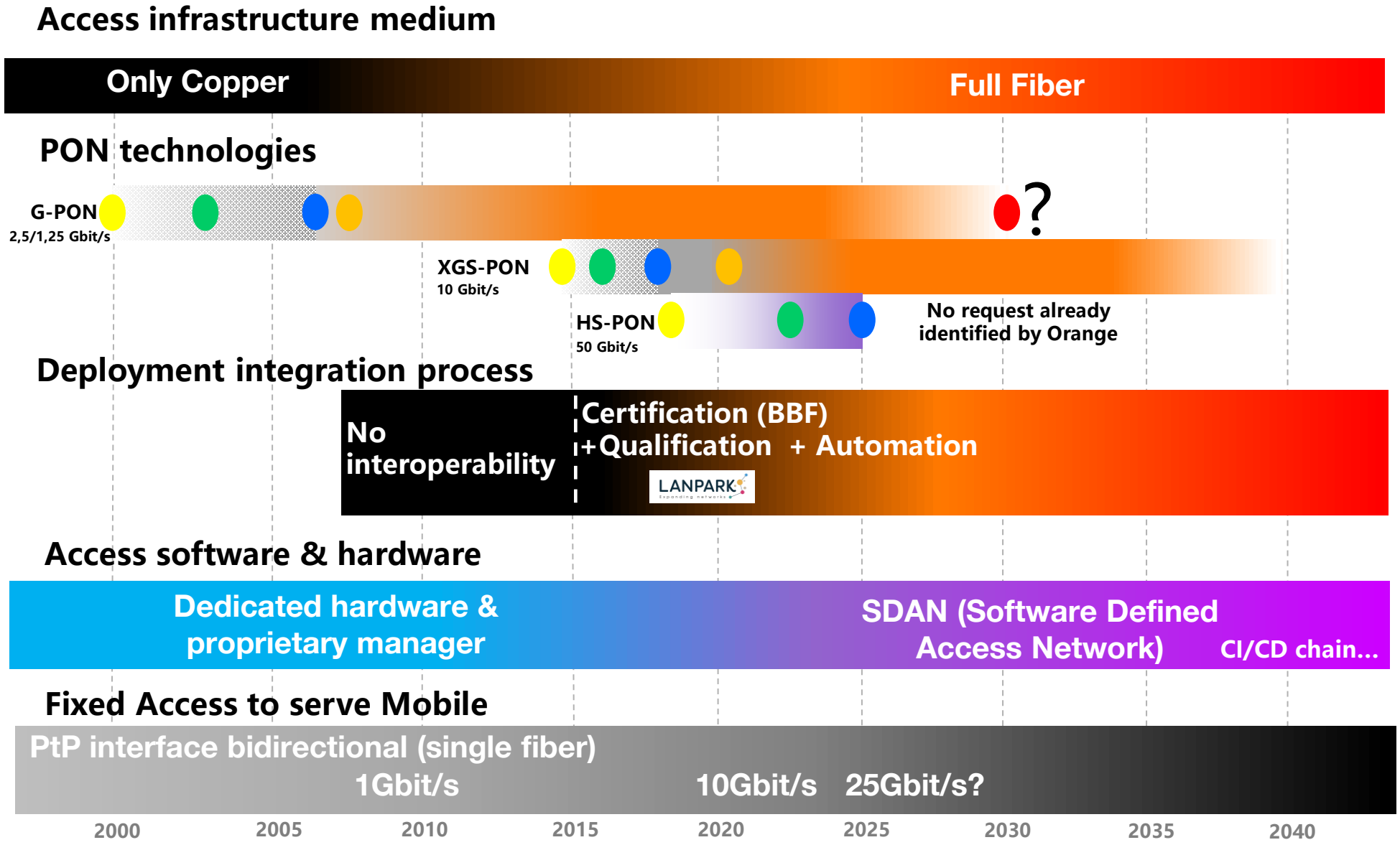
Optical access



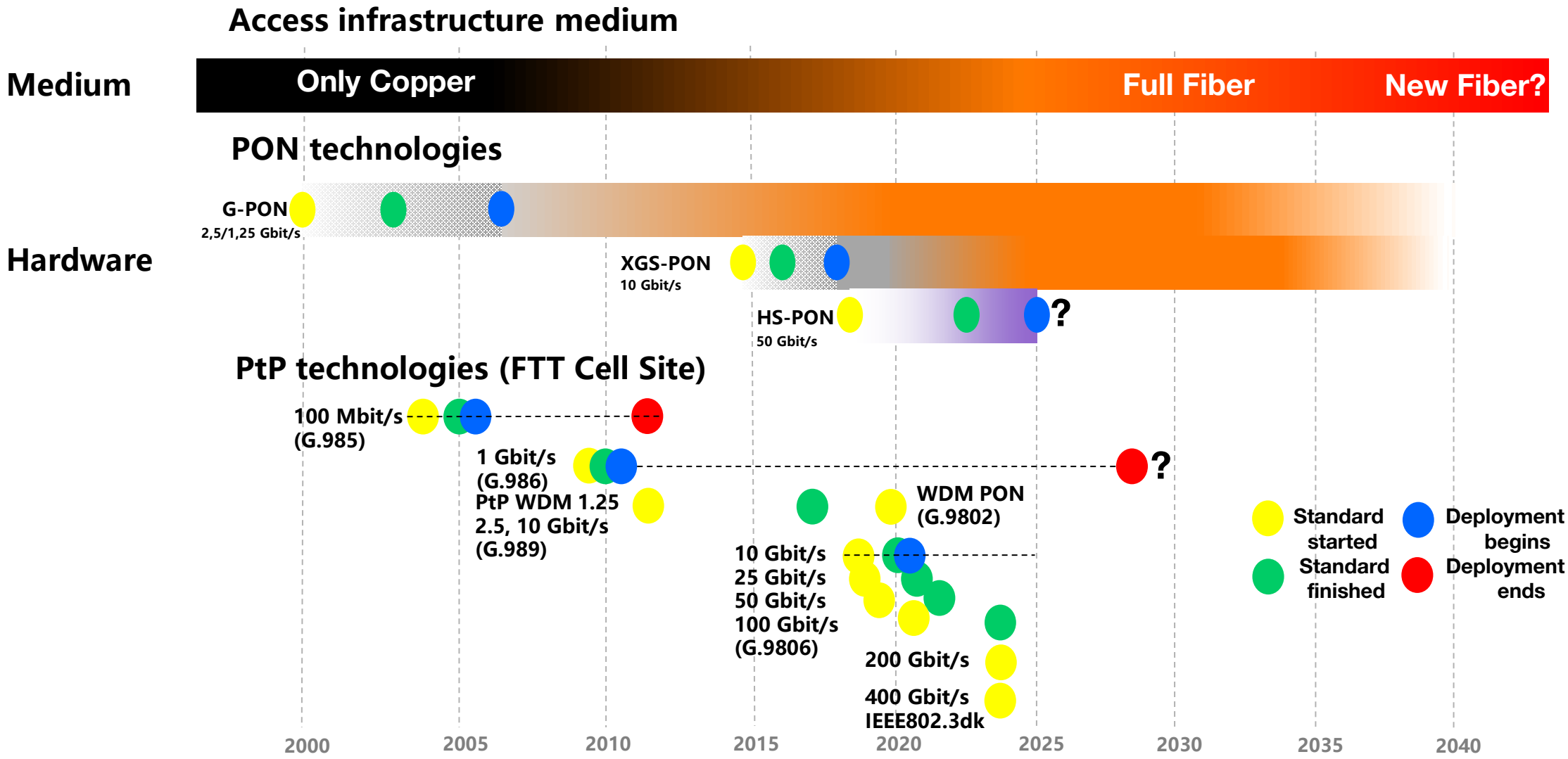
Optical access

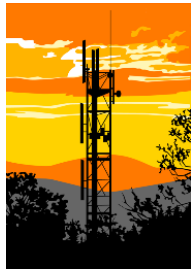


The right technology to maintain high quality fixed access

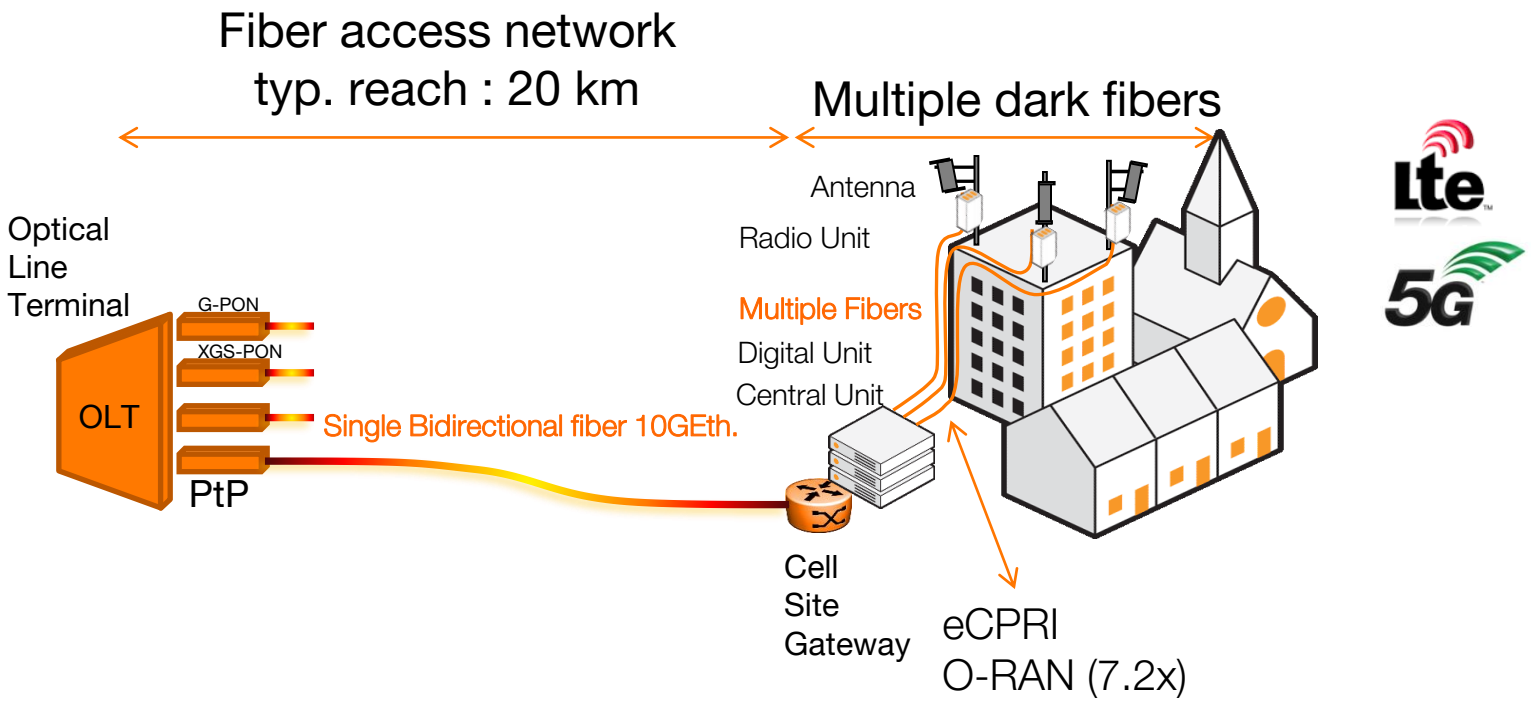


Photonics in 6G related to Orange's access networks





OLT and PtP fiber are the right companions for Mobile X-haul

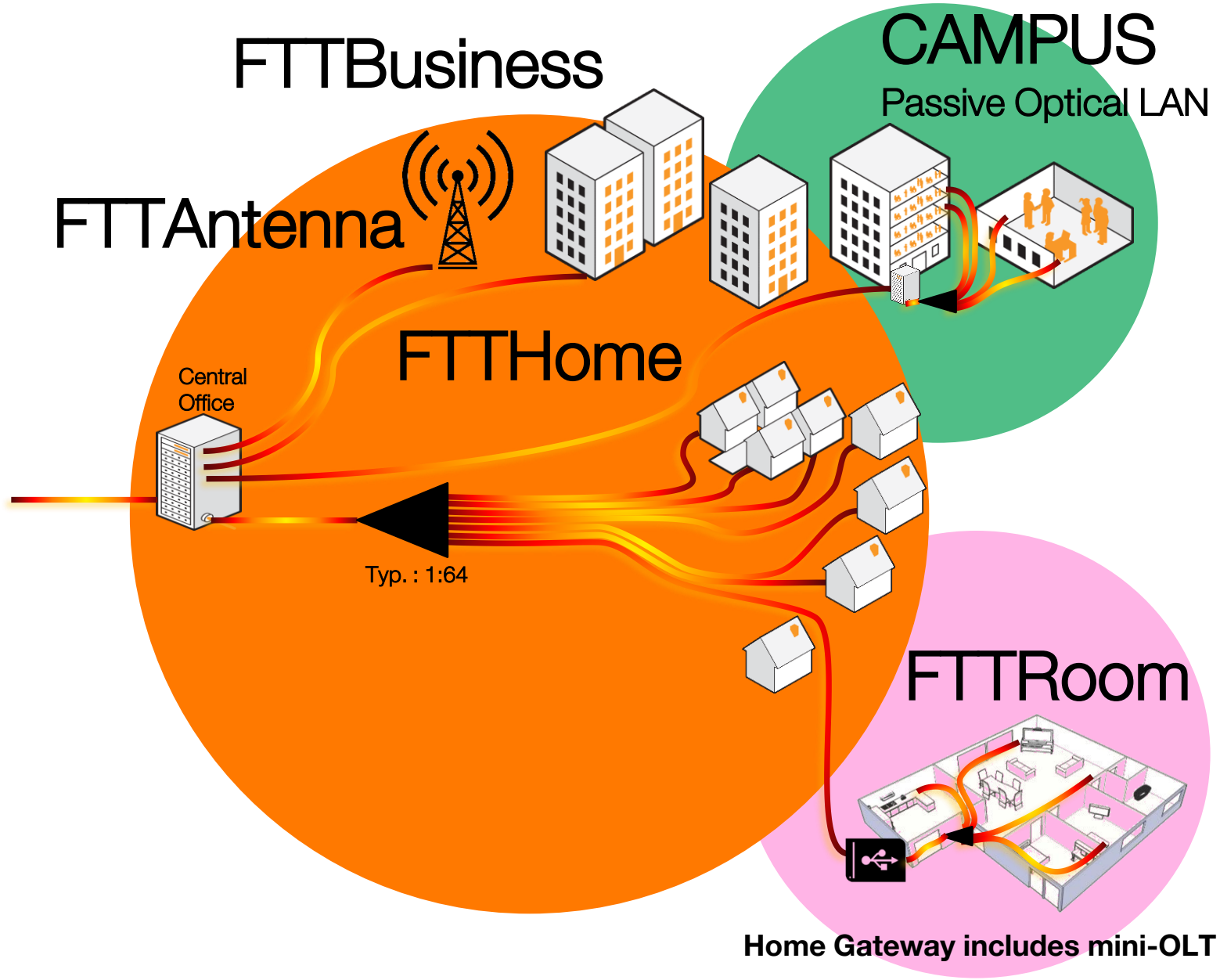


Fiber access for mobile backhaul (midhaul)

Legacy backhaul is based on PtP Ethernet 10 GEth with PtPv2 synchronization feature, in future 25 GEth.

Single fiber operation with Bidirectional transceiver is preferred.

Optical access standardisation



2018, major Decision Orange France: all new large tertiary buildings (over 500 people) will have a POL (Passive Optical LAN) infrastructure

Technology & business cases evaluation

Charlety
2015
90 people

Marcadet
2016
200 people

Lyon St Priest
2017
400 people

La Marseillaise
19/Q1
950 people

La Défense Agora
19/Q4
950 people

Bagneux Résonance
20/Q1
1000 people

Rennes Atalante
20/Q1
865 people

Lyon 2020
20/Q3
1960 people

Villejuif 2
21/Q1
1100 people

Orange Head Quarter
21/Q3
2800 people

Montpellier
21/Q3
1100 people

Toulouse Balma
21/Q4
1230 people

+10 to come

Evaluation phase | **Generalisation phase** | **Extension under study for**
-smaller new buildings
-existing large buildings

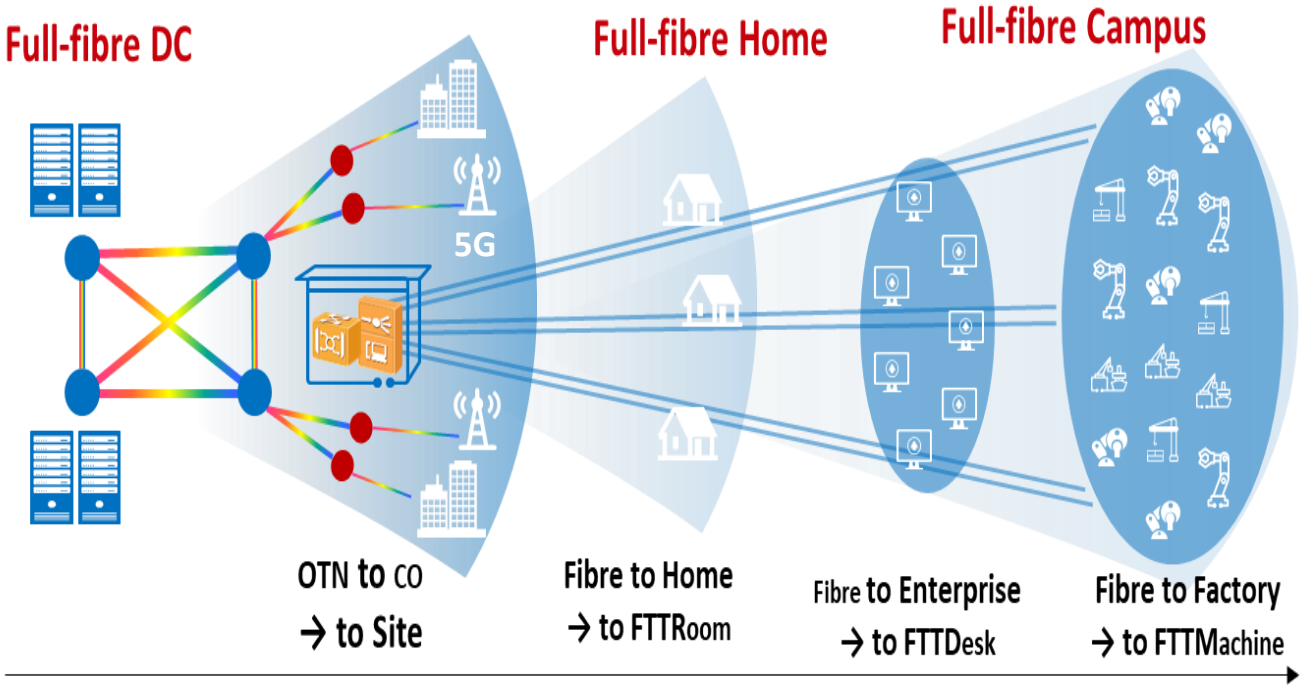
2015 2018 2019 2020 2021 2025

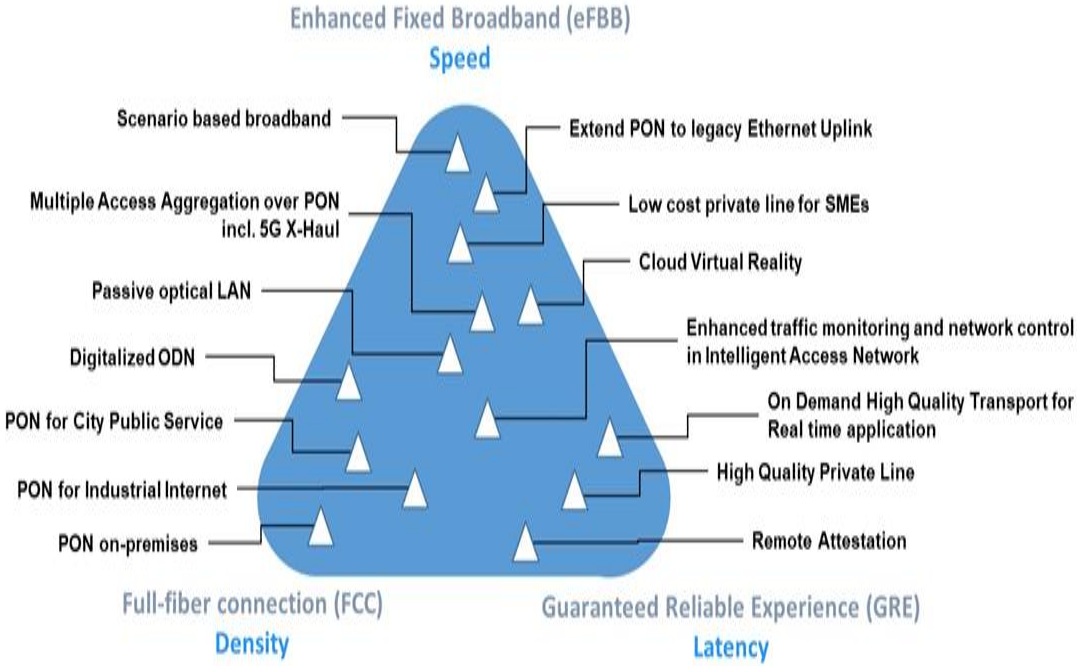
ETSI F5G Vision: Fiber to Everywhere & Everything

ETSI F5G plays a similar role to NGMN or GSMA, for fixed networks.

Fiber connectivity is becoming ubiquitous, extending from last “mile” to last “meter”

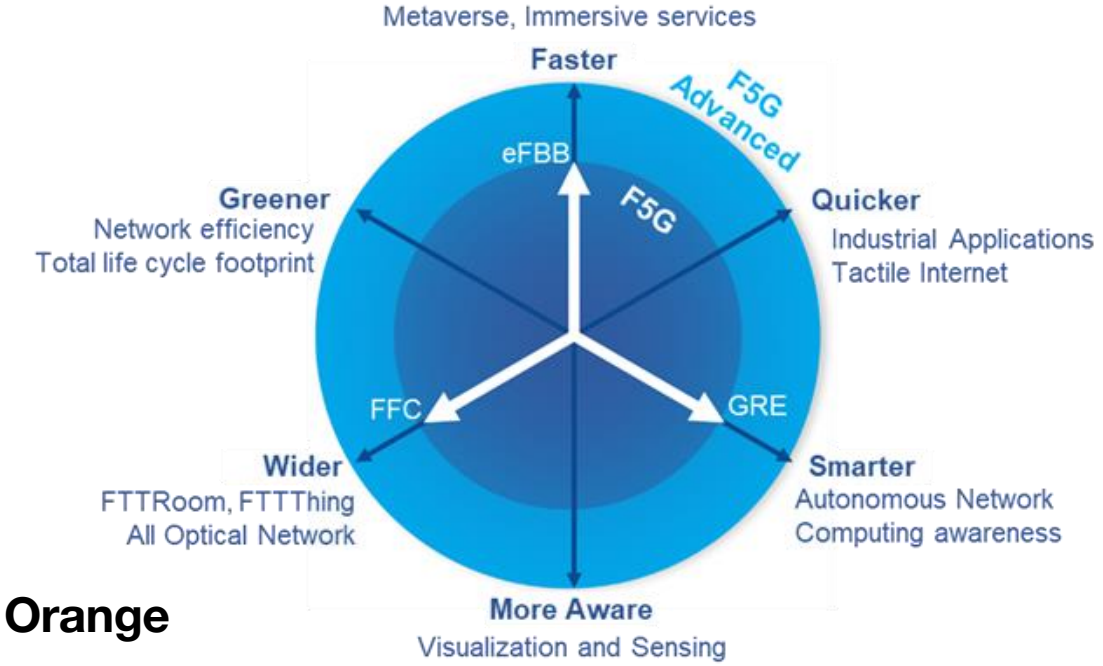
F5G enables many new use cases, expanding the application space of 5G





References: https://www.etsi.org/committee/f5g;
https://www.etsi.org/deliver/etsi_gr/F5G/001_099/002/01.01.01_60/gr_F5G002v010101p.pdf (Released in February 2021).

Other topics (ETSI ISG F5G)



Passive Optical LAN: already in deployment at Orange

FTTRoom, FTTThing: already mass market in China

Fiber to the Industry: market ecosystem in construction

Energy efficiency: coordination with Home LAN, OLT optical backplane, Co-Packaged Optics,…

Latency control: Dynamic Bandwidth Allocation for PON, Cooperative Transport Interface

Optical network-based Sensing: niche market / values of sensing DATAs

Conclusion

Key points

1. Step1 : The optical fiber medium coverage. Preserve passive FTTH and PtP optical fiber infrastructure.

2. Hardware step : The use of multi-PON OLT cards, ports, transceiver and fiber gateways. Insure OLT / ONU interoperability with certification program & qualification tests with more and more automation

3. Software step : Modernization of OLT management (SDAN) and telemetry

4. Next step: Fiber to everything, everywhere: FTTRoom, FTTIndustry, POL, autonomous PON, fiber sensing…

Thank You

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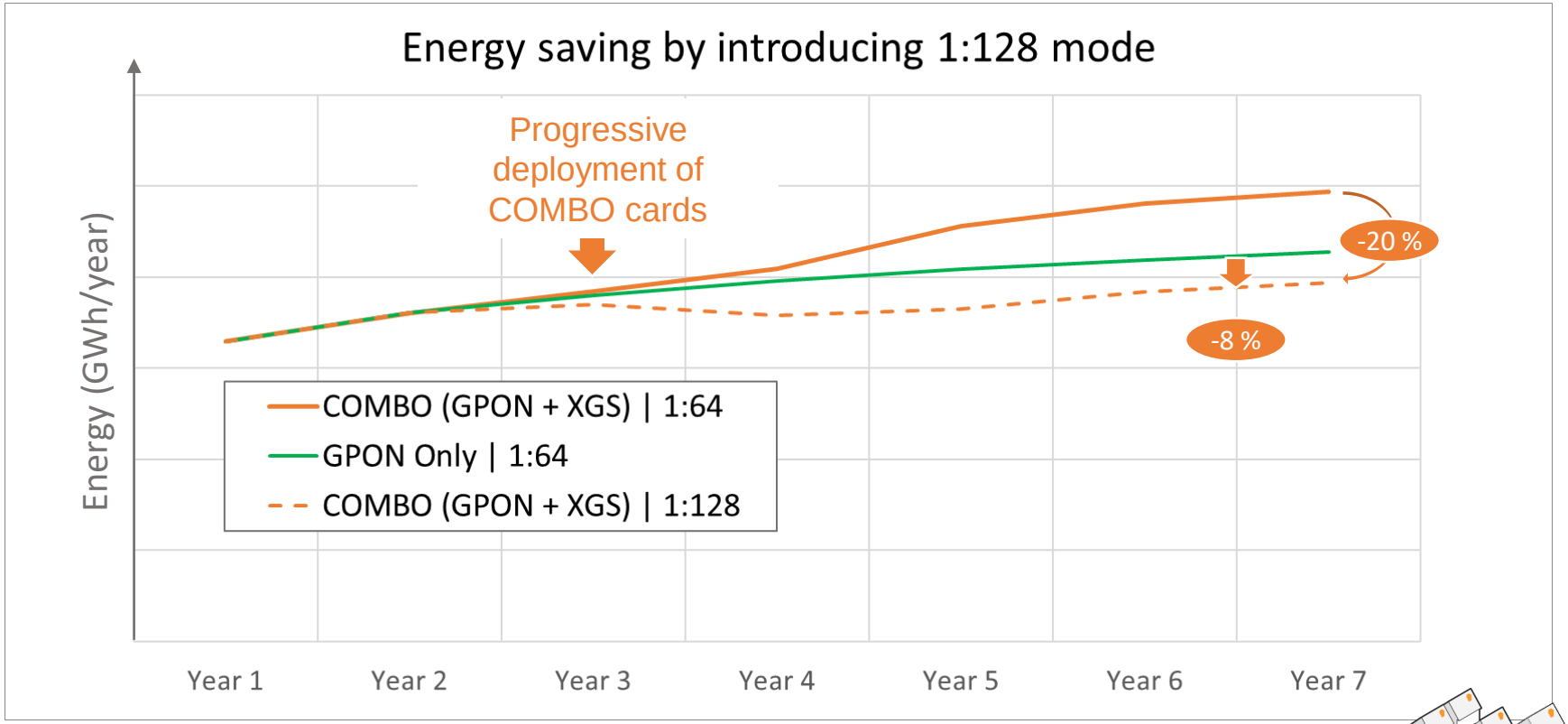
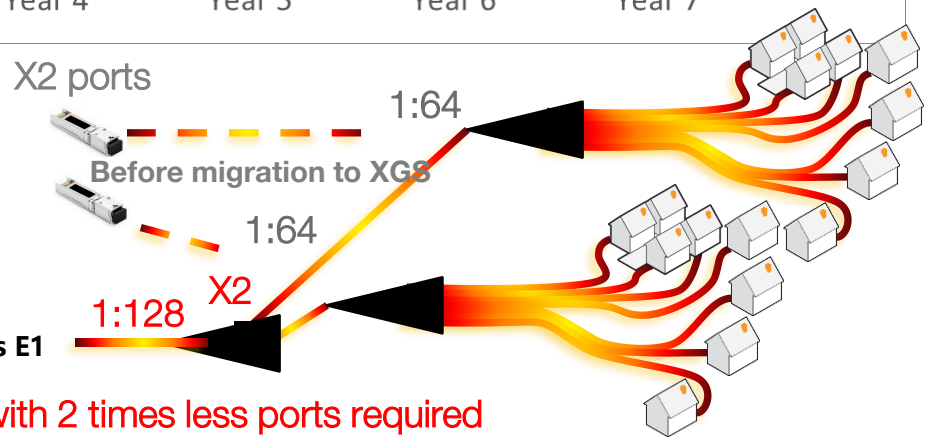
Sustainable and energy efficiency Increase splitting ratio : 64 ⇒ 128



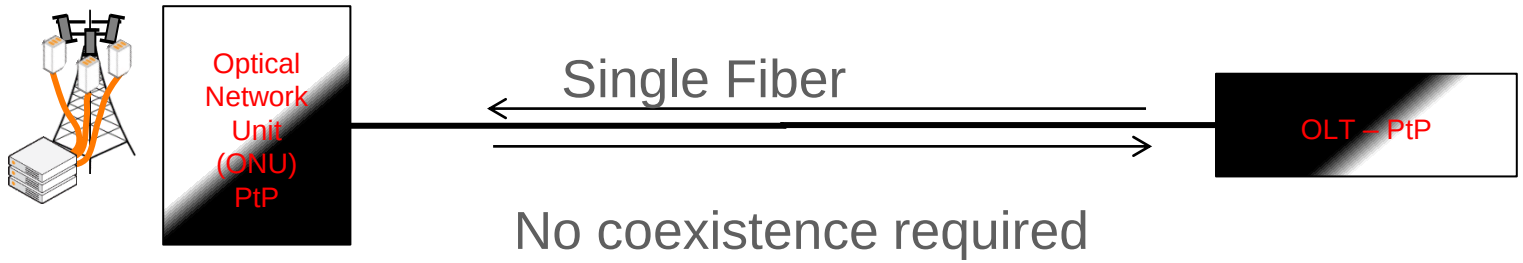
G-PON only: Class B+

MPM G&XGS-PON: Class E1



2 PON technologies in single port with 2 times less ports required

PtP bidirectional optical fiber



Optical Budget class

	Class S	Class SL	Class SU	Class A	Class BL	Class B-	Class B
Minimum loss	0 dB	0 dB	5 dB	5 dB	10 dB	10 dB	10 dB
Maximum loss	15 dB	10 dB	15 dB	20 dB	20 dB	23 dB	25 dB

Nominal distance considered 10, 20, 40 km

ITU-T	Line Rate	Wavelength Down (nm)	Wavelength Up (nm)
G.985	100 Mbit/s	1530 +/-50	1310 +/-50
G.986	1 Gbit/s	1490 +/-10	1310 +/-50
G.9806	10 Gbit/s	1330 +/-10	1270 +/-10
G.9806	25 Gbit/s	1314 +/-8	1289 +/-8
G.9806	50 Gbit/s (PAM4)	1314 +/-8	1289 +/-8
G.9806	100 Gbit/s (PAM4)	1309.1 +/1	1304.6 +/-1

Fiber for smart Home: FTTRoom

Deeper fiber to connect everything at Home: Fiber to the Room

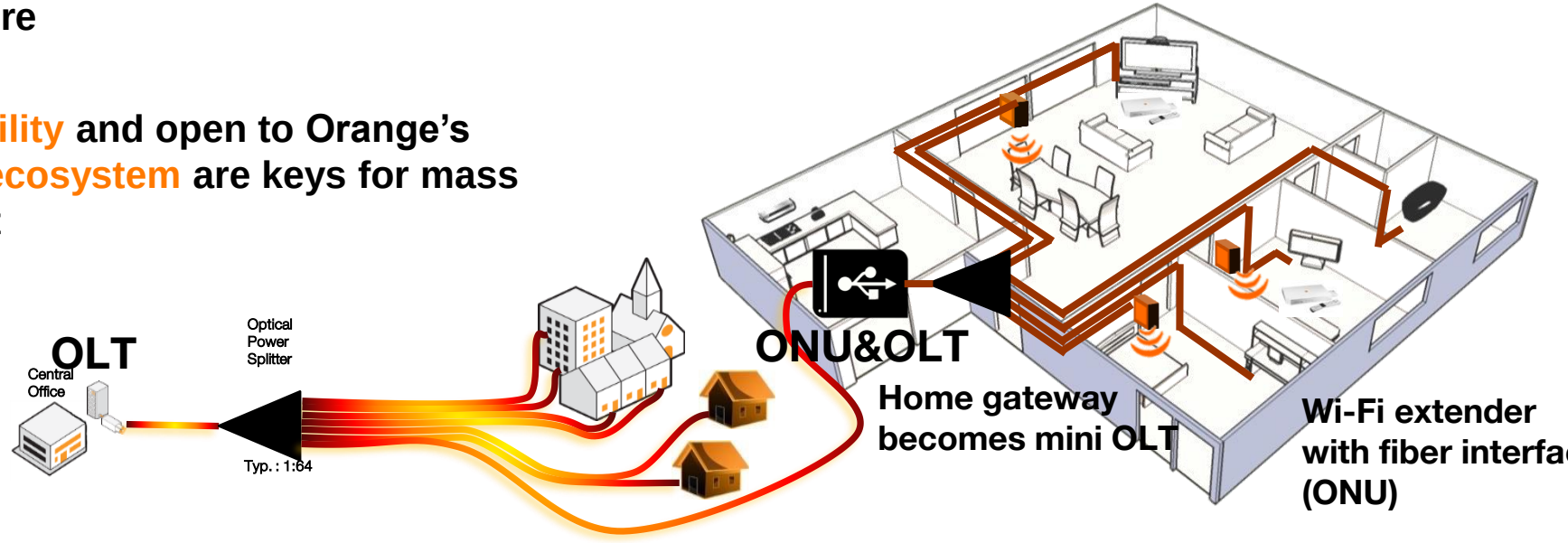
Two PON technologies cascaded

FTTRoom: an ideal Wi-Fi backhauling. But do we need it (vs. Wi-Fi mesh, Access point with Cat5/6) ?

Home network infrastructure associating optical fiber and radio for a wireless end connectivity to the very high bit rate services everywhere in the home or small enterprise

Skills opportunity: A pool technicians (network operation) with the FTTH skills in time for FTTRoom

Fiber To The Room: today G-PON based; perennial infrastructure (fiber) permitting higher throughput in the future

« FTTH like » experience for users & continuity of our field expertise up to the rooms

Interoperability and open to Orange's HomeLAN ecosystem are keys for mass deployment