Future-Proof Existing Multimode Fiber Cabling Infrastructure to Support Increasing Bandwidth Demand

Is transforming multimode fibers into singlemode fibers possible ?

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SHAPING THE LIGHT

Outline

- Increased capacity need in Local Area Networks
- Modal dispersion is limiting capacity on multimode fibers
- How to overcome this issue?
- A new dimension: the shape of the light
- Multimode fiber plant upgrade use cases

Bandwidth consuming apps in the LAN

- WiFi (802.11ac up to 7Gb/s)
- VoIP, video-conference
- CCTV, smart building, smart factory, etc.
- Virtualization, cloud computing
- Connected objects, BYOD
- Consumer/industrial IoT up to 20Gb/s
- Smart building, smart factory
- …
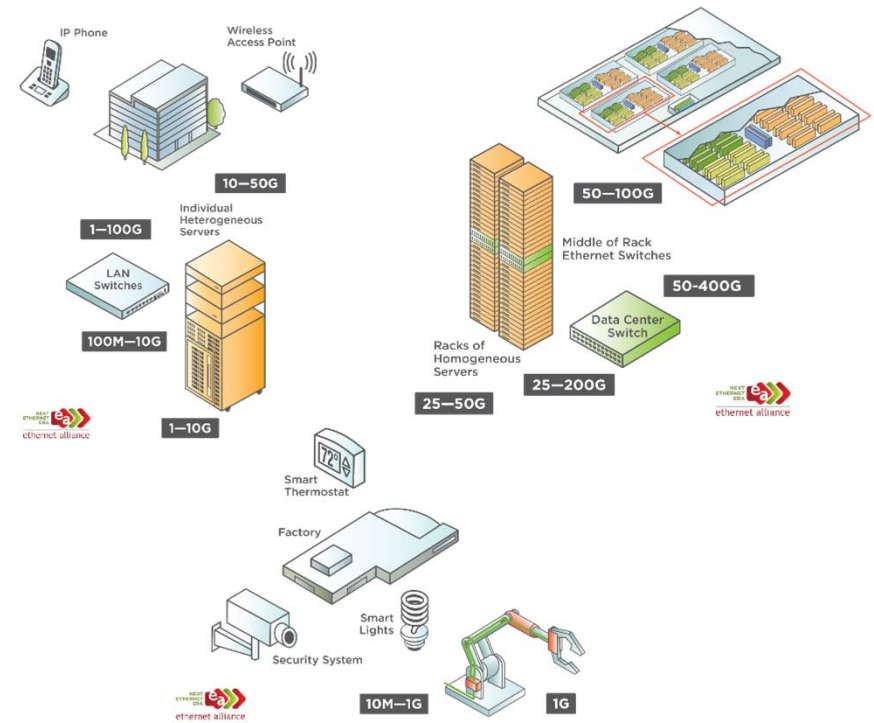
Increased bandwidth capacity need

ETHERNET SPEEDS
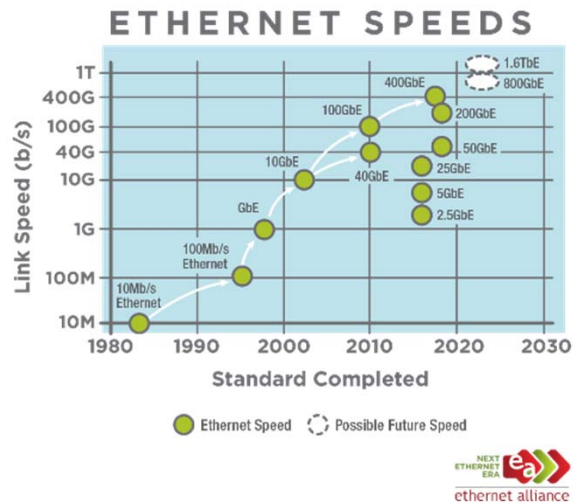
> New standards mean more bandwidth and versatility for tomorrow's Ethernet networks

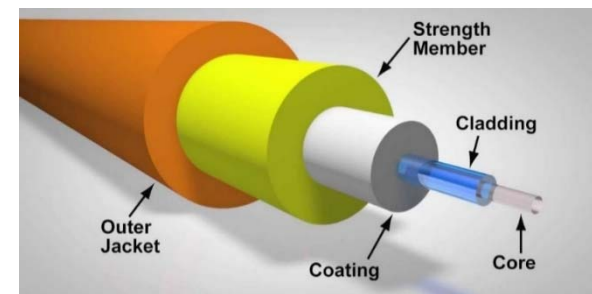**Bandwidth-intensive applications + latency-aware traffic types**

> **LAN cabling infrastructures need to support ever-growing bit rates**

Optical fiber: quick reminder

Low linear loss, low footprint, EM insensitivity
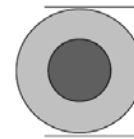

Differentiation of optical fibers according to :

- **Geometrical properties**

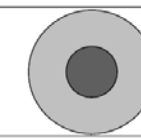- **Index profile** (graded index or step index)
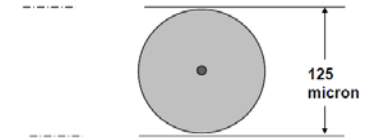

Multimode Fiber (MMF)   *SingleMode Fiber (SMF)*

62.5 micron   50 micron   ~8 micron

125 micron

OM1   OM2/OM3/ OM4/OM5

MMF everywhere but bandwidth limited

Limited bandwidth = Maximum reach decreases when bit rate increases

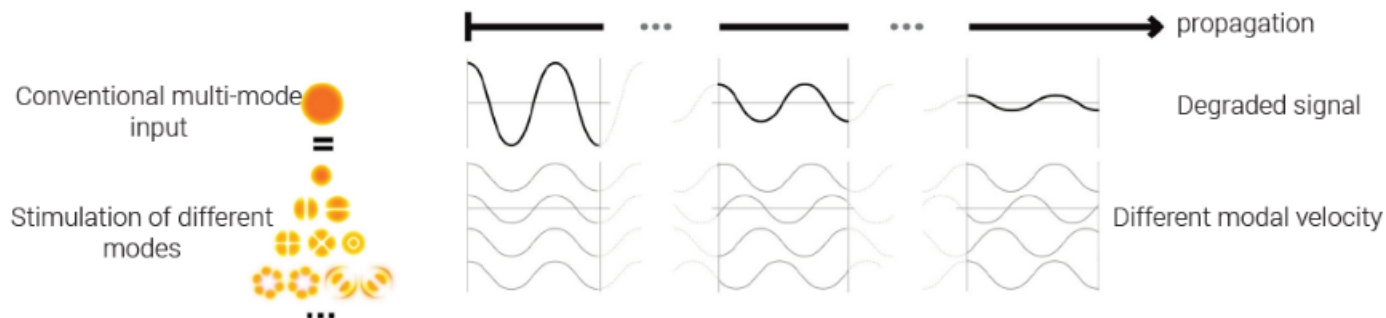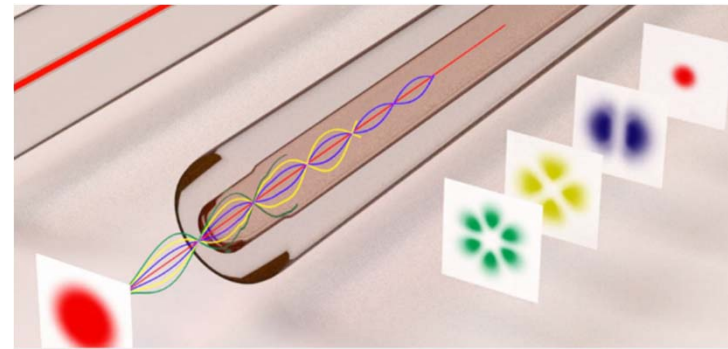| Maximum reach with MM transceivers (850 nm)	100 Mb/s	1 Gb/s	10 Gb/s
OM1 (62.5/125 μm)	2000 m	300 m	35 m
OM2 (50/125 μm)	2000 m	550 m	80 m
OM3 (50/125 μm)	2000 m	600 m	300 m
OM4 (50/125 μm	2000 m	600 m	500 m

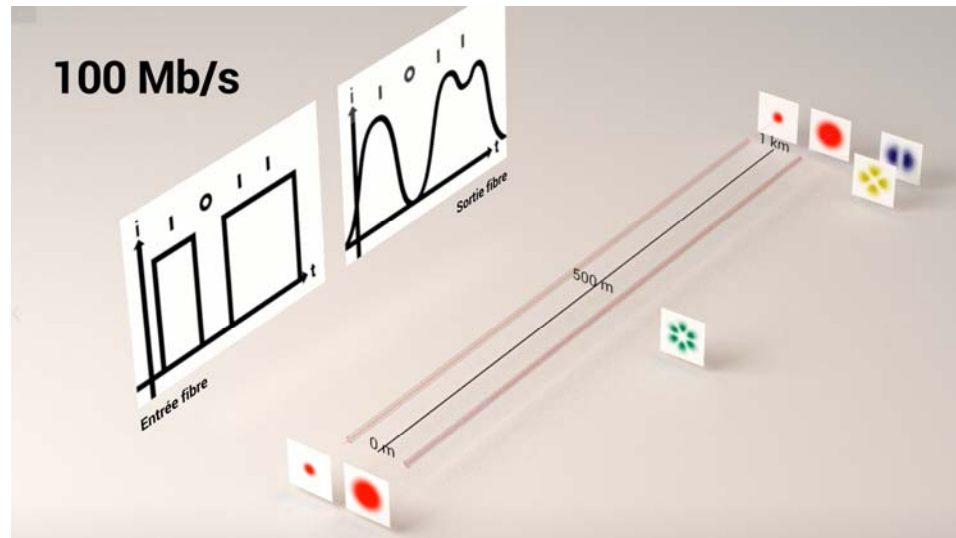The cause of this limitation: **modal dispersion**

Modal dispersion

Distorsion mechanism occuring in multimode fibers

Different modal speeds

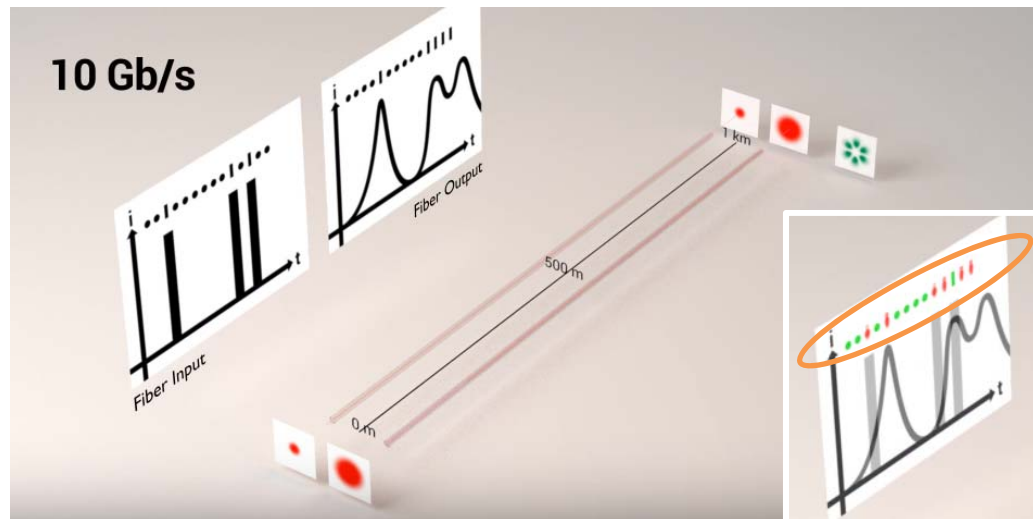**Distorsion of optical pulse** during propagation

Modal dispersion at 100 Mb/s : minimal impact

Pulse spreading without impact on transmission quality

Modal dispersion at 10 Gb/s : Poor transmission quality
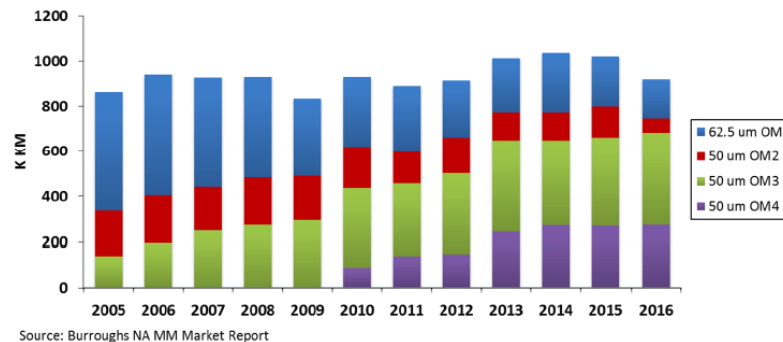

> ➢ Degraded bit error rate

How to increase bit rates over MMF links ?

MMFs cannot cope with the capacity need

75% of fibers in LAN are **MMFs**

1 Mkm MMF deployed every year

35% existing MMFs are **limited to 1 Gb/s max**

Source: Burroughs NA MM Market Report

New fiber roll-out to replace MMFs is often expensive and complex!

Overcoming the MMF limitation issue?

Advanced modulation format to increase spectral efficiency
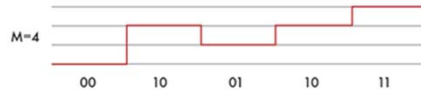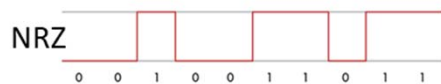
Overcoming the MMF limitation issue?

Parallelization

MPO
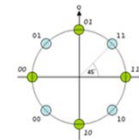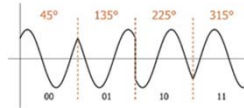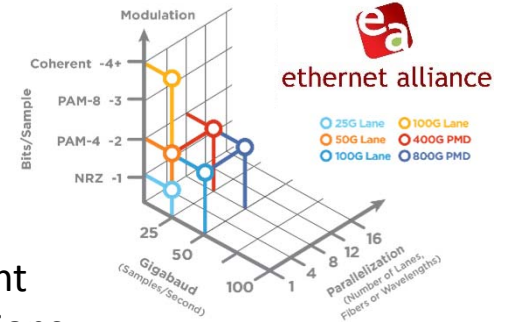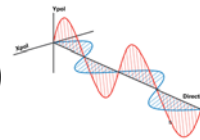
MMF bandwidth limitation bypass (e.g. 40G-SR4, 100G-SR10)

Multi-fibers connectors (MPO/MTP) 8 to 72 fibers

QSFP transceivers

Mainly recommended for new installation
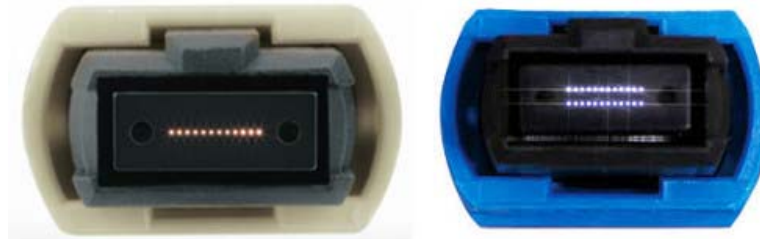
Overcoming the MMF limitation issue?

Wavelength Division Multiplexing (WDM)

Enables one to create several channels over one fiber

➢ Channel capacity is still limited by the MMF max capacity!

Sometimes integrated into transceivers

    e.g. 10GBASE-LX4 (4x2,5Gb/s) ou 100GBASE-LR4 (4x25Gb/s)

Rarely used for MMF LAN upgrade

SWDM over OM5 (Wide Band MMF)

Wavelength

Total Bandwidth Comparison
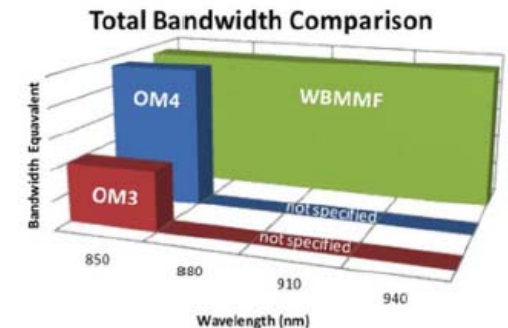
Overcoming the MMF limitation issue?

LRM Transceivers (IEEE 802.3aq) + mode conditioning patchcord
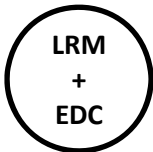
- **offset launch** technique : less excited modes reducing the impact of modal dispersion
- **+** signal processing : **electronic dispersion compensation** (EDC)
- At 10 Gb/s will not work for OM1 / OM2 fibers longer than 220 m
- Not guaranteed to work on all infrastructures

LRM + EDC
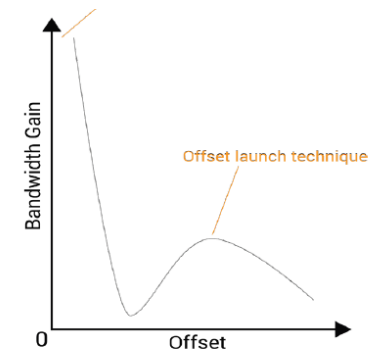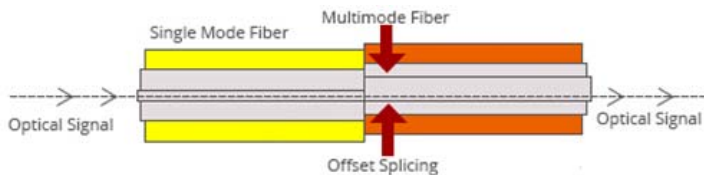
Theoritical MMF bandwidth gain according to launching conditions

(Re-)Deploying fibers:
end users pros&cons

Currently the most common solution is to replace the existing MMF

- Possibility to **install latest generation fibers (SMF, new gen MMF)**
- Increase of bandwidth over long distances

- **Audit** required (availability and condition of the cable ducts)
- **Long and complex** installation
- **Civil engineering work**
- **Expensive** (several tens €/m if complexity)
- Etc.

> ➤ Is there **another alternative** to address the problem of bandwidth limitation in MMF LANs??

Another dimension: the shape of the light

It is possible to **avoid modal dispersion by coupling and detecting precisely the modes within the MMF**.

Multi-Mode Fiber
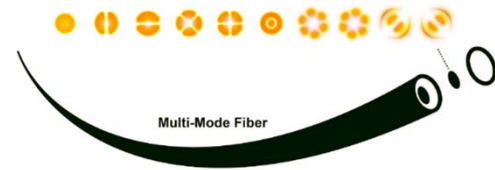
MPLC : Multi-Plane Light Conversion technology
➤ **passive optical process** derived from quantum optics **to shape the light**

Several solutions to increase bit rates :

- **Excite only one mode** to have a **singlemode transmission**
- **Excite multiple modes** and perform **modal multiplexing** (Space Division Multiplexing)

Addressing modes inside MMF

SMF-MMF modal adapter

- Quasi-singlemode transmission over MMF
- **High capacity channel**
- **IL<2dB**
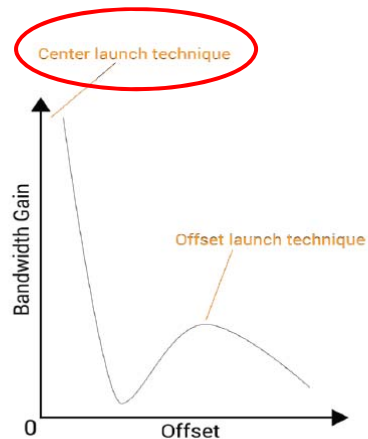
Theoritical MMF bandwidth gain according to launching conditions

Space Division Multiplexing (SDM)

- Mode group multiplexing
- Modal mux/demux at both end of the link (**IL<3.5dB**)
- **Up to 4 independent modal channels** over MMF
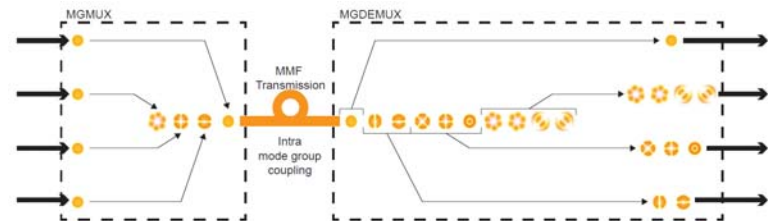
New horizons

Limit at 100 Tb/s per fiber with current technologies

Spatial dimension (SDM) opens new perspectives

➢ *(world record in 2017)* MPLC technology has allowed the transmission of
10 Peta-bit/s (10 million Gb/s!) **over one fiber**
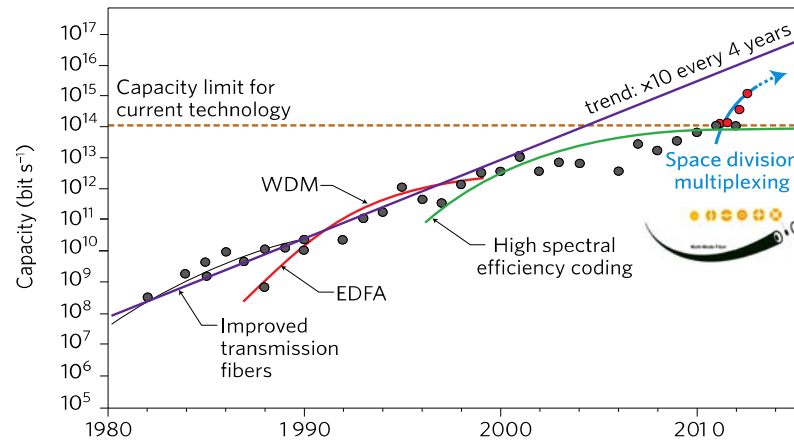
Remove MMF bandwidth limitation to upgrade LAN cabling infrastructure

Increased capacity

High capacity channels (10+ Gb/s), **WDM compatible**
Adaptable to the network topology (point to point, star, POL)

Compatible with standard fibers and transceivers

Any type of **multi-mode fiber 62.5/125 µm or 50/125 µm (up to 10km)**
Any type of **single-mode transceiver, Transparent to communication protocol**

Reduced cost

3 times less expensive than a fiber roll-out; **up to 10 times** less expensive if complexities exist
Passive system: no additional cost of consumption, cooling, monitoring
Installation takes **only few hours**

How implement modal adapter?
(for standard Ethernet LAN)

Upgrade several MMFs of the network with a single component

Only at the core of the network - No installation required at remote sites if link < 800m

Reach extender modal adapter to extend **to 6 miles high bit rates MMF link**
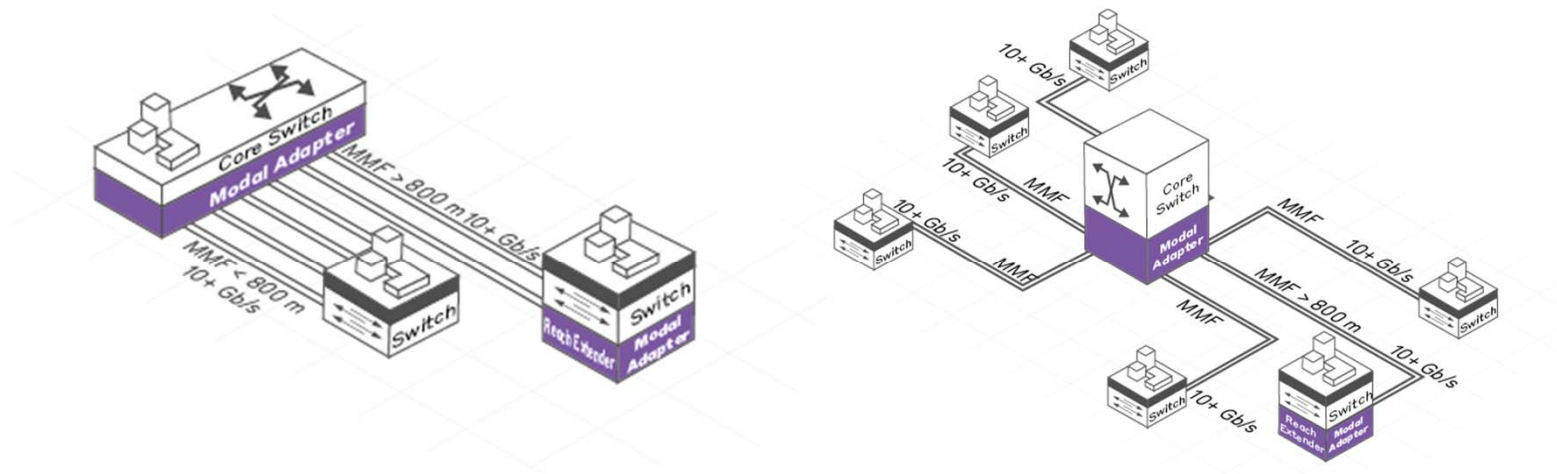
How implement modal adapter?
(for Passive Optical LAN)

Controls the **spatial modes coupling** and **adapts MMFs to SMFs by simple replacement of an optical splitter**

Facilitates the **transition to Passive Optical LAN on existing cabling infrastructure** (GPON and XGPON over MMF)
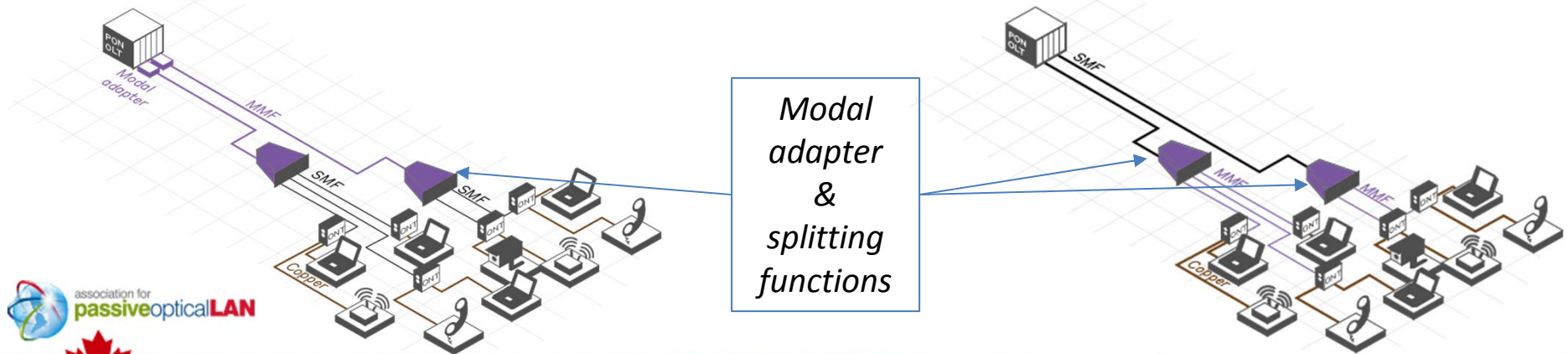
Modal dimension tested and validated

100 Gb/s CWDM4 over 1km OM1 with modal adapter

160 Gb/s over 1km OM4 with SDM

14.5 Tb/s over 2200 m OM2 with SDM+WDM

160 Gb/s over 2km OM3 with SDM

100 Gb/s CWDM4 over 2km of OM3 with modal adapter

GPON & XG-PON1 transmission over MMF

GPON & XGS-PON transmission over MMF

Unique technology for a global problem

The problem of MMF bandwidth limitation is found on various typologies and topologies of networks

- University / School
- Hospital
- Factory
- Military sites
- Shopping center
- Ski resort

- Urban community
- Amusement park
- Airport
- Sports complex
- Museum
- …

Let's analyze some use cases

Smart factory

Automotive factory in Canada, **OM1 MMF** (0.35 to 0.45 miles) **limited at 100 Mb/s**

10 Gb/s capacity needed over several links

➢ New CCTV system, « smart factory », various equipment controlled by WiFi

No free cable conduits under buildings and parkings

➢ **Can not block site entries for civil engineering** (24/24-7/7 site)

✓ MPLC technology at the network core

  10 Gb/s over each link, with an easy upgrade path to 40-100 Gb/s

  4 hours of installation vs days for fiber roll out
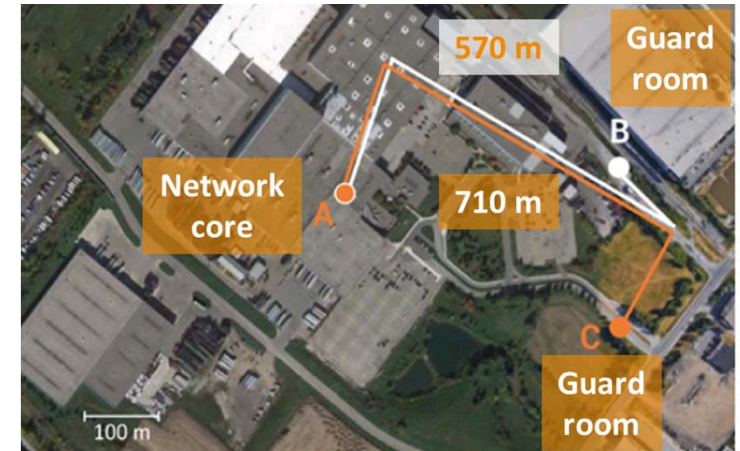
Better connectivity at school

School district in Arkansas, US

Severals OM1 links **between 430 and 1740 ft**, limited at 100 Mb/s or 1 Gb/s, star topology

Innovative program « **one student, one computer** »

10Gb/s needed for DAS (Distributed Antenna System)

- ➢ **Infrastructure upgraded in 1 day** + financial savings
- ➢ Next step :**upgrade the entire network with MPLC technology**

Digital transition in small town

MPLC technology enabled a city in France to enhance its network capacity by **overcoming MMF links bottleneck without new fiber layout**.

OM1 backbone links limited to 1 Gb/s - No free cable duct

➢ **5x less expensive than a new fiber deployment**, avoiding civil engineering through roads

➢ **3 hours of installation** vs days for fiber roll out

Transforming MMF into SMF, it is possible !

Local Area Network fiber infrastructure **mainly composed of multimode fiber**

MMF = bandwidth limitation (due to modal dispersion)

Depending on the need, **on the shelf solutions to overcome MMF bandwidth limitation** (advanced modulation, parallelization, mode conditioning, MPLC modal adapter)

MPLC (Multi-Plane Light Conversion)

  Light shaping innovative passive technology **to harness the full potential of MMF**

  Overcome modal dispersion to increase MMF capacity

  Alternative to fiber (re)cabling to meet ever growing bandwidth demand (standard Ethernet LAN & Passive Optical LAN)