Choice of optical access innovations to meet today's needs and support the challenges of tomorrow

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Abstract: The aims of this paper are to illustrate the major trends for optical access innovations capable of meeting present and future requirements. It also highlights what are the main technology enablers for identified use cases.

1. Introduction

In this paper, we describe the trends of technological evolutions for access networks [1, 2] and discuss how the companies should use the optical technologies to transform this natively mass market. We propose to enlighten the reader on three main trends for optical access that are i. to preserve the financial investments, ii. to improve and promote synergy with Home LAN (Local Area Network) and iii. to break the walls between massive FTTH (Fiber To The Home) market and others businesses. In addition to innovative optical access technologies, we are convinced that the passive optical network (PON) is and will be the natural optimal solution that will allow energy efficient connectivity for tomorrow's networks thanks also to power-saving operational modes.

In optical access networks, the adoption of technological innovations is always defied by the importance of network investments. In order to deliver an augmented connectivity to several millions of customers, the less disruptive and most market mature technologies available are often privileged. The investment part dedicated to the optical passive infrastructure (also named ODN Optical Distribution Network.) plays a main role in the innovation strategy. All optical innovations must allow preserving the existing and coming network generations for several decades. An optical access generation generally has a very long life cycle and investment costs must be optimized in the long-term. For instance G-PON - Gigabit capable Passive Optical Network standard started in 2000, finished in 2003. First deployments began in 2006 and this generation is still in being deployed today. The learning curves of future optical access technologies must be compatible with a replacement business policy. In other words, the difference between the target cost of future optical access generation and the G-PON must be suitable to be supported by the revenue growth based on customers' offers.

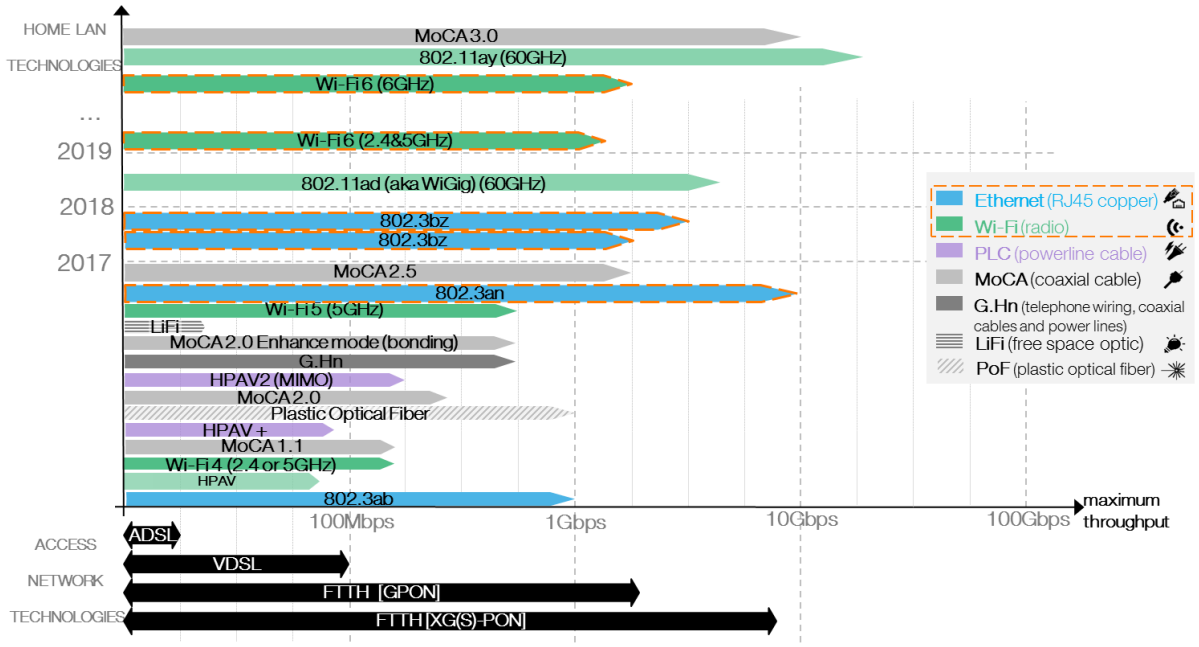

Fig. 1. Illustration of Home LAN connectivity and access network technologies.

For residential customers, the coming decade will certainly propose a single network segment block based on the bonding of the FTTH and the Home LAN. From customers' perspective, the proof of an augmented connectivity by an optical technology relies on their wireless experiences (ex. WiFi). Improvement of in-house connectivity quality from standard WiFi to smart WiFi is a must to introduce a relevant customer experience for XGS-PON (10 Gigabit symmetrical capable Passive Optical Network). We can consider thus that the roadmaps of PON and Home LAN connectivity generations are linked for the coming decade. Figure 1 illustrates the present and coming Home LAN connectivity generations for wireless (in green), Ethernet cable (in blue) and other alternative mediums (powerline cable, coaxial cable, plastic optical fiber, free space optics).
In additions, the deployment of the first FTTH generations enables other technologies to be proposed thanks to this full fiber network. The maturity of optical access technologies for mass FTTH deployment is paving the way for a largest fiber market size with, for example, applications for the mobile antennas and optical LAN connectivities. Typically, the OLT (Optical Line Terminal) shelf can enable FTTAntenna by using dedicated Point to Point (PtP) or PON cards. The passive and active parts of fiber access networks are and will be the companion of mobile networks for backhaul and fronthaul [3]. Moreover, the maturity of passive and active optical access solutions based on G-PON and the coming XGS-PON allows relatively effortlessly for LAN campus solutions that follow FTTH expectations. Passive Optical LAN (POL) based on such mature PON technologies will provide fiber deeper and deeper into the customers' household devices and will also serve next generation high bit-rate wireless links for which air propagation could be a limitation. This first approach for campus or hospital with POL [4], will certainly offer initiatives for FTTRoom in the coming decade.
After this introduction, we propose to consider a second section about high speed line rates in access networks. In the third section, we consider the required key optical innovations for a large market adoption. Lastly, in the sections 4 and 5, we make some considerations about the impact of access node virtualization and automation innovations.

2. High speed line rates access networks

This decade begins with XGS-PON deployment initiatives. OLT MPM (Multi-PON Module) with optical integration of passive and active functions is the key enabler to simplified coexistence and migration schemes. In the coming decade, access network standardization should finalize the High-Speed PON (HSP) specification working at 50 Gbit/s in downstream with optionally multi-rate schemes [5]. . OLT MPM for this generation should be the driver for optical technology integration innovation. At the end of this decade, 100 Gbit/s should also be considered [6]. When new generation PON systems are considered, the coexistence with legacy PONs generations in relation with spectrum allocation and the reuse of existing passive infrastructure must be considered as one of the main technical challenges. Targeting an optical power budget of 30 dB minimum remains a challenge and that opens doors for new opto-electronical technical solutions with their extracost: analogue and digital signal processing, coherent technologies, optical boosters and pre-amplifiers... Otherwise, it will be necessary to consider reducing the optical splitting ratio and provide more investment in passive infrastructure to enrich the ODN trunk part with more optical fibers.

3. Key optical innovations for a largest market share

Future innovations must ensure that the optical access fiber to support other markets than FTTH such as 1) the bidirectional PtP up to 100 Gbit/s or more, 2) new classes of reduced optical budget for POL and FTTRoom to serve reduced reach and point to multipoint level, 3) FTTAntenna capable to support 5G and 6G expectations about low latency, high availability, 4) pluggable transceiver-less approaches, with chipsets relying on integrated in-board optics instead of BOSA (Bi-directional Optical Sub Assembly) ONU (Optical Network Unit) boards. Would it be possible to integrate the optical interface inside the ONU chipset? Finally, it is primordial that these optical (physical layer) enablers are proposed considering interoperability as the major criteria for mass industrialization.

4. Impact of access node virtualization

Considerable work has been already achieved for virtualizing network elements that compose the wireline network: Customer Premise Equipment (CPE), Optical Line Terminal (OLT), Ethernet aggregation switches and Broadband Network Gateway (BNG). This effort consists in disaggregating some given equipment into elementary functions and use SDN (Software- Defined Network) and NFV (Network function virtualization) techniques to respectively allow abstraction of an underlying network [7] and virtualize elementary network functions. These virtualized elementary functions can then be re-assembled in a framework to recompose functional pieces of the network and run as SDN applications and/or micro network services (VNF) on generic hardware, even time-critical applications such as DBA (Dynamic Bandwidth Assignment) [8]. This approach also allows reusing elementary virtualized

functions to recompose different and customized network functions which the service provider can then instantiate and orchestrate to "easily" compose new services. The term virtual OLT (or vOLT) refers a lot of different approaches to redesign the OLT using such disaggregation/recomposition approach or simply abstracting it from the network controller (the controller then manages an Open Flow switch). A few hardware manufacturers have already produced some pizza-box OLTs based on the former Open Compute Project (OCP) specifications. NTT [9] and Tibit Comm. [10] both proposed to push the generic hardware concept to its limit, designing SFP-OLTs to be inserted in regular switches/routers. The coming decade will correspond to the timeline for vOLT to converge to a common conception and establish a market reality.

5. Impact of access node automation

Another less radical approach than redesigning the network elements for achieving some levels of agility in the wireline access consists in re-engineering the management plane of the network elements, named SDAN (Software-Defined Access Network). Ideally, the management plane of an OLT should natively be vendor agnostic. If it was the case, all operational procedures would be defined once and used and reused for all the equipment of a given type. Over the last decades, all attempts for standardizing the management interfaces of the network elements failed though, mostly because vendors were quite reluctant at risking losing a large part of their business. Consequently, vendors kept proposing their products and their native proprietary management systems. This obliges the operator to adapt its OSS (Operations Support System) to different proprietary management interfaces, which is time consuming and requires quite a significant effort in terms of OSS development. But for this new decade, things are changing. Thanks to the emergence of SDN and the lobbying efforts from network service providers to better automate its operational processes, the introduction of software in the telecommunication industry gives SDAN solutions and opportunity allowing telcos to manage the access nodes themselves as well as create new kinds of orchestration at the service layer. Last but not least, the SNMP (Simple Network Management Protocol) management protocol and its associated data-modelling language in use today are pretty old and were inherently not well designed to comply with data-models promoted by the standards. SNMP is also currently used for pulling statistics and counters from the network elements (performance monitoring, troubleshooting). However, SNMP is not well designed for massive data collections. NETCONF (Network Configuration Protocol) interfaces and YANG (Yet Another Next Generation) data-models for PON are now proposed (cf. BBF TR385). They were born from SNMP limitations and are gaining some momentum so we forecast that they will replace SNMP. The coming decade will correspond to a network migration and operation with natively NETCONF/YANG access equipment leveraging on a clear separation between the network node management layer and the service design and management layer. Access networks automation will be the major use case but such enabler allows coordinating the access and Home LAN networks, the energy efficiency policies and etc… The challenge, for next decade, will be also to define the business model with certification process for Open OMCI (ONU Management and Control lnterface) to achieve interoperability based on software compliance.

5. Conclusion

To summarize, we have given general view for optical access innovations for the coming decade. The general trends are the preserving the investments of previous decade (mainly for passive infrastructure but also active equipment), the merging of optical access and Home LAN and the use of PON technologies beyond FTTH.

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