Energy Efficiency in Multi-Access Technologies with a Disaggregated Architecture

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Abstract: We describe key technologies for a greener ICT for the fixed & mobile access, in-building optical backbones including a novel cooling technology, for DC to ensure energy savings and flexibility for different ICT market segments.

1. Introduction

The climate change, pushing the worldwide community to reduce the primary greenhouse gaz (the CO_2), will push tomorrow all the industry to adopt new directions. It is therefore important to analyze what can be done at the ICT level to control the emissions of CO_2 by adopting innovative approaches through eco-design and eco-management. But before revisiting the networks elements of the ICT, it is important to identify where the energy saving is strongly required. Between 2010 and 2015, the Greentouch initiative elaborated a tool called GWATT to identify the critical networks sections. The study showed that the periphery of the network is the most sensitive. As an example, in 2013, the repartition of the power consumption for the ICT was the following: 39 GWatt for the devices ending the network at home (computers, smart phones, printers, tablets, …), 13.7 GWatt for home and enterprises, 21.6 GWatt for Access and Aggregation, 3,6 GWatt for the metro, 0.7 GWatt for the edge, 0.4 GWatt for the Core and 43 GWatt for the service Core & Data Centers [1]. These figures indicated then that we need to pay attention to the home & enterprises, to the access & aggregation and to Data Centers ICT segments.

The focus will be on the far edge covering distances not exceeding 20 km. Edge data centers are then required at the central office to guarantee small latencies (< 1ms). New business potentials are identified for low latency & efficient transport in the multi-access domain with demands for more throughputs and smaller latencies. This will be possible through a massive deployment of the 5G technology offering extreme mobile broadband, massive machine communication and critical machine communication, and to anticipate an evolution towards 6G. The disaggregation is then vital to address these new constraining features. The challenge will be then to propose models able to offer energy savings for the multi-access part in a disaggregated access network.

In this paper we will be then focused on the multi-access that includes the pure fixed access, the RAN and the in-building part parts. The first part of the paper will be then focused on the fixed access and on the identification of promising directions to reduce the energy consumption while offering more guaranteed bit rates at the user side. The second part will address the Radio Access Network and more particularly the xhauling part. The third part of this paper will be focused on the in-building part, with a focus on the access points, and on optical backbones targeting low TCO/bit and easy upgrades. Finally, a fourth part will address the data centers and innovative approaches at the cooling level to do energy savings. The conclusion will recall the main advantages of the technologies proposed.

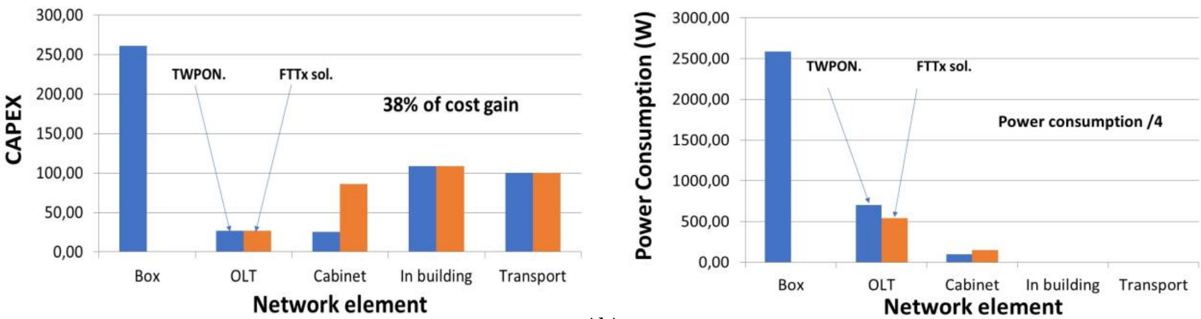
2. Fixed access

The access network is adopting today passive optical technologies. In complementary to EPONs systems we have seen a deployment of GPON systems, today of XGS-PON systems and tomorrow 50 and 100 Gbit/s PON systems [2]. The tendency is to increase the bit rate to offer better quality services at the use side.
In this paper we analyze a complementary approach consisting in terminating the PON system, not at the user side but in the basement of the building or to the distribution point. The first advantage is by adopting an intermediate interface, we can then disaggregate the bit rate in the distribution point to reduce the physical bit rate at the subscriber side. The second advantage when we relocate the ONU or ONT in the rack of the building we can share the processing capabilities among the different subscribers and have a low cost ONU board. The third advantage is that we can apply new techniques for the transport of data (in particular, bit interleaving [3]) when the data transmission is synchronous. Finally, the last advantage of this approach is that we are independent to the type of wires deployed in the building (cooper of fibers).

For the reference we adopted a WDM TDM PON, with 8 wavelengths, each wavelength connected to 32 users, leading to a total connectivity of 256 users. The total capacity of the PON is then 80 Gbit/s. The distance between the ONT/ONU and the OLT is 20 kms max.

For the solution proposed we adopted a Fiber to the Building/Curbe approach, with 1 user having 10G, 55 users having 1G, 200 users having 100M to provide a flexible offer. The total capacity is close to 85 Gbit/s that is slightly higher than the reference. The distance between the node in the building and the OLT is 20 kms max.

The results shown in fig. 1 demonstrate that we can have a low TCO/bit when adopting an eco-design approach.



a)b)

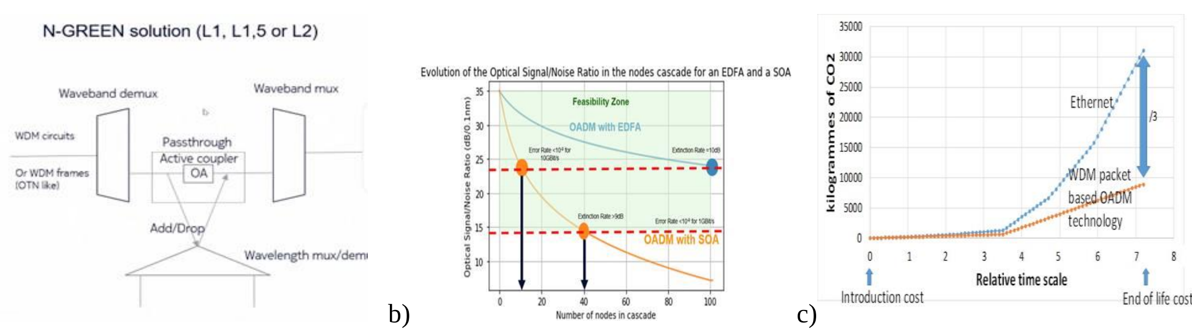
Figure 1: Comparison FTTx solution wr to TWPON systems a) cost analysis, b) power consumption analysis

2. Crosshauling

We propose here a technology for the fronthauling or Xhauling part not exceeding 20 km of distance to enable a 1ms of RTD. A preprocessing of the data in the basement of the Antennas can relax the physical bit rate for the data communication between the antennas and the Base Band Unit (BBU). Depending on the processing (options 6, 7a, 7b or 7c) we can then limit dramatically the physical bit rate to better control the cost and the power consumption. The technology proposed in an optical add/drop multiplexer embedding an optical amplification to perform high cascade.

The structure of the OADM is mainly composed of optical couplers, passive filters, optical amplifiers based on gated Semiconductor Optical Amplifiers (SOA) for a slotted version or Erbium Doped Fiber Amplifiers for a circuit version [4]. The calculation of the Optical Signal to Noise Ratio (OSNR) shows an excellent node cascade (100 nodes with direct detection at 10Gbit/s per wavelength and with EDFAs). This solution was designed for an option 6 processing (just before the MAC processing option) to have in all cases a maximum required bit rate of 5,64 Gbit/s according to the 3GPP Release 14, TR 38.801 V14.0.0 (2017-03)) instead of 157,3 Gbit/s for pure fronthauling (no pre-processing and adoption of option 8).

Figure 2a shows the structure of the OADM, figure 2b shows the performance is cascade of the OADM proposed when adopting a SOA or an EDFA for the embedded amplification and figure 2c shows the reduction of CO2 emissions when adopting the solution proposed.



a) b) c)

Figure 2: a) structure of the OADM, b) performance of the OADM c) gain in term of CO_2 emissions

We demonstrated that the energy consumption of the OADM proposed could be reduced when compared to a pure Ethernet technology. This technology is then adapted to any use case when a large point of connections is required and when the energy consumption is a critical constraint.

3. In-building use case

For in-building applications we need low power consuming access points, and backbones offering a high quality of service under severe energy constraints. In addition, it is important to deploy a transparent backbone to be able to upgrade the access points with no impact on the network infrastructure that must be generally designed for a long-term operation. The solution proposed combines optical wired and wireless technologies in a 5G global context, to offer high bit rate access points, and transparent optical backbones. The optical backbone can be similar to the technology proposed for the Xhauling as described previously. A particular attention is for the access point where a light communication technology could complement a RF technology, to experience minimum power consumption.

With the massive deployment of LEDs, the objective is here to exploit some of the LEDs as optical antennas to transmit data. This technology, commonly called LiFi, will provide then a service continuity in an heterogeneous 5G model to offer high bit rate connections, security and low power consumption As an example, the extra power consumption required to add a driver including a modulator/demodulator and photoreceiver is in the range of few Watts, and can be < 1 Watt for some technologies. Devices on the market shows that the modem can have a power consumption as low as 300 mW. With such a power consumption, it becomes then possible to deploy a high bit rate multi-access network while respecting the energy consumption constraints for in-building use cases.

By combining wired and wireless optical technologies we can reach a minimum energy consumption. As an example, for ADEME in France, the energy consumption of cities is shared into 5,6 TWh, for outdoor lighting and 7 THz for in-building lighting. It is then fundamental to propose new innovative technologies through an exploitation of the potential of optical technologies to control the global energy consumption while offering new added services in line while guaranteeing the Key Performance Indicators (KPIs) of the 5G technology.

4. Thermal management of data centers or central offices

In this study, we propose a novel thermal management technology that leverages the thermosyphon-based working principle through the use of low boiling point dielectric fluids via phase change heat transfer processes for data centers. In particular, evaporating flow is used to remove the heat from the hardware components, while condensing flow is used to reject the heat to the secondary side coolant, which can be air-based or liquid-based depending on the installations. The proposed thermal management technology is passive and the flow recirculation is ensured via the balance between the buoyancy force (two-phase mixture generated by the evaporation) and gravity force (liquid generated by the condensation). The main advantages compared to traditional direct and indirect air-based cooling implementations can be summarized as follows: higher heat density dissipations; lower complexity and higher level of reliability; easier integration for heat reuse applications; higher flexibility for implementation in any type of hardware, whether it is a pizza box or vertically oriented architecture. In addition, compared to existing air-based cooling technology, the proposed thermal management solution will allow for a significant reduction in carbon emissions because of the large reduction in overhead energy dedicated to cooling.

5. Conclusion

We proposed in this paper different new directions to reduce the energy consumption of the ICT in sensitive networks segments: the vertical markets and the fixed & mobile access network and in the data centers. To reduce the energy consumption, new approaches are required to identify eco-designed technologies that could be eco-managed for an optimum energy saving. For data centers innovative cooling technologies are shown to address an additional energy consumption reduction in the multi-access segments.

6. References

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