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Towards networks of the future: SDN paradigm introduction to PON networking for business applications

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Abstract—The paper is devoted to consideration of an innovative access network dedicated to B2B (Business To Business) applications. We present a network design based on passive optical LAN architecture utilizing proven GPON technology. The major advantage of the solution is an introduction of SDN paradigm to PON networking. Thanks to such approach network configuration can be easily adapted to business customers' demands and needs that can change dynamically. The proposed solution provides a high level of service flexibility and supports sophisticated methods allowing user traffic forwarding in effective way within the considered architecture.

I. Introduction

In RECENT years Internet traffic is skyrocketing (traffic growth is exponential) as users are consuming more and more Internet services (e.g. video or cloud based solutions). The problem is often highlighted by telecommunications providers but high growth is also observed by organizations like enterprises, universities, governmental entities. Thus many institutions have to adapt and bolster their traditional IT and network infrastructure in order to handle that phenomenon.

In this chapter the overview of legacy campus networks, typically used by institutions, is given. Also LAN (and WAN access) solutions provided to business customers are described.

A. Office networks overview

Nowadays access to Internet is prevalent among companies. Moreover many enterprises have own intranet. In order to provide connectivity to different devices likes PC, laptops or tablets in-building network infrastructure is needed. It can be composed of a single modem/router but also tens of devices and substantial amount of transmission media (optical fibers, twisted pair cables etc.). In case of big organizations all those components form a campus network– computer network interconnecting LANs (Local Area Networks) within a limited geographical area. The infrastructure is usually owned by campus owner / tenant e.g. enterprise, university, hospital.

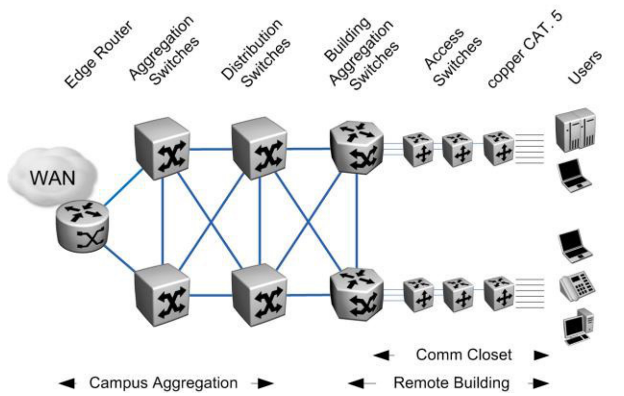

Fig. 1 Campus network hierarchy

Early LANs were large flat networks with peer to peer Layer 2 (L2) communication based on Ethernet [4]. It was a simple approach but with network growth ultimately led to disruptions (e.g. due to broadcast storms). Over the time Layer 3 (L3) has been introduced dividing campus network into smaller segments (allowing avoiding such problems). Additionally numbers of different solutions like VLANs (Virtual LANs [5]), RSTP (Rapid Spanning Tree Protocol [6]) or IP subnets have been developed making campus networks easier to maintain and manage.

Also the topology evolved towards more hierarchical and structured design. 4-tier network architecture (see Fig. 1) has become common ([8], [10]). In that approach access layer provides connectivity to end devices with copper twisted pairs (usually UTP CAT. 5 – Unshielded Twisted Pair Category 5, nowadays CAT. 6 cables are gaining popularity). Fast Ethernet or Gigabit Ethernet (100BASE-TX or 1000BASE-T [4]) are typically used. Access layer contains multiple L2 switches. They are located nearby users, e.g. in communication closets on each floor of the building. At the next level additional switches aggregate traffic for each building (concentrating multiple access layer switches) Interconnection between access layer switches and building aggregation switches can be provided with copper cables, or with fibers. Building aggregation switches are connected to campus aggregation and distribution switches which then connect to router (being a gateway to external networks). As a transmission medium for interconnecting building aggregation with campus aggregation segments fiber optic cables are often used due to higher bandwidth requirements (i.e. 10 GbE interfaces) and distance.

Tiered network design gives flexibility in terms of supporting numerous functions and end devices (for example growth of client population can be accommodated by adding access layer switches, but that approach is costly). The logical division for different layers does not need to be done with physical tiers; access and aggregation can be provided on the same equipment. It can be especially useful in case of smaller campus simplifying management of reduced number of devices [9].

Important to note is fact that legacy Ethernet-based campus networks have significant drawbacks. Maximum length of copper Ethernet cables is limited to 100 meters. In fact 4-tier topology with switches on each floor is an answer to that limitation. Ethernet LAN requires a cable connection to every single user port. This means significant number of access layer switches and wires (copper cables) and at the end results in high costs. High-frequency signals (used for Fast and Gigabit Ethernet) require more sophisticated copper cable constructions which are physically larger than for lower frequencies (necessary to avoid signal disturbances). In consequence the space required for racks, communication closets is large. Crucial amount of heat is produced, power consumption is high. Management of high number of active devices is not easy.

For those reasons legacy Ethernet LAN is not always the best answer for campus network requirements. That is why an important issue is to find a more effective approach for office networks infrastructure.

B. Scenarios for B2B services

B2B (Business to Business) telecommunications services' landscape is diverse. It includes services like Internet access, POTS (Plain Old Telephony Service), VoIP (Voice over IP), dedicated links, VPN (Virtual Private Network), etc. One can distinguish large (Enterprise), medium (SME – Small and Medium Enterprises) and small (SOHO – Small Office Home Office) market segments. However service overlapping (the same services) is possible, but often there are special offers for different segments.

Services' requirements largely depend on type of customer. Big entity owning campus network (and considerable number of network equipment) has other needs than company with small branches scattered around the country (and with lack of its own interconnection) and than small company located in single office building.

For entity with campus network usually telecommunications operator provides its services to location where campus edge router is placed, further propagation is the responsibility of the entity itself (compare Fig. 1). In the second case (several branches) it is important to provide interconnection among branches.

For office building, in which many companies are located, there are two most common infrastructure scenarios (see Fig. 2). First one is based on existing copper CAT. 3 cables which reach customers' desk / office and can be reused by telcos. Modem or router is the termination point of the services (Fig. 2 Scenario A).

In the second scenario office building has infrastructure based on active Ethernet LAN with copper cables CAT. 5 (Fig. 2 Scenario B). Telecommunications operators need to provide its interconnecting cables up to building's technology room. Separation of services / between different operators can be provided on logical level e.g. by means of VLANs.

For both scenarios the only responsibility of telco is to somehow access business customers. Herein, one could think of a new role for operators targeting office buildings environment: what added values are possible to be identified

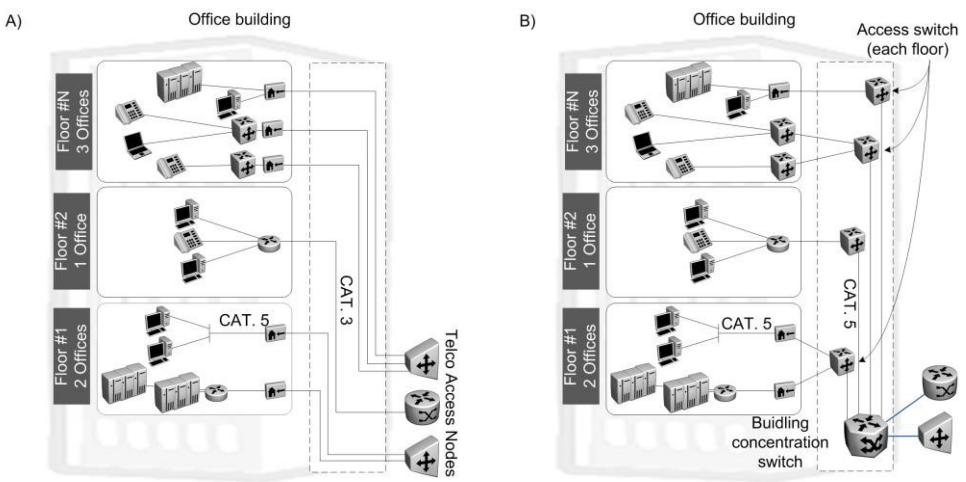

Fig. 2 Legacy infrastructure in office buildings. Scenario A: Telecommunication operators' cables CAT. 3 up to the office.
Scenario B: In-building infrastructure based on Active Ethernet LAN (copper cables CAT. 5)

if telcos take the responsibility of building and administrating the entire in-building office network?

II. Optical LAN

Optical LAN is a new approach for office networks infrastructure and an answer to limitations of legacy Ethernet LANs. All-fiber LAN interconnecting existing Ethernet end devices allows reducing costs and making the network more reliable.

Proposed solution is based on GPON (Gigabit Passive Optical Network) [1]. It is standardized, well known and widely adopted telecommunications access technology, used by many operators worldwide. GPON uses point-to-multipoint topology and employ fiber optics as a transmission medium. As a real passive solution – no active equipment is used in-between GPON Access Node: OLT (Optical Line Termination) and line termination at customer side: ONT (Optical Network Termination). In campus network based on Optical LAN number of active equipment is significantly reduced comparing to traditional LAN scenario. From OLT GPON port a single strand of fiber goes out to a passive optical splitter(s) which splits the signal onto fibers terminating at up to 64 (or even 128) ONTs (see Fig. 3). All the fibers, splitters connected to one GPON port on OLT form a GPON tree. ONT device terminates GPON transmission and provides 10/100/1000-BaseT Ethernet connectivity to desktop equipment such as PC computers, laptops, voice over IP phones, and video phones using regular copper patchcords (or by 802.11 WiFi). ONT can be located on customer's desk (ONT per desk) or in office closet (ONT per office). Those two options are called respectively: Fiber-to-the-Desktop (FTTD) or a Fiber-to-the-Communications (FTTC) room. High flexibility of Optical LAN solution allows reusing existing copper infrastructure in buildings (for example GPON access is terminated on ONT located in the floor communication closet, from where existing copper cables are used up to customer's desk, see Fig. 3 – Floor #2).

Thanks to fiber optics-based transmission Optical LAN is a long reach access solution – maximum reach is equal to 20 km in a standard mode. It is a tremendous improvement comparing to traditional copper Ethernet (100 m.). It allows placing OLT in distant locations, giving high flexibility in network design (in case of campus network OLT no longer need to be installed in the same building in which customers reside).

GPON technology assures 2.488 Gbps of downstream bandwidth and 1.244 Gbps of upstream bandwidth. Bandwidth is shared among customers connected to the same GPON tree. Advanced GPON QoS mechanisms assure appropriate bandwidth distribution among many users and different applications.

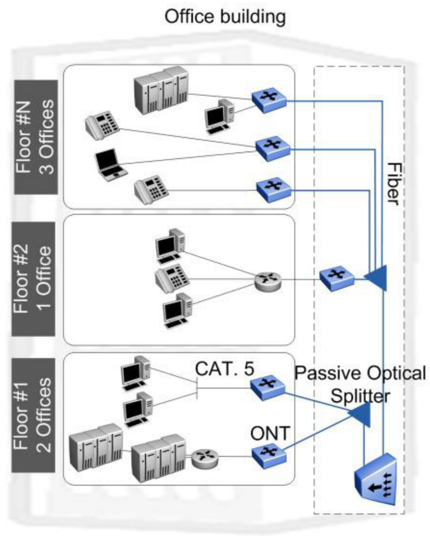

Fig. 3 Office building infrastructure based on Optical LAN

Optical LAN solutions are present in portfolio of several vendors (e.g. Motorola [11], Tellabs [12], Zhone [13]). According to vendors estimations introducing of Optical LAN will reduce power consumption by up to 65%, space requirements by up to 90%, capital costs related to network elements by up to 74% [13]. Optical LAN is seen as a new paradigm in campus networking allowing optimization of investments and at the same time improving overall efficiency of the network.

III. A Novel Approach to B2B

In this chapter we formulate three postulates, which are, from our perspective, crucial for deploying future proof access networks for business applications:

1. Applying Optical LAN concept

Currently Optical LAN vendors target big entities with large campus networks. In typical deployment Optical LAN is used by only one organization – the owner and the administrator of the campus network. Office buildings with many tenants, each of them having its own LAN network (at least up to some point) are not yet addressed.

In this paper we propose a solution to that deficiency. It is based on concept known from telecommunications world where many customers are connected to the same Access Node (different users served on the same equipment). In our proposition enterprises no longer need to operate any active network equipment or to build networks itself. LAN becomes a service, provided in similar fashion as e.g. Internet access. LAN service provider is responsible for service creation, administration and adjustment according to needs of customers (enterprises using LAN). That also means that network infrastructure is built for offices by LAN service provider. In fact such network is similar to GPON access networks used by telecommunications operators to provide services to its customers. For B2B scenario different customers are also served by the same GPON OLT unit.

2. A new role for telecommunications operators

Telecommunications operators are well positioned to play the role of Optical LAN service providers. Usually they have necessary experience with GPON technology, operational resources and existing access network. Telcos are able to deploy optical fiber LAN in office buildings and to provide flexibility in management, service creation and administration.

Such approach has many advantages in terms of optimal usage of network resources. Single OLT can be used for several buildings, even if they are located in distant areas (due to long reach offered by GPON technology which capabilities in terms of maximum physical reach are not fully used in current optical LAN implementations). Also interconnection of distant branches becomes easier (in specific cases they can be served by the same OLT). Additionally a new type of services can be introduced called Office LAN services: e.g. on-demand LAN connections between companies located in the same building, access to in-building monitoring system, etc.

This novel approach also creates a new business model for telecommunications companies who become Optical LAN operator (builder and administrator). This opportunity to find new B2B market seems to be a good argument in convincing telco players to work on such solutions.

3. Business-user-oriented access network design

Another assumption for the presented approach is that it is based on user-oriented access network design. Service portfolio dedicated to business customers is typically more complex than the one for residential users. For business applications customized services need to be taken into account. Moreover, customer demands can change dynamically over short periods of time. That is why a challenge for networks deployed in business environments is to provide a high level of service flexibility and to forward user traffic in effective way. To meet those requirements we present in this paper an access network architecture based on SDN (Software-Defined Networking) paradigm which assumes data plane and control plane abstractions separation ([17]). Thanks to such approach network devices become programmable units. In practice it means that network configuration can be easily adapted to the fast-changing needs.

IV. SDN-BASED GPON SOLUTION FOR BUSINESS APPLICATIONS

In order to introduce SDN paradigm to GPONs area one can propose different methods to accomplish that. One of the possible ways would be to develop a brand new protocol allowing GPON devices to become programmable units. Such approach is supposed to be an appropriate one for designing an optimal logical architecture of OLT and ONT in the scope of data processing and forwarding. However, development of generic SDN-based protocol for GPON would require a lot of standardization efforts and probably it would take a few years to obtain a solution being ready for deployment. Moreover, it would be limited to GPON technology and thus it could not be applied for other network types and applications.

In this paper we present another approach. We propose a solution based on OpenFlow ([16]) which is the most widely deployed SDN-based protocol. OpenFlow Switch architecture consists of at least three parts ([15]) – see Fig. 4:

- Flow Table(s) – a structure within switch implementation with an associated actions with each flow entry; the Flow Tables define the ways of how the traffic flows have to be processed by the switch
- Controller – an external unit running a remote control process that manages the switch via the OpenFlow protocol; the Controller can add, remove and update flow entries from the Flow Table(s)
- Secure Channel (also called OpenFlow Channel) – a channel which enables a communication (i.e. sending packets and commands) between the Controller and the switch

For a more detailed description of OpenFlow-specific logical components and functions please refer to [15].

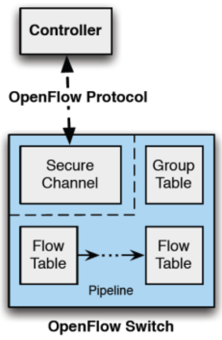

Fig. 4 OpenFlow Switch logical scheme (source: [17])

OpenFlow was originally designed for L2/L3 switches (or routers) equipped with native Ethernet-based physical interfaces. That is why it is important to notice that it is useless to implement pure OpenFlow in GPON OLTs and ONTs. The reason for that is simple: although GPON effectively carries Ethernet frames, in practice it operates at Layer 1 (according the OSI model) with its own dedicated framing and GEM (GPON Encapsulation Method) protocol used for encapsulation higher-layer Protocol Data Units (e.g. Ethernet frames) into GTC (GPON Transmission Convergence) layer. The current specification of Open Flow protocol does not support such kind of non-Ethernet-based physical interfaces. That is why some additional GPON-related functions have to be introduced to OpenFlow.

A. SDN-based protocol for GPON

A single logical connection within the GPON system is called GEM Port and it is identified by GEM Port-ID. A GEM Port can be considered as a channel within GTC layer and is capable to transport one or more traffic flows. In the upstream direction GPON system also utilizes T-CONTs (Transmission Containers) corresponding to allocated timeslots within TDMA multiplexing existing in GPON. Each T-CONT represents a group of logical connections (GEM Ports) that appear as a single entity for the purpose of upstream bandwidth assignment on the PON (see Fig. 5 – GPON-specific traffic entities identifiers are pointed in brackets).

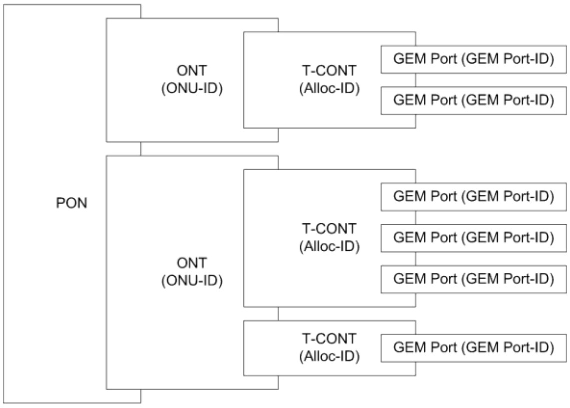

Fig. 5 Upstream multiplexing in GPON system

Each T-CONT can be seen as an instance of upstream queue with a certain bandwidth profile (a set of bandwidth parameters). The bandwidth assignment model applied in GPON system effectively introduces a strict priority hierarchy of the assigned bandwidth components ([2]):

- fixed bandwidth: with highest priority
- assured bandwidth
- non-assured bandwidth
- best-effort bandwidth: with lowest priority

Five T-CONT types are defined by [2]. Depending on the traffic type (latency-sensitive traffic, data transmission, etc.) the most appropriate T-CONT type should be selected to carry considered traffic flows.

Upstream user traffic (Ethernet frames) is encapsulated into GEM Ports and then into T-CONTs. Each GPON ONT uses its own set of T-CONTs and GEM ports, a unique one within a GPON tree which ONT belongs to. A single GEM Port can be encapsulated into only one T-CONT, however a single T-CONT may encapsulate multiple GEM ports. In downstream direction only GEM Ports are used to carry traffic flows since no TDMA multiplexing exists there and thus the notion of T-CONT is not relevant for GPON downstream transmission. For a more detailed explanation please refer to [2].

One of the key aspects of GPON-based network applications is to ensure effective traffic forwarding on the GTC layer. In order to do that it is important to define appropriate rules (consistent and unambiguous ones) allowing to map traffic flows incoming from users to appropriate GEM Ports. In most of commercial implementations mapping rules "built-in" GPON ONTs are mono-criterion- i.e. mapping is based on only one of the following criteria like: VLAN ID (Virtual LAN identifier), p-bit ([5]) or UNI (user port number on ONT). For some cases also double-criterion combinations of aforementioned parameters are available (e.g. VLAN ID + UNI) for the mapping purpose. Since GPON was originally designed for B2C (Business to Customer) market segment for which only Triple-Play (Internet, ToIP and IPTV) services are considered such approach was sufficient. For business applications where not only service portfolio is more complex but also customized services are taken into account, much more sophisticated methods (i.e. mapping rules) are required in order to ensure effective traffic forwarding through the system ([14]). In most scenarios currently deployed GPON ONT with limited set of hardcoded mapping and forwarding functions would not be able to address such needs. In such cases software upgrade is needed but it leads to higher operational costs - especially if business customer demands changes dynamically and it is possible that new set of functions is required. For such a scenario multiple software upgrades have to be taken into account.

The solution for the issue is SDN-based protocol for GPON allowing OLT and ONT to become programmable units. In this paper we propose OpenFlow-based solution. As mentioned before the current specification of OpenFlow protocol does not support GPON natively. That is why our vision is to introduce GPON-related functions to the specification in order to develop a protocol extension which we called OpenFlowPLUS.

The main assumption for the OpenFlowPLUS is that it inherits all the functionality, architecture and capabilities of original OpenFlow. The essential improvement is an introduction of GPON-related functions to the protocol in terms of traffic forwarding in order to make the solution relevant also for GPON technology.

According to OpenFlow Switch architectural assumptions each device (OLT, ONT) within considered GPON tree contains Flow Table(s) and communicates over a Secure Channel with remote Controller via OpenFlowPLUS protocol (see Fig. 6).

For that purpose OLT and ONTs are supposed to have IP address configured. Since Controller and OLT are assumed to be connected to IP/Ethernet network they can establish L3 connection. ONTs are accessible by Controller only via OLT. One could take advantage of that and for the purpose of OpenFlowPLUS messages exchange between ONTs and Controller make use of GPON-specific mechanisms defined by [3]. In such a scenario protocol messages are transported through the PON via a dedicated OMCI (ONT Management and Control Interface) channel towards OLT and then they are sent directly to the Controller using OLT's Secure Channel. Obviously, employing OMCI by OpenFlowPLUS for some new applications does not mean that the protocol takes the control over the entire GPON system. All functions which are out of the scope of traffic mapping and forwarding (e.g. ONT discovery and provisioning-related functions, Dynamic Bandwidth Allocation mechanism, optical layer supervision, alarms and performance monitoring etc.) are assumed to be realized in traditional way, i.e. in line with recommendations defined in [2] and [3]. That is why an optimal approach seems to be adding OpenFlowPLUS controller as a functional module to the standard EMS (Element Management System) managing the system.

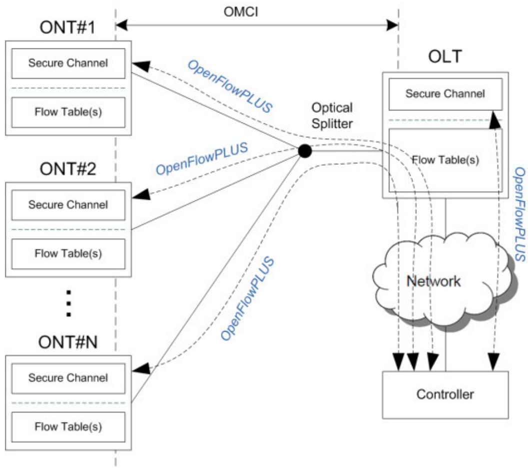

Fig. 6 OpenFlowPLUS–based GPON solution overview

As mentioned before the idea of OpenFlowsPLUS is to provide GPON-related functions to the protocol in terms of traffic mapping and forwarding. Similarly to original OpenFlow, OpenFlowPLUS is assumed to use Flow Table(s) which perform packet lookups, modification and forwarding. Each Flow Table contains multiple flow entries. Each flow entry contains:

- match fields – to match against packets; match fields include packet header fields (e.g. VLAN ID, MPLS label, IP destination address, TCP source port, etc.), an ingress port and metadata that pass information between tables; flow entries match packets in priority order, with the first matching entry in each table being used ([15])
- counters – which can be maintained for each port, table, flow, etc.
- instructions – operations which are executed when a packet matches a flow entry

Instructions define the ways of how single action is processed. Actions represent operations of packet modification or forwarding to the specified port. Actions are grouped by different action types, for instance pop action type (e.g. pop VLAN header action), set action type (e.g. set MPLS traffic class action), etc. Instructions executed during OpenFlowPLUS pipeline processing can either add appropriate actions to the current action set (a set of actions that are accumulated when the packet is processed by the tables and that are executed after exiting the processing pipeline by the packet), or force some actions to be applied immediately. OpenFlowPLUS defines new actions which are relevant to GPON technology. The considered functions are presented in Table I.

TABLE I.
MAIN GPON-RELATED FORWARDING FUNCTIONS PROVIDED BY *OPENFLOWPLUS*

GPON unit	Action type /Action	Remarks
ONT, OLT	gpon: Map to GEM Port	introduction of a new action to the original OpenFlow action set function: mapping Ethernet frames to particular GEM Port instance
ONT	gpon; Map to T-CONT	introduction of a new action to the original OpenFlow action set function: mapping GEM Ports to particular T-CONT instance
ONT, OLT	output	action modification when executed for GPON interfaces new function: GTC framing before forwarding the packet on the GPON port

OpenFlowPLUS introduces a brand new action type called gpon related to GPON-specific mapping methods. The considered action type provides two actions: Map to GEM Port action which represents an operation of mapping Ethernet frames to particular GEM Port instance and Map to T-CONT action which represents an operation of mapping GEM Ports to particular T-CONT instance. Additionally the new functionality for original OpenFlow output action is supposed to be supported: when a packet is destined to be forwarded to the GPON port, GTC framing is performed for the packet before exiting the interface. The aforementioned protocol improvements are the main GPON-related forwarding and mapping functions provided by OpenFlowPLUS.

B. Use case

In this section we present a possible application for SDN-based GPON concept which is proposed in the paper. The following assumptions are made for the considered use case:

- the solution is dedicated to business customers who reside in office buildings
- operator acts not only as a service provider but is responsible also for administration of in-building network
- in-building network is based on Optical LAN solution
- different service types can be offered: Internet access, Metro Ethernet (corporate connections), cloud computing-based services, office LAN services; the considered traffic flows are listed in Table II
- access network architecture is based on OpenFlowPLUS GPON solution (see Fig. 7)

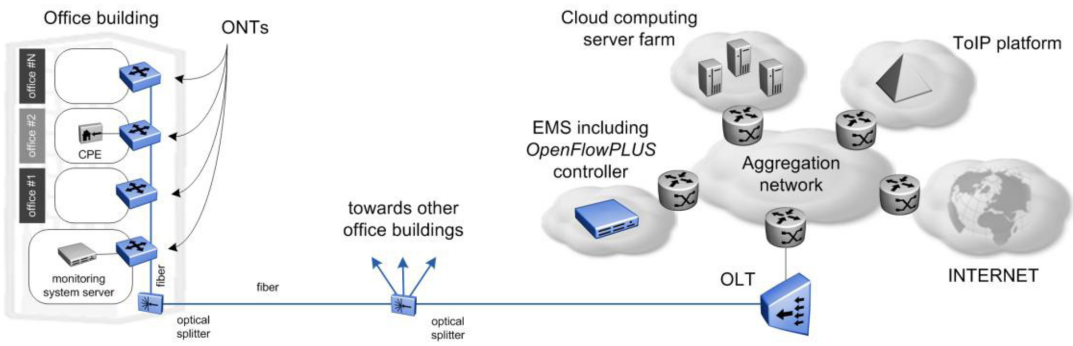

Fig. 7 OpenFlowPLUS-based architecture for business applications overview

TABLE II.
SERVICES AND TRAFFIC FLOWS OVERVIEW

Flow ID	Traffic flow/service	Remarks
F#1	Internet Access: HTTP, FTP, etc.	standard Internet services
F#2	Internet Access: web-based application hosting	connections from Internet are established using HTTPS (SSL + HTTP) protocol (TCP port 443)
F#3	Internet Access: remote access to intelligent installation system controller	connections from Internet to intelligent installation system controller physically located in the office are based on KNXnet/IP protocol (port 3671); IP address of the controller: IP@1.3
F#4	Metro Ethernet: connections to remote company branch	remote company branch is supposed to use IP@2.X address pool;
F#5	ToIP (telephony over IP)	IP phones used in the office are assumed to mark IP ToS field with DSCP "EF" value; IP address of ToIP platform: IP@4.1
F#6	Office LAN: on-demand connections to different companies located in the same building	connections allowed for a designated sub-pools of addresses from IP@1.X and IP@priv (office) and IP@3.X (different company office)
F#7	Office LAN: access to in-building monitoring systems	in-building monitoring system server is assumed to be connected to a dedicated ONT with IP address: IP@5.1
F#8	Cloud computing: remote storage, backups	IP address of cloud computing server: IP@6.1

Each office in the building is connected to the optical network via ONT. Copper cables terminated with RJ-45 sockets are deployed in office rooms. Each user device (PC, IP phone, application server, etc.) is connected to one of multiple Ethernet LAN ports which ONT is equipped with (see Fig. 8). ONT aggregates the entire traffic incoming from user terminals (this traffic contains no VLAN tags) and provides the functionality of L3 gateway. Public IPv4 addresses are assigned to ONT (IP@1.1) and to some selected user devices: web-based application server – IP@1.2 and intelligent installation system controller – IP@1.3. For other devices private addressing is used (IP@priv). ONT is assumed to act as an internal DHCP server for that purpose. Any kind of additional CPE (Customer Premise Equipment) is not required in the considered network.

Thanks to applying OpenFlowPLUS sophisticated mapping rules are supported in order to ensure effective traffic forwarding through the GPON. As an example we show how flow entries match fields with corresponding instructions can be defined within ONT Flow Table for traffic flows transmitted in upstream direction (see Table III).

Based on the user traffic to GPON-specific instances mapping methods (using limited set of parameters like VLAN ID, pbit, UNI) which are currently supported in typical commercial implementations it would be very difficult or even impossible to follow the traffic forwarding model presented in considered use case. For instance, in traditional approach it would be impossible to map traffic flows F#1 and F#3 to different GEM Ports if they originated from the same end-device. The proposed solution is very flexible and convenient from customer perspective. Since OpenFlowPLUS-based GPON is a programmable system its configuration can be easily adapted to support new services and business needs when they appear.

Presented access network model supports also openness for alternative operators what is typically required by country-specific regulations. Each customer served by another operator connects a dedicated CPE to the ONT which is configured as a bridge that passes assigned VLAN(s) through the system up to the first alternative operator's switch or router (see "office #2" in Fig. 7).

V. CONCLUSION

In the paper we presented a novel approach to deploy optical access networks addressed to B2B market segment where we defined a new role for telcos. The major advantage of our solution is its flexibility thanks to introduction of SDN paradigm to GPON-based networking. We believe our work

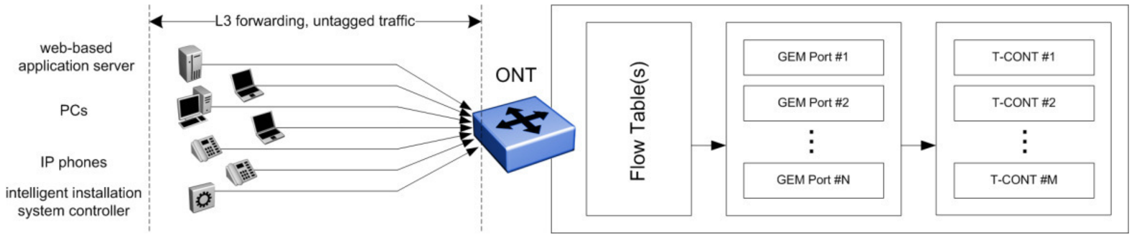

Fig. 8 OpenFlowPLUS-based ONT logical scheme

can be considered as a conceptual framework for further analysis and solution development.

TABLE III.
MATCH FIELDS AND INSTRUCTIONS FOR FLOWS INCOMING TO ONT

match fields of flow entries (in priority order)	Matched flow	Instructions
IPv4 dst = IP@4.1 AND IPv4 ToS bits = EF	F#5	Apply-Actions { Map to GEM Port: 1 Map to T-CONT: 1 (type 1)}
IPv4 dst = IP@2.X	F#4	Apply-Actions { Push VLAN header Set VLAN ID: 1001 Set VLAN priority: 3 Map to GEM Port: 2 Map to T-CONT: 2 (type 2)}
IPv4 dst = IP@3.X	F#6	Apply-Actions { Push VLAN header Set VLAN ID: 301 Set VLAN priority: 3 Map to GEM Port: 3 Map to T-CONT: 3 (type 2)}
IPv4 src = IP@1.2 AND TCP src port = 443	F#2	Apply-Actions { Set IPv4 ToS bits = CS2 Map to GEM Port: 4 Map to T-CONT: 4 (type 3)}
IPv4 src = IP@1.3 AND TCP src port = 3671	F#3	Apply-Actions { Set IPv4 ToS bits = CS1 Map to GEM Port: 5 Map to T-CONT: 4 (type 3)}
IPv4 dst = IP@5.1	F#7	Apply-Actions { Push VLAN header Set VLAN ID: 200 Set VLAN priority: 1 Map to GEM Port: 6 Map to T-CONT: 5 (type 2)}
IPv4 dst = IP@6.1	F#8	Apply-Actions { Set IPv4 ToS bits = CS2 Map to GEM Port: 7 Map to T-CONT: 6 (type 2)}
IPv4 dst != {IP@1.X, IP@priv, IP@2.X, IP@3.X, IP@4.1, IP@5.1, IP@6.1}	F#1	Apply-Actions { Set IPv4 ToS bits = none Map to GEM Port: 8 Map to T-CONT: 4 (type 3)}

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