Network architecture and resource management framework for convergence of mobile and optical access networks

Theofanis G. Orphanoudakis, Evangelos A. Kosmatos, George Lyberopoulos, Dimitrios Kagklis, Stelios Sartzetakis, Konstantinos Demestichas

***Abstract*—** The increasing demand for converged media services across Europe promotes the deployment of a range of broadband network technologies. Existing and emerging services that become available to the end user are currently supported by wireline access technologies such as relatively limited capacity cable modems, and ADSL or high capacity FTTx/VDSL as well as wireless technologies such as HSDPA, WiFi and WiMax. However, in order to achieve the required data rate, cell distances have to be small. This will result in a large number of cells to be interconnected to the mobile backhaul network. Serving a large number of cells with point to point links is extremely inefficient. This makes backhaul architectures based on Passive Optical Networks (PONs) very attractive. In this convergent networking scenario seamless mobility across this heterogeneous network infrastructure and service portability across segments of different technologies still face severe limitations. While international standards evolve to enable interoperability there is still a need for an integrated resource management framework and flexible service delivery mechanisms. A main objective is to achieve superior performance in terms of capacity, dynamic resource allocation, Quality of Service (QoS) and flexible service provisioning models supporting fast network reconfiguration, efficient network management and reduced cost (CapEx/OpEx). In this work we present an architecture and a resource allocation framework that allow autonomic operation and Service Level Agreement (SLA) negotiation between the mobile network operator (MNO) and the backhaul provider.

***Keywords*—** LTE, PON, MAC, Wireless Backhauling, Wireless Optical Convergence.

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This work was supported by the 09ΣYN-71-698 CONFES (Converged Network Infrastructure Enabling Resource Optimization and Flexible Service Provisioning) project, partially funded by the Greek General Secretariat of Research and Technology (GSRT).

I. Introduction

THE continuous evolution in mobile access network technologies (GSM/ GPRS/ EDGE, 3G/HSPA+ /LTE) combined with the high usage of data services, driven by the availability of new mobile devices (smart-phones, tablets, other portable equipment) supporting faster data rates as well as the rapid rise of mobile applications, lead to dramatic increases of OPEX backhaul costs that may either threaten business model viability or be transferred to the end-user. Besides it is questionable whether the contemporary backhaul technologies could support these high traffic volumes and traffic variations; especially in an environment which should allow users to download at very high speeds (e.g. 20-30Mb/s). As a result, new future-proof backhaul technologies should be introduced aiming at cost minimization, without risking the Quality of Service (QoS), while addressing the high traffic fluctuations.

Revolutionary changes happen at the same time in the last mile of fixed line providers who are increasingly deploying PONs that funnel traffic concentrated from their access network residential and small business customers over large capacity photonic metropolitan area and core networks. TDMA PONs offer the significant advantage of cost-effective port and traffic consolidation. Apart from the lower cost compared with dedicated fibers for the initial deployment, PONs retain the extra comfort of a secure, gradual and future-proof evolution path. A serendipitous synergy emerges between these two developments presenting the opportunity to accelerate cash flows for both the mobile and the fixed operator.

Traffic from mobile operators could fill a large part (e.g., 10 to 50%) of a PON serving as mobile backhaul network raising system utilization and easing the funding of the initial costly phase for the fixed network operator, but at the same time will enable the mobile operator to find at a reasonable cost a way to fully extend the capacity of a base station as demand for data services reaches that sensitive stage where the wireless infrastructure is lacking in capacity while it is too early to consider a dedicated fiber backhaul. This financially sensitive interim stage provides a window of opportunity easing the high initial capital expenditure for both operators while raising revenue accrual.

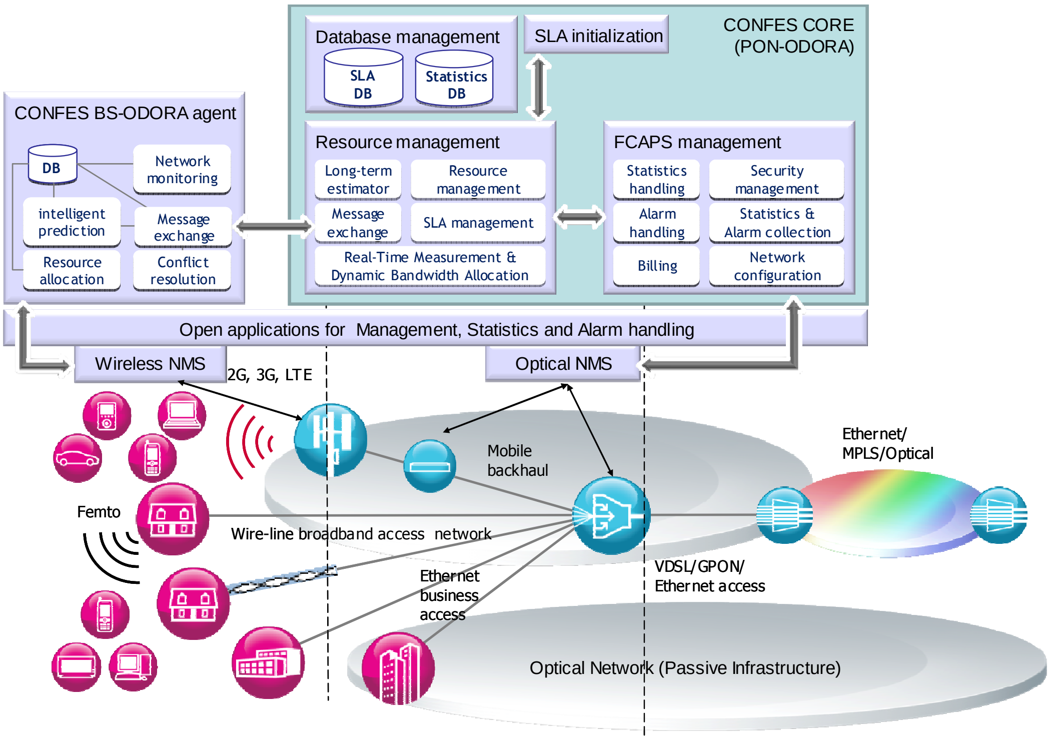


Fig. 1: Typical CONFES system architecture

An equally important advantage of this approach is the future-proof nature of access PONs evolving towards their next-generation upgrades e.g., through OFDM or WDM solutions that removes the danger of obsolescence featuring a well understood and studied evolutionary path to any desired rate and any degree of sharing up to dedicated lightpath links.

The initial paradigm change from a fixed pipe to a shared medium TDMA PON provides further flexibility and potential for multiplexing gain carrying further financial gain in the form of increased exploitation of the backhaul infrastructure. However, to exhaust the utilization potential without quality degradation risks, requires a novel functional block which will monitor and coordinate the bandwidth management offered to the mobile operator in a more sophisticated fashion than warranted by the residential or the other business users of the PON. The way this functionality is designed in the CONFES project is the focus of this work.

The design of these enhanced functional modules to enable fixed-mobile convergence and unified resource management will be described in the following sections of this paper. Specifically, in Section II we describe the CONFES high level architecture and in Section III we describe the CONFES approach towards dynamic SLAs that make best use of the enhanced functionality. In Section IV we describe the overall resource allocation framework and in more detail in Section V and Section VI we describe the main CONFES agents that are designed to support the enhanced functionality. In Section VII we describe their implementation over open network management interfaces of commercially available network platforms. Finally Section VIII concludes our paper.

II. CONFES System Architecture

To address the technical and economic challenges, for both MNOs and PON operators, towards the development of a viable business model, CONFES project adopted a converged network architecture based on PON technology that may support multiple candidate users (e.g. mobile operators, residential users, corporate users). CONFES aims at the exploitation of the Dynamic Bandwidth Allocation (DBA) capability of PON networks to achieve more economical models (as it may support more customers without needing infrastructure expansions) and at the same time to accommodate traffic bursts, peaks and seasonality variations (see winter or summer destinations), by taking advantage of the traffic lows. Dynamic allocation is the only solution in order not to over-dimension an LTE backhaul network because of the heavy fluctuation in traffic demand. An optimal network resource management should be developed.

A main novelty of CONFES is the introduction of new dynamic Service Level Agreements (SLAs) to cope with both predictable and unpredictable traffic events, adaptable to traffic fluctuations, upgradable temporarily to address a traffic demanding incident (see special events like concerts, sports events), capable of supporting the introduction of new services in a flexible way. The CONFES SLAs are designed to support both critical real-time services (signaling, voice, call/session continuity) as well as traffic migration (e.g. multiple active data sessions on a high-speed moving train). An additional requirement is the support for multiple charging models, incl. based on monthly fee, actual usage, etc.

Fig. 1 illustrates in principle the high level CONFES system architecture, which consists of a PON operator aiming to serve one or multiple MNOs (each having connected one or more mobile Base Stations - BSs) on top of its regular users (business and residential customers). The CONFES system architecture is an overlay network infrastructure spanning across both PON and MNO operators. As shown, it consists of two main blocks:

- The PON-ODORA (Optical & Dynamic Optical Resource Allocation) CONFES Core agent, responsible for the PON MAC and SLA management functions, and
- The BS-ODORA CONFES agent (per connected BS), responsible for calculating BS bandwidth needs and entering into SLA negotiations with the PON-ODORA CONFES agent on SLA modifications.

The main challenges of the CONFES functionality concern the dynamic management of the SLAs between the fixed and mobile operators, as well as the delay and MAC fine-tuning issues [1]. The novelty of the CONFES approach lies in the translation of the new possibilities offered by PON into negotiable SLA parameters for the benefit of the MNO. Hence, the DBA potential can be exploited according to the changing service needs of the BS. As a result, there will be the same level of QoS offered with less committed resources (hence lower costs) than would be necessary without the ODORA unit.

As a starting point, the PON inherently possesses dynamic bandwidth management at ms timescales via its DBA residing in their MAC protocol [1]-[5]. Under its guidance, packets are classified per quality class and arrival time and arranged one behind the other in perfect and gapless succession multiplexed towards a single input port of the Optical Line Terminal (OLT). However, at a higher time scale level, the traffic service must be agreed for the purpose of quality control, billing and dimensioning. Hence, the need for SLAs and regarding simple customers a peak rate is the main parameter under control.

With a PON serving time-sensitive traffic, a trade-off emerges between excessive over-provisioning leading to poor resource utilization and higher utilisation risking loss of QoS. Service prioritization can however protect sensitive traffic without significant over-provisioning in conjunction with the DBA which is a reservation protocol, i.e. arriving packets at the upstream (towards the core) queues request service indicating their queue length in a report field, and then the MAC controller at the head-end allocates upstream transmission grants enough to allow them to relieve the full content of their queues.

III. Service Level Agreements in CONFES

The CONFES consortium follows the methodology proposed by the TM Forum [6], in order to introduce a new type of SLA capable to support both mobile access technologies and business/home users over PONs. Example considerations of a SLA that could address a LTE MNO CONFES user are listed below:

- The increasing bandwidth requirements of LTE and LTE-Advanced mobile networks (up to 1Gb/s for a 3-sectored LTE site).
- Orientation to a dynamic backbone network resource allocation scheme, instead of the legacy static allocation of 2G and 3G networks performed by allocating one or more dedicated xDSL or wireless microwave links per BS accommodating traffic fluctuations.
- Support of the sophisticated QoS capabilities offered by the LTE and ISPs to their end-users (by exploiting LTE Classes of Service - CoS). Backhaul networks should support different SLA parameters per CoS under a unique SLA between MNOs/ISPs and the PON operator.
- Guaranteed and additional traffic rate should be changed in an escalated manner and based on the user needs, as recommended by the NGMN Alliance [7] for mobile networks backhauling. More specifically, the NGMN Alliance recommends permitting the adjustment of the data traffic rate indices at 2 Mb/s steps for 2-30 Mb/s rates, at 10 Mb/s steps for 30-100 Mb/s rates and at 100 Mb/s steps for rates over 100 Mb/s.
- Scalable billing according to data traffic rates/usage (guaranteed and additional) per CoS should be considered.
- The data traffic rate indices should be aggregated on either per ONU basis or per one or more xPON of broader geographical areas.
- The KQIs, threshold values and their expressions shall be based on the following KPIs [7]: Data traffic rates (guaranteed/additional), Delay, Jitter, Packet loss, Bit error rate.
- SLAs should be applicable to GPON, EPON and other future PON technologies. For example, GPON technology (ITU-T G.984.3 standard [2]) offers two guaranteed bandwidth classes (fixed CIR and assured AIR) and two additional classes (non-assured & best-effort) with lower priority. Fixed (or committed) class offers guaranteed bandwidth through static allocation of resources, while assured class offers guaranteed bandwidth through DBA algorithm as shown in Fig. 2.

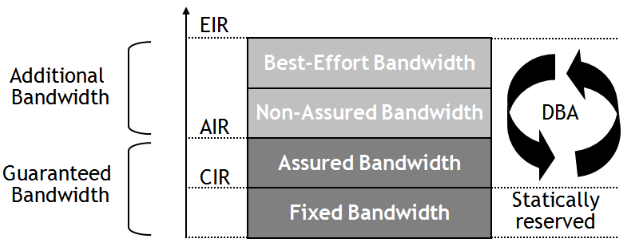


Fig. 2: GPON data traffic rates classes

In Table 1, the SLA parameters segregated into technology dependent and independent ones are shown. This matrix could be differentiated per CoS.

		Service Parameter Categories	
		Technology Dependent	**Technology Independent**
Service View	**Individual User View**	• Min Guaranteed (Fixed, Assured) Data Rate • Max Additional Information Rate • Max Packet Transfer Delay • Max Packet Jitter • Max Packet Loss • Max Bit Error Rate	• Min Availability Time • Max Time to Repair • Minimum Time Between Failures
	Aggregate View	• Mean Guaranteed (Fixed, Assured) Data Rate • Mean Additional Information Rate • Mean Packet Transfer Delay • Mean Packet Jitter • Mean Packet Loss • Mean Bit Error Rate	• Mean Availability Time • Mean Time To Repair • Mean time Between Failure

Table 1: SLA analysis matrix

IV. CONFES Optical & Dynamic Optical Resource Allocation Framework

The enhanced DBA capabilities of GPON can be exploited in order to best exploit the available capacity of a PON access network and increase its utilization allowing shared access to a number of users under different SLAs. However, what is even more challenging when considering enhanced services like mobile backhauling within the CONFES resource allocation framework is the capability of dynamic SLAs that can adapt to time varying load patterns at different time scales. Such traffic fluctuations are usual in current mobile networks providing high speed Internet access and multimedia applications to mobile users (Fig. 3). In this context cell utilization should be carefully planned using off-line as well as on-line optimization algorithms and the selection of appropriate SLA parameters to guarantee application QoS should be performed using automated tools.

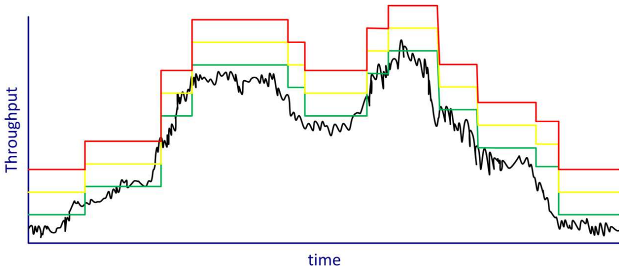


Fig. 3: Time varying data traffic profile that usually appears in mobile networks and relation to CIR, AIR and EIR ITU-T G.984.3 PON MAC parameters

Furthermore, an additional feature of PON technology serving as a wireless backhaul network is its capability to dynamically (re)configure resources per serviced segment (BS) and overcome the limitation of fixed provisioning (i.e. pre-assigning resources in a static manner), which leads to inefficient usage of network resources. What is missing from existing technologies in this scenario is the "tool set" that will enable what is called in the context of the CONFES vision capacity migration. Capacity migration can be triggered by statistically unlikely user behavior like massive spatial redistribution of user calls, rare events or even user/terminal driven decisions for hand-over based on specific QoS criteria etc. Such an example is depicted in Fig. 4. However, in the context of next generation networks such phaenomena will constitute expected networking conditions, when applications like cloud computing, multimedia peer-to-peer networks and other distributed applications coupled with high user mobility are gradually introduced in the provider's future service bundles.

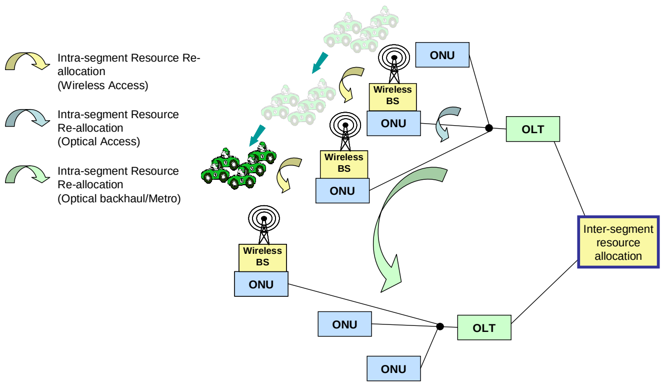


Fig. 4: CONFES Potential Capacity Migration Scenario

In order to accomplish this, two key-elements are needed: (i) appropriate management modules both at the base station side, as well as at the optical elements side; (ii) an appropriate protocol for transporting the base station backhaul resource requirements from the base station to the associated optical resource allocation module. The first key-element will be realized through the introduction and development of the ODORA management modules at the BS, ONU and OLT sides. The second key-element will be realized through the introduction and implementation of the Optimal and Dynamic Optical Resource Allocation Protocol (ODORAP). The conceptual overview of this proposed management functionality is depicted in Fig. 5 detailing the high level architecture shown in Fig. 1.

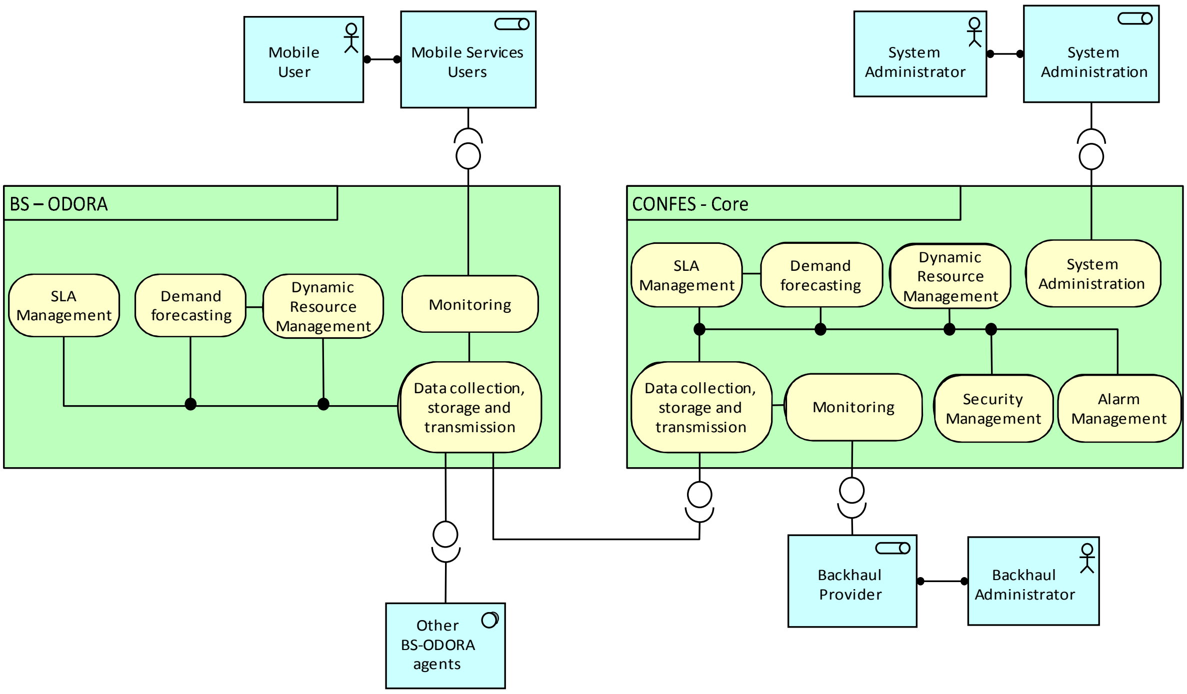


Fig. 5: CONFES Archimate® Architectural Description and Communication Interfaces

In essence, the BS-ODORA management module will be responsible for determining in real-time the backhaul resource requirements of the base station. This is feasible since the base station is aware of the traffic load that it handles on the radio interface, thus the required backhaul resources can be inferred, by properly matching the radio traffic load degree into a level/amount of required backhaul resources. Parameters associated to the base station's traffic load include the number of active sessions, the number of standby users (EPS-only), traffic demand, user priorities, requested Quality of Service levels, etc. The specifics of the implementation of this management module might differ for each type of RAN (Radio Access Network), e.g. between 2G/GPRS, UTRAN/HSPA and E-UTRAN, but, despite this fact, the BS-ODORA management module must in any case provide the same interface towards the ONU-ODORA management module, effectively hiding the implementation details. CONFES will also enable the BS-ODORA management module with traffic prediction functionality, based on historical traffic-load measurements and statistical data, which will allow for efficient proactive resource allocation management. Implementation will focus on the cases of UTRAN/HSPA and E-UTRAN.

Moving forward, the ONU-ODORA management module will be responsible for relaying the determined backhaul resources requirements to the OLT-ODORA management module, through the ODORAP protocol. The OLT-ODORA management module will process the requirements coming from multiple ONUs in order to produce an efficient resource allocation decision, which will affect the bandwidth that will be made available to each of the served ONUs. The ODORAP protocol is designed so as to convey the specified data between the ONU-ODORA and the OLT-ODORA management modules. Mechanisms for controlling the periodicity in which resource requirements updates are received by the OLT are also developed. Both periodic and on-request retrieval and transmission of resource requirements should be supported.

As with all signaling functions, the goal of CONFES is not to alter the main philosophy of the mobile network operations as specified by 3GPP, but rather to ensure 3GPP-compliant operation of the proposed converged network. This will eventually lead to faster development and reduced time-to-market. Session management, and Quality of Service (QoS) in particular, is an important operational aspect for 3GPP standards.

Such concepts towards converged network operation have appeared in the past either as protocol specific adaptations to support cross-layer optimization (e.g. [9]) or as generic mediation platforms based on some kind of middleware to support service creation over a different networking underlying infrastructures [10], [11]. However, the CONFES approach offers additionally the features for unified resource management and dynamic SLA negotiation enhancing resource utilization and contributing towards cost reduction.

V. The PON-ODORA Management System

As mentioned, the full exploitation of the multiplexing gain opportunity requires a much more elaborate BW management scheme than is warranted for the residential traffic. Therefore, a central issue in this environment is how to respond to the different timescales of the traffic change and for this two hierarchical levels are envisaged in the PON-ODORA unit of Fig. 1. One handles the pre-arranged SLAs and the slow long-term changes and the other handles the fast changes in an autonomic manner (Real-Time Measurement module) as shown in Fig. 1. The first objective of the new functionality is to let each operator have control of his side of the negotiation so the mobile operator will issue bandwidth requests and the PON operator will respond with what is in a position to satisfy. This way a service bandwidth framework will be established defining the upper and lower limits of the traffic agreement.

A. *Bandwidth Management Subsystem*

The CONFES architecture interacts with the underlay technologies (see Fig. 1) via the open North Bound Interfaces of each technology's Network Management System (NMS). The PON-ODORA performs management according to the FCAPS (Fault, Configuration, Accounting, Performance, Security) model [8], including the blocks of:

- (F) Alarm Management which handles the alarms collected by the Collection of Alarms & Statistics block
- (C) Configuration-reconfiguration of PON network
- (A) Accounting is partially supported by the Resource Management & SLA Management
- (P) Performance Management
- (S) Security Management

To achieve optimal usage of PON resources offering services on a pay per use model, the SLA initialization unit provides the initial requirements based on agreements between PON and business customers, MNOs, residential customers (depending on the region, the number of customers, etc.). The agreed SLAs are maintained in DBs, along with the data collected by the blocks of the FCAPS model.

Starting from the initial SLA requirements and utilizing the Long-term estimator and Real-time measurement based resource allocation units, the PON-ODORA performs a detailed exercise to determine the network resources needed on daily, weekly and monthly basis per customer category, type of service, geographical region and the respective (re)configuration in order to offer the customers the optimal QoS. Concluding on this exercise, the Resource Management system reserves the required resources and interacts with blocks of the SLA Management, Performance Management and Alarm Management monitoring to verify that the usage of the network resources does not violate the threshold set. The latter are strictly linked with SLA terms, and are based on the PON operator's business plan. In case a breach of SLA is identified (e.g. a threshold is exceeded, sudden increase of BS traffic, fiber cut, natural disaster in an area) the SLA Management block is triggered to take action.

Last but not least SLA Management is the heart of the Resource Management unit since it is responsible on one hand to check the SLA DB, and on the other hand to interact with the Real-time measurement and DBA block and other blocks of the PON network, and proceed with the appropriate actions for resolving traffic peak issues, so as to offer the guaranteed QoS to all customers. As soon as the appropriate action is concluded a real time (re)configuration of the PON network is triggered accordingly.

B. *The Resource management Subsystem*

The autonomic resource management subsystem at the heart of the CONFES core (PON-ODORA), shown in Fig. 6 is the Real-time measurement subsystem which carries out crucial traffic measurements and characterisation [12] and is based on the well-known concept of the Leaky Bucket (LB) embedded in a marking scheme [13].

The LB uses two parameters, the rate and the bucket size and in this case two such LBs are employed, one for the Peak Information Rate (PIR), which is the sum of CIR and EIR, with a small bucket size P (the size of about 5 average packet, i.e. about 5k bytes) and one for the CIR with a bucket size R (about 5% of the total ONU buffer size). These rates are set by the Resource Management subsystem. They may vary at different hours of the day or day of the week, based on historical data collected and kept in the historical DB. Flows constrained by the (CIR, R) LB set must always be served by the PON and they are counted as green. While not using their full rate, spare capacity can be used for other PON users.

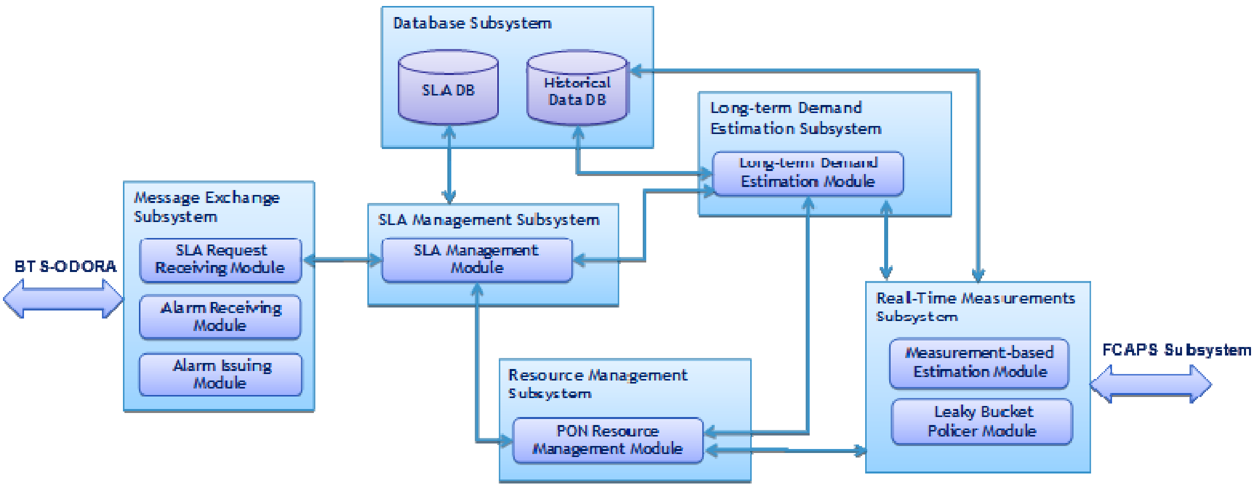


Fig. 6:The Resource management Subsystem

Packets exceeding the (CIR, R) LB but not (PIR, P) are counted as yellow and will be served only if spare capacity is available. Finally, packets exceeding the (PIR, P) constraint are counted as red and will be blocked. A detailed algorithm to estimate the (CIR, R) parameters of user flows and to translate them into negotiable SLA parameters is described in [14].

The real-time module obtains parameters from the SLA management module (which carries out the negotiations with the BS-ODORA via the message exchange subsystem) and reports back to it periodically and after certain events. When the number of yellow packets exceeds a threshold in any given hourly period, though not blocked (as are red packets) may trigger a renegotiation by the PON-ODORA towards BS-ODORA and new higher CIR and EIR may be agreed. This is decided by the long-term estimator. Similarly prolonged lower usage may lead to lowering the reserved BW. Foreseeable events that will require increased BW (e.g. games, festivals, concerts) in the vicinity of the station, can be manually programmed into the NMS and create new reservations of limited duration that are passed into the subsystem for monitoring. When first the BS-ODORA linking to the PON is commissioned, the initial SLA parameters can be tentative values defined by the MNO based on experience (historical data), but are gradually updated by the real-time measurements and in this fashion, the working profile of each BS is created per hour of the day, day of the week and/or even month of the year (useful for BS residing is summer holiday resorts, office areas, etc.). These data are kept in the historical DataDB and can be used in deciding and even predicting demand in the long-term estimator.

VI. The BS-ODORA Management System

The functional architecture of the proposed BS-ODORA Management System is depicted in Fig. 7, while the functionality of each identified module is described in what follows.

Intelligent Prediction System: At the MNO side as mentioned above the BS-ODORA agent in parallel implements traffic metering and intelligent forecasting functions to determine SLA conformance (verification) as well as potential SLA reconfiguration actions in case of either scheduled or unpredicted events.

The BS load estimator of BS-ODORA is executed independently from the PON-ODORA Resource Management unit, which is responsible for SLA acceptance procedures. BS-ODORA exploits the local information made available by the BS including: the number of cells, the active users per cell, active services per CoS per cell ($COUNT_{i,j}$), bandwidth profiles (in terms of committed $SG_{i,j}$, estimated average and excess rates), the available bandwidth ($TS_{MAX,i}$) and spectrum mask per cell. Based on these values a guaranteed R_G and additional non-assured R_E service rates can be requested by the PON calculated as:

$$R_{G,i,j} = COUNT_{i,j} \times S_{G,i,j}$$

and

$$R_E = \min\{\alpha \times R_{CUR,i,j} + \beta \times max(COUNT_{i,j}) \times S_{MAX,i,j}, TS_{MAX,i}\},$$

where the α, β factors can be selected through a combination of intelligent traffic monitoring and historical statistical data.

Conflict Resolution System: The Conflict Resolution System receives alerts by the Alert Receiving Module of the Message Exchange System and consists of two modules:

- The Resource Negotiation Module: When the PON is overloaded for a short period of time and is unable to satisfy the request for resources issued by the BS-ODORA module, the Resource Negotiation Module is responsible for negotiating a reduced amount of resources, leading to a degradation of the QoS experienced by some mobile users.
- The Handoff Triggering Module: In case the PON cannot satisfy the demand for the required resources, either due to overloading or other reason, the Handoff Triggering Module initiates an inter-OLT handoff procedure as a fall-back solution, in order to avoid the degradation of the QoS offered to mobile users.

Message Exchange System: The BS-ODORA agent is responsible for relaying the determined backhaul resources requirements to the PON-ODORA through the ODORAP protocol. This process is similar to the proposed X2-C interface 3GPP Release 8 Specifications “Load Indicator” procedure whose purpose is to allow an eNodeB to signal its load condition to neighbouring eNodeBs. The Message Exchange System (MES) is the system responsible for the communication of the base station with the PON, and it consists of three modules:

- The Alert Issuing Module: Its main responsibility is to receive alerts from the Intelligent Prediction System, when a significant differentiation between the short-term and mid-term traffic demand predictions is detected. After receiving an alert, it informs the PON and issues a request for extra resources.
- The Alert Receiving Module: The Alert Receiving

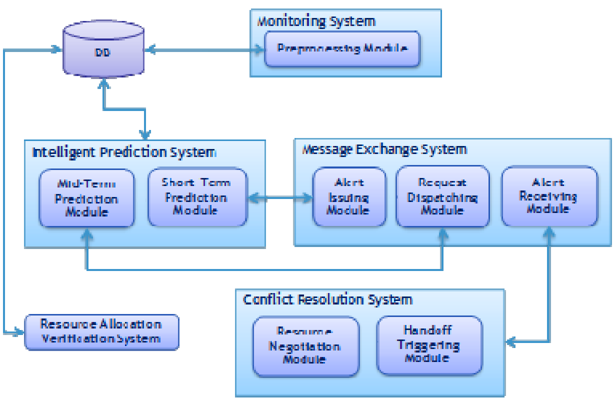


Fig. 7: BS-ODORA Functional Architecture

Module is responsible for receiving alerts issued by the PON, and informing the Conflict Resolution System accordingly.

- The Request Dispatching Module: This module retrieves the predicted resources demand from the Mid-term Prediction Module, and issues an appropriate request for resources to the PON.

Database: The Database is responsible for maintaining current network status at any given time as the later is provided the Monitoring System (MS). Thus, it keeps a record of the historical data of network conditions. Furthermore, it maintains the prediction performed by the Mid-term Prediction Module, as well as the short-term prediction provided by the Short-term Prediction Module, and the respective deviation. A record of backhaul resources allocated to the base station, as retrieved by the Resource Allocation Verification System, is also maintained in this database.

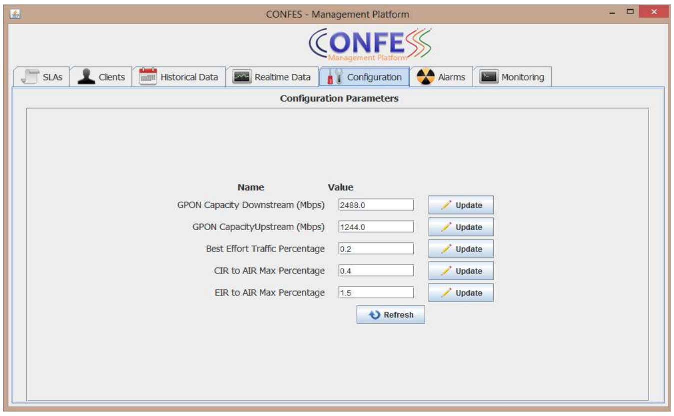
VII. CONFES IMPLEMENTATION

As mentioned above the CONFES system implements a distributed overlay architecture comprising a Core sub-system (PON-ODORA) where the overall SLA management is performed and multiple CONFES BS-ODORA Agents which provide all the required information needed for PON-ODORA to secure the optimal SLA management. The CONFES architecture interacts with the underlay technologies via the open North Bound Interfaces of each technology's Network Management System (NMS).

The deployment of a CONFES converged network requires the implementation the CONFES agents on the nodes of the wireless and PON segments. We have demonstrated the feasibility of this solution using commercially available modules that were integrated in the end-to-end CONFES scenario enhanced with the CONFES prototypes including the extensions to the Control and Management Planes. The CONFES modules were integrated on the Alcatel-Lucent Access Management System (AMS), which is designed to deliver a complete management solution for the Alcatel-Lucent ISAM product family, covering both DSL and fiber-based broadband access solutions. The AMS architecture allows a broader range of supported hardware and the use of secure protocols to communicate with the network elements that support these protocols. Interfaces to the OSS include both the legacy TL1 protocol as well as a new Web Services interface based on XML/SOAP. AMS is based on a state-of-the-art management platform, which is Java-based, modular and scalable, providing all the management needs for configuration, maintenance and troubleshooting operations. The AMS client is a separate software entity that runs either on a Windows-based PC or Solaris-based work-station. The 5520 client software is distributed from the AMS application server through an IP-link.

The AMS platform is completed by an additional set of Enhanced Applications (EA), which is a collection of products which include APC and SDC. APC (Access Provisioning Center) facilitates integration of service provisioning OSS to underlying access resources. SDC (Statistics and Data Collector) performs intelligent collection and dispatching of network data to performance and QoS applications. Network and service configuration can be achieved through ALU's open Northbound interface (XML, SOAP) that is used for service provisioning. In the open interface operations, the OSS client uses the templates created with APC GUI and can only specify the arguments.

The final objective is to integrate on this common CONFES platform the functional elements, resource allocation



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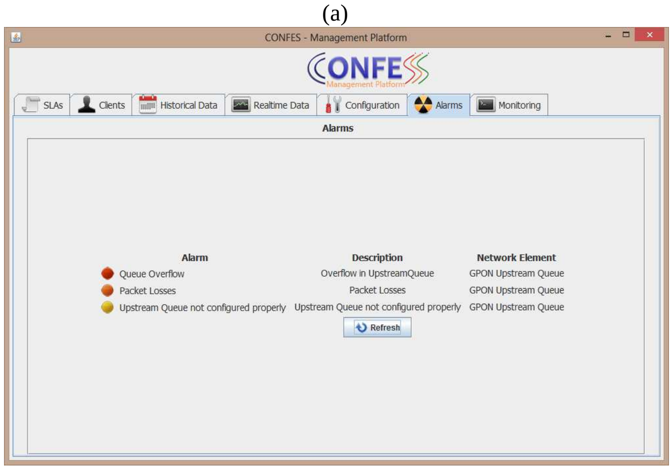
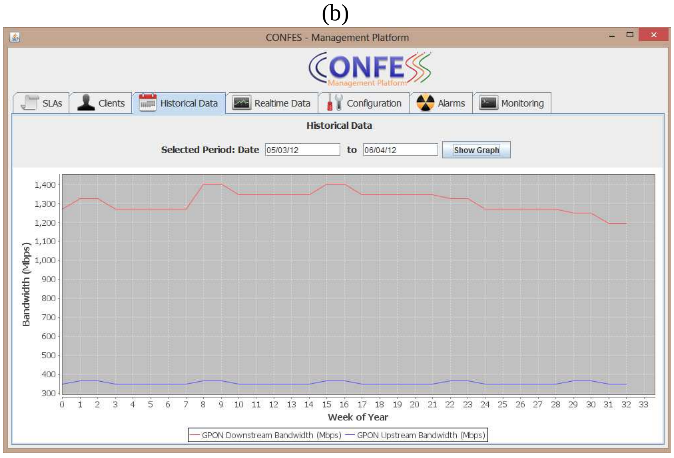


(b)



(c)

Fig. 8:CONFES core Graphical User Interface (GUI) – main management console views of (a) basic PON parameter configuration (b) alarm monitoring and (c) resource usage and historical data representation

algorithms and information exchange protocols in order to validate the concept and be able to conduct a number of evaluation scenarios that can lead to quantitative analysis of results. Experiments on the final demonstrator will be performed using both real services from use cases as defined by the service provider as well as with traffic patterns and measurement tools that will be developed. The integration of the CONFES ODORA agents into a unified resource allocation and monitoring framework enabling network convergence was performed as described above and a Graphical User Interface (GUI) was developed to improve user experience and allow network administrators to gain a better insight on the network operation. Indicative instance of the CONFES GUI are shown in Fig. 8. The CONFES GUI allows easy basic network configuration and parameter setup, SLA management, alarm and performance monitoring and statistics representation through different charts through a common platform.

VIII. CONCLUSIONS

The widespread deployment of PON systems for fixed communications comes at a time that mobile backhaul systems are stressed by the spreading of smart phones and the concomitant fast rise in data rates due to the introduction of next generation access network technologies. Thus, the use of PON for mobile traffic backhauling provides an opportunity that cannot be missed as it offers a smooth migration path both in technical as well as financial terms for both operators. To take advantage of the PON utilization potential without quality degradation, novel functionality is required which will monitor and coordinate the bandwidth management between the two operators to mutual advantage. The design and development of this functionality is the focus of the CONFES project and as shown in this work the use of traffic measurements, traffic prediction and optimized SLA handling can improve the service offered without the waste of static over-provisioning.

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