Multi-traffic capable DSLAM Design

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Abstract: The multiple revenue possibilities provided by the IP based networks stimulate the Internet Service Providers and Telecom Providers to move to ADSL Transport Networks that are entirely IP based. Ethernet/PPP traffic is also attractive because it provides authentication, security and accounting features. These types of traffic can become a common presence in ADSL networks by devising DSLAMs that are able to extract the IP and Ethernet traffic inside the DSLAM itself. The paper propose a DSLAM architecture that can accomodate a large range of deployments and uses advanced learning techniques to optimize its performances. A prototype of this architecture was implemented on a platform based on Intel IXP 2350 network processor and the obtained test results shows that the architecture is ready for a production implementation.

Key–Words: Communication Networks, Internet Technologies, Hardwired Communications, ADSL, traffic forwarding.

1 Introduction

Modern Internet Service Providers (ISPs) and Telecom operators try to benefit from the potential to access three revenue streams from a single IP packet network, triple-play systems comprised of voice, video and data are a common presence in the today IP networks. Also, PPP over Ethernet traffic is interesting because using it the clients can be authenticated and an efficient accounting policy can be implemented. However, many of them are still constrained to use the old telephonic line infrastructure due to its widespread and to the costs incurred by a replacement. ADSL ([7],[8]) is the *de facto* standard for data transmission over telephonic lines and, traditionally, ADSL was designed for centralised ATM (Asynchronous Transfer Mode) based networks. The paper proposes a new architecture for ADSL deployments that allows to accommodate both Ethernet and ATM traffic. The new capabilities are possible by adding intelligence in the design of the Digital Subscriber Line Access Multiplexer (DSLAM). The trend to add new capabilities to DSLAM units is fairly common in the current ADSL related research and development. For example, in [6], it was discussed the possibility that DSLAM to gain capabilities to detect traffic anomalies, a high importance features for ISPs that are confronted with serious loses due to malicious traffic. Also, DSLAM units with IP capabilities were discussed in [5] and [1]. Our approach of DSLAM unit is characterized by high performances, low costs, and it uses machine learning algorithms to optimize its results. Most important, a single unit can manage various types of traffic and can replace several equipments with different functions. If the Internet Service Providers can use a single type of equipment then their maintenance and personal training costs significantly drop.

The paper starts by providing a high level view of an ADSL based network followed by the description of the new architecture proposed for the DSLAM unit. We conclude with an implementation of a DSLAM prototype on an Intel IXP 2350 based platform and with a discussion of the obtained performances.

2 ADSL based networks

Asymmetric Digital Subscriber Line (ADSL) is a data communications technology that enables faster data transmission over copper telephone lines than a conventional voiceband modem can provide. It does this by utilizing frequencies that are not used by a voice telephone call. A splitter allows a single telephone connection to be used for both ADSL service and voice calls at the same time. At the central office the line generally terminates at a DSLAM where another frequency splitter separates the voice band signal for the POTS (Plain Old Telephone Services). Data carried by the ADSL is typically routed over the telephone company's data network and eventually reaches a conventional Internet network.

The overall structure of an ADSL based network is depicted in the figure 1 and the components are

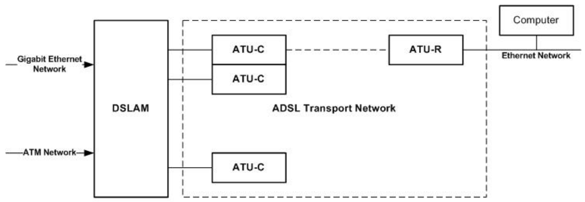

Figure 1: ADLS Network: Overall architecture

shortly described in the following paragraphs:

- *ATU-C* and *ATU-R*. An *ATU* (ADSL Transceiver Unit) is a device that provides ADSL transmission over the telephone line. The device at the telecommunication operator side is the *ATU-C* (Central), which is a line card plugged into the DSLAM. The unit at the customer's side is the *ATU-R* (Remote), which is either an external modem or a card plugged into the PC.

- *DSLAM*. A DSLAM (DSL Access Multiplexor) is a central office device for ADSL service that intermixes voice traffic and DSL traffic onto a customer's DSL line. It also separates incoming phone and data signals and directs them onto the appropriate carrier's network.

In the rest of the paper, the data traffic directed to the *ATU-R* and Customer Premise Equipments (CPEs) is called *downstream* traffic. The data traffic that has as source the *ATU-R* and is directed to the data transmission provider premises is called *upstream* traffic.

3 System Design

3.1 Protocol Hierarchies in ADSL Networks

ADSL networks can be used to carry different types of traffic. The most common protocols that are encountered in ADSL networks are presented in the figure 2 where a hierarchical representation is used to expose the relations between the involved protocols. There are two main types of traffic:

- IP based traffic. This traffic carries IP datagrams and the corresponding hierarchies of protocols are presented in the figures 2a), 2b), 2d) and 2f).

- Ethernet/PPP traffic. This traffic transports Ethernet frames and it is usually used by PPP based deployments. The hierarchies of protocols for this type of traffic are illustrated in the figures 2c) and 2e).

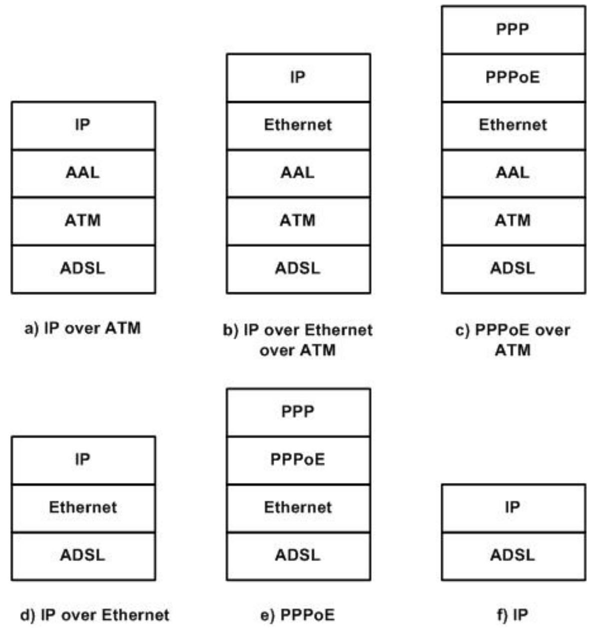

Figure 2: Protocol hierarchies used in ADLS Networks

3.2 DSLAM Architecture

Let us present the design of an intelligent DSLAM that can accommodate all types of traffic that were identified above and provides effective traffic forwarding methods. The architecture presented in Fig. 3 has two processing chains, one for IP datagrams and one for Ethernet frames. These chains correspond to the two main types of traffic identified in the section 3.1 and have two components that perform the following tasks:

- Adaptation Layer connects DSLAM to a broadband network, Ethernet or ATM, and makes this network transparent for the ADSL network.

- Forwarder sends the traffic to the appropriate ATU-C on the appropriate channel.

For Telecom and Internet Service Providers, this solution assures an unified and integrated setup for all types of network deployment, centralized management, and simplified procedures for maintenance and personal training.

3.3 DSLAM Forwarder Designs

The main contribution of this paper is proposal of architectures for two DSLAM forwarder units that extract the IP and Ethernet traffic inside the DSLAM itself. Consequently, the traffic inside the ADSL transport network depicted in figure 1 will be entirely IP

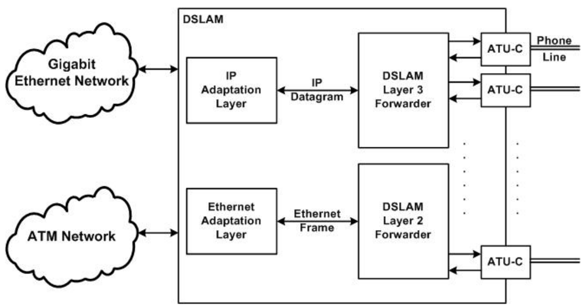

Figure 3: DSLAM overall architecture. The design can accommodate several types of traffic.

or Ethernet based. This approach is different from the traditional DSLAMs, which use ATM technology to connect to upstream ATM routers/switches, and assures lower capital expenditure and operational expenditure and a richer set of features and functionality.

3.3.1 DSLAM Layer 3 Forwarder

The most of the functionality of the *DSLAM* is accomplished by the *DSLAM Forwarder* units. This section considers DSLAM Layer 3 Forwarder, an unit that performs the following main tasks:

- Selects the appropiate *ATU-C* units for the IP datagrams received on downstream by performing a *layer 3 switch* functionality.
- Acts as a *DHCP Tagging Agent* to manage the DHCP traffic issued by CPEs.
- Identifies the channels in *ATU-C*s that will be used to transmit the *downstream* IP datagrams.

The architecture of the *DSLAM Layer 3 Forwarder*, presented in figure 4, includes three main blocks, *Layer 3 Switch*, *DHCP Tagging Agent* and *Channel Selection*, one for each above mentioned tasks.

IP datagrams received on *downstream* from *IP Adaptation Layer* are processed in accordance with the algorithm 1. Similarly, the algorithm 2 describes the processing of the IP datagrams received on *upstream* from *ATU-C*s.

3.3.2 DSLAM Layer 2 Forwarder

This forwarder must process Ethernet frames that transports PPP traffic in accordance with [3]. The next paragraphs will presents the basics of the PPP traffic in order to better understand the DSLAM Layer 2 Forwarder functionality.

PPP deployments include an *Access Concentrator* that closes PPP traffic at ADSL network level.

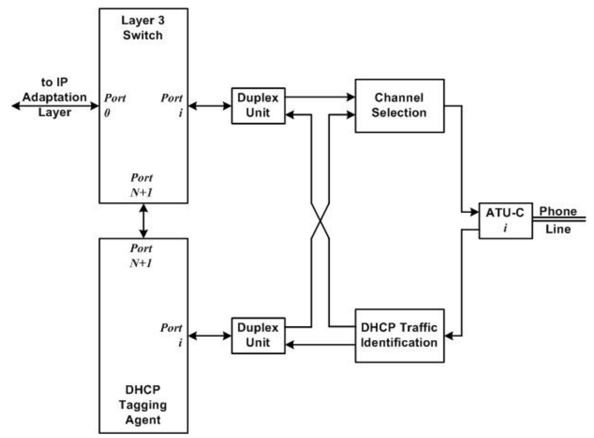

Figure 4: DSLAM Layer 3 Forwarder: Structure and data flows diagram.

PPP based communication is composed from standard messages exchanged between users' terminals and *Access Concentrator* and has two stages: *Discovery* and *Session*. During *Discovery*, the terminal equipment gain access to the network through a selected *Access Concentrator*. In this process, the terminal equipment is authenticated and retrieves the parameters of the services that it can access. *Session* is the stage where data transfer is accomplished.

A typical *PPPoE* message includes the following fields that are analyzed by the *DSLAM Layer 2 Forwarder*:

- Ethernet MAC Destination Address (6 bytes);
- Ethernet MAC Source Address (6 bytes);
- Ethernet Type (2 bytes);
- Ethernet Payload including: Code (1 byte), Session ID (2 bytes), Length (2 bytes), *PPoE* Payload (variable size).

In *Discovery* stage, *PPPoE* traffic is identified by the value 0x8863 for the Ethernet type field. Similarly, the value 0x8864 in the Ethernet type field identifies the *Session* stage. During *Discovery*, the following four types of messages are exchanged:

- PADI (PPPoE Active Discovery Initiation) represents the broadcast messages sent by terminal equipments to find an *Access Concentrator*. This type of messages is identified by the pair (CODE=0x09, Session ID=0x0000).
- PADO (PPPoE Active Discovery Offer) represents the unicast messages sent by *Access Concentrator* to announce itself. These messages

Algorithm 1 Downstream IP datagram processing inside DSLAM Layer 3 Forwarder

1: **if** IP datagram contains DHCP traffic (DHCP Offer, ACK, NACK, Force renew) **then**
2: *Layer 3 Switch* forwards the IP datagram on the port $N+1$ to *DHCP Tagging Agent*.
3: *DHCP Tagging Agent* establishes *ATU-C* unit that should receive the DHCP data, changes the IP datagram and forwards the resulted datagram on the port that corresponds to the identified *ATU-C*.
4: **else**
5: *Layer 3 Switch* identifies the *ATU-C* that should receive the IP datagram (identification is based on the IP destination address from the IP datagram) and forwards the datagram on the port that corresponds to the identified *ATU-C*.
6: **end if**
7: *Channel Selection* module attached to the *ATU-C* takes the received IP datagrams and performs a classification process in order to find the appropiate channel to transmit data to *ATU-R*.

are identifies by the pair (CODE=0x07, Session ID=0x0000).

- PADR (PPPoE Active Discovery Request) represents the unicast messages sent by terminal equipments that request to start a *PPPoE* session. These messages are identified by (CODE=0x19, Session ID=0x0000).

- PADS (PPPoE Active Discovery Session-confirmation) includes the unicast messages sent by *Access Concentrator* to indicate the service parameters for an accepted *PPPoE* session. For these messages, CODE=0x65 and $Session\ ID \neq 0$ is a value assigned by *Access Concentrator* to uniquely identify the *PPPoE* session.

Session stage begins when a *PPPoE* session is established. *PPP* data are sent encapsulated in *PPPoE* unicast messages. These messages have CODE=0x0000 and *Session ID* must not change for the entire *PPPoE* session and must be the value assigned in the *Discovery* stage.

The architecture of the *DSLAM Layer 2 Forwarder* is exposed in the figure 5 and the functionality is described by the algorithms 3 and 4.

Algorithm 2 Upstream IP datagram processing inside DSLAM Layer 3 Forwarder

1: **if** IP datagram contains DHCP traffic (Discover, Request, Inform, Decline) **then**
2: *DHCP Splitter* forwards the datagram to *DHCP Tagging Agent* unit.
3: *DHCP Tagging Agent* sends the datagram on the port $N+1$ to the *Layer 3 Switch* unit.
4: **else**
5: *DHCP Splitter* forwards the datagram to the *Layer 3 Switch* unit.
6: **end if**
7: *Layer 3 Switch* unit forwards the IP datagram on the port 0 to the *IP Adaptation Layer*.

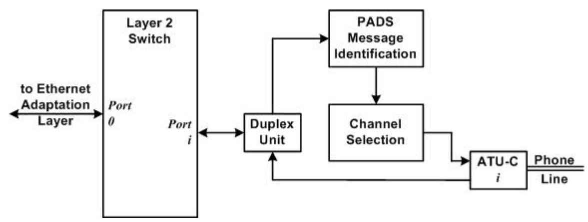

Figure 5: DSLAM Layer 2 Forwarder: Structure and data flows diagram.

3.4 Channel Selection Algorithm

An *ATU-C* unit has several channels denoted by AS_0,...,AS_3,LS_0,..,LS_2 that can be used to carry data to the correspondent *ATU-R*. The channel to be used is identified by analyzing the fields included in the received IP datagrams or in the received Ethernet frames. The values of these fields are matched with the preconditions of the rules from a predefined set. If a rule that matches is found then conclusion of the rule identifies the channel, which will be used to transmit data, and also the type of the processing path (fast or interleaved). In order that the classification rules to be efficiently processed, they are organized into a decision tree structure by the adaptive algorithm described in [4]. It should be mentioned that, for the Ethernet/PPP traffic, if a *Session ID* is available then *Channel Selection* can use it to find directly the appropriate channel.

4 DSLAM Implementation

The new functionality of the proposed DSLAM unit requires more computational power and memory resources than a conventional DSLAM unit. Consequently, for implementation was chosen a platform

Algorithm 3 Downstream Ethernet frame processing inside DSLAM Layer 2 Forwarder

Layer 2 Switch identifies the destination *ATU-C*.
Duplex unit forwards the packet to the *PADS Message Identification* block.
if *PADS Message Identification* detects a *PADS* message **then**
    Extract *Session ID*
end if
Forward all data including *Session ID* if available to *Channel Selection* block.
if *Channel Selection* receives a *Session ID* **then**
    Session ID directly identifies the corresponding *ATU-C* channel.
else
    Channel Selection executes a search algorithm to find the *ATU-C* corresponding channel based on the packet fields.
end if

Algorithm 4 Upstream Ethernet frame processing inside DSLAM Layer 2 Forwarder

Duplex unit forwards the upstream data to *Layer 2 Switch* unit.
Layer 2 Switch sends the data to the *Ethernet Adaptation* unit.

based on Intel *IXP 2350* networks processor. This processor, whose schema is presented in figure 6, features 5 computational units: one XScale unit suitable for general purpose computing and 4 microengines that are designed for fast data path processing. *Channel Selection* units that have a more complex logic were placed on XScale. *Layer 3 Switch* unit and *DHCP Tagging Agent* units are running mostly on microengines and only the exception IP datagrams are treated on XScale, as is presented in the deployment diagram from figure 7. The communication between XScale and microengines is assured by the fast dual port MSG-SRAM memory. Here, it should be mentioned that *Layer 3 Switch* should maintain a table of learned IP addresses and should be able to perform fast searches on this table. In order to achieve these objectives, the table of IP addresses was organized as a fast hash table using a structure described in [2]. *Layer 2 Switch* is implemented in same way but it stores MAC addresses instead of IP addresses. In this way, the proposed architecture can take advantages of the different types of memories that are available on *IXP 2350*. QDR-SRAM memory, which is faster, stores the hash keys used during searches, and

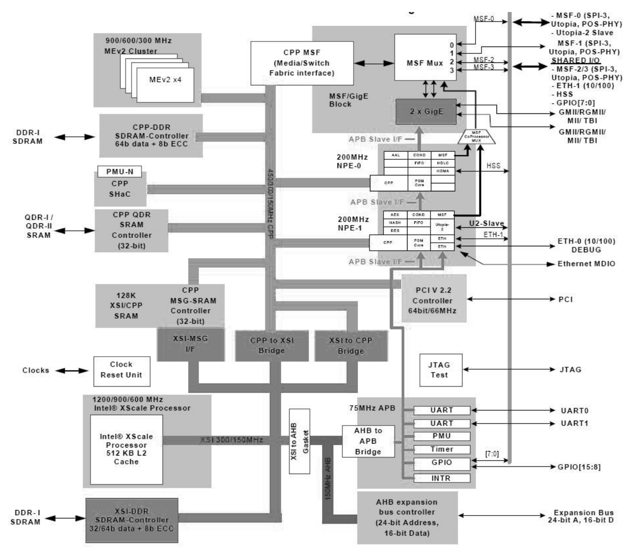

Figure 6: Intel IXP 2350 block diagram.

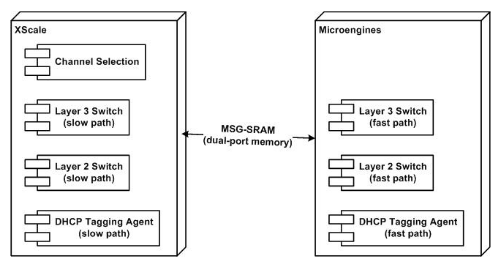

Figure 7: DSLAM Implementation deployment diagram. Most of the IP datagrams are processed only by the fast path components of Layer 3 Switch and DHCP Tagging Agent. The slow path components of the aforementioned units only considers the exceptional cases.

CPP-DRAM memory, which is slower, stores the full IP addresses and the index of the associated *ATU-C*.

The performances of the proposed architecture are illustrated in the diagrams from the figures 8, 9, 10 and 11 (the measurements were performed by using the dedicated tools from the Intel IXA 4.3 SDK). It can be observed that the architecture has low computational and memory requirements regarding to the capabilities of the Intel IXP 2350 platform. Consequently, new functionality can be added to DSLAM with no danger that an excesive load of the platform to appear.

5 Conclusion

The paper proposes an architecture of a modern DSLAM for ADSL networks that can accommodate both Ethernet and ATM traffic and supports all com-

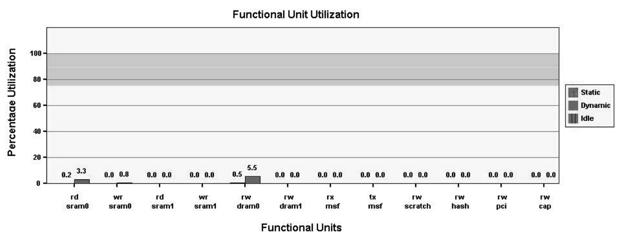

Figure 8: Utilization of the memory zones of the Intel IXP 2350 chipset is under 6%.

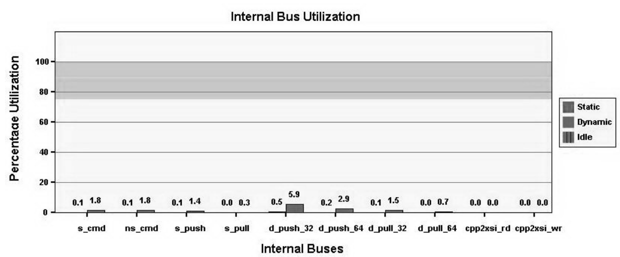

Figure 9: Utilization of the IXP 2350 internal buses is under 6%.

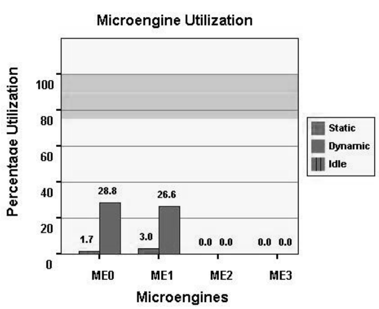

Figure 10: Microengines usage is under 30%. ME0 is used for the egress path and ME1 by the ingress path. ME2 and ME3 are not used by our DSLAM implementation.

mon types of deployments. This architecture allows to *ISP*s to gain the revenues provided by the IP based networks, that can carry voice, video and data traffic and still to use the old telephonic line infrastructure. Ethernet/PPP traffic is also possible with is inherent authentication and accounting benefits. A prototype of the system was implemented on a platform based on the Intel *IXP 2350* network processor. The gathered performance results show that the proposed architecture is ready for a production implementation.

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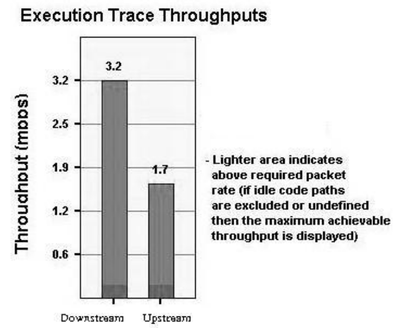

Figure 11: Throughputs for the unicast data traffic (ingress and egress). Throughputs are measured megabytes per seconds. The traffic was composed from 64 bytes IP datagrams and 78 bytes Ethernet frames.

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