Modelling ADSL with IP and ATM Performance Study

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Abstract
This paper describes ADSL (Asymmetric Digital Subscriber Line) simulation model developed using COMNET III. ADSL is integrated with IP (Internet Protocol) and ATM (Asynchronous Transfer Mode) in order to provide QoS (Quality of Service). Using this model, a comparison study between networks using IP over ATM over ADSL and IP over ADSL is provided.

I. Introduction

Internet private users are not connected directly to high-speed backbones. Most private users are connected to ISPs (Internet Service Providers), via normal copper telephone lines with a maximum data rate of 56.6 Kbps by analogue modem. The Internet services nowadays include multimedia sources requiring more "bandwidth". Digital Subscriber Line (DSL) is a technology that solves the bottleneck problem, occurring in the "last mile" of the network between Network Service Provider (NSP) and users, DSL improves bandwidth (up to 52 Mbps) using ordinary telephone lines, but bandwidth is not guaranteed [1]. QoS features are an integral part of ATM; this switching technique predefines a connection with QoS parameters constant over the complete connection time. However, IP, the quasi standard on the web, provides a connectionless best effort delivery service. This means that IP's datagram based packets are not suited to real-time traffic. The integration of IP over ATM over DSL, could be the solution towards a high-speed network for private users by ordinary telephone lines, providing a connection with Quality of Service guaranteed. Within the following sections simulation models developed using COMNET III is presented in order to study the integration of xDSL, ATM and IP [2]. Results and conclusions are also given in the last section.

II. Simulation Modeling

Modeling ADSL. ATM can be modeled directly as a transport protocol in COMNET III. The different type of services like CBR (Constant Bit Rate), VBR (Variable Bit Rate), etc. are simulated by setting the basic transport protocol parameters and the parameters of the rate control function to appropriate values according to the traffic descriptors of the service been modeled. A session source is used to describe the application data in terms of its Inter arrival Time (IaT), its message size, destination, etc [3]. IP over ATM can be modeled directly using the transit network building block, available on COMNET III, this building block would represent the ATM backbone. Instead of specifying the ATM transport protocol parameters at a traffic source, they are specified at the transit network details. The source would take on the parameter set of the TCP/IP protocol. It is possible to simulate ATM services [4] by using multiple service classes, different classes of packets can be transmitted to the same destination using different protocol parameters.

Modeling ATM over ADSL. To integrate ATM over ADSL, a link with variable bandwidth should be used, because ADSL bandwidth is not constant. ADSL can't be modeled directly because no point-to-point link offering variable bandwidth exists in COMNET III. One possible solution is to use a Virtual Circuit object available on COMNET III to constrain the burst size to a limit and to represent the maximum bandwidth available of an ADSL connection. The primary purpose of these objects is to specify the burst constraints for traffic on these VCs. Burst sizes are measured with a leaky bucket algorithm. The leaky-bucket burst is the amount of data accepted by the virtual circuit for the previous interval of time [3].

The virtual circuit uses the burst size calculation to determine how to handle a frame entering the network from an access link. If the frame would result in the burst is over the *committed burst size* plus *excess burst* size, then the virtual circuit will immediately drop the frame. (This feature represents the maximum bandwidth of an ADSL connection.) If the frame results in the burst size being over the committed burst size, then the frame will be marked *Discard Eligible* (DE), otherwise, the frame is marked normal. The DE or normal frame will be successfully transmitted to the exit access link [3]. There is one separate VC for the upstream and downstream channels to simulate the asymmetric character of ADSL. Figure 1 shows the model that was used to verify the results between COMNET III and ADSL-ATM features. It is a layered model, which consists of one client and one corresponding server. Both nodes are connected to a transit network with the name "ADSL-ATM" to integrate the features of ATM in this model. Using the "Client Request" source the client generates a request, which is sent via the "telephony line" to the server, which answers with the "Server Respond" source. CBR is the used protocol. Values like message size and (IaT) Inter arrival Time of the two sources are not the most important. Both sources should only send "enough" messages constantly, and the message size has to be "big enough" such that VCs reach the maximum bandwidth. VCs cannot exist on their own in a transit network. One solution is a WAN cloud named "ADSL" within a transit network. However, in COMNET III VC must be connected to a link. Because of this, "Link 1" and "Link 2" are present in this model. These links must be

connected to an "Access Point". The link parameters in this model should not interfere "too much" with the simulation, so they are set up with "default" parameters, which means that for example the bandwidth and buffer size are unlimited. The WAN itself cannot be connected directly to the "Access Points" of the transit network. Point-to-point links ("Client Link", "Server Link") and routers ("C Router", "S Router") have to be used within COMNET III to couple the cloud to the active nodes. Once again, these nodes are set up with "default" parameters in order to not interfere with the simulation.
To simulate an ADSL connection with bandwidth between 700 kbps and 1,500 kbps [6], it is found that Virtual Circuit parameters should be as follow: the Committed Burst Size (CBS) parameter gets the value 800 kb, the Excess Burst Size (EBS) parameter gets the value 700 kb and the Committed Info Rate (CIR) parameter as the minimum of the bandwidth range (here: CIR = 700 kb). This has the advantage that no frames under the minimum transmission rate are marked Discard Eligible (DE) in the ATM network and hence not dropped.

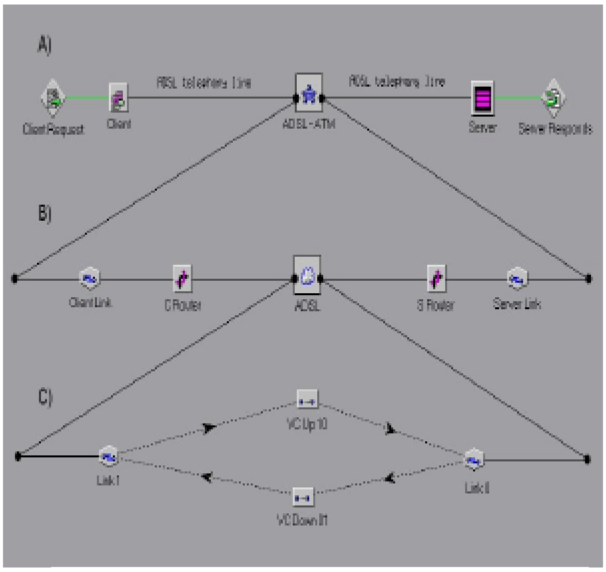

FIGURE 1: Layered Model of DSL-ATM

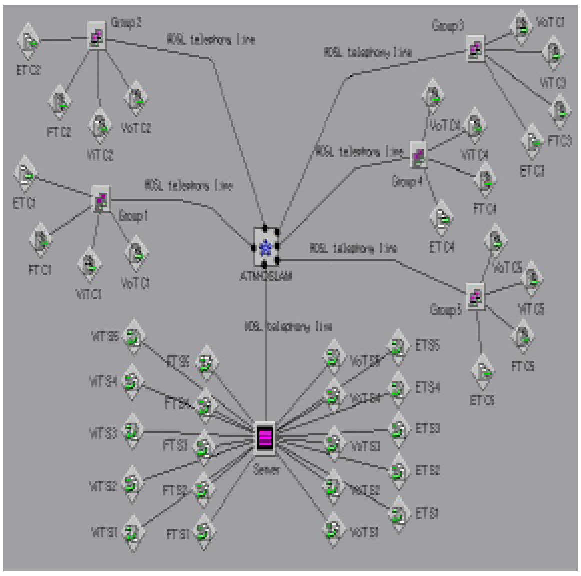

FIGURE 2: IP over ATM over ADSL

The simulation evaluates QoS features like end-to-end delays, utilization, burst size and frames lost in a network using IP and ADSL with and without ATM [7]. The designed model provides end users with an ADSL connection to the Central Office (CO). The CO is represented by the transit network with the name ATM-DSLAM in the middle of the picture and connects the server via a VDSL line to the Digital Subscriber Access Multiplexer (DSLAM). This is a CO device used to aggregate data traffic from many DSL subscribers into one high-speed signal for hand-off to the datacom network. Model includes five clients (Group 1, … , Group 5) and one server. Both types are modeled as COMNET III Computer & Communication nodes with their default values.

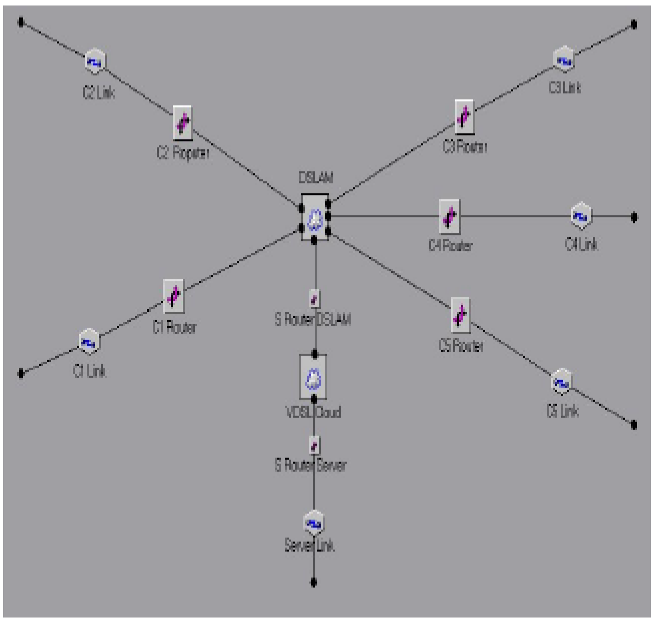

FIGURE 3: Transit Network

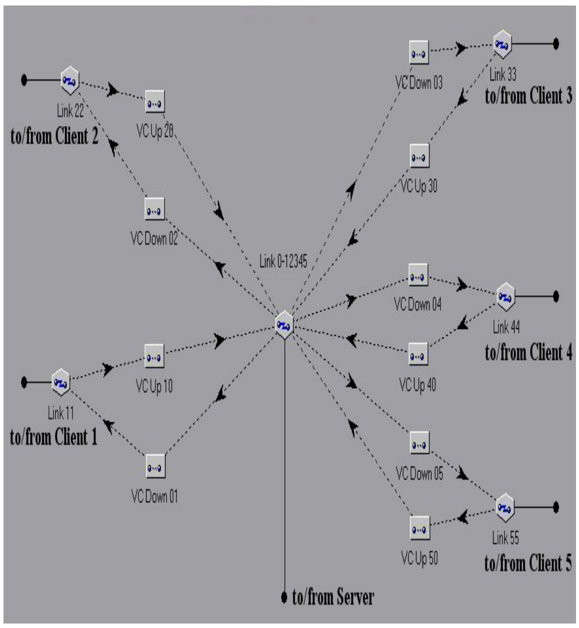

FIGURE 4: DSLAM for 5 clients

Modeling of IP over ATM over ADSL. Each client is hooked up to four different traffic sources including different service classes to represent the remote traffic in the network. The server includes the matching traffic sources. Session sources are used to reflect the connection-oriented nature of ATM for CBR service applications (e.g. Voice Transfer (VoT)), VBR service applications (e.g. Video Transfer (ViT)) and Available Bit Rate (ABR) service applications (e.g. File Transfer (FT)). The ATM-DSLAM in the model represents the Transit Network in the Figure 2. In this Transit network DSLAM element is shown in figure 3.

Each data source uses TCP/IP on top of ATM and ADSL, or only ADSL. TCP/IP is used to reflect the "quasi standard" on the web. Every different service application gets another network service level. With this information, the transit network knows which service category must be used inside the transit network. During simulation the traffic will be segmented into TCP/IP packets at the source. Upon arrival at the transit network these TCP/IP packets will then be further segmented into ATM cells following the chosen service class.

The VCs represent the upload and download paths from the ADSL connection. The download path offers a bandwidth between 700 kbps and 1500 kbps. This means that *Committed Info Rate* (CIR) is set to 700 kbps, *Committed Burst Size* (CBS) is chosen as 800 kb and *Excess Burst Size* (EBS) gets the value 700 kb. The upload link offers a bandwidth between 300 kbps and 700 kbps (CIR=300kbps,CBS=400kb and EBS=300 kb). The VDSL connection offers 30 MB for the download and 6 MB for the upload. These parameters are chosen very high because they should not represent a bottleneck.

Each of the data sources is programmed to transmit messages exponentially, with a mean size of 5,000 bytes, 10,000 bytes, … , 35,000 bytes and interarrival time (IaT) exponentially distributed with a mean of 1 second. All traffic in the model is symmetric between the clients and the server. For a more realistic integration of ATM service categories, additionally priorities are given to the sources. CBR gets the highest priority, followed by VBR, ABR and UBR.

Types of data traffic. The Voice Traffic (VoT) has constant rate control parameters for CBR are 64 kbps PCM shaped by the leaky bucket algorithm. Video Traffic (ViT) or Video-on-demand with its asymmetric character is a possible application for this model construct. The video packets are transmitted across the ATM network using the VBR service class. The variable rate control parameters for this service class is Peak Cell Rate (PCR), Sustainable Cell Rate (SCR) and Minimum Cell Rate (MCR). The ADSL download path offers a maximum of 1,500 kbps. The VoT uses 64 kbps. This means that the PCR for the download can be a maximum of 1,436 kbps (= 1,500 kbps – 64 kbps). The PCR for the ADSL upload path is 636 kbps (= 700kbps – 64 kbps). The SCR is half of the PCR. Half was chosen because ViT and File Transfer (FT) have to share the remaining bandwidth.

The used COMNET III model is in contrast to the message size changing steadily to see the reaction of the model. All traffic parameters stay constant, as the bandwidth offered by the link is not changed. Greater message sizes mean a longer transmission time. The File Transfer (FT) also originates at every computer group. Again, the destination is always the server, which answers to the request with the corresponding respond source. FT is a typical example for ABR. Table 1 summarizes the traffic parameters used in the model.

Service Class (ATM Adaptation Layer)	PCR (kbps) down/up	MCR kbps down/up	SCR kbps down/up
CBR (AAL1)	64/64	-/-	-/-
VBR (AAL3/4)	1436/636	0/0	0/0
ABR (AAL5)	1436/636	1/1	-/-
UBR (AAL5)	100/100	-/-	-/-

TABLE 1: ATM network service parameters.

Two different modes of the same model should be compared, on the one hand, the *IP ATM ADSL* (IAA) network with its ATM features and on the other hand the pure *IP ADSL* (IA) network without any QoS features. The keys for deleting the ATM features are the service network levels, which are defined in every link. Additionally, a TCP/IP service category is added to ATM service categories. Using these categories TCP/IP packets will stay alive within the transit network and are not segmented into ATM cells.

III. Results and conclusions

The message sizes of the FT, ViT and VoT are varied in the model, in order to "measure" some QoS features, the following values are used: 5k, 15k, 25k and 35k bytes. The results for packet delay response, of the different services modelled were reported in [2], it was found that real time services (VoT and ViT) have less maximum packet delays in the IAA network, than FT. The reason for higher delays for non real time service (FT) is the fact that this service uses ABR with a lower priority. Another QoS feature is the utilisation of links. Table 2 shows the results of links within the WAN cloud. "Links 11" to "Link55" and the Virtual Circuits (VC) represent the ADSL integration. "Link 0-123452" represents the DSLAM. The utilisation is time-averaged over

the replication, where at each event, the utilisation is the number of busy circuits divided by the total number of circuits [2].
Utilisation of the IAA network model is lower than the IA network model. The average utilization in IAA is 30%, this is three times less than the average utilization of IA network model (90%).

Access Link	5k IA	5K IAA	15K IA	15K IAA	25K IA	25K IAA	35K IA	35K IAA
Link 0-12345 entry	0.36	0.1	0.35	0.1	0.21	0.05	0.14	0.03
exit	0.27	0.23	0.42	0.36	0.42	0.36	0.42	0.36
Link 33 entry	90.88	20.18	99.98	31.98	99.98	31.86	99.98	31.77
exit	13.88	8.17	3.38	8.19	2.6	4.77	2.39	2.37
Link 22 entry	22.08	20.2	98.21	30.88	99.53	31.87	99.64	31.78
exit	7.68	8.58	12.31	7.78	7.88	4.48	4.68	2.15
Link 11 entry	19.32	19.84	99.36	32.0	99.98	31.89	99.98	31.82
exit	6.84	8.25	12.46	7.68	6.18	4.6	4.35	4.00
Link 44 entry	98.5	22.08	99.98	32.14	99.98	31.89	99.98	31.86
exit	14.1	9.28	3.98	8.87	3.31	3.66	2.39	1.91
Link 55 entry	17.24	15.84	96.87	26.74	99.76	27.69	99.66	27.42
exit	5.51	6.04	15.13	6.02	8.19	3.24	4.62	2.54

TABLE 2: Access link utilisation 5 kb, 15 kb

The number of dropped frames is related to link utilisation, lower link utilisation means less dropped frames. The link utilisation in the IAA network model is always less than 32% with no frames being dropped (Table 3).
The simulated models have shown clearly the advantage for real time services when ATM was integrated into *IP ADSL* (IA) networks. Using higher message sizes (15,000 bytes, 25,000 bytes and 35,000 bytes) the results are much better for IAA networks and real time applications.

Cloud: Access Link		Frames 25 000 bytes				Frames 35 000 bytes			
		Accepted		Dropped		Accepted		Dropped	
		IA	IAA	IA	IAA	IA	IAA	IA	IAA
Link 0-12345	Entry	46596	733997	0	0	43277	288879	0	0
	Exit	37282	259277	0	0	35308	158320	0	0
Link 33	Entry	6792	53202	5855	0	6722	32567	5900	0
	Exit	8375	16992	0	0	8324	5296	0	0
Link 22	Entry	7911	53221	7478	0	7342	32542	6536	0
	Exit	10040	15972	0	0	8935	4494	0	0
Link 11	Entry	7607	53262	6941	0	7320	32587	6386	0
	Exit	9480	16392	0	0	8869	944	0	0
Link 44	Entry	6941	53268	6170	0	6629	32691	3027	0
	Exit	8643	13061	0	0	8295	4527	0	0
Link 55	Entry	8031	46324	7351	0	7295	27933	6467	0
	Exit	10058	11580	0	0	8854	5129	0	0

TABLE 3: Accepted, dropped frames of access links, 25 kb, 35 kb.

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