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The Implementation of the CPS Scenario

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The Implementation of the CPS Scenario

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1 Introduction

Pricing schemes form the essential part of a business model for Internet Service Providers (ISP). A pricing scheme applied to the transport of data in an IP network needs to cope with a number of issues of the IP technology utilized as well as with ISP’s economic requirements and goals.

The Cumulus Pricing Scheme (CPS) [7] proposes a paradigm shift and argues that the problem of Internet pricing is not a matter of complexity, but instead a problem of mapping multiple and multi-dimensional time-scales. The developed scheme shows a simple, transparent, market-managed, and feasible Internet pricing scheme[1].

CPS is a flat rate scheme founding on SLA contracts between customers and ISP, whereby the customer may be an ISP. It provides individual and dynamic adaption of flat rates on long-time scales due to SLA contract violations or renegotiations. The compliance of the contract is motivated and supported by a feedback mechanism, the Cumulus Points (CP), and the liberty for deviations on short-time scales, due to statistical metering and average CP accumulation mechanisms [13], [14], [15]. With respect to the contract and its technical parameters, CPS offers in its basic concept no dedicated metric to be applied solely, although the volume and the bandwidth a user may utilize during communications states a well-known example.

The CPS scenario has been developed, implemented, and experienced with. Since CPS determines a new idea, additional conceptional and theoretical topics are under detailed investigation. This concerns mainly the process of gathering knowledge and experiences in contract metrics, i.e. contract terminology and contract negotiation. Furthermore, heuristics are collected with the intention to define appropriate stimuli and parameter for a simulation initialization and a detailed scenario definition.

This document presents the fine design and implementation of the CPS scenario and presents those details on how it can be embedded into the Charging and Accounting System (CAS) [17] developed within the M3I project. After that an overview on the networking environment is given on which experiments have been running. The experiment setup and component configuration is described step by step. Finally, results from these experiments are presented and discussed.

2 CPS Fine Design and Implementation

The fine design of the Cumulus Pricing Scheme (CPS) scenario for the M3I project follows the design dimensions outlined in [16]. The following section gives an overview on how CPS can be embedded in the CAS architecture. After that the development environment for the CPS implementation is presented and the implementation is described in detail.

2.1 Overview

The Charging and Accounting System (CAS) [17] developed within the M3I project provides a generic and modular charging system in support of various pricing schemes applicable to different communication technologies [12], [15]. Figure 1 gives an overview on how the

1.In M3I terminology [10], the developed scheme is determined by all features of a tariff scheme. However, for comparisons with “traditional” Internet “pricing work”, the older and less precise term has been utilized. Pricing Mechanisms, as described in [6], are applicable.

CPS scenario can be adapted to the CAS. It is important to note that the CAS doesn't have to be changed for that purpose, it is scenario independent.

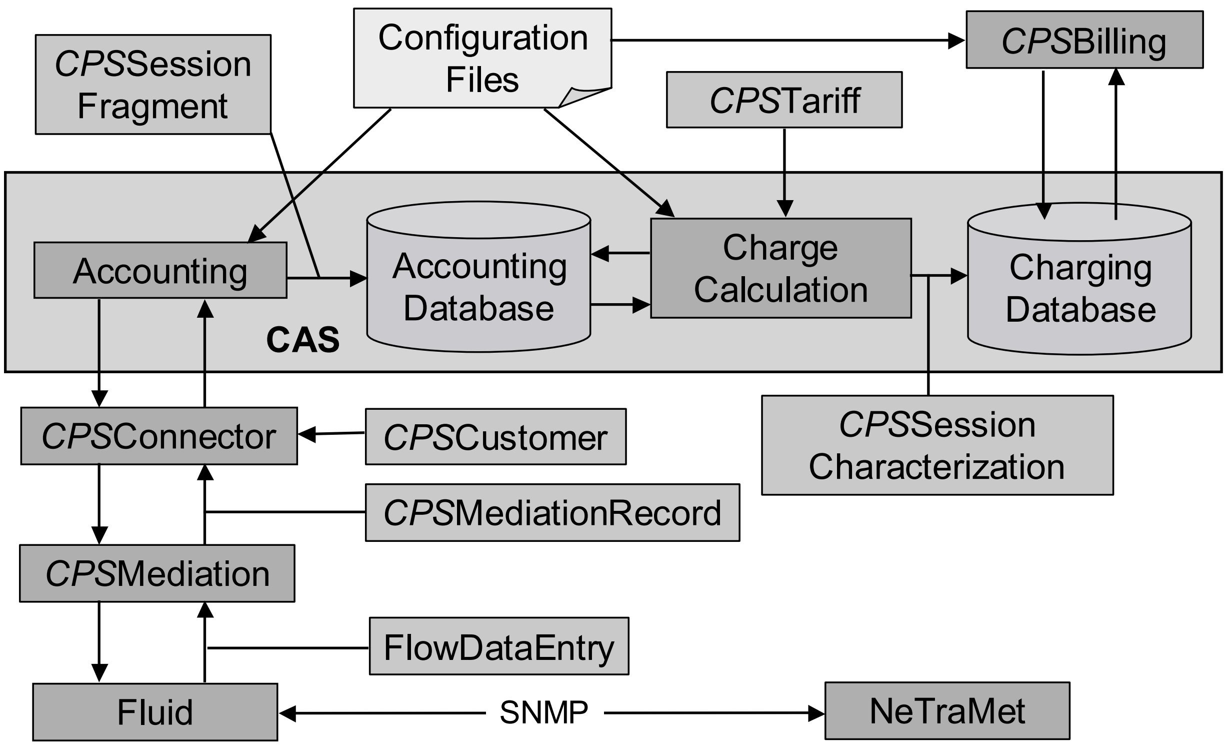


Figure 1: Overview on the CPS Scenario Embedded in the CAS

In a few words the CAS simply provides two components, each of which with an appropriate database. They are able to account and charge for any service. It is up to the designer of a particular scenario, what the CAS is actually accounting and charging for. For this purpose the respective components need to be instantiated accordingly.

In the CPS scenario the CAS needs to account for traffic flows, *e.g.*, in terms of volume or bandwidth, and charge for the consumption of it over a certain time duration (charging interval). This charging period is also termed a session, since in the CPS scenario the duration of all sessions are of equal size during the entire contract, *e.g.*, a week or a month, and this dimension is usually much longer than the duration of a single flow.

To adapt the CPS scenario to the CAS, basically components termed with a preceding "CPS" had to be implemented. There are on one hand data type components describing the structure of the data that is handled by the system. *E.g.*, two components CPSSessionFragment and CPSSessionCharacterization provide the data structures used by the CAS to store the data elements in the databases. In the CPS scenario this may encompass volume or bandwidth data of the traffic measured and information about whom the traffic belongs to and how it needs to be charged, described by, *e.g.*, user id, contract id, service id, and session id.

On the other hand, there are components that need to produce and process this data, *e.g.*, the CPSConnector component that connects the CAS to the mediation component. It is responsible for the combination of session information provided by the CPSCustomer component with the flow data provided by the CPSMediation component.

The real CPS related mechanisms are implemented in the CPSTariff component that provides the thresholds and reaction rules, and in the CPSBilling component which serves as an interface to the customer specifying the red or green cumulus points a customer receives for a specific usage of the service and the accumulation of them over time.

2.2 Development Environment

This section briefly describes the technology used for implementing and running the CPS scenario. Later on in Section 3.3 it is shown where different components have been placed in the networking environment in order to run the experiments.

Programming language: Since the CAS is completely written in Java to be able to distribute it over several machines, the CPS scenario had to be developed using same language. For the implementation of CPS, Java 2 has been used as part of JDK 1.2 [23]. Java is available for many platforms. The code is therefore portable and has successfully been tested on FreeBSD, Solaris and Windows.

Database: The CAS needs to be connected to a SQL-capable database, which it uses to store the Accounting and Charging records. As proposed in [17], the MySQL database [24] was chosen for this purpose.

Operating System: As mentioned above, the implementation can be ported to many different platforms. For the experiments described later in Section 4, a FreeBSD / Solaris testbed was used, but the Java code could also be running on a Windows machine. The networking environment used for the experiments is described more detailed in Section 2.8.

Other Tools: In order to provide a real and complete environment to run the CPS scenario quite a few other components needed to be obtained and installed in the testbed. The traffic measurements on the meter hosts are done by NeTraMet [26]. NeMaC [26] is used as the meter manager and Fluid [21] serves as a Java interface to the meter. Fluid has slightly been changed; this component is described more detailed in Section 2.4.1. Further on Fluid uses the SNMPv2 Java class library from AdventNet [22] to communicate with the meter over the SNMP protocol. Finally, to run the experiments, DBS [20] was chosen as the traffic generator, as it fulfilled most of the requirements. An overview on various evaluated traffic generation tools is given in Section 4.1.

2.3 Package Structure

To obtain a clear view on the organization of the software implemented, the package structure and inheritance relations of the Java source code is presented in Figure 2. Afterwards, detailed class descriptions are discussed in Section 2.4 and Section 2.5.

For the CPS scenario a new package *org.m3i.examples.ethz.CPSdemo* was created and embedded in the overall package structure used in the M3I project. Most of these Java classes extend or implement other components of the M3I structure. Apart from these another three classes have been added to the new package. The CPSCustomer class has been created to provide the session information used in the CAS. It can easily be replaced later by the customer support component, which is not part of the CAS yet. The CPSMediation class is used to create and manage Fluid objects and transforms the flow data into mediation records. Finally, Fluid has also been added to the new package.

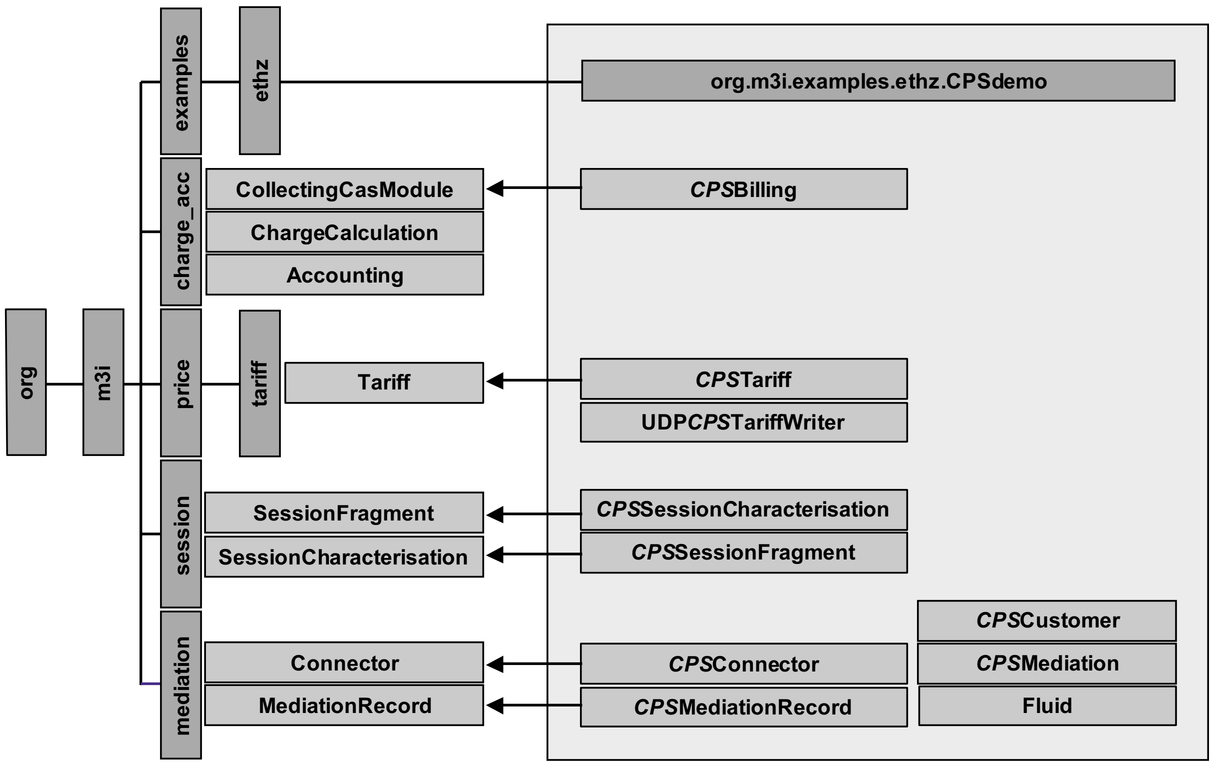


Figure 2: CPS Scenario Package Structure

2.4 Component Type Classes

As in the CAS, the relevant classes of the CPS scenario can be grouped into two major groups. On one hand there are data type classes that are representing the structure of the data which gets passed around. On the other hand there are component type classes that are handling this data. This section presents these component classes while the next section will present the data classes. A short description of these classes and their functionality will be given in each case. This includes a description of each method and its purpose. However, this description will not contain any details about passed parameters and also fields of classes will not be shown. For more detailed information please have a look at the code itself.

2.4.1 Fluid

Fluid is a Java interface to NeTraMet [26] and was made within the scope of [21]. It uses the SNMPv2 Java class library from AdventNet [22] to connect to and read from the NeTraMet meter using the rulefiles uploaded to NeTraMet by NeMaC [26]. Using the architecture design described in [28], Fluid is the meter reader, NeMaC the meter manager and NeTraMet the meter. NeTraMet records the traffic data, *e.g.*, the volume, of every single packet going through a specific network interface and combines them into flows and aggregates them over time. In doing so, it follows the policy defined in the rulefile provided by the manager. Periodically, Fluid collects the flow data, using the SNMP protocol and the Flow Meter MIB [28].

Fluid originally provided a Java applet interface and some additional methods that has been removed in this version. Some other methods have been added to provide the interface to the CPSMediation class. These new methods are shown in Table 1.

Method name	**Purpose**
getMeterUptime	Returns the time since the respective meter has been started.
getMeterTimeout	Returns the timeout for that meter after which a flow expires.
getNextData	Using this method the Fluid class can be asked to do the next data query and return collected flows in a hashtable.

Table 1: Methods of the Fluid Class (in Addition to the Original Fluid Class)

Herein the rest of the functionality provided by Fluid is described shortly. To connect Fluid to the meter, the specific hostname, SNMP portnumber and the correct community name and ruleset number need to be provided. The init method starts the SNMP API and loads the MIB files corresponding to the Flow Meter MIB [28]. The method dothemainquery, which is periodically invoked by the getNextData method, creates a session with the meter, and does synchronous and asynchronous queries to it to receive the flow data information. This information is then handed over to the CPSMediation class.

2.4.2 CPSMediation

The CPSMediation class instantiates a Fluid object for every meter host to collect the measured flow data by that host. As NeTraMet only provides the aggregated data over time the previous values need to be stored and to produce mediation records the difference between two entries is used.

From time to time this internal storage of flow data needs to be cleaned up. Therefore the timeout value of every flow is periodically checked using the method removeExpiredFlows. The main methods are described in Table 2.

2.4.3 CPSConnector

As the CPSConnector class inherits from the generic connector class *org.m3i.mediation.Connector*, it needs to implement several methods of that class. These methods are not described within this document. The CPSConnector class is mainly used to connect the CAS to the mediation component, i.e. the CPSMediation class. First, the mediation class needs to be started as a thread to collect the flow data. Then the CPSConnector class basically transfers the mediation records created by the CPSMediation class, to the accounting component to record it in the accounting database. Apart from that the CPSConnector class appends the necessary session information to the mediation records. This information is provided by the CPSCustomer class described below. The session information of the current customers is compared with the actual flow information and then appended to those records. The main methods for these purposes are shown in Table 3.

2.4.4 UDPCPSTariffWriter

This class is used to provide the ChargeCalculation component with the tariff information stored in a CPSTariff data object. The UDPCPSTariffWriter class reads the according data from a file and creates a CPSTariff object using them. Later on, an interface to the contract

Method name	Purpose
run	Overrides the run method of java.lang.Thread. Invokes the getNextDataFrom-Readers and removeExpiredFlows methods periodically using the pollingIn-terval parameter.
removeExpiredFlows	Checks the internal hashtable for any expired flows, i.e. flow entries that exceeded the timeout parameter of the reader, and deletes them.
getMediationRecords	Provided interface to the CPSConnector class. Returns all the Mediation-Records present in the internal buffer and removes them locally.
getNextDataFromRead-ers	Asks all the readers, i.e. Fluid objects to get the next flow data from their meters and submit them in a hashtable of FlowDataEntries. Checks for any flows that have previously been present and if so, invokes the createMedia-tionRecord method.
createMediationRecord	Creates a CPSMediationRecord out of two consecutive FlowDataEntries, i.e. calculates the number of bytes since last time and the resulting current aver-age bandwidth for this flow.

Table 2: Methods of the CPSMediation Class

Method name	Purpose
initConnector	Inits the CPSConnector class setting the names of the meter hosts and the polling frequency.
getAllAvailableData	This method should return all available MediationRecords together, but it is not implemented yet, as the Accounting class doesn’t need it.
getNextData	Returns the next MediationRecord. This is the interface to the Accounting class. If all current MediationRecords have been submitted new data is requested from the CPSMediation class and the checkSessions method is invoked.
getNextRecord	Searches for the customer a MediationRecord belongs to and completes it with the according customer data and session information. If no customer could be found, the record is discarded.
checkSessions	Checks for any expired sessions based on the customer information, increments the session counter and informs the ChargeCalculation com-ponent about it using the createDummyMediationRecord method.
createDummyMediation-Record	Creates a MediationRecord containing only the customer data and session information and marks the record as last.
addCustomer	Interface to add a new CPSCustomer to the CPSConnector class. This enables the connector to sort out the MediationRecords and complete them with the necessary customer information.
removeCustomer	Removes the customer information from the connector.

Table 3: Methods of the CPSConnector Class

database, which is not part of the CAS yet, could be appended to retrieve the tariff and contract information from there. This may not be required if the charge calculation is provided with an interface to the customer database, so that CP threshold values corresponding to a specific contract ID can directly be received from there.

The CPS tariff writer uses the methods provided by the classes of the *org.m3i.price.mech.comms package* to send the tariff information to the ChargeCalculation as an XML or binary document using the UDP protocol. As there were some bugs in the XML version of the TariffWriter, this part of the CPS scenario is not working yet but may be corrected in a future version. The main methods are shown in Table 4.

Method name	Purpose
sendTariff	Reads in the tariff file, creates a CPSTariff object and tries to send it to the charge calculation component.
main	Creates a new TariffWriter and invokes the sendTariff method.

Table 4: Methods of the UDPCPSTariffWriter Class

2.4.5 CPSBilling

This is a simple class inheriting from the CollectingCasModule. It collects the charging records from the charging database and stores them periodically in a HTML document. This document serves as a simple billing interface to the customer and is shortly described in Section 2.7. It could easily be changed or extended later. After the collection the charging record is assumed to be ‘billed’ and the field of the charging record inside the database is set accordingly. If the cumulated charging records have less or more CPs than mentioned in the reaction threshold, the reaction rule is called and a contract re-negotiation needs to take place. However, this feature has not been implemented yet. All of this is done in the ‘collectAndProcessRecords’ method. A short overview on the methods is shown in Figure 5.

Method name	Purpose
saveAsHTML	Stores the billing information, i.e. the assigned cumulus points in a HTML document to provide a simple user interface accessible by any HTML browser.
collectAndProcess-Records	Retrieves session characterizations from charging data bases.
main	Starts the CPSBilling.

Table 5: Methods of the CPSBilling Class

2.5 Data Type Classes

The previous section presented the different component classes the CPS scenario is build of. However, these are not the only classes which are of importance. An abstract view on the CPS scenario embedded in the CAS structure is that it handles large amounts of different data. Following the object oriented approach and the predefined structure in the CAS this data is represented by different data classes. Moreover, they include some functionality related to this data. Different data type classes which were created for that purpose are presented in this section.

2.5.1 FlowDataEntry

The FlowDataEntry class was taken over from [21]. It is part of Fluid’s netramet package and is used by the Fluid class to store the flow information retrieved by the meter. It was slightly extended to provide some additional information. Since CPSMediationRecords contain almost the same information, these data fields are described in Section 2.5.2 more detailed.

2.5.2 CPSMediationRecord

The CPSMediationRecord class extends the abstract class MediationRecord and implements all the required methods. It is used by various component classes to create a mediation record. Data fields describing the mediation record are shown in Table 6.

Variable name	Description
flowDataToOctets, flowDataFromOctets	Number of bytes for this flow since last query (for both directions)
flowDataToPDUs, flowDataFromPDUs	Number of packets for this flow since last query (for both directions)
flowDataToBandwidth, flowDataFromBandwidth	Average bandwidth for this flow (for both directions)
flowDataToECTPDUs, flowDataFromECTPDUs	ECN ECT packets (for both directions)
flowDataToCEPDUs, flowDataFromCEPDUs	ECN CE packets (for both directions)
flowDataDSCP	Diffserv codepoint field of the IP header
flowDataSourcePeerAddress	IP address of the source host
flowDataSourceTransAddress	TCP/UDP port of the source host
flowDataDestPeerAddress	IP address of the destination host
flowDataDestTransAddress	TCP/UDP port of the destination host
isFirst	First record of a session
isLast	Last record of a session
customerId	Customer number
contractId	Contract number (used for the tariff)
serviceId	Service number (reservated for later use)
sessionId	Session counter
recordSource	Hostname of the meter host
flowId	Flow number provided by the meter

Table 6: Variables of the CPSMediationRecord Class

2.5.3 CPSCustomer

The CPSCustomer class has been created to provide the session information used in the CAS. It is used by the CPSConnector to append the necessary session information to the mediation records. The session information of the current customers is compared with the actual flow information and then appended to those records. This class could easily be replaced later by the customer support component, which is not part of the CAS yet. The

Method name	Purpose
sessionHasExpired	Check if the current session for this customer has expired.
startFirstSession	Start the session for the first time.
startNextSession	Start the next session. The sessionStartTime is incremented by the sessionDura-tionTime.

Table 7: Methods of the CPSCustomer Class

methods of this class are shown in Table 7.

2.5.4 CPSSessionFragment

The CPSSessionFragment class contains mainly the same information as a mediation record. It extends the SessionFragment class and implements therefore the method initFromMediationRecord to initialize the attributes. It contains both the flow data and the session information and is used by the accounting compontent to create a new record in the accounting database.

2.5.5 CPSSessionCharacterisation

The CPSSessionCharacterization class collects all session fragments belonging to a session that have been pulled from the accounting database by the charge calculation. It extends the SessionCharacterisation class and therefore implements the initFromFragments method which calculates the total resource usage accumulating session fragments. This class is used by the charge calculation to create charging records. The mainly provided data fields are shown in Table 8. Fields providing ECN, DSCP and the like need to be added here in future according to the respective design.

Variable name	Purpose
totalUpVolume, totalDownVolume	Total number of bytes for the session in either directions.
totalUpPackets, totalDownPackets	Total number of packets for the session in either directions.
averageUpBandwidth, averageDownBandwidth	Average bandwidth during the session in either directions.

Table 8: Variables of the CPSSessionCharacterisation Class

2.5.6 CPSTariff

In the Cumulus Pricing Scheme, which is described in [7] more detailed, the user is not directly charged for usage, he just pays a flat rate fee. But there is a set of thresholds which limit the consumption for over- and also underusage. The user is given red or green points if her service usage exceeds a certain CP threshold value mentioned in the user contract. These cumulus points can also be accumulated over time. If they exceed a certain level, the reaction rule will be applied, *e.g.*, the contract will be redefined. The CPSTariff class extends the Tariff class from the M3I project. It is used to carry the information about predefined service contracts, threshold values and reaction rules. The charge calculation gets these informations from the UDPCPSTariffWriter component and uses it to charge for the service usage. The main method that is provided to calculate the cumulus points is getChargeAdvice which is invoked by the charge calculation. It compares the service usage over a session with the CP threshold values and assigns the appropriate cumulus points.

2.6 Data Flows

In the last two sections component type classes and data type classes used to implement the CPS scenario in the CAS have been explained in detail. However, for a more clear view about what exactly happens in the implementation it is sometimes useful to have a closer and more specific look on data flows themselves. Therefore in this section it is recapitulated where and how data is processed using the down-top approach. In Figure 3 this data flow is shown.

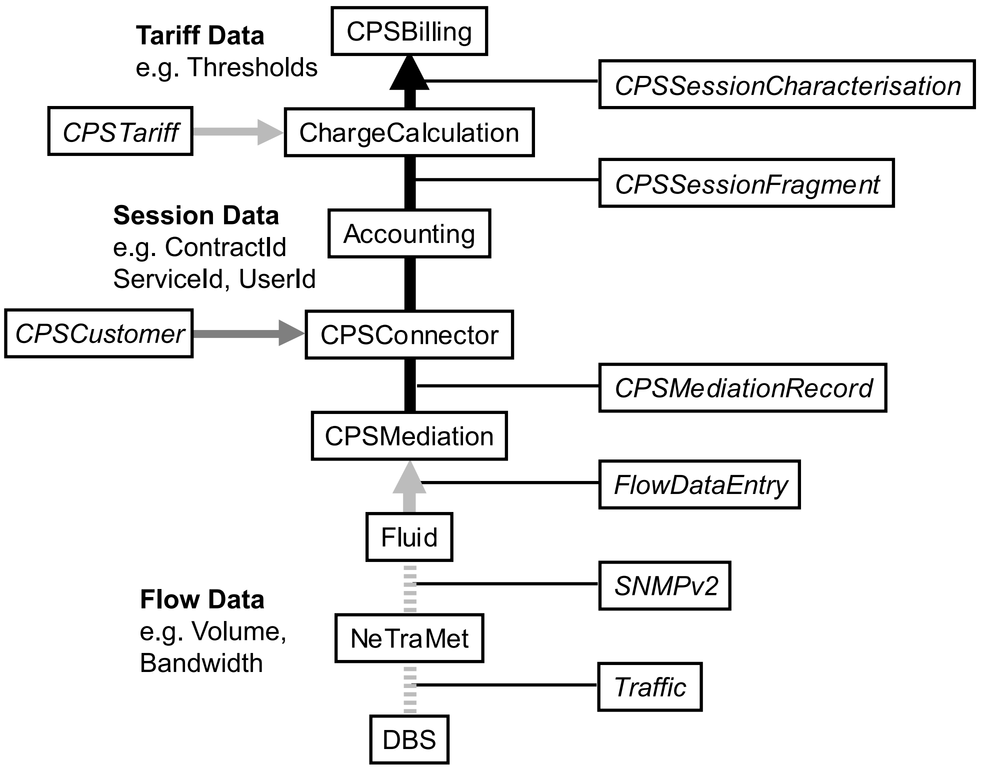


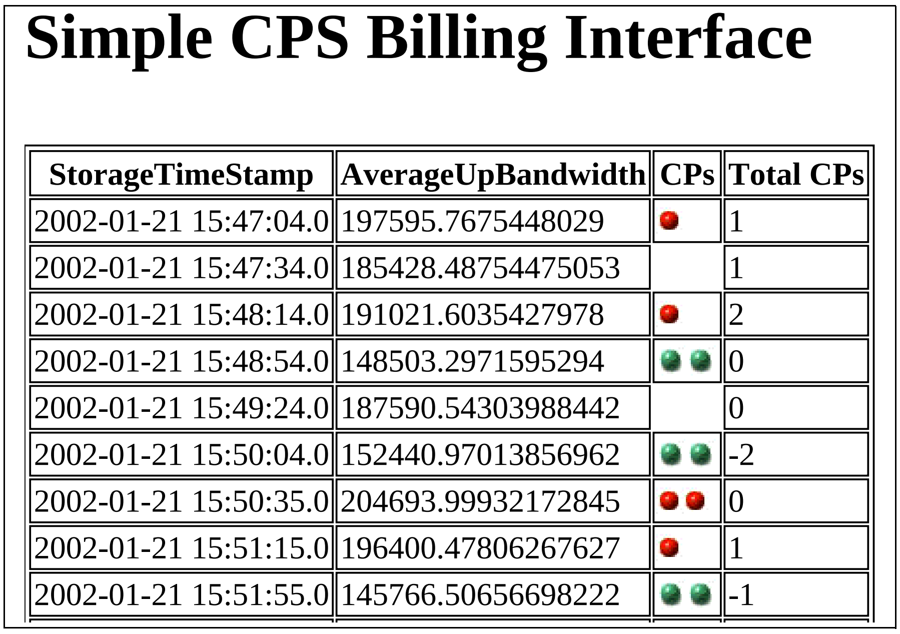
Figure 3: Data Flow in the CPS Scenario

First of all, real traffic needs to be flowing through a physical network interface. There are several possibilities to achieve this as described later in Section 4.1. In the CPS experiments DBS is used to generate traffic as already mentioned above. The generated traffic is then measured by NeTraMet which combines the traffic, i.e. the single packets into flows based on rules that have been provided by NeMaC. Then, periodically, using the SNMPv2 protocol the meter reader, i.e. Fluid reads out traffic flows which are currently present on the meter host. This encompasses, *e.g.*, the number of accumulated bytes, packets or even ECN bits for a flow specified by its source and destination address. Since differential numbers instead of accumulated numbers need to be calculated for further processing, the flow data is then transformed by the CPSMediation class into mediation records using the difference of two consecutive flow entries. Until here the data processing is completely independent from the rest of the application, since the CPSMediation class is running as a thread on its own. However, it must be considered that the internal data buffer of the CPSMediation class is not infinite and can therefore overflow if the data is not collected continuously.

The CPSConnector class fetches mediation records from the CPSMediation component and appends the session information to those records that belong to a certain customer. Records for which there are no appropriate owners are discarded. The CPSConnector class can also generate mediation records itself. For instance, a dummy record is generated to terminate a session if it exceeds the session duration. In the Accounting class records provided by the CPSConnector are transformed into CPSSessionFragments and stored in the accounting database. From there, the charge calculation collects all session fragments belonging to a session that has a start point and an end point and creates a CPSSessionCharacterisation. Moreover it calculates the charge for the service usage during that session applying the CPS tariff used for the appropriate service contract. The result is stored in the charging database, from where the CPSBilling class gets the billing information and creates a CPS billing interface using them.

2.7 User Interface

As described above, a simple user interface is created by the CPSBilling class to communicate the charge to the customer in terms of assigned cumulus points for every session and accumulated over time. The CPSBilling collects charging records from the charging database and stores them periodically in a HTML document. This document serves as a simple interface to the customer and can easily be represented in a HTML browser as shown in Figure 4. It could simply be changed or extended in future.



Simple CPS Billing Interface

StorageTimeStamp	AverageUpBandwidth	CPs	Total CPs
2002-01-21 15:47:04.0	197595.7675448029	🔴	1
2002-01-21 15:47:34.0	185428.48754475053		1
2002-01-21 15:48:14.0	191021.6035427978	🔴	2
2002-01-21 15:48:54.0	148503.2971595294	🟢🟢	0
2002-01-21 15:49:24.0	187590.54303988442		0
2002-01-21 15:50:04.0	152440.97013856962	🟢🟢	-2
2002-01-21 15:50:35.0	204693.99932172845	🔴🔴	0
2002-01-21 15:51:15.0	196400.47806267627	🔴	1
2002-01-21 15:51:55.0	145766.50656698222	🟢🟢	-1

Figure 4: CPS User Interface

2.8 Connection Setup

Apart from the above described implementation components, there has also been some effort on the design and implementation of a user interface for the connection setup, i.e. the setup of a user session. Since this part was not used in the current CPS experiments, it was placed in the appendix, Section 11.

3 Networking Environment

The develompent and testing of software for the M3I project and especially the CPS implementation is supported by a small testnetwork. The following section aims to give a small and understandable overview of the applied computer infrastructure.

3.1 Overview Testbed

An overview on the testbed is given in Figure 5. Actually the test network consists of five PCs and a Solaris workstation. Three PCs are used as routers (RA, RB and RC[2]) and they are enabled for DiffServ using the AltQ software. The remaining PCs (HA, HB[3]) and the Solaris workstation (HC) are used as normal hosts, whereas each one provides two IP-interfaces, i.e. two IP-addresses for the test-experiments, so that a virtual net of six hosts and three routers can be simulated, that span together totally six subnets. The existence of two IP-addresses per host leads also to the routing policy of this testbed. Traffic forwarding to a destination interface ending with 1 is specified clockwise and traffic to the 2 counterclockwise, respectively.

2.RA, RB and RC stand for router A, B and C respectively.
3.HA, HB and HC stand for host A, B and C respectively.

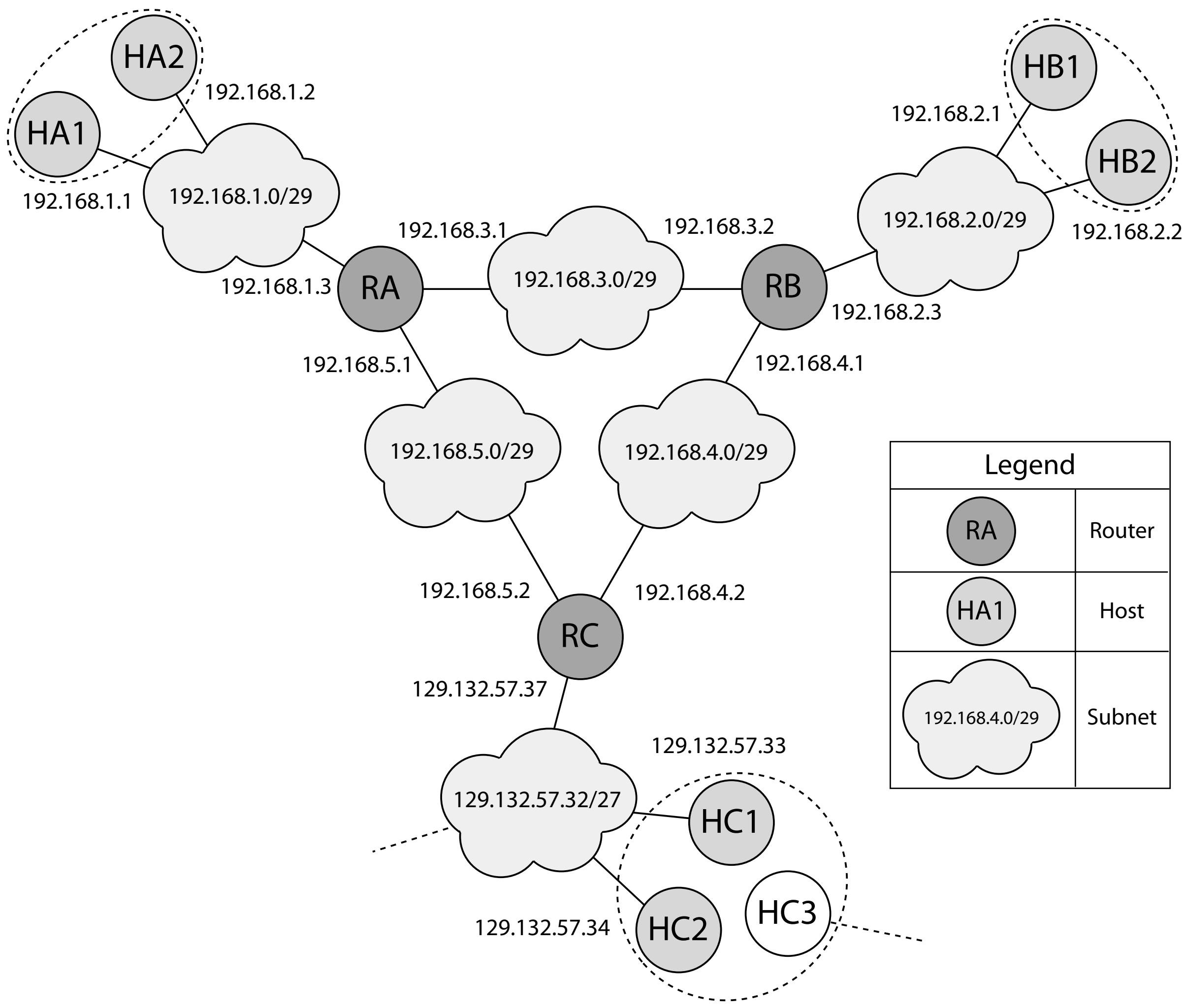


Figure 5: Overview on the Testbed used for the CPS Experiments

3.2 DiffServ Environment

As mentioned above the three routers are capable to handle traffic according to the DiffServ mechanisms. This is achieved by using AltQ which is available for FreeBSD, the operating system currently installed on these routers. A detailed description of the AltQ configuration is not given in this document, as these DiffServ mechanisms have not yet been considered in detail for running experiments with CPS. However, experiments reading out the DiffServ codepoint have been successful, as both NeTraMet and the CPS implementation are capable of handling this data field. On the other hand, no problems have been encountered yet in charging for traffic of different levels of service classes.

3.3 Component Location

This section provides a detailed overview on various components of the test network and the CPS scenario described in Section 2 and shows where they are located in the network to perform the experiments described later. As already mentioned, most of the components of the CAS and the CPS implementation can be distributed when it is necessary to achieve a better performance. However, in the CPS experiments the option of, *e.g.*, distributing the CAS is not used to keep the setup simple. Therefore most of the components are located on one machine, i.e. router RC and only the traffic measurements are performed on other machines, i.e. router RA or RB. The location of these various components is shown in

	RA	**RB**	**RC**	**HA**	**HB**	**HC**
OS	FreeBSD 4.2	FreeBSD 4.2	FreeBSD 4.2	FreeBSD 4.1.1	FreeBSD 4.2	SunOS 5.7
DiffServ	AltQ	AltQ	AltQ			
Java	jdk1.2.2	jdk1.2.2	jdk1.2.2	jdk1.1.8	jdk1.1.8	jdk1.2.2
Database			mySQL			
Traffic Meter	NeTraMet	NeTraMet	NeMaC			
Traffic Generator			dbsc	dbsd	dbsd	

Table 9: Development Environment and Component Location on the Testbed

Table 9.

4 Experiment Setup

In this section the set up of a real environment to run the following experiments with the CPS scenario is described in step-by-step mode. First a closer look into possibilities for generating the necessary traffic is taken. Secondly, it is shown how all testbed components are configured and in which sequence they need to be started to run experiments.

4.1 Traffic Generation

There exist many possibilities to generate network traffic. In search of a good tool for traffic generation quite a few options were evaluated. First, requirements are presented that the tool should be able to meet. Then an overview is given on various tools that have been evaluated for such purpose. Finally, the traffic pattern is discussed that should be generated by the tool.

4.1.1 Requirements

First of all, within a real environment, traffic flowing through physical network interfaces and real protocol stacks needed to be generated. So rather than a tool for network simulation, a software needed to be found that generates real traffic flowing through physically distributed components. Since it was important to have a traffic pattern which is changing over time, in order to cause the generation of cumulus points, the traffic generator should further be able to generate varying traffic, reading the data, *e.g.*, out of a configuration file. Finally, both TCP and UDP traffic should be generated by the tool.

4.1.2 Tools Evaluation

Three different traffic generators were evaluated to find out which one fulfills best the above requirements. An overview on the evaluation is shown in Table 10.

With Iperf [18], it was not possible to specify a varying traffic pattern, since only a constant

	Iperf	**Mgen**	**DBS**
Can it specify the traffic pattern?	No	Yes	Yes
Can it handle large traffic data files?	n/a	No	Yes
Can it send TCP packets?	Yes	No	Yes
Can it send UDP packets?	Yes	Yes	Yes
Can it set the DSCP / TOS field?	No	Yes	No
Can it set the ECN field?	No	No	No

Table 10: Comparison of the Evaluated Traffic Generation Tools

traffic flow could be generated. Therefore Mgen [19] was tested as well which was able to do so. However, some problems were encountered especially which larger configuration files, i.e. data with above 100’000 samples. It was just taking too long to fill the data buffer using that big data files. Only DBS [20] finally fulfilled all requirements. However, it will not be possible to set the ECN field used for further experiments as described later in Section 7.1.

4.1.3 Traffic Pattern

As it was now possible to generate specific traffic patterns, there were again several possibilities to generate traffic. The simplest thing would have been to use randomly generated traffic, *e.g.*, normal distributed traffic described by the mean value and the standard deviation. However, this is artifically generated traffic and doesn’t really create a real environment. Therefore some real traffic was sampled using one of the routers between the ETH and the TIK Institute. The pattern of this traffic is shown in Figure 6. It consists of 172800 data samples during 10 working days (2 weeks), i.e. one sample every 5 seconds. Based on that traffic pattern it was now possible to create an environment that was quite close to a real one. While extrapolating that pattern over time, one would even be able to generate real traffic over a longer timescale. The sampled traffic data will further be analysed in Section 4.4 to specify the according CP thresholds. In Section 5 the results of a comparison between using artifical traffic and real traffic will be shown.

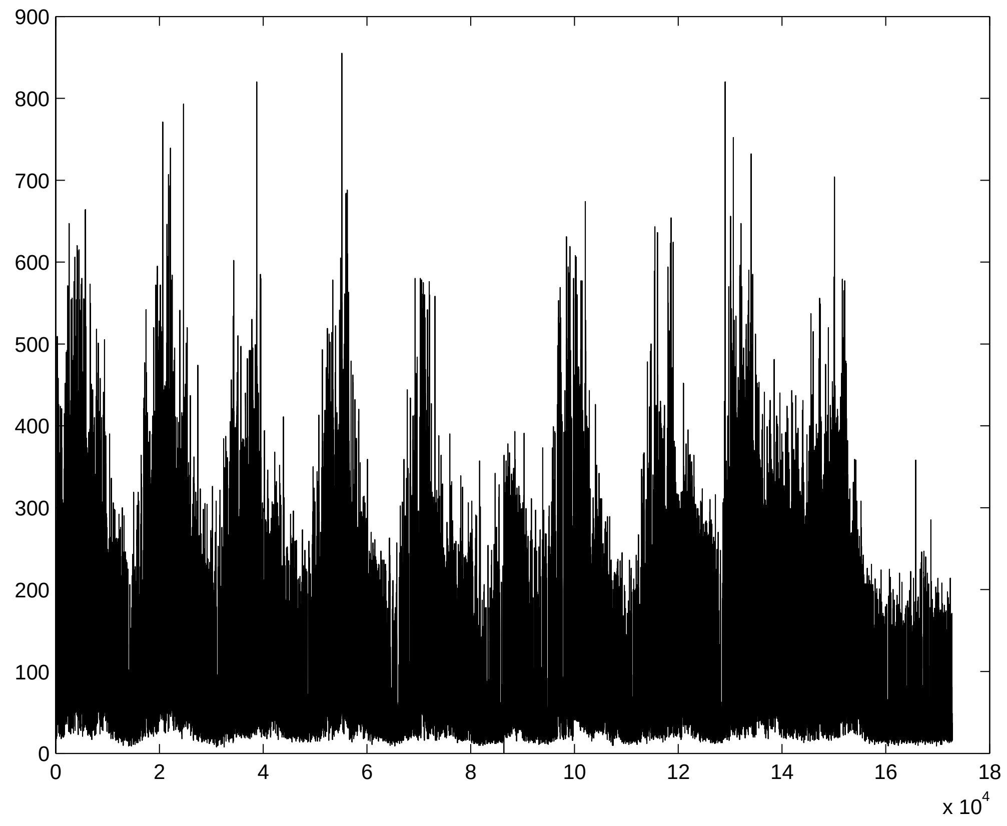


Figure 6: Traffic Pattern Sampled from an ETH Router

4.2 DBS Configuration

To generate the traffic according to the pattern shown in Figure 6, an appropriate configuration file needed to be created for DBS. To realize a certain traffic bandwidth during a sampling/sending interval according to the sampled data, there were two different possibilities:

a) defining the number of packets all of an equal size and

b) defining the size of a single packet to be sent within that interval.

Both options seemed to be reasonable, however, the second possibility had the disadvantage of the limited packet size for IP packets. The smallest possible size of a packet would be 60 byte (18 byte payload in UDP) and the highest 1514 byte (1472 byte payload). For the CPS experiments it was therefore decided to use a constant packet size of 100 bytes (58 byte payload) and use the number of packets as a variable parameter. The determination of the sending interval is discussed later in Section 4.3.

The resulting configuration file for DBS, that is shown in Figure 7, was create by a shell script using the sampled data as input. It creates a flow from the sender to the receiver following the specified pattern.

```
{
sender {
   hostname = HA2;
   port = 12300;
   mem_align = 58;
   pattern {
   3074.000, 58, 0.05, 0.0;
   6844.000, 58, 0.05, 0.0;
   ...
   1160.00, 58, 0.05, 0.0;
   }
}
receiver {
   hostname = HB1;
   port = 12301;
   mem_align = 58;
   pattern { 58, 58, 0.05, 0.0}
}
```

Figure 7: DBS Configuration File for the Traffic Generation

4.3 Experiment Parameters and Timescales

It is important to consider that since CPS is a charging mechanism on the longer timescale the experiments with this scenario would also absorb a long time. Therefore it is more

Fullname	**Parameter**	**Description**
Sending Interval	T_{Sn}	Time interval of sending the next packet(s) by the traffic generator, i.e. the granularity of the traffic. Within this interval the bandwidth of the traffic is constant.
Sampling Interval	T_{Sm}	Time interval of sampling the traffic data by the meter, i.e. the granularity of the meter.
Session Duration / Charging Interval	T_S	Duration of a session, i.e. the time interval of charging for a session.
Contract Duration / Experiment Duration	T_C	Duration of the contract period, i.e. the duration of the whole experiment.
Thresholds	θ_n	Thresholds determined in the tariff for assigning the cumulus points.
Experiment Timefactor	f	Factor between the real timescale and the experiment timescale.
Accounting Frequency	T_A	Time interval of collecting mediation records used for the Accounting class in the CAS.
Charging Frequency	T_{Ch}	Time interval of collecting session fragments used for the ChargeCalculation class in the CAS.
Billing Frequency	T_B	Time interval of collecting session characterisations used for the CPSBilling class.

Table 11: Parameters used for the CPS Experiments

convenient to scale the time a little bit. When talking about scaling the time it is important to note that the traffic volume needs also to be scaled, since it is not possible to just sending the same traffic volume in a shorter time because of the limited physical bandwidth. However, it is no problem to scale the volume, if the granularity of the traffic load can be kept the same. Using the granularity described in the previous section, i.e. 100 bytes per packet, was suitable for the experiments.

The time parameters in the CPS scenario that are subject to be scaled are listed in Table 11. It is importent to note that the time cannot be scaled to much. Obviously the bottleneck was between the flow meter and the meter reader, i.e. the sampling interval T_{Sm} which could not be made smaller than around 0.5 seconds. So to achieve the same granularity as the generated traffic, i.e. 5 seconds, the highest possible timefactor f would be 10. This limitation is definitely depending on the delay between the meter and the reader. Therefore better results could be achieved if the meter would be located on the same host as the reader. However, this was only a problem for running the experiments but not for the CPS scenario in a whole. Therefore it was not worth to further increase this performance, although there would be possibilities to achieve this, *e.g.*, through pipelining, i.e. asynchronous requests. In the experiments the timefactor was just increased by resampling the traffic measurements, i.e. loosing a little bit of granularity. The actual timescales used for the experiments are shown in Section 5.

4.4 Threshold Calculation

A major effort was the choice of reasonable values for the CP thresholds. [8] is a good tutorial on how to choose these thresholds based on the mean value and the standard deviation of the traffic. However, it is assumed that the traffic is close to normal distribution. Figure 8 shows the probability function of the sampled traffic pattern of Figure 6. Obviously the assuption of normal distribution is no longer valid, at least for this level of granularity, i.e. averaged values over 5 seconds. Only for average values over a longer timescale, the probability function might migrate towards normal distribution, however, the procedure for non-normal distribution described in [29] is better applicable. According to that, the absolute thresholds can be calculated as follows.

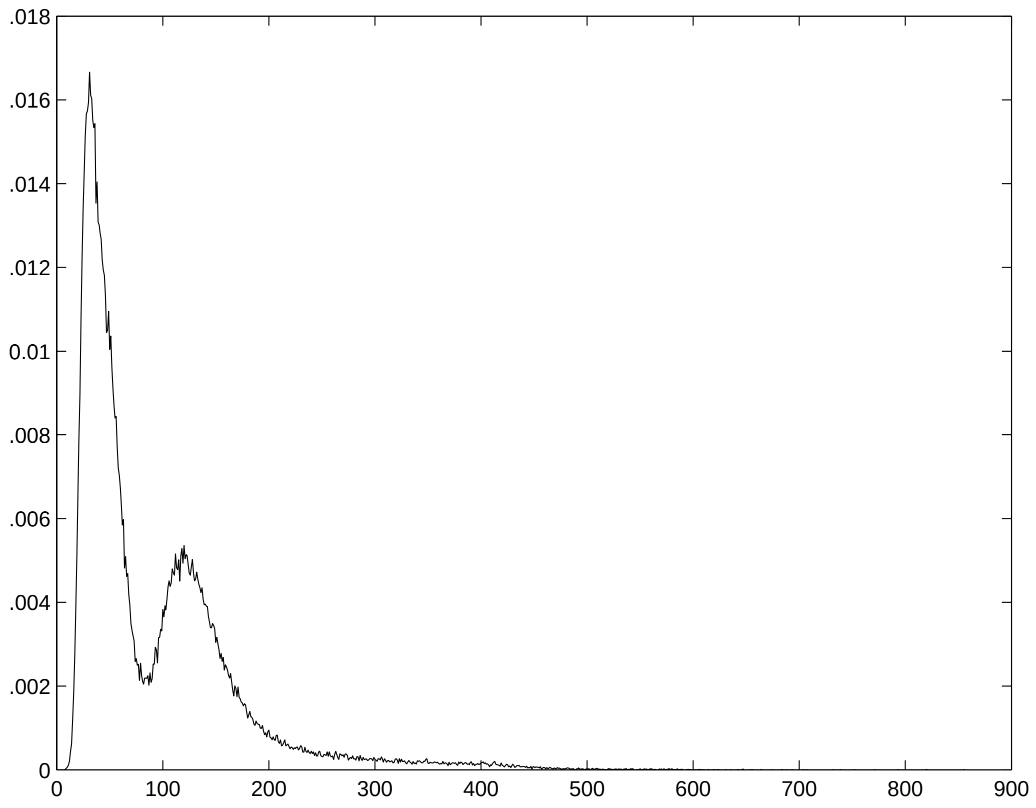


Figure 8: Probability Density Function of the Sampled Traffic Pattern

Assume that the traffic is described by the probability density function $f(x)$ and the respective discrete probability distribution $F(x) = \int^{x} f(y)dy = \text{Prob}\{\text{measured traffic} \leq x\}$.

This distribution can be calculated by numerical integration of the respective histogram. Let η_n describe the probability that the measured traffic is within the interval $[\vartheta_{-n};\vartheta_n]$. This yields absolute thresholds $\vartheta_{\pm n} = F^{-1}\left(\frac{1 \pm \eta_n}{2}\right)$ where F^{-1} describes the inverse probability distribution function. The so calculated absolute thresholds are shown in Table 12. The

η	ϑ_{-n}	ϑ_n
90 %	79.0	102.4
99 %	69.1	112.3

Table 12: Calcualted Thresholds for the Sampled Traffic

respective mean is 90.7 [kbits/s].

4.5 Experiment Invocation Process (Running the Scenario)

This section describes all the steps for running the CPS scenario. First, all components need to be properly configured. Then the scenario needs to be started in the correct sequence. To configure the components, the according configuration files have to be adapted to the current experiment, i.e. the time parameters need to be set to reasonable values and other variables must be configured correctly.

CAS Configuration: The provided configuration file acc.cfg.CPSdemo for the Accounting and cc.cfg.CPSdemo for the ChargeCalculation need to be adapted. This especially includees setting the right location of the databases, the input frequencies and the data type classes. In addition to that the URL of the connection configuration file needs to be indicated in acc.cfg.CPSdemo.

CPS Configuration: For the connector class the conn.cfg.CPSdemo needs to be adaped. An example is shown in Figure 9. PollingFrequency is the periodtime in seconds of reading out data from the meter. More than one meter host can be configured.

```
[org.m3i.mediation.Connector]
class=org.m3i.examples.ethz.CPSdemo.CPSConnector

[org.m3i.examples.ethz.CPSdemo.CPSConnector settings]
MeterHost=RA
MeterHost=RB
PollingFrequency=0.5

[org.m3i.examples.ethz.CPSdemo.CPSConnector default attributes]
```

Figure 9: Connector Configuration File used in the CPS scenario

The file tariff.cfg is used to configure the CPSTariff class. N is the number of thresholds on either side of the target mean value. M is the number of contracts provided. The bandwidth thresholds are measured in bytes/s. An example of the tariff file is shown in Figure 10.

```
N 2 M 5
contractId 4 160000 170000 181431 190000 200000
contractId 1 160000 170000 181431 190000 200000
contractId 2 160000 170000 181431 190000 200000
contractId 3 160000 170000 181431 190000 200000
contractId 0 160000 170000 181431 190000 200000
```

Figure 10: Tariff Configuration File used in the CPS scenario

Finally, the bil.cfg.CPSdemo needs to be configured correctly to setup the connection to the charging database used by the CPSBilling component and the according input frequency.

NeTraMet Configuration: To setup NeTraMet one needs to create an appropriate srl-file, *e.g.*, <hostname>.testbed.srl shown in Figure 11 and compile it into a rulefile using the srl compiler which is included in [26]. After that NeMaC is invoked to send this file to NeTraMet as described in the next section.

```
# NeMaC srl file RA.testbed.srl
#
# @hausheer

SET 2;
FORMAT
FlowRuleSet FlowIndex SourcePeerType SourceTransType
SourcePeerAddress DestPeerAddress
SourceTransAddress DestTransAddress
ToPDUs FromPDUs  ToOctets FromOctets
FirstTime LastTime DSCodePoint;

if SourcePeerType == IP save;
else ignore;

if SourceTransType == tcp || SourceTransType == udp {

   save SourcePeerType;
   save SourceTransType;
   save SourcePeerAddress;
   save SourceTransAddress;
   save DestPeerAddress;
   save DestTransAddress;
   save DSCodePoint;

   count;
}
```

Figure 11: NeMaC SRL File used in the CPS Scenario

Database Setup: Before all the components can be started, the database has to be created used by the CAS for storing the accounting and charging records. The file cas_26_06_01.sql contains to most actual version of the database structure compatible with the current CAS version.

Component Invocation Procedure: Now the components can be started in the correct sequence. For that purpose a shell script cpsrun.sh has been written that makes it easier to start everything. Make sure that the path, classpath and all other variables are set correctly for your environment. The script opens a new terminal for every process. First NeTraMet needs to be started on the meter host and configured by NeMaC. Then the Accounting component can be invoked to start the measurements and data storage. Now the traffic can be generated. Therefore two DBS daemons, i.e. dbsd, have to be started, a sender and a receiver according to the DBS configuration file, and one controller, i.e. dbsc. The charge calculation and the billing component can be started at any point of this procedure. All the provided options of the script are shown in Figure 12. The CPSManager and the CSDaemon components as well as the NeMaCServer are not used in the CPS experiments. For a simpler traffic pattern the dummy traffic components can also be started, i.e. Iperf clients and servers.

```
bash-2.04$ ./cpsrun.sh
usage: cpsrun.sh n
n:
 1: Running CPSManager on Host HA1
 2: Running CPSManager on Host HB1

 3: Running CSDaemon on Edge Router RA
 4: Running CSDaemon on Edge Router RB

 5: Running NeTraMet on RA
 6: Running NeTraMet on RB
 7: Running NeMaCServer on Charging Host (RC)

 8: Running the Charge Calculation (on RC)
 9: Running the Billing (on RC)
10: Running Tariff Writer (on RC) => not working yet!
11: Running Accounting (on RC)

12: Running Dummy Traffic Server on HA1
13: Running Dummy Traffic Server on HB1
14: Running Dummy Traffic Client on HA1
15: Running Dummy Traffic Client on HB1

16: Running NeMaC for RA on RC
17: Running NeMaC for RB on RC

18: Running DBS Controller on RC
19: Running DBS Daemon on HA2 (Sender)
20: Running DBS Daemon on HB1 (Receiver)
```

Figure 12: CPS Run Script Options

5 Experiment Results

This section discusses various detailed experiments that have been run on the testbed using the CPS implementation described above. It is important to note that there are many different possibilities to run these experiments and it is important to indicate initially which kind of results are to be shown. Potential issues include:

1. Show the performance of the CPS implementation by, *e.g.*, monitoring the usage of memory, cpu or network bandwidth, addressing the potential bottlenecks and limitations and show how scalable the system is,
2. Comparing the output of the CPS pricing mechanism, i.e. the assignment of cumulus points using different kinds of traffic patterns as input,
3. Comparing CPS while varying the various experiment parameters and timescales shown in Table 11 or
4. Comparing CPS with other pricing mechanisms, *e.g.*, ECN based pricing.

Since the implementation determines a prototype and has not been optimized for maximum scalability and performance, it is not useful with respect to topic (1.) to investigate on all performance issues at the moment and this will be part of future work. However, since CPS does not count on every single packet, but rather measures traffic only every now and then, it can be stated that CPS is able to produce valuable results without too much effort in terms of accounting and, therefore, the overall system performance is of less relevance on the whole.

On the other hand, topic (2.) is of high relevance and some of these results will be presented in Section 5.1. Also topic (3.) was interesting to look at and a few examples of those experiments are shown later in Section 5.2.

For a comparing statement on the CPS concept and its detailed behavior, however, it would be necessary to compare it with other scenarios, *e.g.*, with a pricing based on ECN as mentioned in topic (4.). Unfortunately, ECN is still a quite new technology with hardly any support in terms of available implementations. Therefore, it was yet not possible to run CPS and ECN experiments in parallel. But it is still an important motivation to do this in the future. Some of the most important remaining steps are discussed in Section 7.1.

5.1 The Relevance of the Traffic Pattern

As already discussed above in Section 4.1.3 the traffic pattern used as input for the CPS scenario is of high importance. While it does not make sence to run experiments based on a constant traffic flow except for measuring performance related issues, only varying traffic patterns were compared. In this experiment, both artificial traffic based on random numbers and real traffic following a special traffic pattern was generated. The real traffic was sampled from a real router as described previously in Section 4.1.3 and shown in Figure 6. The artificial traffic was generated based on numbers chosen from a normal distribution.

Table 13 shows the exact parameters used in these experiments. The mean value and standard deviation of the sampled real traffic was calculated and the same parameters were used to generate the random numbers for the artifical traffic. The thresholds were calculated using the standard deviation of the real traffic averaged over the charging interval. Also the same thresholds were used for both experiments. The charging interval was intentionally set to a small value, i.e. 1 hour.

In Figure 13 the accumulated cumulus points over time are shown for both experiments.

Parameter	**Value (in real time)**
Sampling Interval T_{Sn}	5 s
Charging Interval T_S	3’600 s (1h)
Experiment Duration T_C	864’000 s (10 d)
Mean value of the traffic	90.7 kbit/s
Standard deviation of the traffic	75.3 kbit/s
Standard deviation of the traffic average over T_S	33.7 kbit/s
Thresholds	[9.9 46.9 134.5 171.6] kbit/s

Table 13: Parameters used in Experiment 1

While the artifical traffic doesn’t effect any cumulus points, the curve for the real traffic obviously follows the actual situation, i.e. arises in times of a higher usage and falls in times of lower usage. The reason why artifical traffic leads to such stable output is the absence of a pattern that follows the real internet usage, which is usually higher during the day and lower during the night. This is of course dependent on where the traffic is measured. The traffic pattern for a private customer is usually different from the pattern of a business customer or even the pattern between two internet providers.

For longer charging intervals than used in the experiments, *e.g.*, 1 month, this different behaviour of artifical and real traffic might be equalized a little bit, but still major differences remain and can be extrapolated due to the customers behaviour, *e.g.*, less internet usage during holiday seasons, general growth of the internet etc.

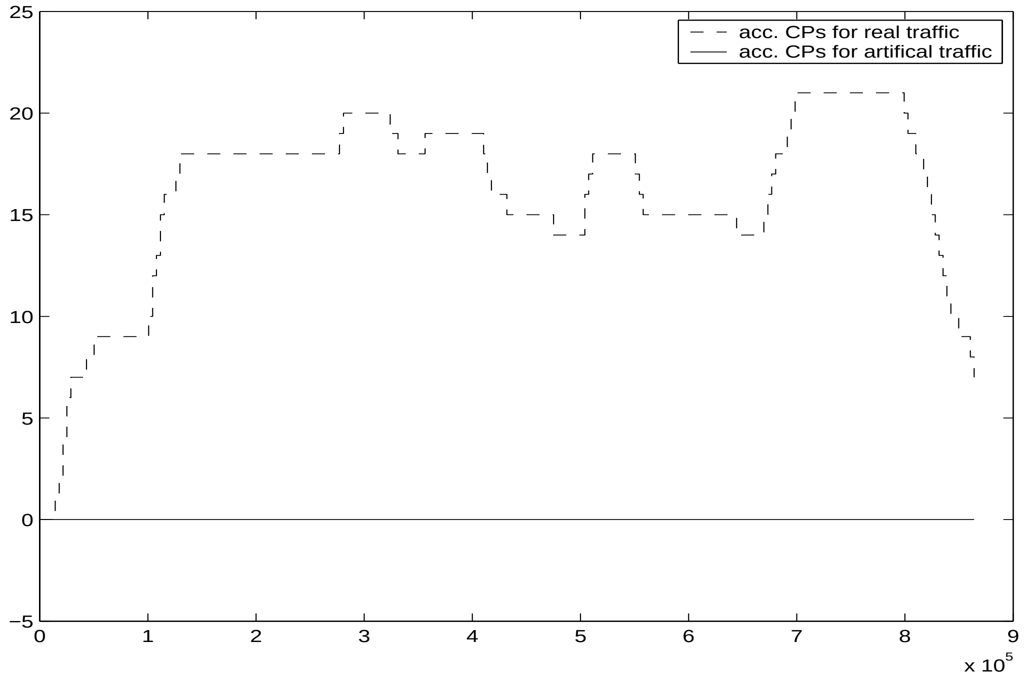


Figure 13: Accumulated Cumulus Points over Time

Therefore it is very important that, apart from the mean value and the standard deviation of the traffic, the specific traffic pattern should always be taken into account in a real case. The sampling interval and the charging interval need to be specified carefully depending on these figures.

5.2 Parameter Tuning

Parameter	Real Time	Experiment Time
f	1	1/100
T_{Sn}	5 s	50 ms
T_{Sm}	50 s	0.5 s
T_C	20 d = 1728000 s	4.8 h = 17280 s
T_A	8.33 min = 500 s	5 s
T_{Ch}	8.33 min = 500 s	5 s
T_B	33.33 min = 2000 s	20 s

Table 14: Parameter Settings in Experiment 1

There are several parameters that can be varyied as presented above in Section 4.3. For the following experiments the parameters were specified as shown in Table 14.

The experiment timefactor f, the sending interval T_{Sn} and the experiment duration T_C were not changed during these experiments. For the parameters accounting frequency T_A, charging frequency T_{Ch} and billing frequency T_B suitable values were chosen. They shouldn’t be to small for performance reasons and also not too large, i.e. at least smaller than the charging interval. The sampling interval was also not varyied during these experiments, as these results were already shown in [30]. Therefore the only two remaining degrees of freedom that were varyied are the charging intervals T_S and the CPS thresholds. These appropriate results were described in Section 5.2.1 and Section 5.2.2, respectively.

5.2.1 Varying the Charging Interval

In Figure 14 the accumulated cumulus points for the different experiments using a varyied charging interval T_S were shown. It is obvious that for a smaller charging interval the resulting curve is more “unstable”, i.e. follows the original traffic pattern.

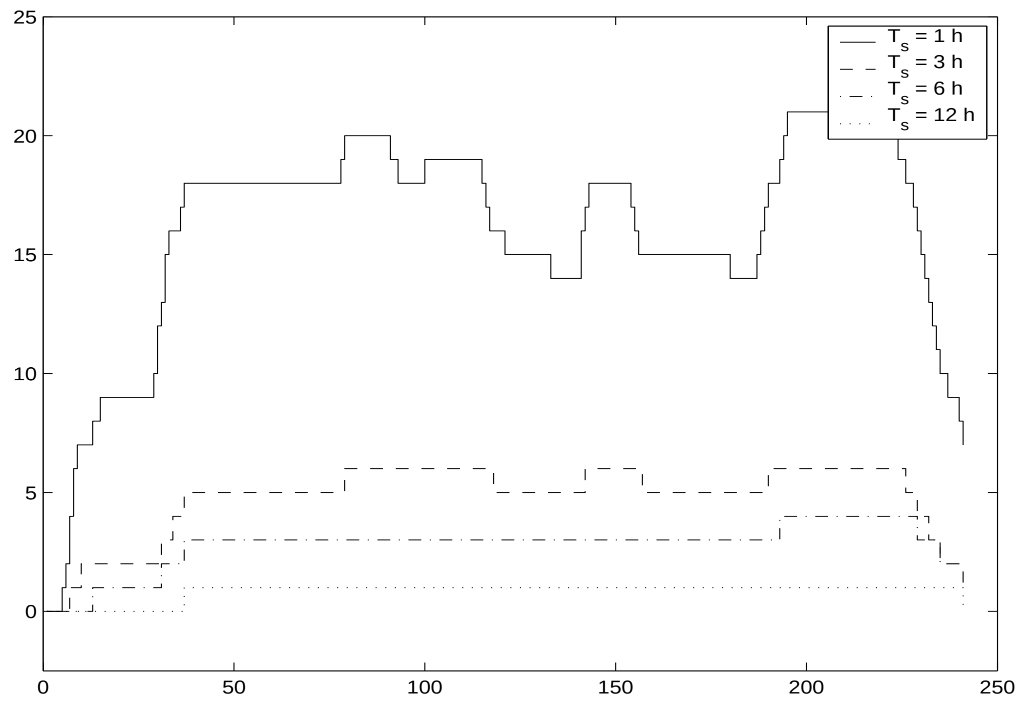


Figure 14: Accumulated Cumulus Points with Changing ChargingInterval

5.2.2 Varying the CPS Thresholds

For varyied CPS thresholds a similar behaviour can be observed. Figure 15 shows the appropriate curves for different thresholds. The thresholds were calculated using the averages over different durations as mentioned in the legend. For smaller averages the thresholds become larger, due to a higher signal variance. The accumulated cumulus points therefore become “unstable” for higher thresholds.

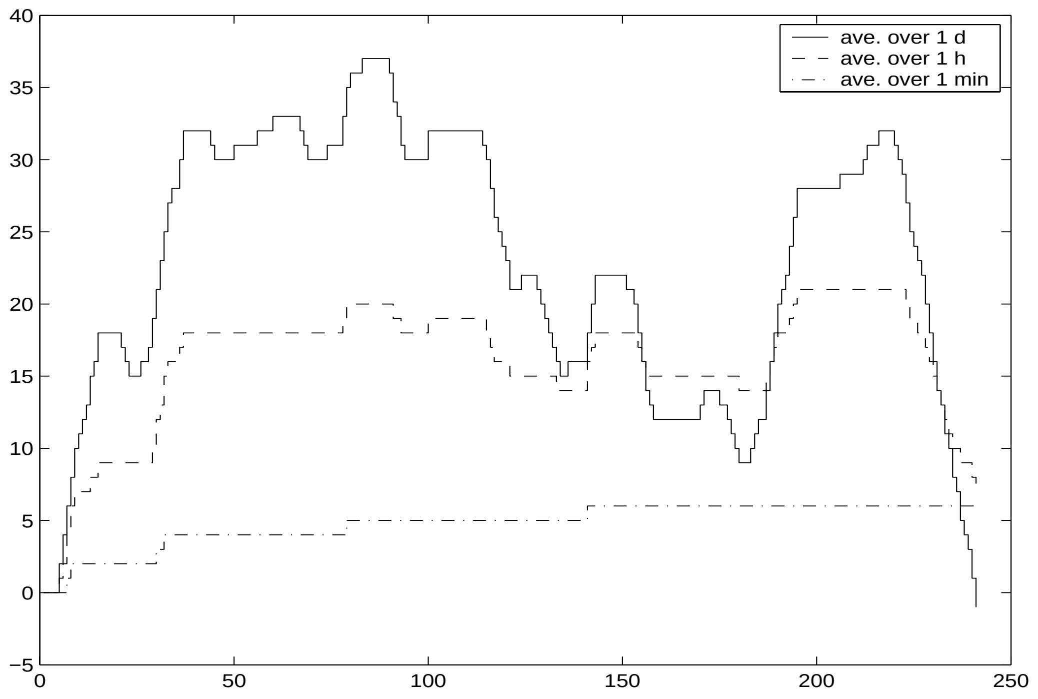


Figure 15: Accumulated Cumulus Points with Changing Thresholds

6 Summary and Conclusions

The design and prototypical implementation of the CPS scenario with the CAS of the M3I project revealed that CPS could quite simply be adapted to the structure of the CAS components. Due to its modular design and the simplicity of the CPS concept it was possible to create together a highly scalable and configurable traffic charging scenario, as all components components can easily be distributed and the traffic sampling and charging intervals can be varied. Since the customer support component was not yet implemented in the CAS, it was necessary to create a CPSCustomer class that provides the session information which is important in the CPS scenario. However, this class could easily be replaced, when the customer support component will be added to the CAS.

The experiments showed that the implementation code could sucessfully be tested on a FreeBSD / Solaris testbed and even other platforms might be used due to the usage of portable Java code.

It was hard to find a suitable traffic generator to run the simulation experiments. But finally, the experiments performed verified the feasibility of the CPS concept for a real environment and reached a good performance. The experiments showed the different behaviours of the CPS mechanism using varyied technical parameters. However, for further comparisons it would be necessary to run further experiments and compare them with other pricing mechanisms, *e.g.*, ECN-based pricing.

7 Future Work

7.1 Comparison of CPS with ECN

The various experiments that have been performed showed that CPS pricing is highly scalable in terms of the accounting effort with only few waste on the precision of measurements. However, for a better statement about the technical effort, performance and precision CPS needs to be compared with other scenarios, *e.g.*, pricing based on ECN. Hence our motivation is to compare CPS and ECN on a technical, functional and economical level in detail and based on a real environment.

It is not trivial though to define a test case in order to compare CPS and ECN technically. On the one hand it is difficult to avoid the problem of comparing apples and oranges. ECN pricing is based on charges in the shorter time scale, whereas CPS charges on a longer timescale. Other than in the ECN scenario, where a user agent makes the decisions on behalf of the user, in CPS a real human user controls the traffic based on the price. Therefore it is necessary to build a user model in order to simulate the reaction of the user on the price.

On the other hand, as ECN is still a quite new technology, hardly any implementations support ECN today. Altq supports ECN but only for experimental use. However, the problem still remains, that ECN marks are set upon a artificially congested link. Among the evaluated traffic generators, *e.g.*, DBS, Mgen and Iperf, there was none that supports setting the ECN bit in addition to the other requirements. Also NeTraMet that was used for the flow measurements doesn’t support ECN in its current official version.

For all the above reasons it was decided to wait for more ECN-”enabled” tools in order to setup a realistic test environment to run the comparison experiments.

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9 Abbreviations

AAAC	Authentication, Authorization, Accounting and Charging
CAS	Charging and Accounting System
CDR	Call Detail Record
CH	Confoederatio Helvetica, Switzerland
CPS	Cumulus Pricing Scheme
D	Germany, Deutschland
DB	Database
DBS	Distributed Benchmark System
DiffServ	Differentiated Services Internet Architecture
DSCP	Differentiated Services Code Point
ECN	Explicit Congestion Notification
EPC	Enterprise Policy Control
ETH	Eidgenössische Technische Hochschule Zürich
GR	Greece, Hellas
HTML	HyperText Markup Language
HP	Hewlett Packard
ID	Identifier
IPDR	Internet Protocol Data Record
JDBC	Java Database Connectivity
JDK	Java Development Kit
N	Norway, Norge
ISP	Internet Service Provider
M3I	Market Managed Multi-service Internet
QoS	Quality-of-Service
RSVP	Resource Reservation Protocol
SNMP	Simple Network Management Protocol
SQL	Structured Query Language
TCP	Transmission Control Protocol
TIK	Institut für Technische Informatik und Kommunikationsnetze
TUD	Technische Universität Darmstadt
UDP	User Datagram Protocol
UK	United Kingdom
URL	Uniform Resource Locator

WP	Work Package
XML	Extensible Markup Language

10 Acknowledgements

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11 Appendix

As previously mentioned in Section 2.8, the design and implementation of the user interface for the connection setup is presented here. The following section addresses the components of such an interface and connections to other parts like AA-Server and Enterprise Policy Control (EPC). After that a short description of the implementation is given.

11.1 Initialization Design (User End)

Figure 16 shows the design of a user connection setup.

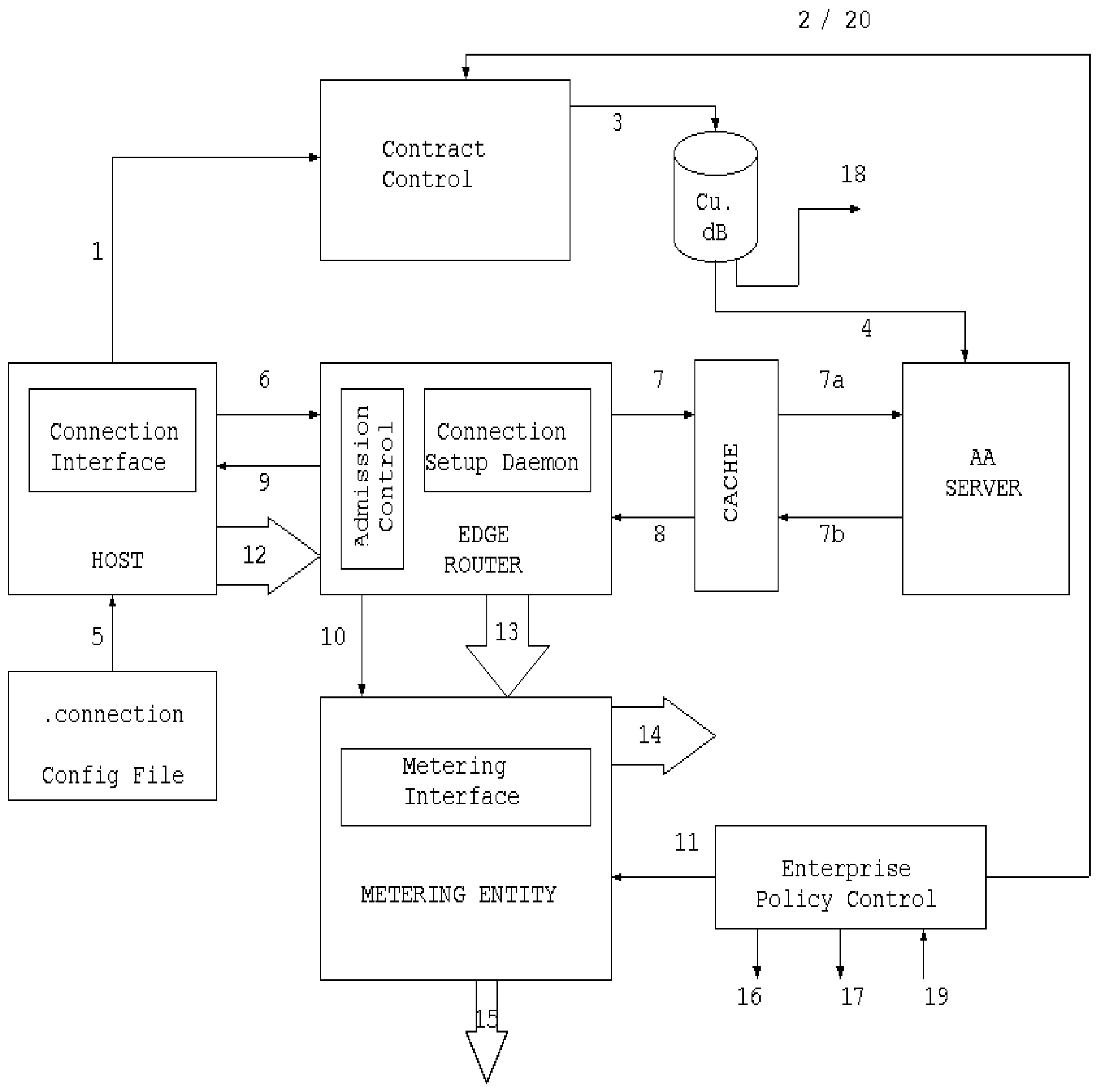

Figure 16: Initialization Design (User End)

Description

1. Contract Negotiation: This is part of the setup phase where the contract is signed between the user and the ISP. This can be done in two way, the customer gives his requirements or by using the Probe Phase.
2. The Enterprise Policy Control is used in the contract negotiation process.
3. The Contract Information is then stored in the Customer Database.
4. This is information is send to the 'AAA' server to update its internal Database. This has to include the following data:

Contract id, All the Customers and corresponding Users of the Contract. It must also contain some service information i.e. the Traffic classes allowed and the approximate maximum bandwidth required.

The Contract may itseft contain more data, such as charging and pricing information.

5. Initialization Phase: The user starts the CPS Connection Interface. The parameters for the connection setup can be entered directly or loaded from a .connection file in the users home directory. This may contain the following information: User Id, Customer Id, Contract Id, Source and Destination addresses (IP address + Port), Date and Service requirements.
6. Connection Request: The Connection Interface sends request to the Edge Router. This includes the following information (currently BE:AF:EF correspond to numeric values as service Id.):

```
<contract_id>:= number
<user_id>:= number
<customer_id>:= number
<date>:= <hour>:<minutes>:<seconds>:<day>:<month>:<year>
<source>:=<IP_address>:<port>
<destination>:=<IP_address>:<port>
<service>:=<BE:AF:EF>:<bandwidth>
```

7. The Connection Setup Deamon on the Edge Router passes the connection request to its cache. If the request matches some entry in the cache, the request is granted via path 8 or else path 7a is taken. The 'AAA' server is passed the user connection request. The permission grant (/deny) is passed to the cache via 7b. The Cache then updates the last entry.
8. The permission grant(/deny) information is passed to the Connection Setup Daemon. Internally the Connection Setup Daemon passes this information to the Admission Control which now can allow(/deny) the user traffic to flow.
9. The Permission Grant(/Deny) is send to the Connection Interface. The Connection can now be used by the user.
10. The user connection request is send to the Metering Interface if permission has been granted.
11. The EPC provides the Metering Interface with the sampling rate according to the policies setup for that particular contract. Now the user traffic which flows through the edge router is metered.
12. This is the user traffic flow. (NeTraMet copies the packets by entering into promicious mode and then analyses the packet information.).
13. Represents the user data flow to the meter (just for representation)
14. Represents the user data flow out of the meter.(just for representation)
15. The data produced by the meter flows to the Mediation Interface. This would be in the form of flow files. Snmp queries can be used to query the meter regarding the flow status.
16. Flow of the Policy Information from EPC to the Data Collection/ Accounting Unit.
17. Flow of the Policy Information from EPC to the Charge Calculation Unit.
18. The Customer Information is provided to the Charge Calculation Unit.
19. The Feedback information from the Charging Database to update the EPC.
20. EPC along with the feedback input from the billing database may cause the user to renegotiate the Contract according to the Reaction Rule.

Description of Components

1. Configuration File: This is the default setup file which is loaded when the user runs the CPS connection setup. This file contains some default parameters such as the user id, customer id, source address. It may also contain information like contract id, destination address and service parameters, which are stored from the last connection setup done by the user.
2. Connection Interface: This interface deals with the connection setup procedure. It initially loads the .connection file, the user can change whatever data he wants. It then sends a request to the Setup Daemon on the Edge Router. It also accepts the permission grant (/deny) from the Edge Router and displays it to the User.
3. Admission Control: This interface prevents the user from sending data to the network without having the permission to do so. It also contributes to the setup phase by checking the user request and passing it to the connection daemon only if the service request can be guaranteed, for example if bandwidth can be accomodated.
4. Connection Setup Daemon: This deamon listens to the user connection requests. It passes the request for authentication and authorization to the cache. It also accepts the permission grant (/deny) from the cache and pass it to the user and the Addmission Control. On connection grant it passes the user request to the Metering Interface.
5. Contract Control: This entity is responsible for the contract negotiation phase and also renegotiation. It gets Policy Information from EPC. The Contracts are stored in the customer database.The Contract may contain Contract id, all the Customers and corresponding Users of the Contract, service information i.e. the Traffic classes allowed and the approximate maximum bandwidth required, and also the charging and pricing information.
6. Cache: This is used for optimization. It would contain the user request / grant information. On a user request it checks if it is in the cache, it found it immediately sends a grant reply back. If not found it passes the information to the AA server.
7. AA Server: This is the authentication and the authorization server. It gets the user request and grants(/denies) it on the basis of its database of contract information. The information about the contract must contain at least that which are mentioned above.
8. Metering Interface: This interface connects to the metering entity. It gets policy information from EPC and the user information from the setup daemon on the Edge Router. On getting the user information and corresponding sampling rate from EPC, it starts to query the meter for user data. It write a simple rule file (.srl) compiles it to a rule file for NeMaC, which is the meter Manager and Meter Reader. It then starts NeMaC. When it recieves new requests it merges the rule file, starts a new instance of NeMaC with this rule file and then kills the earlier instance. Thus there is no loss of data due to the overlap of times. For each meter a different instance of this program is created which starts NeMaC for that particular meter. The flow information is stored as flow file(but it is not used right now). SNMP requests are made to the meter to get the flow information from it.
9. Enterprise Policy Control: This has all the Policy information corresponding to the contracts. It affects the Data Collection/ Accounting and the Charge Calculation entities. The Charging Database may have some effect on EPC and cause contract renegotiation.

11.2 Installation and Operating Issues

In this part each of the class file is explained in detail, and consists of three parts each. In the first part the class is explained in detail, in the next part way to run it explained and finally any bug or future work possible is explained. All the files are in the org.m3i.examples.ethz.CPSdemo package.

11.2.1 CPSManager

This class is adapted from the Flow Manager used in flowdemo package. It creates a frame where the user can see the existing sessions and also add new sessions or delete them. It is passes the edge router to which it has to connect. On a create new session call, it starts an instance of CPSCreator. On end a session it calls the sendDisconnectRequest. In this request, the session to be removed is taken, and the flow information corresponding to this is send to the edge router for further action, and the session table is updated. This request is similar to the one send by CPSCreator explained below, just that it is tagged with “2” to denote deletion of session instead of “1” which is for creation of a session.

This is run at the by the end user (client) when he wants to use CPS (or the ISP service in general case). He runs the: java org.m3i.examples.ethz.CPSdemo.CPSManager <edge-router>, where <edge-router> is the immediate next edge router for the diffserv boundry.

The button corresponding to Session Information is not yet completed. It can be used to display the complete session information which is already stored in the Vector cpsv. By looking at the time stamp corresponding to flow start, and the current time stamp, the total up time can be displayed to the user. Also currently the List shows the complete session information pushed into the Vector, instead this information could be parsed and a better display is possible. Also on quit, it does no send a delete request for the remaining sessions this could be added.

11.2.2 CPSCreator

This class is instantiated and called when the user wants to start a new session. This has a function similar to that of Flow Creator. It gets the edge router from the parent, i.e. the CPS manager. The user can fill in the information required for setting the connection, i.e. Contract Id, User Id, Customer Id, Source and Destination address, Service Type and Bandwidth required. When the connectionRequestEvent function is called, a socket connection is established with the edge router at port 1025. A daemon is running at this port which accepts this socket request. A string message is send which is of the format: <contractID> <userID> <customerID> <time> <sourceIP> <sourcePort> <destIP> <destPort> <serviceType> <rate>. A tag “1” is added to it to signify its a create session message. This string is added to the Vector cpsv of the parent. After this it waits for an incoming message from the Daemon, if its a “OK” message it opens a dialog showing that the user can now start using the service, else a deny dialog is displayed.

This class is automatically initialized by the CPSManager, no user intervention required. Just he has to fill in the details and press the “send connection request” button.

The button for “save” and the interface ‘5’ of the initialization design has not been implemented as yet. A config file may be produced on save which stores the information put in by the user. When the user uses this the next time, the values stored in the config file could be displayed. Currently all the fields are accepted as strings and no error checking is present.

11.2.3 CSDaemon

This class just accepts incoming socket connections at port 1025 and creates a new CSServerThread. It gets the charging router address from the user input.

This is run at the edge router where Addmission Control and 'AA' functions are to be implemented. Command: java org.m3i.examples.ethz.CPSdemo.CSDaemon <charging-router>, which is the place where all the CAS is installed.

No possible extensions.

11.2.4 CSServerThread

This thread is started by the CSDaemon parent. This establishes a socket connection to the user host. It gets the input from this host, if its a session start request it passes it to the 'AA' server for authentication and authorization. It gets the message from 'AA' and passes this to the user. If the message is 'OK' then it passes the user connection request information to a daemon on the charging router at port 1026. The class is direclty used, no intervention is required.

Several possibilities for extension here. The interface to 'AA' server has been left blank. Currently there is no addmission control. Two parts may be added here. First on analysing the user request and looking at it bandwidth requirement, the edge router itself can decide wether or not to send user request to 'AA' server. Also a cache may be put between the Daemon and 'AA' for easy lookup. To prevent access by any user to the network we can user a software patch for the kernel called ip-tables. This can be programmed to drop all incoming packet except the choosen ones(by their ip, header info.) This can be modified runtime by the Addmission Control module. Also a login/password sequence may be added.

11.2.5 NeMaCServer

This file runs on the Charging Host. This class creates instances of NeMaCDaemon corresponding to each of the metered hosts. It also accepts incoming socket connections on port 1026 and according to their source passes it to the corresponding NeMaCDaemon.

This runs on the Charging Host where NeMaC is installed. It is passed the address of the hosts where the meter is running. It can be run by the command : java org.m3i.examples.ethz.CPSdemo.NeMaCServer <meter-host-list> <PATH>, path corresponds to the place where srl and NeMaC are installed.

Currently only there hosts can be given to the server. Just one more parameter n. To assign the incoming sockets to the NeMaCDaemons, socket.getInetAddress is used but this does not give address of the originating point but to intermediate router, bridge. This has been patched up in the code by stating that RA_RC would correspond to RA, and so on. The way out would be that the edge router sends its address with the message itself.

11.2.6 NeMaCDaemon

This is instantiated by the NeMaCServer corresponding to the meter - host name. This has 2 Vector objects to store session information, and one Process object to store last NeMaC process id. It starts new NeMaC Server Thread objects. Used by NeMaCServer itself.

11.2.7 NeMaCServerThread

This class connects to the incoming socket provided by its parent class. It extracts from it the various parameters send in the user request like contract id, user id, source and destination address etc. It stores this information in the parent Vector cmrs. It also generates a string of the form shown below, and puts it into a Vector sessions : SourcePeerAddress == "+sourceIP+" && SourceTransAddress == "+sourcePort+" && DestPeerAddress == "+destIP+" && DestTransAddress == "+destPort+". This is used to create a rule file. Next part is writing a srl file. A srl file is created with the file name <meter-host>.testbed.srl. The fouth line is the SETstatement, describing the rule set number. Next is the FORMAT statement, which tells NeTraMet what details to write down in the flow files produced. After that we have a statement : if SourcePeerType == IP save; else ignore; here if the packets received by NeTraMet are IP then they are copied else ignored. Next statement says that if the packets are of tcp or udp type only the save them. Next statement is the main filter to identify flows by their 4 address parameters which are known. Only these packets are counted. The filter statement is generated using the Vector sessions, which was described above. If there is more than one session then an or symbol (||) is put between two such statements. The file creation process is done whenever the Vector sessions is updated by new session or delete session. Next this file is compiled to a rule file with the name <meter-host>.testbed.rules. The thread waits till the file is compiled. Now NeMaC(meter manager) is started. The parametes passed to the NeMaC are : -c <sampling-time> the rate at which NeMaC should query the meter for new data. -r <rule-file name> name of the rule file ie. meter-host.testbed.rules. The meter-host name, the snmp community name and the owner of this meter. This process is started and its processID is stored in the parent variable process, and the earlier process is now terminated. A <meter-host>.session file is also written to communicate with the CAS connector the ongoing sessions. No user intervention required.

There is no need for format statement as the flow files produced by NeMaC are not used. If possible there may be some other way to communicate with the connector the ongoing sessions, may be using RMI objects. Earlier different instances of NeMaC were used for each session, but this was inefficient and also due to the SET field there was a limitation of only 10 possible rule files to be uploaded.