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ACCOUNTING IN QoS -ENABLED IP NETWORKS

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Abstract: *This paper presents an overview of the advanced transport-based accounting management in IP networks with differentiated services (DiffServ). We first provide a survey and taxonomy of accounting management functions, including metering, pricing, charging, billing, payment and information provisioning. An overview of pricing models for DiffServ networks has been presented. We also consider IETF accounting management framework and accounting protocols. Finally, several advanced proposals for accounting management architectures in DiffServ IP networks have been addressed.*

Keywords: *Internet protocol, Quality of Service, Differentiated Services, Accounting, Metering, Pricing, Charging, Billing*

1. Introduction

The growing demand for deploying quality of service (QoS) in IP-based networks poses a number of issues related with the accounting functions. Accounting in advanced multiservice IP-based networks can be structured either as transport-based or content-based [1]. The transport accounting assumes charging of users for transfer of some amount of information over the IP-based network. In QoS-enabled IP networks there is a need for shifting from simple charging schemes such as duration based or flat rate based charging towards the usage based charging [2], with different tariffs assigned to different service classes. Still, operators of QoS-enabled networks require simple charging schemes with which they can fairly recover costs from their users and effectively allocate network resources. The goal of the content-based accounting is to charge users for the contents of services that are delivered over IP network. The interest in content accounting arises with the fast growth of commercial offerings over the IP networks, e.g. video on demand, software distribution and mobile IP services.

This paper presents an overview of the advanced transport-based accounting management, focusing to QoS-enabled IP networks with differentiated services (DiffServ). We first present a survey and taxonomy of accounting management functions, including metering, pricing, charging, billing, payment and information provisioning. Further, an overview of pricing schemes for DiffServ networks has been presented, considering different pricing models and their relations with traffic contracts. The IETF accounting management framework and accounting protocols have also been considered. Finally, advanced proposals for the DiffServ accounting management architectures have been addressed, including policy based accounting, programmable accounting management and cooperative accounting management through QoS Manager entity.

2. Accounting management functions

Accounting management refers to the set of functions which enables the use of the network service to be measured and the costs for such use to be determined [3]. The accounting management encompasses several different processes[1]: metering, pricing, charging, billing, payment and information provisioning, as illustrated in Fig. 1.

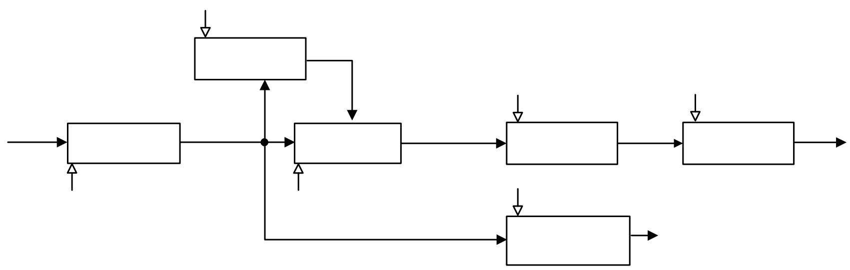

Figure 1. *Relations between accounting management functions*

The metering process involves monitoring, measuring and collecting of resource usage information, related to a single customer's service utilization. It provides the accounting data, which represent the collection of resource consumption data, for the purposes of pricing, charging and information provisioning.

Pricing is the process of determining tariffs, i.e. cost per unit. The pricing process provides pricing data as input to charging process. It is based on particular pricing mechanism and controlled by a pricing policy. The pricing table keeps the information about the price to be charged for the use of resources.

The charging process combines the tariffs and the results of metering to charge the customers. The output of charging process is the charge per party (customer, service provider, content provider) based on the pricing data and the resource usage data. As control data, this function uses a charging policy and a distribution policy, which determines how the charge is distributed over the involved parties.

The billing process produces an invoice on the basis of the charge per party. The process can be configured by means of the billing policy, e.g., how often a bill is made. The payment process results in the actual transfer of money, based on an invoice as input. It can make use of an electronic payment system and might be influenced by a payment policy (e.g., pay-before, pay-now or pay-later). The information provisioning process

[1] In this paper, we use the term accounting in its original and broader sense, compliant with the ITU-T TMN (Telecommunications Management Network) definition. Recently, the term accounting has also been used as a synonym of the more restricted process of metering [4], [5]. Besides, frequent synonyms for pricing and charging are cost allocation and rating, respectively [4].

provides user information and audit information to all parties involved in the service exploitation. The processes of billing, payment and information provisioning may also be used for capacity planning and trend analysis.

3. A survey of pricing schemes for DiffServ IP networks

Considering scalability as a fundamental requirement for multiservice IP networks, the DiffServ approach to QoS provisioning comprises standard-compliant [6], [7] or proprietary architectures that have a common property that packets belonging to different traffic flows, but with similar QoS requirements, may be associated to the same service class and processed at the network nodes in the same manner. Complex processing operations are performed at the edge routers, while core routers perform simple and fast operations.

In general, pricing schemes have to be defined and evaluated with respect to the heterogeneous technical, economic and social aspects [8]. The main evaluation criteria encompass efficiency in the sense of maximizing utilities of customers and the provider, fairness and feasibility. Additional challenge of DiffServ-based services pricing is to adjust to DiffServ framework main features: simplicity, operation over the existing IP-based infrastructure and pushing complexity to the network edge.

In the DiffServ network, QoS is negotiated between the provider and the user (end user or another IP domain) for each traffic flow and this process results in the contract called Service Level Agreement (SLA). SLA can be negotiated either statically or dynamically, in which case a signaling protocol for negotiation of on-demand service is required. SLA consists of a set of descriptors and associated attributes that describe the particular service class and the traffic profile. It also includes information about tariff and billing principles, as well as penalties for both user and provider in the case of contract violation. The logical structure of SLA [9] is presented in Fig. 2. Service Level Specification (SLS) describes technical parameters of the SLA. Traffic conditioning agreement (TCA) is a part of the SLA that defines rules for packet classification and traffic profiles, by description of temporal traffic properties, e.g. the rate and burst size. Metering, marking, shaping and discarding rules are also defined, in order to enforce customer's traffic to a particular profile. Traffic Conditioning Specification (TCS) is a technical part of the TCA and also a constitutional part of the SLS.

TCS parameters are a means for control of the amount of resources that each IP flow is using. Therefore, a DiffServ pricing scheme can co-estimate TCS parameters in order to charge the user [10]. Relationship of the TCS and the pricing scheme is illustrated in Fig. 2, on the example of well-known token bucket conditioner. Common notation for token bucket is TB (r, b), where r represents the rate of tokens, while b denotes the depth of the bucket. Parameter r corresponds to the peak or committed information rate and can be used to estimate bandwidth usage, while parameter b represents a measure of peak or committed traffic burst size and can be used to evaluate buffer occupation in network routers.

SLA is a starting point for accounting management in the DiffServ network. Although different classifications of pricing mechanisms are possible [11], we will further address three main categories of schemes and their relationship with the DiffServ SLA: (1) static pricing, (2) dynamic pricing and (3) hybrid pricing. Relationship of the SLA and the pricing mechanism parameters is illustrated in Fig. 2.

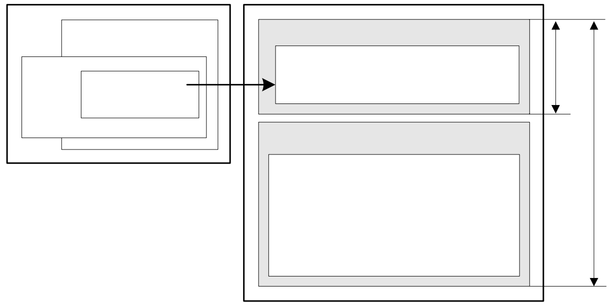

Figure 2. *SLA and its relationship with pricing mechanism parameters*

The use of SLA as the only component of pricing scheme leads to a **static** or **a priori** pricing, which is based on anticipation of resources usage, according to corresponding SLA terms. In the broader sense, static approach corresponds to the expected capacity pricing, introduced by Clark [12] and originally designed for ATM and Integrated Services (IntServ) IP networks. Expected capacity represents the user's expectations in the sense of one or more performance metrics, when the network is congested. It can be specified in many ways, including minimum required capacity, maximum delay or an effective bandwidth[2] [2], [13]. Expected capacity pricing may be applied at the edge routers, thus fulfilling the basic DiffServ objectives.

The main advantage of static pricing refers to its simplicity – measurements of the traffic are not required at all. However, deficiencies concern charging of users who either under-utilize or over-utilize resources that correspond to their contracted traffic profiles. In the former case, a user would be charged for more resources than it actually consumes. In the latter case, there is a risk of exhaustion of resources, and consequently deterioration of QoS delivered to legitimate customers, without penalties for users who over-utilize the resources.

Dynamic or **a posteriori pricing** is an opposed approach, in which tariff is determined as a cost per unit of consumption and according to level of QoS guarantees provided for the observed service class. Such approach is similar to a number of traditional usage-based pricing schemes that have been proposed to handle short-term congestion, e.g. responsive pricing and smart market pricing (please refer to [8] and associated references for the in-depth description and evaluation of those mechanisms). Responsive pricing supposes that users are adaptive to cost changes and considers price as an efficient feedback mechanism for congestion control. A smart market pricing scheme introduces additional usage charge when the network is congested. This charge is determined by auction, in which the user bids a price for each packet, thus expressing his readiness to pay extra money for transmission under unfavorable conditions. Yang proposed a pricing strategy for admission control procedure and bandwidth assignment in the DiffServ network, based on auctioning in which each customer proposes a desired bandwidth, duration of service and a price that he is willing to pay for it [11]. The service

[2] Effective bandwidth is a measure of resource usage, which takes into account statistical characteristics of the traffic source type and the QoS requirements.

provider collects all information and produces parameters for each service class, which are then used to decide which customers to admit.

Recently, Di Sorte et al. have introduced a notion of virtual delay (QoS index) as an efficient parameter for flexible defining of usage-based tariff criteria [14]. They suppose that from the cost point of view, the QoS guarantees in terms of end-to-end delay, delay jitter and loss probability can be modeled as an equivalent service with a given delay, without any jitter and losses. The tariff is then modeled as a monotonic, non-increasing function of virtual delay, while usage-based charging is performed on the basis of tariff, connection duration time and the amount of traffic volume exchanged.

The main problem with dynamic pricing refers to the need of intensive monitoring of network resources in order to dynamically adjust per-class prices to resources usage and the QoS provided for each service class. Another problem arises from a purely economic point of view, because real economic efficiency for the provider allowing highly variable utility functions over short-term intervals seems to be an unrealistic objective [8].

Bouras and Sevasti tried to combine benefits and to mitigate deficiencies of both static and dynamic pricing models, proposing a **hybrid model of DiffServ pricing**, in which tariffs for particular service classes alter over reasonable service provisioning intervals [10], [15]. They believe that prices in DiffServ framework should initially play the role of mediator between the user and the provider, thus forcing the customer to wisely select the most appropriate traffic profile. The objective of pricing mechanism for each customer C_j should be maximizing the following relation:

$$U_{s_k}(L_i) + U(Q_{s_k}) - p_{s_k}(L_i) \ , \tag{1}$$

where $U_{s_k}(L_i)$ is the utility perceived by C_j through an SLA with traffic profile L_i for service s_k, $U(Q_{s_k})$ is the utility (either positive or negative) of the customer C_j from a set of quality guarantees (Q_{s_k}) offered by the service s_k and $p_{s_k}(L_i)$ is the price that has to be paid by C_j signed with the L_i SLA and receiving the treatment of s_k.

Opposed to usage-based monitoring per unit of consumption, charging is performed according to an initial charge for the purchased traffic profile and the deviations from contracted traffic profile during each service provisioning interval. Such approach requires less storage of monitoring data and can be implemented only at the edge routers, in which traffic conditioning is performed. The provider may force customers to adjust properly to their contracted traffic profiles through an appropriate pricing policy, e.g. by pricing schemes that increase exponentially the price as the amount of out-of-profile ingress traffic increases.

4. The IETF accounting management framework and accounting protocols

IETF has established the accounting management framework, with the objective to provide a set of tools that can be used to meet the requirements of different applications [4]. The accounting architecture involves interactions between network devices, accounting servers and billing servers, as illustrated in Fig. 3. The network device collects resource usage data in the form of accounting metrics, which it then transfers to an accounting server either via accounting protocol or by generating its own session records. The accounting server then produces the accounting data and submits the session records to a billing server, which handles charging and billing, but may also carry out pricing, auditing, trend analysis or capacity planning functions. The accounting server must be capable to distinguish between inter and intra-domain accounting events and to route them appropriately.

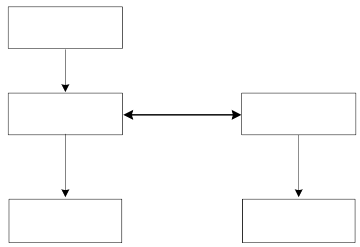

Figure 3. *The IETF accounting architecture* [4]

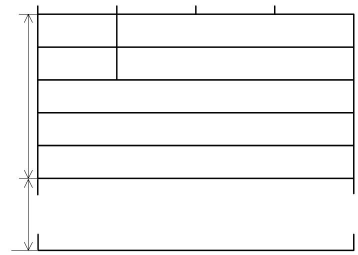

Figure 4. *The Diameter message format* [16]

Accounting is closely linked to other classes of network functionality, most notably authentication and authorization. Authentication is needed to assure that the right user is being charged, while authorization guarantees that accounting data is only made available to authorized parties. For that reason, authentication, authorization and accounting (AAA) functionality is often considered in combination and implemented on a single server, using the same protocols.

The IETF AAA working group primary deals with the network access and appropriate protocols. AAA protocols such as RADIUS (Remote Authentication Dial In User Service) and TACACS (Terminal Access Controller Access Control System) were initially deployed to provide dial-up and terminal server access. With the growth of the Internet and the introduction of new access technologies, including wireless, DSL, Mobile IP and Ethernet, routers and network access servers have increased in complexity and density, putting new demands on AAA protocols. Recently, the Diameter base protocol [16] has been adopted as a preferred AAA protocol, intended to provide a framework for applications such as network access or IP mobility. The general format of Diameter message is depicted in Fig. 4. All data delivered by the protocol is in the form of attribute value pairs (AVPs). Accounting data are transferred through a pair of messages: *Accounting Request* and *Accounting Answer*. AVPs associated with those messages support transporting of user authentication information, transporting of service specific authorization information and exchanging resource usage information, which may be used for accounting purposes, capacity planning, etc. The base protocol may be used by itself for accounting purposes only, or it may be used with particular Diameter applications, such as Mobile IPv4 or network access server.

Besides the Diameter, it may still be expected that a widespread SNMP (Simple Network Management Protocol) will continue to play a role in accounting management [1]. This is closely related with remote retrieving of traffic flow measured data that can be used for accounting purposes and are stored in network elements as a part of standardized MIB (Management Information Base) which is called Meter MIB [17].

5. Advanced DiffServ accounting management architectures

A. Policy based accounting

The role of different control policies in the set of accounting management functions has been addressed in Section 2. An approach that uses accounting policies to describe the configuration of an accounting architecture in a standardized way has been proposed in [18] by the IRTF AAAARCH (AAA Architecture) research group. This work has been motivated by recognition that different providers have different accounting requirements, which may change frequently [1]. The work extends the generic IETF AAA architecture by introducing the relations between different functions that are involved in the accounting process and the required building blocks for an accounting architecture. Accounting policies can be exchanged between AAA entities by AAA protocol, in order to share configuration information. Remote configuration of network elements involved in the accounting process may be performed by means of SNMP or COPS (Common Open Policy Service) protocol. It is assumed that a suitable policy language can be chosen from existing or upcoming standards.

The example of the usage of accounting policies for service setup in the DiffServ network managed by bandwidth broker [7] is presented in Fig 5. The user issues a service request to the AAA server. The service request includes service class parameters, accounting and QoS auditing. After successful authentication and authorization, the AAA server extracts the application specific information (ASI) from the request and passes them to the application specific module (ASM). The ASM then evaluates service provisioning policies and translates the ASI into appropriate configuration information for the service equipment. For the given example, the service equipment consists of bandwidth broker, metering and QoS auditing. This results in sending a bandwidth request (which asks for a service class with the given parameters) to the bandwidth broker, a request to the metering equipment for comprehensive accounting and a request to the QoS auditing equipment for measurement of particular performance metrics. The bandwidth broker then configures the DiffServ domain to provide the forwarding according to specified class. For the metering and the QoS auditing, local configuration policies exist for setting up the service, including metering location, record types, report intervals, appropriate measurement methods, etc.

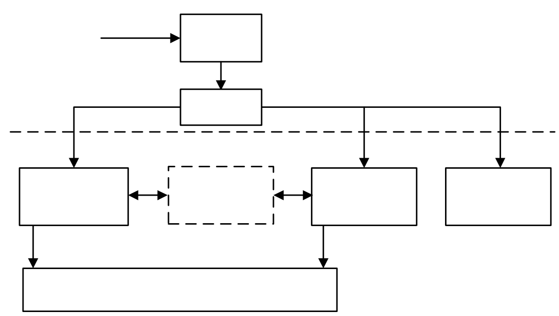

Figure 5. *DiffServ service provision setup* [18]

B. Programmable accounting management

Applying programmable networks for purpose of efficient real-time pricing and charging on per-packet basis has been proposed in [19]. The basic idea is to relocate the process of selecting the most suitable service class from end hosts to edge nodes. For that purpose, each edge router should be designed as a programmable router, as depicted in Fig. 6. Each customer runs its own code on the corresponding edge router to decide which service class to buy for each packet. The input parameters of the customer's code may encompass provider's tariffs (which may change dynamically), current network performance parameters, traffic profile of each customer's flow, maximum cost that the customer may afford, etc. The customer's process marks each packet for the selected service class and forwards it to the node scheduler. The customer's code may be executed either on the sender's or receiver's side, depending on the fact which party is responsible to pay for the selected service.

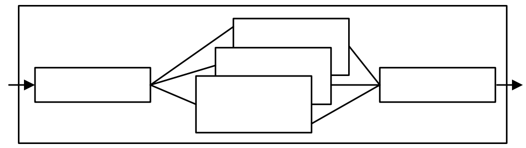

Figure 6. *Charging mechanism as a customer process inside the network node* [19]

Programmable networks seem to provide a promising solution for decentralized intra and inter-domain accounting management of virtual private networks (VPNs), supporting DiffServ. A portion of accounting management tasks may be executed at the edge nodes, including metering, dynamic pricing and charging as described above, processing of accounting data and configuring MIBs. Logical partitioning of each MIB allows segregation of the accounting information among different VPN customers.

C. Cooperative accounting management through QoS Manager

In [20] we have proposed a functional model of the QoS Manager (QM), which upgrades the bandwidth broker concept from [7] towards an end-to-end QoS management architecture, compliant with the TMN structure and functionality. QM is a per-domain entity which is responsible for SLA management, network resource management, configuration management, security management, etc. Each QM maintains the view of its domain resources through the resource state table. QoS is negotiated dynamically through an appropriate signaling protocol.

The role of QM in accounting management, which uses dynamic or hybrid pricing scheme is depicted in Fig. 7. The end user forwards SLA request for its traffic flow to AAA server, which performs authentication and authorization and forwards the request to the SLA Manager. SLA Manager is a constitutional part of the QM, which encompasses functions of the business and service management layers. It evaluates the SLA request, associates the flow with the corresponding service class and the initial tariff profile and forwards it to the Network Resource Manager. The Network Resource Manager decides about entering a new traffic flow through an admission control procedure, allocates appropriate network resources and issues parameters for configuration of metering equipment and QoS configuration of network elements. Remote parameters configuring may be performed e.g. by means of the SNMP protocol.

Metering equipment is responsible for producing of accounting records, which are forwarded to the pricing mechanism (located at the SLA Manager) and to the AAA server. Accounting records may encompass connection duration time, traffic volume exchanged, resource usage data, achieved QoS in terms of values of relevant performance metrics for the required service class, etc. The pricing mechanism then uses the accounting records together with the technical parameters of the traffic contract (SLS) and the information on domain resource state to determine the tariff and forwards pricing data to AAA server. The AAA server processes the accounting records and pricing data to provide the input for the billing server, which performs charging and billing and generates the invoice to the end user.

In a cooperative multi-domain scenario, end-to-end SLA is negotiated through concatenation of bilateral SLAs between pairs of adjacent domains, by means of a QoS signaling protocol. Accounting data and domain accounting policies are transferred through an accounting protocol. Cooperative scenario assumes agreement between the group of domain administrations on certain baselines needed for deployment of inter-domain QoS, e.g. SLS formats, a set of performance metrics, a set of metering data, measuring points and measuring methods, reporting requirements etc.

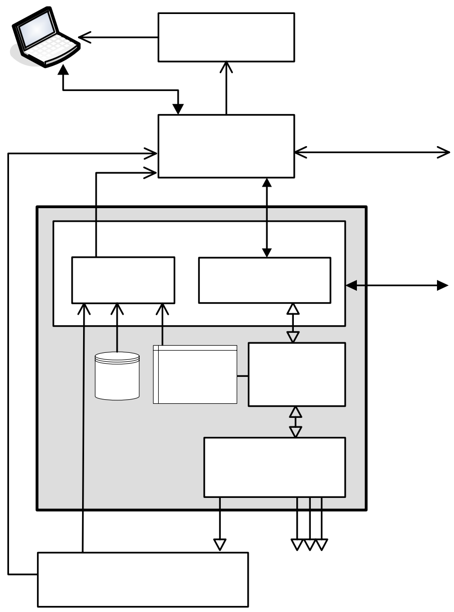

Figure 7. *The role of the QoS Manager in cooperative accounting management*

6. Conclusion

Implementing QoS in next generation IP-based networks requires sophisticated accounting management systems, primary with respect to metering, pricing and charging functions. DiffServ pricing mechanisms should provide satisfying utilities for both the provider and the user, still preserving implementation efficiency and feasibility. They should rely on per-flow traffic contracts, but they also have to take into account the dynamic information about resource consumption and achieved QoS level.

Transport accounting is the subject of various research projects and is being standardized by the IETF. The IETF AAA working group has selected the Diameter as preferred accounting protocol but it may be expected that the widespread SNMP will still play a role in accounting. This paper has also addressed three advanced architectural proposals for accounting management in the DiffServ environment. Research work is still needed toward end-to-end QoS management architecture, including accounting management functions in multi-domain scenarios.

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Sadržaj: *U radu je prikazan pregled rešenja za upravljanje tarifiranjem pri prenosu informacija kroz IP mrežu sa diferenciranim servisima (DiffServ). Objašnjene su funkcije upravljanja tarifiranjem koje obuhvataju merenje, određivanje tarifa, zaduženje korisnika za obračun, fakturisanje, naplatu i informacione servise. Prikazani su principi i modeli određivanja tarifa u DiffServ mreži. Zatim su razmatrani IETF okvirni rad za upravljanje tarifiranjem i pridruženi protokoli. Na kraju su opisana osnovna svojstva savremenih arhitektura, predloženih za upravljanje tarifiranjem u DiffServ mreži.*

Ključne reči: *Internet protokol, Kvalitet servisa, Diferencirani servisi, Tarifiranje, Merenje, Određivanje tarifa, Obračun, Naplata*

TARIFIRANJE U MULTISERVISNIM IP MREŽAMA

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