How to Combine Edge Pricing and End-to-End Performance Management Efficiently

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Abstract
This paper deals with the interworking between the performance and accounting/pricing functionality of network management from an end-to-end perspective. A careful analysis of the ITU recommendations M.3400 and M.3010 allows the formulation of a general set of ideas about possible synergies between both management areas. This concept is extended to related Internet-driven approaches for charging Internet services.

1. INTRODUCTION

In parallel to the emerging Quality-of-Service (QoS) proposals for the Internet that have led to the IETF IntServ and DiffServ architectures, also the area of charging and pricing Internet services has recently experienced a tremendous growth in interest. Traditionally, there has been a close link between the quality of an Internet service and the price to be charged for it. Surprisingly enough, the analogous relationship between charging and performance management has not gained comparable attention in the research community so far. The aim of this paper is to present a couple of fundamental considerations about this connection. Specifically, we focus on end-to-end performance management and edge pricing [8], which is characterized by concentrating charging functionalities at the edges of the network (e.g. access routers) and has become one of the central paradigms for charging Internet services.

Starting point for the following considerations are the management concepts as developped by the ITU, specifically we refer to the definition of the layered structure for management systems as specified by the M.3010 and the function specification for end-to-end network management as specified by the M.3400 recommendations. Both these documents are in general not dedicated to circuit-switched networks and thus present a general framework for convergent voice/data networks.

The main motivation for using M.3010 [1] is the logical separation of the different parts of the value chain performed there: besides a layer that is related to the network provider and deals with network elements (Element Management Layer EML), we find separate end-to-end layers for the network provider (Network Management Layer NML), the service provider (Service Management Layer SML) and for business-internal applications (Business Management Layer BML). M.3400 [2] on the other hand defines function blocks for all topics relevant to network management. In the context of this paper, especially performance management and accounting management are topics of main interest. It is important to note that the function sets of M.3400 can be thought of being orthogonal to the layered structure of M.3010.

The rest of the paper is structured as follows: Section 2 summarizes a general QoS architecture concept, before section 3 provides a new view on end-to-end accounting and performance management in the context of QoS management. Based on this analysis, in section 4 an entity-relationship model between performance management and accounting management is derived, which is compared to a Charging and Accounting System (CAS) for Internet services in section 5. Section 6 presents some characteristic examples for possible synergy effects between e2e-PM and e2e-AM. Finally, section 7 provides some concluding remarks.

2. A QOS ARCHITECTURE CONCEPT

Using [3] for a general description of the QoS building blocks in connection with communication resources as well as the corresponding QoS management functions leads to an overall picture as follows:

The QoS building blocks are defined as

- the **network**, containing resource managers for bandwidth, CPU and buffers both for the transport and access media;
- the **communication subsystem**, providing communication-related functions (thus enhancing the network services) for applications as well as resource managers for the configuration of protocols for supporting the respective services;
- the **operating system**, supporting both the communication subsystem and the application process within end systems and containing resource managers for processor capacities, buffer space etc.

The QoS management functions as identified in [3] are:

- **QoS definition**, i.e. the description of the requested service including QoS parameters, general service and type-of-service parameters;
- **QoS mapping**, consisting of two types of automated mappings: one between visible QoS parameters and the system internal QoS parameters that are not visible to the applications, the other mapping type being related to further system internal interfaces;
- **QoS negotiation**, dealing with the distribution of service requirements to all entities involved, entailing both local and end-to-end negotiations;
- **QoS maintenance**, ensuring that the requested and negotiated QoS will be indeed supported;
- **QoS monitoring**, including the computation of the current values of the QoS parameters and the identification of context violations.

3. PERFORMANCE AND ACCOUNTING MANAGEMENT IN THE CONTEXT OF QOS MANAGEMENT

Obviously, both end-to-end performance management (e2e-PM) and end-to-end accounting management (e2e-AM) play an important role in the context of QoS management. This section focusses on key issues of both topics, describing the intimate relationship between QoS management, performance management and accounting management.

There are two qualitatively different aspects to be taken into account when talking about e2e-PM:

- support of reactive properties of a TMN: via statistical analysis the behaviour of the network can be monitored and corrected;
- support of proactive properties of a TMN: via mathematical models e2e-PM can aid in measuring, planning, provisioning and maintaining quality standards.
- The specific tasks for the support of QoS management can be described in two different ways. On the one hand, they can be characterized as monitoring and evaluating parameters for connection establishment, connection retention, billing integrity, keeping and examining log files about system states history and cooperation with fault management in order to establish possible resource failures as well as with configuration management to change routing and load control parameters.

On the other hand, [2] characterizes the tasks of e2e-PM in terms of functional blocks. One of those, called “Performance Quality Assurance”, is dedicated to the support of QoS management. It is part of the decision processes establishing the quality measures that are appropriate to PM. The functions defined within this function blocks are

- QoS performance goal setting (guideline management for the assessment of all QoS performance measures),
- Network performance goal setting (guidelines for assessing network performance with focus on quality and availability of network services),
- Subscriber service quality criteria query (enabling the customer to enquire about PM information),
- QoS performance assessment (giving access to the summary assessment of the combined QoS performance measurements comparing the measured quality to the quality goals),
- Network performance assessment (providing access to the summary assessment of the network performance quality and its availability),
- Network Elements (NE) performance assessment (providing access to the collective analysis of an NE’s availability via performance parameters for service assurance and offerings),
- Data integrity check (providing indications whether performance data have been invalidated).

The other functional blocks defined in [2] which perform the necessary actions in order to enable “Performance Quality Assurance” to work and which are crucial to all three QoS management functions enumerated above are Performance Monitoring, Performance Management Control and Performance Analysis.

The connection between accounting management and QoS is on the one hand given by the obvious fact that tariff differentiation is based on the kind of quality provided/requested (except for pure flat rate schemes). This is true for the NML, SML and BML. On the other

hand there are less obvious activities supporting the mentioned tariffing/pricing schemes, reaching from the collection of accounting data up to the execution of feasibility checks.

In contrast to the treatment of PM, [2] does not provide a function set group dedicated to QoS. The ones identified as necessary for an e2e-AM are:

- Usage Measurement, based on efficient data collection from NEs.
- Tariffing/Pricing, where according to [2], a tariff is defined as a set of data within an NE, used for the determination of the amount to be charged for service usage.
- Collection and Finance, intended for the provision of financial data for the TMN for administration of customer accounts, customer information on balances, definition of payment dates and payment reception.
- Enterprise Control, supporting the TMN with respect to an exact, careful control over the flow of proper funds within the enterprise and between enterprise and its owners/creditors.

The function sets of those four groups can be divided into two classes, according to whether they are directly concerned with QoS or not. The rest of this section provides a short survey on the first of these classes, whereas the members of the other class are treated in the following section within the synergy discussion.

The largest group of functions directly related to QoS concerns Usage Measurements and includes function sets on

- planning of the measurement process,
- aggregating,
- validating,
- monitoring and
- storing of usage data.

All these items directly influence the quality of data and results of the measurement procedure. Specifically, the storage function sets are concerned with business continuity, disaster recovery and access to raw data on usage records, errors and reports.

The Tariffing/Pricing function set group contains

- pricing strategy,
- costing,
- settlement policy and
- feature pricing.

All four topics are again directly related to QoS as they represent the direct translation between service levels and tariff schemes.

The Collection and Finance block of functions includes

- planning of the billing process and
- general ledger.

These function sets deal with the assignment of values to QoS levels, either by deciding on the assignement strategy or by verifying the correctness of assignment.

The Enterprise Control block contains only one function set of interest, i.e.

- budgeting.

This function set takes care of budget modifications in case of performance diverging from objectives.

4. ON THE RELATIONSHIP BETWEEN PERFORMANCE AND ACCOUNTING MANAGEMENT

In the previous sections, the relationship between e2e-AM and QoS has been investigated. This section deals with the resulting relationship between both subjects and develops an entity-relationship model as result. The various areas of interworking will be analyzed layer by layer according to M.3010.

Element Management Layer:
The overlapping interests of e2e-PM and e2e-AM on the EML include the following:

- PM requires to assess the performance of an NE, encompassing the detection, counting, storage and reporting of events (like packets per time, holding time, calls per second, packets discarded, thresholds crossed etc.)
- AM possess according to M.3400 a so-called “Usage Accumulation Function Set”, meant to include all activities to get the relevant data per service per client. Depending on the protocol stack used for transporting the information, the above event list will aslo constitute the relevant data from the NE for AM on the NE level.
- Both PM and AM need to validate their validate their data. This happens on the EML as well as on higher layers. In both cases, edited, syntactically and semantically constrained data are analyzed.

Network Management Layer:

- Formulation of strategies is the first striking similarity between AM and PM on the NML. For PM, QoS performance goals and the corresponding assessment rules have to be formulated. AM supports processes and systems, putting down goals to efficiently measure the usage of products and services. Both management areas need to consider time frames as well as volumes for their rule finding, depending on the service.

- In order to get an overall picture of the network, both PM and AM need to correlate the data. For an efficient data mining, which might span different domains, the same sort of structural information is necessary.
- Another point, which is of common interest to both management areas, is the monitoring of data on a network wide scale. The detection of errors in recording data, network routing and potential fraud will, in all probability, be derived from the same data sets, using very similar functionality.
- Also of common interest to PM and AM is the long term storage of raw measurement data. The mathematical methods used for forecasts based on those data will in both areas probably be very similar.

Service Management Layer:

- On the SML the most obvious point of common interest is the summary of a customer's performance (for one service, or all services, or one product etc.). This can represent the basis for all charging records produced for this customer.

Business Management Layer:

This layer is of a very proprietary nature, which only admits remarks of a very general nature. One could imagine that the general ledger function set of AM, which also provides for the tracing of all forms of income and expenses, will analyze the performance data of all layers, probably using PM functions to corroborate the results arrived at by AM.

Summarizing the previous analysis yields an Entity-Relationship-Model as depicted in Figure 1.

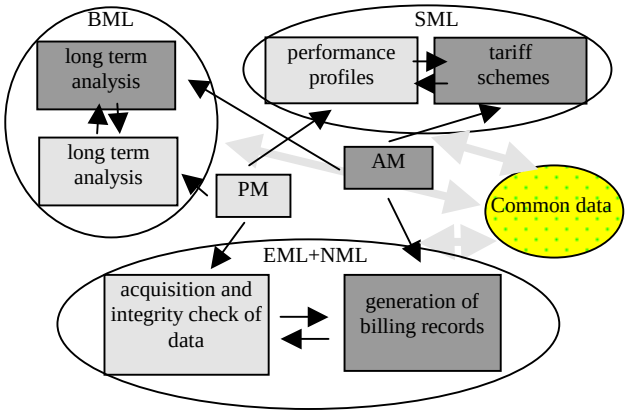

Figure 1. Entity-Relationship Diagram AM/PM

The relationship between AM and PM is structured according to the end-to-end management layers. Within EML/NML, the data acquisition module is prerequisite to the generation of billing records, whereas the latter requests certain data sets from the acquisition module. Within the SML the performance profiles are usually mapped to tariff schemes. On the other hand, changing tariff schemes can imply performance profile updates as well. Finally, both PM and AM perform correlated long term analyses within the BML, using the raw data collected by EML/NML. All entity blocks use and feed the same common data base.

5. COMPARISON TO A CHARGING AND ACCOUNTING SYSTEM FOR EDGE PRICING

Independent of the ITU approach investigated so far, similar concepts have been developed within the Internet community for the design of Charging and Accounting Schemes (CAS) as e.g. described in [3]. Note that in this context, accounting is used in the sense of acquiring and summarizing of information (accounting records) in relation to a customer's service utilization, expressed in metered resource consumption, e.g., for the end-system, applications, calls, or connections. Additionally, charging is the overall term for the calculation of a price for given accounting records and its consolidation into charging records, while mapping technical values into monetary units.

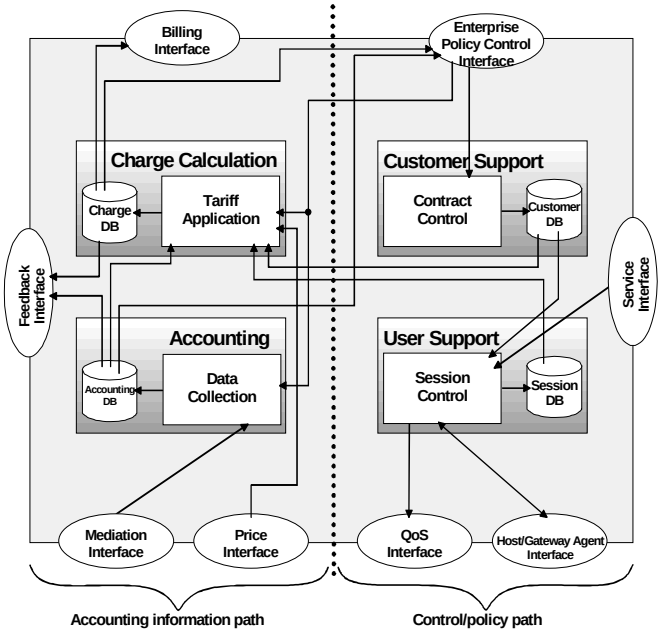

Figure 2. Charging and Accounting System (from [4])

Figure 2 depicts the general architecture of a CAS as developed by Stiller et al. (for details see [4]). The right

half of the figure describes the control/policy mechanisms necessary for running the system and is of no further interest in our context. The important parts of the system are the Accounting module (including data collection) which directly relates to the data acquisition functionality of PM (in the EML/NML) and the Charge Calculation module (including tariff application) which corresponds to the Tariff Schemes block of AM. As far as the BML is concerned, cost modeling [5] provides the long-term background for managing the CAS efficiently. Therefore, we note as an important result of our analysis that the structures fundamental to both ITU PM/AM and Internet-driven charging and prizing systems can be mapped fairly efficiently onto each other. This eventually allows to design an end-to-end charging and pricing system spanning both switching- and packet-oriented network technologies.

Assuming a second perspective, we can view the entity-relationship model of Fig. 1 also in terms of the various time-scales involved. In this sense, the above model turns out to be very close to a special version of an edge pricing framework that has recently been proposed as Cumulus Pricing Scheme (CPS). CPS unites long-term elements (like a contract between customer and provider specifying expected resource usage and defining a corresponding flat rate) with a medium-term feedback mechanism (indicating possible violations of the basic contract without having immediate consequences) and short-term measurements of the actual resource usage [5]. Therefore, the basic three-fold structure as developed from the analysis of PM and AM applies here as well. For further details about CPS we refer to [6, 7]

6. SYNERGY EFFECTS

The synergies between AM and PM may be put into three different categories: First, as clear from the treatment of the EML, the common use of data yields the development of one common data base only. This leads to the second category, i.e. the mathematical algorithms applied on those data. In section 4, it has been demonstrated that the goals of performance management and billing are very similar, both concerning the quality and the integrity of their output. As a tariff describes the financial equivalent to a certain QoS (and thus performance) level, the mathematical and technical means to achieve the aims of both management areas will be very close to each other. The third category pertains to the way strategies are formulated for the data acquisition on all management layers. It is to be supposed that the integrity check of one of the two areas will be sufficient also for the other area to proceed with the certified data. This might include a major saving of processing time and power, especially in networks of big carriers or international enterprises.

7. SUMMARY AND CONCLUSIONS

This paper has analyzed the ITU approach towards performance and accounting management as well as Internet tariff and pricing approaches. This comparison has shed light on possible synergies exploiting the apparent parallel structures of the corresponding fundamental frameworks. Additionally, the matching between ITU accounting concepts and IETF charging and pricing mechanisms has been described. Current and future work is dedicated to defining a modern performance management structure which allows to realize the expected synergies between performance management and edge pricing in a convergent voice/data network.

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