A Bootstrap Mechanism for NGN QoS Profiling

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Abstract: Quality of Service (QoS) is a very important aspect in Next Generation Telecommunication Networks. A traffic-saving QoS monitoring concept, based on the virtual grouping of user terminals, has been developed. This paper shows a bootstrap issue existing within this concept, and introduces a mechanism supporting the reliable initialisation of the monitoring concept.

1 Introduction

Quality of Service (QoS) is one of the key features of the NGN (Next Generation Networks) concept. Unfortunately, as amongst others stated in [PK05], the active control of network resources within an IP transport network results in a considerable amount of resource management traffic. In order to address this issue, an integrated framework for comprehensive QoS control in SIP-based NGN has been introduced in [We08]. A traffic-saving QoS monitoring concept is included within this framework. This concept is based on virtual grouping of user terminals by the similarity of their experienced QoS. From each virtual group, only one user terminal has to be monitored, and conclusions can be drawn on the QoS experienced by all other group members. To assign a user terminal to a virtual group, its QoS profile is matched with the QoS profile of user terminals chosen as references for their respective virtual groups.

According to previous research, the QoS profile of an NGN user terminal was found to be best represented by a sequence of IP packet jitter values (packet inter-arrival delay variance) within a defined time slot. An ART 2 ANN (Adaptive Resonance Theory 2 Artifical Neural Network) [CG87] has been chosen for the matching of QoS profiles and, hence, for assigning NGN user terminals to virtual groups. In [We09a] it has been proven that an ART 2 ANN is generally suitable for comparing packet jitter value patterns.

An ART 2 ANN provides a number of setup parameters, of which the vigilance parameter ρ is the most effective. It strongly influences the degree of similarity that patterns have to exhibit in order to be assigned to the same group. The most suitable value for ρ directly depends on the characteristics of the patterns to be matched. In [We09b] a mechanism has been introduced to automatically determine the most suitable ρ value for arbitrary numbers of jitter patterns. Note that this mechanism is based on the distinguishability of at least two reference jitter patterns which are known to represent different virtual groups. This mechanism is periodically applied within the continuing grouping process of the QoS control framework introduced in [We08].

Regarding the initial start-up of the grouping process, a general bootstrapping issue occurs. The most suitable ρ value for a set of jitter patterns can only be reliably identified if the set consists of at least two reference patterns, each representing a different virtual group. This is also true for the classification of the initial patterns available after the framework start-up. However, in order to reliably identify the group affiliations of the first jitter patterns available, a most suitable ρ value is required. Hence, without being aware of the group affiliations of at least the first two jitter patterns available, any further classification will be potentially inaccurate. This paper proposes a mechanism to solve this bootstrapping issue. Initial tests have been accomplished and are introduced within this paper.

2 Next Generation Networks (NGN) and Quality of Service (QoS)

In 2004, the ITU-T (International Telecommunication Union – Telecommunication Standardization Sector) released its definition of NGN in [IT04a]. According to [IT04a], [ET06], and [TW09] the term NGN stands for a telecommunication network concept that can be characterised by a number of key features including, amongst others, "Packet-based data transport" and "Quality of Service support". Although the term "Packet-based data transport" does not refer to any particular technology or protocol, IP (Internet Protocol) is the most likely network protocol choice for an NGN environment according to [TW09]. The use of SIP (Session Initiation Protocol) for NGN service provisioning and signalling is widely accepted, and also suggested in [ET08].

2.1 QoS for real-time telecommunication services

For services provided within telecommunication networks, the term QoS has been defined as the "collective effect of service performance which determines the degree of satisfaction of a user of the service" [IT94]. According to [IT04b], for packet-based media data transport (which is given in NGN), the quality of a real-time based telecommunication service as experienced by a service user directly depends on the network performance of the respective transport network. In [Go03] the network performance of an IP transport network is characterised by the packet loss ratio, the transfer delay, and the transfer delay variation (jitter). These network performance parameters substantially influence the QoS of a real-time communication service as experienced by its users.

2.2 Integrated framework for comprehensive QoS control in SIP-based NGN

The authors previously proposed a framework for QoS control, aiming to address the scalability issues related to QoS provision in SIP-based NGN, described in [PK05] and [We08]. This framework (see Figure 1) is provided with an integrated mechanism for the collection of information on the QoS affecting any ongoing and future media session.

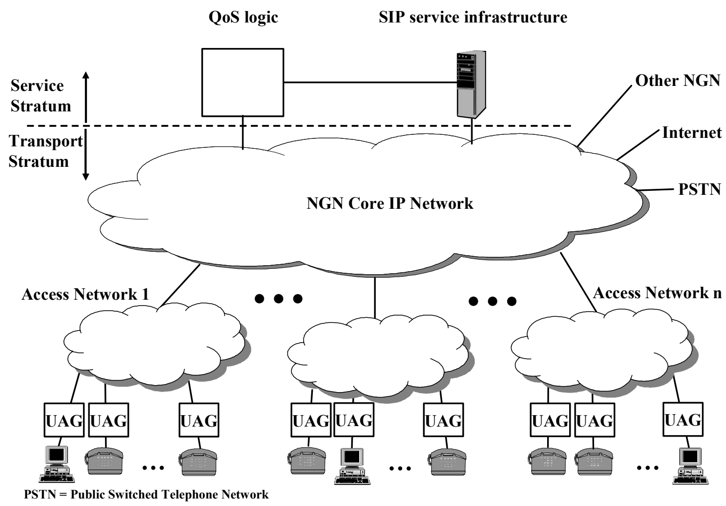

Figure 1: Integrated framework for comprehensive QoS control in SIP-based NGN

In terms of this framework, QoS information consists of delay, jitter, and packet loss values affecting the packets of a respective media data stream. The information is collected in so called user access gates (UAGs) close to the user terminal receiving the respective data stream. In order to minimise the resulting QoS monitoring traffic, only UAGs of selected user terminals (representing a QoS reference point) are queried for information on the QoS conditions experienced by ongoing media sessions. Note that the querying is initiated by the provider's SIP service infrastructure, and triggered by the provider's QoS logic. This requires the identification of virtual groups of user terminals whose members experience similar QoS conditions, and hence, can be represented by a specific reference point. The assignment of user terminals to their respective virtual group is proposed to be performed by the QoS logic entity within the provider infrastructure. The grouping results from the comparison of QoS conditions experienced, and is performed by the support of an Artificial Neural Network (ANN) to allow for an improved real-time processing behaviour. The principle of assigning media streams to virtual groups (or classes, respectively) by the use of an ANN is introduced in section 4 of this paper. A detailed description of the overall framework functionality of QoS information collection is provided in [We08].

3 ART 2 Artificial Neural Networks

Artificial Neural Networks (ANNs) are used in numerous technical applications in order to perform complex tasks such as pattern recognition (or pattern classification), function approximation, prediction/forecasting, optimisation, content-addressable memorising, cybernetics, as well as clustering/categorisation. The latter application is denoted as unsupervised pattern classification in [Ja96].

ART 2 (Adaptive Resonance Theory 2) neural networks can be described as unsupervised-learning neural networks with the ability to compare analogue continuous value sequences with the objective to classify the sequences by their similarities according to [CG87]. This is performed by self-organisation of stable recognition codes generated from the input value sequences. An input sequence, also referred to as a pattern, is interpreted as an n-dimensional vector by an ART network, where n is the number of values comprised by the respective input pattern.

An ART 2 ANN provides n input units and m output units, the latter of which represent m individual output classes. If an arbitrary number of n-dimensional patterns is presented to an ART 2 network, after a predefined number of learning cycles, the network tries to map each pattern to one of m output classes by accomplishing a multi-step comparison process for each pattern. Patterns showing typical similarities are assigned to the same output class. For the comparison and classification of the patterns, the ART 2 ANN interprets every pattern as an n-dimensional vector, where n refers to the number of input values per pattern.

A number of setup parameters are provided by ART 2 ANN, of which the vigilance parameter ρ is the most effective. ρ represents a selectable threshold for the deviation $||r||$ of two n-dimensional vectors u and cp (see equation (1)), where u represents the candidate pattern to be currently classified. Vector cp represents the ART2-internal pattern image of a certain class. With e=0, it is obvious from equation (2) that a reset event is triggered when $||r|| < \rho$. The reset event causes the ART2-internal resumption of the classification process of the respective pattern represented by u_i, excluding the respective class represented by cp_i.

$$r_i = \frac{u_i + cp_i}{e + ||\mathbf{u}|| + ||c\mathbf{p}||} \qquad (1)$$

$$\text{Reset} \Leftrightarrow \frac{\rho}{e + ||\mathbf{r}||} > 1 \qquad (2)$$

Further details on the theory of ART 2 neural networks can be found in [CG87].

4 NGN QoS profiling

The term 'QoS profiling' refers to the virtual grouping of NGN user terminals by QoS conditions encountered. The reason for applying QoS profiling is the reduction of network traffic resulting from comprehensive QoS monitoring.

The integrated NGN QoS control framework briefly introduced in section 2.2 provides a centralised unit for the rating of QoS conditions. It is assumed that all NGN user terminals associated with a virtual group encounter similar QoS conditions. Hence, it is sufficient to choose one group member as the group's reference point and, subsequently, gather and rate QoS condition information from this reference point only. This information is assumed to represent the QoS experienced by any member of the respective virtual group.

Note that at least one reference point has to be chosen per existing virtual group by an arbitrary selection process. Each group's selected reference point is queried to continuously provide QoS information to the framework's centralised QoS rating unit.

4.1 Virtual grouping of NGN user terminals

In order to assign new NGN user terminals to existing virtual groups, their QoS characteristics have to be matched with the QoS characteristics gathered from the reference points. According to our experiments introduced in [We09a], the QoS characteristics of packet streams were found to be best represented by jitter values (see section 2.1) because of their susceptibility to changes within the IP network load utilisation.

In [We09b] a general mechanism was introduced to utilise an ART 2 ANN (see section 3) for the virtual grouping of NGN user terminals by their jitter characteristics. For this purpose, sets of jitter patterns are sequentially presented to the ANN. Figure 2 shows the principles of this mechanism.

After the mechanism start-up, a pattern set is arranged. It comprises all reference patterns (each representing an autonomous virtual group) plus one Pattern Under Test (PUT). Note that all patterns must be synchronised in time. An initial value for the ART 2 vigilance parameter ρ is set and the pattern set is presented to the ART 2 ANN and several classification runs are performed sequentially. After each run, ρ is adapted for the next run, until a ρ value is found so that all reference patterns are identified and assigned to different classes by the ANN (the finally determined ρ value is considered the most suitable ρ value for this specific pattern set). If the PUT matches one of the reference patterns, the ANN assigns the PUT automatically to the class represented by the reference. If the PUT could not be assigned to any class, a new virtual group is established and the PUT is the first member of the new group (and, hence, automatically becomes the reference of this group). This mechanism is periodically applied within the continuing grouping process of the QoS control framework introduced in [We08].

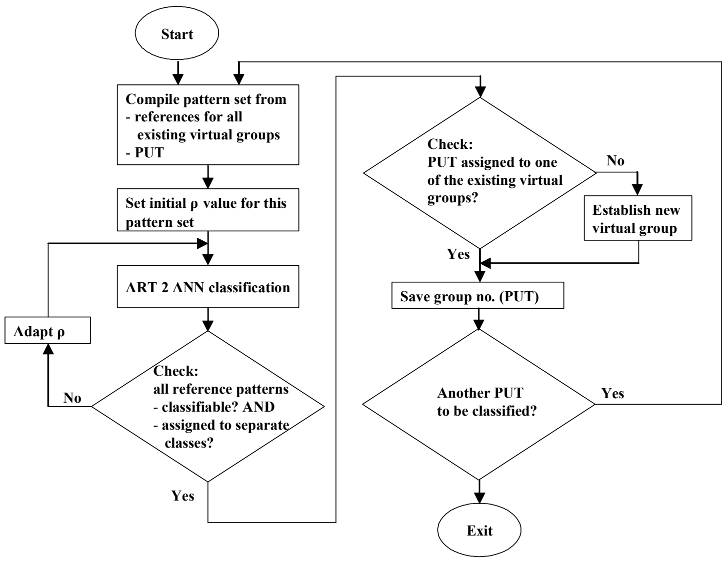

Figure 2: Mechanism for the virtual grouping of NGN user terminals

4.2 Bootstrap issue

As stated in section 4.1, the mechanism for the virtual grouping of NGN user terminals is based on the distinguishability of reference value patterns, each representing an autonomous virtual group. This distinguishability of references is considered mandatory in order to determine the most suitable ρ value for a specific pattern set. In turn, the most suitable ρ value is required to reliably identify the group affiliation of the respective PUT.

Reference patterns originate from ordinary NGN user terminals. These user terminals might be selected as representatives of their virtual groups by any arbitrary algorithm. Note that the assignment of a user terminal to its virtual group is performed before this user terminal might be selected as a group representative.

Also note that, like any other user terminal, a user terminal nominated as a group representative originally was assigned to its group, which typically requires the application of the grouping procedure described in section 4.1. However, the application of this procedure requires the reliable knowledge of the group affiliations of the reference patterns. Hence, the introduced QoS profiling approach lacks of a start-up mechanism providing the required information.

5 A bootstrap mechanism for NGN QoS profiling

As previously mentioned, the NGN QoS profiling approach introduced in [We09b] shows a bootstrap issue. This issue results from the unawareness of the group memberships of the first NGN user terminals who initially exchange media streams after the start-up of the QoS control framework briefly described in section 2.2.

Figure 3 shows a mechanism that solves this bootstrap issue. Note that at least three jitter patterns (monitored synchronously at different NGN user terminals) must be available in order to apply this mechanism. These jitter patterns might be derived from the first three media data streams exchanged after the framework start-up. The idea of this bootstrap mechanism is to detect mutual similarity and discrimination features among those three patterns and, hence, identify their group affiliations. No previous knowledge is required regarding any relationship of the pattern sources.

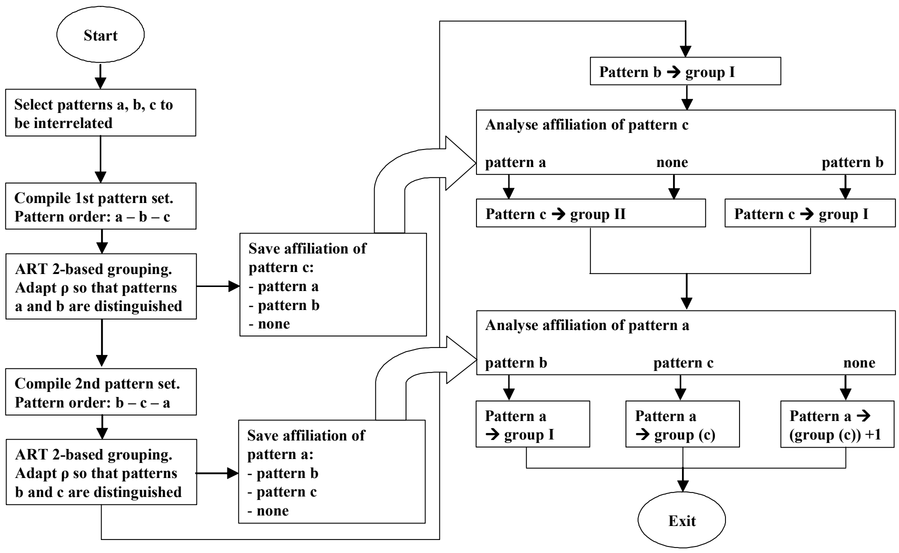

Figure 3: Bootstrap mechanism for NGN QoS profiling

Three jitter value patterns (named a, b, and c) are arranged as a pattern set. According to the mechanism described in section 4.1, a first ART 2-based grouping process is performed. During this grouping process, the pattern set is presented to an ART 2 ANN equipped with two output units (hence, two different classes can be distinguished). The ART 2 vigilance parameter ρ is adapted so that patterns a and b are distinguished, and each of them is assigned to a different output class. Pattern c, as a member of the same pattern set, is also considered within the grouping procedure. Depending on similarity characteristics, it might be assigned to the same output class as pattern a or to the same output class as pattern b. However, if no sufficient similarity is given, pattern c will not be assigned to any existing output class. In any case, the grouping result for pattern c is stored for further processing.

Subsequently, a second grouping process is accomplished, with the same patterns considered. This time, ρ is adapted so that patterns b and c are distinguished and assigned to different output classes. In any case, the affiliation of pattern a is stored.

In the next steps, the patterns are assigned to virtual groups according to their interrelations. Note that pattern b (which represented an ART 2 output class in both classification processes) is considered as the default representative of the virtual group I.

First, the affiliation of pattern c to a specific virtual group is determined. If pattern c was assigned to the output class that had been represented by pattern b in the first classification process, it is obvious that patterns b and c must be considered as members of the same virtual group. In this case, pattern c is associated with virtual group I. If pattern c was not assigned to the class represented by pattern b, pattern c is considered as the default representative of a further virtual group (group II).

Finally, the affiliation of pattern a is analysed, resulting from the second ART 2 classification process. If pattern a had been assigned to a class either represented by pattern b or pattern c, pattern a is assigned to the respective virtual group. If pattern a was not associated with either pattern b or pattern c, pattern a is considered as the default representative of a further virtual group (group II or III, depending on whether class II has already been established).

Table 1 shows all possible affiliations and group associations.

#	Affiliation of pattern c	Affiliation of pattern a	Group I	Group II	Group III
1	a	b	b, a	c	
2	a	c	b	c, a	
3	a	none	b	c	a
4	b	b	b, c, a		
5	b	c	b, c, a		
6	b	none	b, c	a	
7	none	b	b, a	c	
8	none	c	b	c, a	
9	none	none	b	c	a

Table 1: Possible affiliations and group associations of the introduced bootstrap mechanism

With the bootstrap mechanism introduced within this section, the group affiliations of three synchronously monitored jitter patterns can be autonomously identified. Note that no precognition is required regarding group references or most suitable ρ values. Hence, after two virtual groups have successfully distinguished by the bootstrap mechanism introduced within this section, NGN QoS profiling as described in section 4 can be successfully applied.

6 Test and conclusion

The bootstrap mechanism for NGN QoS profiling introduced in section 5 has been exemplarily tested in a proof-of-concept manner. Initial result trends are introduced within this section, and a conclusion is given.

6.1 Test and result trends

Based on the ns-2 network simulator, a SIP-based NGN architecture has been set up, allowing for the simulation of different communication scenarios. Upon session initiation, media flow packets (simulating VoIP calls with G.711 codec) were bidirectional exchanged in a peer-to-peer manner between the user terminals. By the use of the ns-2 trace function, all media packets were recorded and time-stamped at their respective receiving user terminals. The collected data were synchronised and post-processed to extract the per-packet inter-arrival jitter of each media flow. Several pattern sets were arranged, each comprising three patterns to emulate a bootstrap scenario.

Table 2 shows several scenarios considered. The scenarios differ in the number of comprised virtual groups and in the order of the patterns representing the groups. The accuracy stated in Table 2 is related to the correct assignment of patterns to virtual groups by the bootstrap mechanism introduced in section 5 of this paper, with ten different pattern sets (each comprising 3 patterns) tested per scenario.

Scenario No.	**No. of virtual groups included**	**Order of patterns within sets (by group numbers)**	**Accuracy of group assignment achieved**
1	3	I - II - III	100%
2	1	I - I - I	67%
3	2	I - II - II	100%
4	2	I - II - I	100%
5	2	I - I - II	100%

Table 2: Test scenarios for QoS profiling bootstrap mechanism

Table 2 shows that the bootstrap mechanism introduced within this paper provides an excellent assignment accuracy for those scenarios in which the considered jitter patterns comprise more than one virtual group. However, in scenario 2, in which all three patterns included within a pattern set belong to the same virtual group, a limited accuracy is experienced. This is due to the fact that the effectiveness of the bootstrap mechanism introduced within this paper depends on the distinguishability of patterns. However, the distinguishability of patterns belonging to the same virtual group is naturally limited. Those patterns must provide significant similarities in order to be defined as members of the same virtual groups.

6.2 Conclusion

The work presented in this paper improves the framework for comprehensive QoS control in NGN, as initially described in [We08]. The existing QoS profiling mechanism has been completed with a procedure allowing for the initial assignment of NGN user terminals to virtual groups, now providing a good accuracy of classification. This new bootstrap mechanism has been tested in a proof-of-concept manner in a network simulation environment and the result trends were provided within this paper.

The introduced approach suspends the bootstrap issue coming along with the classification of value sequences by similarities through unsupervised learning mechanisms such as ART 2 Artificial Neural Networks.

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