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Novel Methods For Determining QoS Parameters and Thresholds in End user's Service Level Agreement

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ABSTRACT: Service level agreement (SLA) is a powerful tool to formalize the negotiation and agreement between the service provider and service seeker with the scope of service quality characteristics, compensations and tariffs. The service quality description is one the main parts of a SLA which can be characterized by the use of suitable and feasible quality of service (QoS) parameters. Determining suitable QoSparameters is the most important step in SLA codification. In this paper, we propose a novel method for determining the most related QoS parameters for characterizing the service quality in a SLA. The proposed method is a step-by-step algorithm which is based on selecting feasible parameters among a general initial list obtained from international references. The criteria for feasibility are perceivability and measurability from the end user's viewpoint. Our method is general and can be applied to each service. We also leverage on clustering algorithm to prioritize the feasible QoS parameters according to their popularity in international studies. Finally, we propose a statistical method to determine the threshold for the feasible parameters. We provide an interval for each threshold. We show the steps of our proposed methods via a case study as the final part of the paper.

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1.INTRODUCTION

The importance of customer satisfaction in the information and communication technology (ICT) market motivates the network operators, application and service providers to provide high quality services to the end user. Service Level Agreement is a powerful tool for clarifying the provided service quality against the charges and a tool for customer rights protection. In fact, service level agreement is a formal negotiated agreement between a service provider and a customer that specifies the supplied services and level of service quality. SLA helps to clarify what a customer can expect in terms of quality of service. In this regard, SLA builds a clear understanding between a service provider and a customer [1].

A SLA contains several sections that the quality of service description is one of the most important sections. The service quality is expressed in quantifiable terms via QoS parameters which precisely describe the service offered to the end user. The QoS parameters should be measurable from the end user's point of view [2]. Hence, in order to guarantee a good level of service, a fundamental step is determining the appropriate QoS parameters. There are many works related to QoS requirement of the SLA.

In [1], the customer QoS requirement is addressed and the necessities of the quality specification are described. It is noted that the QoS parameters should be measurable and perceivable by the end user. These parameters should only be related to end-to-end service quality. The authors in [2] also investigate the QoS specifications of the SLA and emphasize that SLA should include QoS parameters, corresponding thresholds, measurable methods, measurement period and service schedule (activation time period). Three necessary categories for QoS parameters are specified in [3] including service provisioning, service maintaining and technical requirement. Although these works highlight some general requirements for QoS parameters, they do not provide a comprehensive and systematic method to acquire suitable QoS parameters for a desirable service.

Some works provide a list of suitable QoS parameters for a specific service. Alqahtani et al. in [4], propose a conceptual model to capture the entities of SLA and consider service level objective terms which express the QoS parameters of the Internet of things (IoT) service and associated constraints. A detailed list of appropriate QoS parameters for cloud service SLA is provided in [5]. In [6], the SLA parameters are identified for storage as a service cloud delivering model and a monitoring framework for compliance checking is proposed. The authors of [7] suggest a resource-level metric which guarantees CPU performance. Their suggested metric enables the service provider to dynamically assign resources to the

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users of cloud services. Experimental results demonstrate that the proposed method decreases SLA violations compared to the existing related metrics while guaranteeing QoS. A general classification of SLA metrics and content is proposed in [8]. The authors classify the metrics into five categories based on service object, i.e: Help Desk, Hardware, Network, Software and Storage. They mention that it is possible to divide the composite metrics into smaller metrics and assign them to one of these main object types. The authors of [9] propose an approach for creating SLAs, they clearly describe the dependencies between the features of services and emphasize how key performance indicators (KPIs) and IT infrastructure metrics impress the customers' goals. The QoS parameters provided in these works are valuable as they meet the end-user SLA requirement for a specific service, but these works do not provide a comprehensive approach to obtain appropriate QoS parameters for other services. Our proposed method differs substantially from the existing works in this area as we have provided a comprehensive and systematic method that can be exploited to obtain the end-to-end QoS parameters for the SLA. This method is not limited to a specific scenario and can be applied to a desirable service.

In [10], the authors propose an agent-based framework which utilizes the agents' ability of negotiation, interaction, and cooperation to facilitate autonomous and flexible SLA management. The authors in [11] propose a formal mapping mechanism between QoS parameters in SLA and the network performance metrics and also propose a general SLA monitoring system architecture that can be used to monitor service levels for various services offered by network, Internet and application service providers. In [12], an algorithm for disruption detection of network services for scalable SLA monitoring systems is presented. The framework of the SLA management system to support the SLA is presented in [13]. The kinds of SLA quality metrics and the main functions of a service level management (SLM) system are also studied in this paper. It is worth noting that, SLM assures the service consumer that the organization can provide service levels that meet their needs. The purpose of service level management is to set clear business-based goals for service performance so that service delivery against these goals can be properly evaluated, monitored and managed. All of these studies consider an available SLA and focus on monitoring the defined QoS parameters in the SLA and none of them focus on the fact that which QoS parameters are suitable for describing each service quality.

In this paper, we provide a novel method to characterize the suitable QoS parameters for the SLA. To the best of our knowledge, the current works in the literature provide some QoS parameters for specific services. However, in this paper, we provide a comprehensive method to characterize the suitable QoS parameters incorporated in the end user's SLA for a desirable service. Moreover, we also provide a statistical method to specify the threshold for the appropriate QoS parameters. Our work can help a service provider to characterize the appropriate QoS parameters for the SLA with its customer. The service provider can customize the quality level based on the level of contract with the customer (e.g., Gold, Silver or Bronze) or the condition and facilities of each region (e.g., a rural area). Also, this method can help a regulator to regulate the SLA between operators and the customer and determine the necessary QoS parameters to include in their SLA with the customer (i.e., provide a framework for the SLA that an operator should comply with). Our work has the following features

1) The proposed method provides a step-by-step approach for gathering, filtering and finalizing the suitable QoS parameters in the SLA.

2) This method relies on international references, including telecom regulators, operators and standards to provide a comprehensive initial list of QoS parameters.

3) The proposed method carefully selects the feasible QoS parameters for the end user. In this regard, only the parameters associated with end-to-end service quality are selected. Moreover, the QoS parameters should be measurable from each user's viewpoint.

4) Feasible parameters are prioritized according to their popularity in the references, exploiting clustering algorithm. As a result, feasible parameters which are more repeated in the international references get higher priority to incorporate in the SLA. The output is a prioritized list of feasible parameters which can be used by the service provider to select the QoS parameters for the SLA. Since incorporating a parameter in the SLA induces measurement cost for the service provider, prioritization helps the service provider to decide which parameters are really necessary for the SLA. The parameters with the highest priority (referred to as MANDATORY) are mandatory for the SLA and strongly recommended for the SLA. The parameters with the medium priority (referred to as RECOMMENDED) are recommended to use in the SLA. The parameters with the lowest priority (referred to as OPTIONAL) can be used in SLA optionally.

5) We devise a statistical method to specify the threshold for the appropriate QoS parameters. The thresholds are determined according to the statistical analysis of a set of data, obtained by collecting the parameters thresholds from international studies. This method provides an interval for each threshold. This interval enables the service provider to set the quality level according to the contract level with a customer or based on the facilities in the area.

Moreover, we provide a statistical method to specify the threshold for the appropriate QoS parameters. The thresholds are determined according to the statistical analysis of a set of data, obtained by collecting the parameters thresholds from international studies. This method provides an interval for each threshold. The limits of this interval resemble the stringent and relaxed threshold for acceptable service quality.

The remainder of the paper is organized as follows. Section 2 describes the concept and main components of a SLA. Our proposed method for characterizing the appropriate QoS parameters is described in Section 3. We describe our proposed method for threshold determination in Section 4. In Section 5, we provide a case study to illustrate our proposed methods. Finally, Section 6 concludes the paper.

2.SERVICE LEVEL AGREEMENT

2-1- SLA concept

Generally speaking, a service level agreement is a formal contract between a service provider and a customer that guarantees a specific level of performance and reliability at a certain cost. A precise definition of SLA has been provided in the international standards. For example, according to the ITU standard [14] a SLA is "*a formal agreement between two or more entities that is reached after a negotiating activity with the scope to assess service characteristics, responsibilities and priorities of every part*". In ETSI standard [15] the SLA is defined as "*an agreement that clearly defines the roles and responsibilities of both parties will be of particular benefit if problems arise. The SLA should be used in any case as a means to improve the process and the mutual understanding and not to relieve responsibility of one party on the other party*".

In TM forum SLA has been defined as "*a formal negotiated agreement between two parties. It is a contract that exists between the Service Provider (SP) and the Customer. It is designed to create a common understanding of Quality of Service, priorities, responsibilities, etc. SLAs can cover many aspects of the relationship between the Customer and the SP, such as performance of services, customer care, billing, service provisioning, etc. However, although a SLA can cover such aspects, agreement on the level of service is the primary purpose of a SLA*", [16].

The ITIL standard in [17] defines the SLA as "*an agreement between an IT Service Provider and a Customer. The SLA describes the IT Service, documents Service Level Targets, and specifies the responsibilities of the IT Service Provider and the Customer. A single SLA may cover multiple IT Services or multiple Customers*".

All of the definitions refer to the same basic concept that SLA is a suitable tool for clarifying the agreed obligations between a service provider and a customer that guarantees the quality of the provided service and affirms both parties from their responsibilities.

2-2- SLA components

Generally, as shown in Fig. 1 a SLA comprises some components, including parties information, service information, tariff and billing, compensations and QoS agreement. Definition of the service, detailed service quality targets, mutual responsibilities and other requirements specific to a service are expressed in a SLA. Type of service, additional details about the offered service, conditions of service availability as well as the duration of the service shall be provided. The SLA also describes various levels of the services and the associated prices. The remedies and penalties in the event of non-fulfillment of the committed service quality are also provided in the SLA. A very important and necessary component of a SLA is the QoS agreement which is also referred to as service quality agreement (SQA) [15]. QoS agreement describes the level of quality offered to the customer. The level of quality is expressed quantitatively by the QoS parameters. Definition of QoS parameters, measurement methods, monitoring process as well as content and frequency of reporting are specified in the QoS agreement.

2-3-QoS in SLA

According to the ITU-T recommendations E.800 [18], the QoS definition is "*the collective effect of service performance which determines the degree of satisfaction of a user of the service*" and according to ITU-T E.860 [14], the QoS in a contract is "*the degree of conformance of the service delivered to a user by a provider in accordance with an agreement between them*".

QoS Agreement (i.e., SQA) plays an important role in developing an effective SLA by defining appropriate QoS parameters and assigning proper values to QoS parameters.

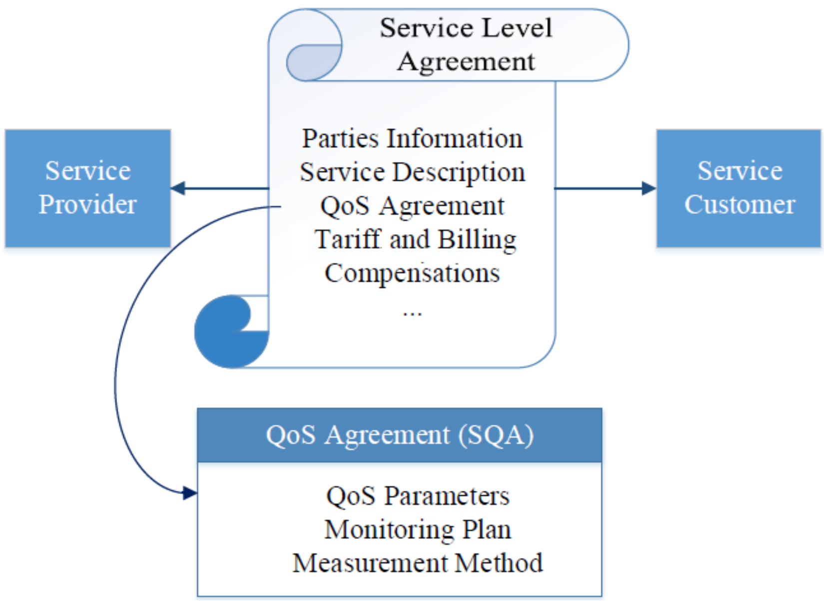

Fig. 1. Common components of a SLA

The importance of QoS agrement in the SLA is highlighted in ITU-T E.860 [14] as follows: "*Definition of QoS parameters is an essential moment in developing a SLA and, in particular, its correspondent QoS Agreement. Indeed behavior of all entities which take part to QoS Agreement is influenced by those parameters. QoS is assessed by assigning proper values to QoS parameters*".

From the customers' point of view, QoS is expressed by parameters that focus on user perceivable effects. A typical user only concerns with end-to-end service quality. The QoS parameters are independent of the internal design of the network and should be quantifiable and measurable. These parameters are designed to be understandable to the customer. The level of quality is expressed by the value assigned to a QoS parameter. This QoS level determines the acceptable range of a parameter value. If the delivered QoS does not meet the commitment in the SLA, a penalty may be paid to the customer for compensation.

The QoS parameters in SLA can be categorized into categories: supporting parameters and technical parameters. The first ones describe the availability of the service and the second ones technically characterize the network performance from the end user's viewpoint.

3.PROPOSED METHOD FOR QOS PARAMETERS DETERMINATION

As mentioned before, the QoS description section is one of the most important sections in a SLA document. There is a big challenge in the codification of this section: "Which parameters are suitable for describing the service quality?" It means that the selection of the most relevant QoS parameters for a particular service, which can properly characterize the service level, is an important stage in developing a SLA. One challenge in determining such parameters is that the QoS parameters in the SLA should be definable and measurable from the end user's perspective.

In this section, we propose a step by step method for determining the proper QoS parameters for a particular service. The basic idea of the proposed method is to utilize the international experiences in regards to QoS parameters in the SLA. In other words, gathering all the possible and suitable QoS parameters for SLA and analyzing them to select the most relevant ones is the foundation of our proposed method. All the possible and suitable QoS parameters can be gathered from three different international experiences references including international telecommunication standards, countries' telecommunication regulatory and national and international top operators.

Our method contains six steps which are introduced in detail as follows.

Step 1: In the first step, a general list of QoS parameters for a particular service should be gathered from the international references.

Step 2: Then, the feasibility study should be performed over the prepared list to determine the feasible QoS parameters to incorporate in the SLA.

Step 3: In this step, the frequency of all the feasible parameters should be counted to specify the popularity of each parameter in the international references.

Step 4: According to the results of steps 2 and 3, the prioritization matrix is drawn in this step.

Step 5: The priority of each parameter can be determined by the use of *k*-means clustering method for feasible parameters.

Step 6: In the final step, the list of prioritized parameters is extracted.

All the steps are explained in detail as follows.

3-1- General list of QoS parameters for a particular service

To acquire a general list of end user QoS parameters for a particular service, an extensive review of references in this regard is necessary. Three different references include: *1*) international telecommunication standards, *2*) telecommunication regulation in different countries and *3*) the experiences of various national and international telecommunication operators.

Some important questions in this step are: "which standards among all?", "which countries among all?" and "which operators among all?". The responses to all these questions are the same. In other words, the selection of each reference completely depends on the policies and the goals of each researcher which focus on this issue. For example, to select a country regulatory some items can be considered like: the generation of the regulatory, the telecommunication regulation in the country and telecom market competition in the country.

3-2- Feasibility study of the parameters

As mentioned before, the QoS parameters in SLA should be definable and measurable from each end user's viewpoint. In other words, these QoS parameters are employed to assess the end-to-end service quality offered to the end user. Thus, they are inherently different from the network-level QoS parameters exploited to investigate the network performance. Hence, among all the gathered parameters, those ones that can be defined and measured for each end user are feasible. We consider two general reasons that make a parameter unmeasurable from the end user side:

1) If the parameter is defined in ratio or its measurement unit is percentage, it is generally not feasible for the end user's SLA. On the other hand, if the parameter is defined in time and measured in time unit, we can consider that parameter as a feasible one for using in the SLA.

2) Also, if the operator cannot monitor the customer side terminal (e.g., because of uncontrollable passive equipment between the operator's presence point and the customer's terminal such that the route is not under operator protection) measuring the technical parameters is not possible.

As a result, some QoS parameters which used by telecom operators to monitor the performance of their networks or exploited by regulator to assess the operator's network cannot be mapped into the end user's SLA, since these parameters are either not measurable for a single end user or could not be monitored at the customer side terminal. For example, call drop rate (CDR) is an important quality parameter which adopted by telecom cellular operators to monitor their network and assure good call quality. This parameter is measured by averaging the ratio of dropped calls among a large number of customers (e.g., within a cell or a zone in the city). However, this parameter cannot be mapped into the end user's SLA because it should be averaged within a time interval which makes it challenging due to the limited number of call samples to calculate a valid and meaningful average.

3-3- Frequency of the parameters

Determining the popularity of the parameters is an important and basic step in our algorithm. The parameter popularity can be determined by counting the number of repetitions (i.e., the frequency of the parameter) in the reference documents. The more a parameter is repeated, the more popular it is. The frequency of the parameters as a weighted score can be applied to specify the prioritization of the parameters.

3-4- Prioritization matrix

After characterizing the feasibility of the parameters and the frequency of them, the results can be visually presented by utilizing a prioritization matrix. The prioritization matrix is a simple tool that helps us to make decision about the priority of the QoS parameters for using in the SLA document of a particular service. Generally, a prioritization matrix is a 2D-visual that shows the relative importance of a set of items based on the criteria. The prioritization matrix can be plotted in several forms depending on the criteria for assessing priorities. In the business literature, a prioritization matrix is a business process analysis for comparing choices using specific criteria and figuring out what to prioritize. For example, a prioritization matrix provides stockholders with a reliable process to decide which proposals to focus on. In this case, the prioritization matrix is simply a 2×2 grid with business value plotted against the implementation feasibility. We have borrowed this concept from the business science. According to the best of our knowledge, this is the first time that prioritization matrix is exploited for determining the SLA QoS parameters. In our research, the prioritization matrix is a chart which shows parameter frequency against the parameter feasibility for SLA. This matrix can be drawn for each service and the quality parameters of that service can be located in it to show the helpful characteristics of the QoS parameters for prioritizing. The prioritization matrix is illustrated in Fig. 2. In this example, the prioritization matrix includes twelve parameters. The prioritization matrix gives us a vision about the importance of the parameters for the SLA. The parameters on the left side are infeasible and thus excluded from the SLA, even if a parameter has high repetition (e.g., QP.7). The parameters in the right-side are feasible and can be exploited in the SLA. A parameter on the top (e.g., QP.1) has high popularity. Thus, it is more suitable for the SLA. However, a parameter in the bottom (e.g., QP.4) has low popularity. Consequently, it may not be very important in the SLA. The parameters in the right-side of the prioritization matrix are selected for prioritization exploiting a clustering algorithm, as discussed in Section 3.5.

3-5- Prioritizing the parameters

Prioritization matrix - discussed in the previous section - helps us to make a suitable decision about the priority and feasibility of the QoS parameters. In our algorithm, we propose three priorities for each parameter. The first priority, *priority 1*, or mandatory priority is for the parameters that are mandatory for the SLA and strongly recommended to use in the SLA. The second priority, *priority 2*, or recommended priority refers to the parameters that are recommended to use in the SLA but there is not a strong recommendation for using them. Finally, the parameters in third priority, *priority*

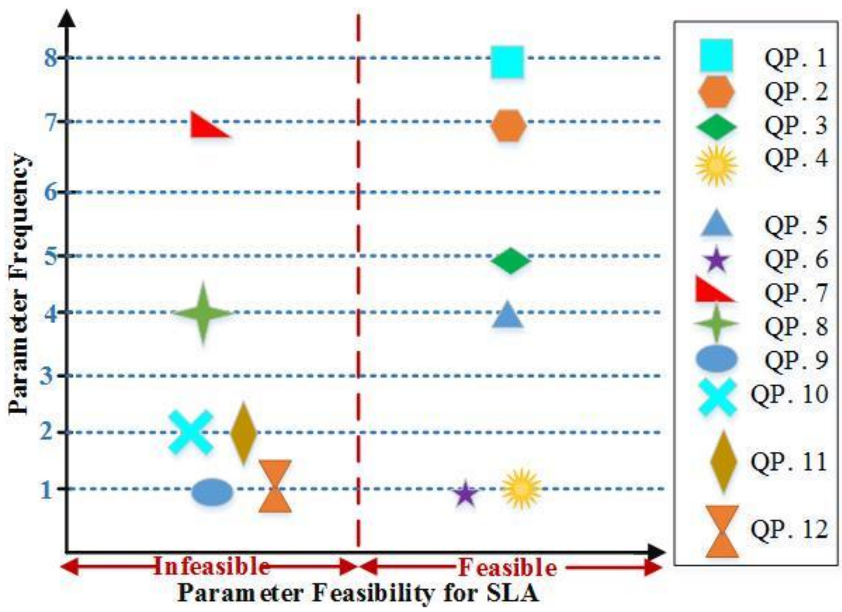

Fig. 2. QoS parameter prioritization matrix

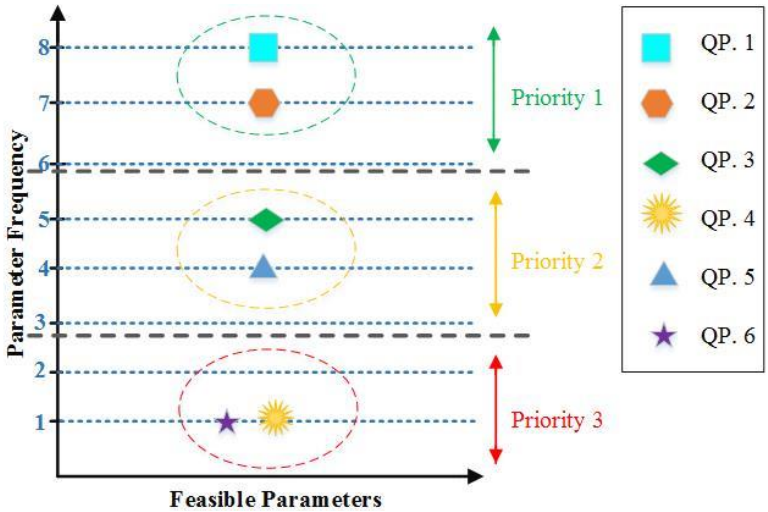

Fig. 3. Applying *k*-mean clustering to prioritize the feasible parameters

Table 1. Final list of appropriate parameters

Priority	QoS Parameters
Mandatory	QP.1
Mandatory	QP.2
Recommended	QP.3
Recommended	QP.4
Optional	QP.5
Optional	QP.6

3, or optional priority can be used in the SLA optionally. For prioritization, a multi-class classification method can be utilized. There are several multi-class classification methods such as Naive Bayes [19], SVM [20], Decision Tree [21], LDA [22], *k*-NN [23] and *k*-mean [24]. Notice that, among the categorization methods mentioned above, Naive Bayes, SVM, Decision Tree, LDA methods require a training dataset for proper performance. These approaches initially perform clustering algorithm on the training set, then they can perform on a testing set. Also, in the *k*-NN method, k data which have the nearest distance to each other are grouped together. In other words, in this method, the number of categories is not predetermined but the number of elements in each category is equal to *k*. Therefore, the *k*-NN method is not suitable for classifications that already have a specified number of classes. The other problem with these methods is that they usually require a lot of data to perform properly. Consequently, their performance is weak when there are few data [25].

k-mean clustering aims to partition n data into *k* clusters in which each data belongs to the cluster with the nearest mean. *k*-mean is a hard clustering method in the sense that in this method the exact boundary between the categories is clear. In other words, there is no overlap between categories [24]. The *k*-mean method is useful when the number of categories is already known. Its main advantage is its high speed and simplicity. Furthermore, unlike the most classification methods, *k*-mean does not require a training phase [25–27]. Typically, the size of data set in our problem is not large, since many of QoS parameters obtained from international references are not suitable for the end-user's SLA (according to the discussion in Sec. 3.2) and pruned in the feasibility study.

Consequently, among all of these methods, the *k*-mean method is suitable for our problem. The reason is twofold: 1) this method does not require any learning (i.e., no training process is necessary for *k*- mean method). 2) This method has proper performance for few data parameters, while many clustering methods need a large data set to achieve good performance.

k-Mean clustering Method: *k*-mean clustering is a method of data classification which aims to partition data into *k* clusters in which each data belongs to the cluster with the nearest mean. Given a set of data $(x_1, x_2, \cdots, x_n)$ *k*-mean clustering aims to partition the n data into $k\ (\leq n)$ sets $\mathbf{S} = \{S_1, S_2, \cdots, S_k\}$ so as to minimize the within-cluster sum of squared error (SSE). In other words, the objective is to find [23]:

$$\arg\min_{\mathbf{S}} \sum_{i=1}^{k} \sum_{x \in S_i} \|x - \mu_i\|^2 \tag{1}$$

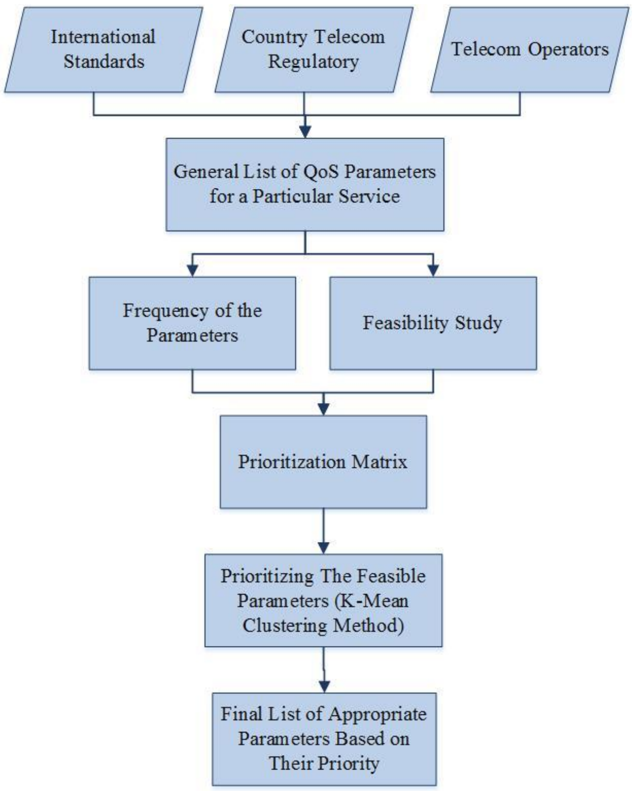

Fig. 4. Flowchart of the proposed method for determining QoS parameters

where μ_i is the mean of the points in S_i. The algorithm works iteratively to assign each data to the nearest cluster. After an iteration, the mean of each cluster is updated. This step is repeated until the value of clusters mean stabilize.

When using k-mean clustering, the right number of clusters should be determined. The number of clusters may be specified by the prioritizing method to incorporate the QoS parameters in the SLA. The QoS parameters may be categorized into L different levels. For example, we can choose three levels: *mandatory*, *recommended* and *optional*. If the level of prioritizing is not predetermined, one effective approach to specify the number of clusters is the *elbow* method. The idea is to run k-mean clustering for a range of cluster size (k) and calculate the SSE. It is worth noting that the sum of SSE decreases as we increase the cluster size (the SSE is zero if k equals the number of data points in the data set). A large number of clusters brings about much complexity to prioritize the QoS parameters. Hence, the goal is to choose a small number of clusters that still has a low SSE. In elbow method, the line chart of SSE versus k, is plotted. The elbow of this line chart represents the best value for k, as the elbow is the point where we start to have a diminishing return by increasing k.

In the aforementioned example, there are six feasible parameters. We assume three prioritization levels. Hence, the number of clustering groups is three (i.e., $k = 3$). After performing k-mean clustering, the group mean points are obtained as $\mu_1 = 1, \mu_2 = 4.5$ and $\mu_3 = 7.5$. Each group contains two parameters. The result is depicted in Fig 3.

3-6- Final list of the appropriate parameters

After the previous steps, the priority of feasible QoS parameters is determined and the final list of the appropriate parameters can be determined by their associated priorities as follows. For the above example, after clustering, we infer that two parameters (i.e., QP.1 and QP.2) have priority 1. These parameters are mandatory for the SLA. Two parameters (i.e., QP.3 and QP.4) have priority 2, which are recommended for the SLA. Finally, the parameters QP.5 and QP.6 have priority 3, which are considered as optional for the SLA. The final list is presented in Table 1.

3-7- The flowchart of the proposed method

The flowchart of the proposed method is depicted in Fig. 4.

4.THE PROPOSED METHOD FOR THRESHOLD DETERMINATION

As mentioned before, quality parameters express the level of quality offered to the customer. The accepted ranges of parameters are determined by threshold values. If the delivered service does not meet the committed quality in the SLA, the service provider should pay compensation to the customer. The service thresholds and the amount of compensation depend on the level of purchased service. The higher the level of service, the more stringent are the QoS thresholds and the service provider is charged for a higher penalty in the case of noncompliance with the committed service quality. On the other hand, the tariff is higher. Thus, there is a direct link between tariff, quality and penalty. Therefore, determining the level of quality by quality parameter thresholds is another important step in SLA codification which is studied in this paper.

After determining the feasible QoS parameters for the SLA, the threshold value of each QoS parameter should be specified. In this section, the proposed method for determining the threshold values of the feasible QoS parameters for the SLA is introduced. By studying various references including international telecommunication standards, countries' telecommunication regulatory and national and international top operators, we obtain a data set for the threshold value of each QoS parameter. Given the variability of this threshold in the studies, we should determine a reasonable threshold in a logical way. In other words, we require a valid scientific method to aggregate these values and specify the appropriate threshold value for each parameter.

One straightforward method is averaging over the set of threshold values obtained from the references and set the mean value as the desirable threshold. This method provides a fixed threshold. Alternatively, we devise a statistical method to determine lower and upper limits for each QoS parameter threshold based on the set of threshold values obtained from the references. The reason to provide an interval – rather than a fixed value – for each threshold is as follows.

1) Since the conditions and facilities of each country

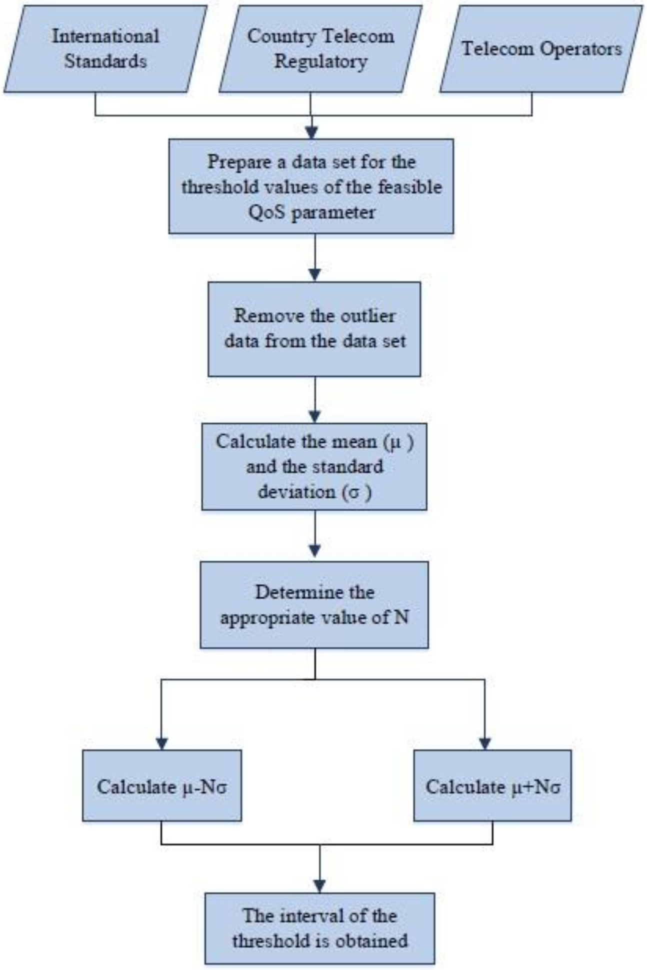

Fig. 5. Flowchart of the proposed method for threshold determination

and even each region in one country are different from other countries and regions, it is not fair and reasonable to consider a fixed threshold for all conditions and regions and forcing the operators to comply with this threshold. For example, infrastructures in rural areas are less developed than urban areas. Consequently, the regulator may be willing to impose a more relaxed QoS requirement for the service offered to a rural customer compared to an urban customer. Our method provides an interval for a threshold where the limits of this interval can be interpreted as the strict and relaxed values for a QoS parameter. Hence, according to infrastructure development and other conditions, the appropriate threshold value can be determined within the interval.

2) On the other hand, providing an interval for a threshold enables us to provide a service with different quality levels. The service provider can provide services of different quality levels and it can offer the customer a higher quality service in return for higher tariffs. The threshold of service quality parameters for different levels can be selected according to the interval obtained from the proposed method. In this case, the thresholds of the QoS parameters should be chosen more strictly for higher tariff levels. For example, if the operator considers five levels (diamond, platinum, gold, silver and bronze) for the quality of its services, it can divide the interval obtained from the proposed method into 5 parts (e.g., 5 equal parts). The most stringent thresholds and the easiest thresholds are selected for diamond and bronze services, respectively.

Our proposed method, which is referred to as N Sigma ($N\sigma$) [28–30], relies on the statistical mean and dispersion of the data set – which is obtained by international studies – to determine an interval for the thresholds of feasible QoS parameters in the SLA. Our method contains four steps which are outlined in the following. Also, the flowchart of the proposed method is depicted in Fig. 5.

Step 1: In initial step, form the data set $\mathbf{S}=\{d_1,d_2,...,d_N\}$, where $d_i, i=1,2,...,N$ are the thresholds which gathered from the international references.

Step 2: Remove the outlier data from the data set and determine the final data set $\mathbf{S}_f$, i.e. $\mathbf{S}_f=\mathbf{S}\setminus\mathbf{S}_o$, where $\mathbf{S}_o$ indicates the set of the outlier data.

Step 3: Calculate the mean (μ) and the standard deviation (σ) of data from (2) and (3), respectively.

$$\mu=\frac{\sum_{d_j\in\mathbf{S}_f} d_j}{N_f} \tag{2}$$

$$\sigma=\sqrt{\frac{\sum_{d_j\in\mathbf{S}_f}\left(d_j-\mu\right)^2}{N_f}} \tag{3}$$

Where N_f is the cardinality of $\mathbf{S}_f$, i.e. $N_f=\left|\mathbf{S}_f\right|$.

Step 4: Determine the appropriate value of N (See Remark1).

Step 5: Determine $\mu-N\sigma$ as the lower bound and $\mu+N\sigma$ as the upper bound of the threshold, respectively. Now, regarding the upper and lower bounds, the interval of the threshold will be specified.

Note that, in our methods the outlier data is the data that significantly differs from the others. In other words, as shown in Fig. 6, the outlier data is far from the other data.

Remark1: In our proposed method N is an integer equal or greater than one. Note that the value of N is determined by the dispersion of the data. The threshold limits for the parameters must be meaningful and reasonable. Also, N should be selected in such a way that the lower bound does not get smaller than the minimum of the collected data and the upper bound does not get larger than the maximum of the collected data; Because the thresholds should comply with the international studies.

5.CASE STUDY

In this section, we illustrate our proposed method via a case study. In this study, we focus on specifying support

Fig. 6. The outlier data significantly differs from the other data

Table 2. General list of support parameters for fixed internet service

ID	Support Parameter	Feasible for SLA
1	% of billing-related complaints	×
2	% of non billing-related complaints	×
3	Promptness in resolving customers complaints	✓
4	Promptness in answering customers calls	✓
5	Fault report rate	×
6	Advance notice for scheduled downtime	✓
7	Fault repair time (mean time to repair)	✓
8	% of customers satisfied with service quality	✓
9	Time taken for service termination after consumer request	✓
10	Accessibility of call centre/customer care	×
11	Time taken for refund of deposit after service closure	✓
12	Service activation time	✓
13	% of user connections in working condition	×
14	% of repaired user connections	×
15	Notification for approaching end of service	✓
16	Period for keeping customers data	✓

quality parameters for the fixed internet service. The service includes both wired and fixed wireless internet services. The data set (countries' national regulatory authorities (NRA) and operators, …) should be carefully selected in order to obtain valuable results. The understudy countries should be selected according to the condition of the target country (i.e., the country we aim to provide the QoS parameters of the SLA, using the proposed algorithm). This selection may be performed as a mixture of countries with similar condition to the target country and the leading countries in this area. Moreover, the more comprehensive and accurate the data samples are, the more valuable are the results. In other words, by studying a larger and more accurate data set, we obtain more useful QoS parameters and more precise threshold values. In this study, the regulators of nine countries including US [31], UK [32], India [33], Bahrain [34], Turkey [35], Malaysia [36], Singapore [37], Iran [38] and Egypt [39] are investigated. The list of countries includes the selection of leading countries in ICT in the world, Asia and the Middle East.

Both national regulatory authorities and operators (communications service provider) within these countries are addressed to select appropriate quality parameters to incorporate in the SLA. The list of telecom operators includes AT&T [40], Verizon [41], Batelco [42], Zain [43], BSNL [44], Telecom Malaysia [45], Turk Telecom [46], Vodafone [47], BT [48], SingTel [49] and StarHub [50]. NRAs devise QoS parameters to assess the overall performance of the operators. Since these parameters evaluate the quality of service within the entire network, they are measured on the average basis. In other words, NRAs measure the average value of each parameter among a large number of customers. On the other hand, a QoS parameter in a SLA measures the service quality received by an end user which cannot be calculated on an average basis. Consequently, many of the QoS parameters

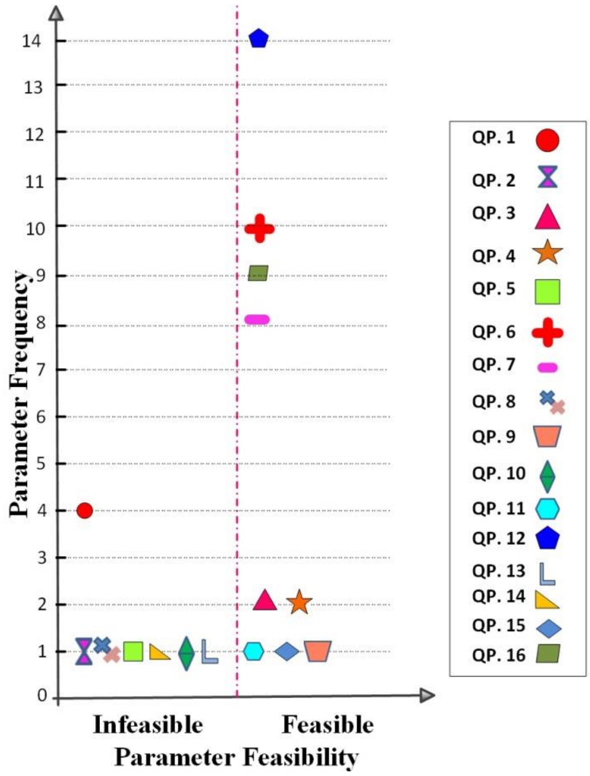

Fig. 7. Prioritization matrix for support parameters of fixed internet service

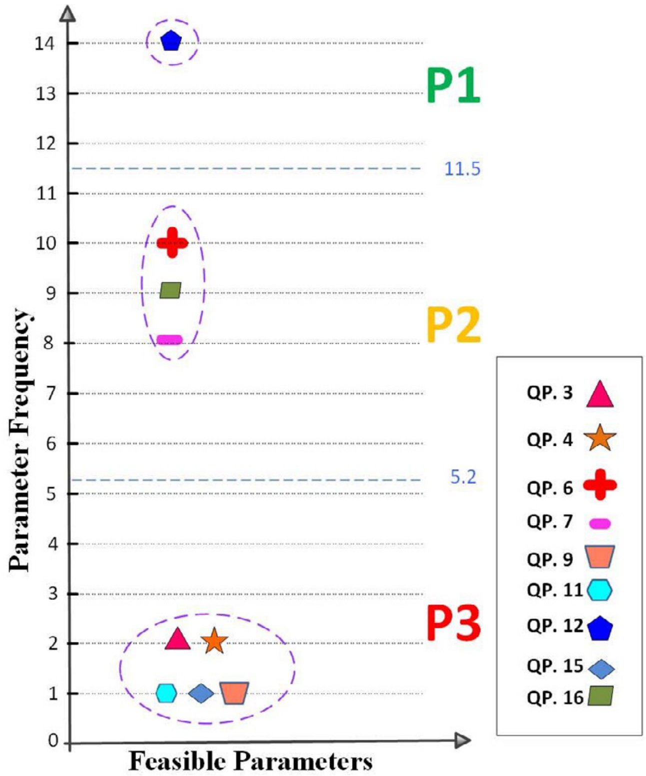

Fig. 8. Applying k-mean clustering method to determine the priority of feasible support parameters

Table 3. Final list of support parameters to incorporate in SLA for fixed internet service

Priority	Support Parameter
Mandatory	Service activation time
Recommended	Advance notice for scheduled downtime
Recommended	Fault repair time (mean time to repair)
Recommended	Period for keeping customers data
Optional	Promptness in resolving customers complaints
Optional	Promptness in answering customers calls
Optional	Notification for approaching end of service
Optional	Time taken for refund of deposit after service closure
Optional	Time taken for service termination after consumer request

assessing the performance of operator networks cannot be mapped into the end user's SLA. In particular, the parameters associated with percentile and rate are usually not appropriate for the end user's SLA. However, the parameters associated with time can be selected, because they can be measured individually.

After studying the mentioned references, i.e., [31–50], a general list of support quality parameters is derived as described in Table 2. Based on the aforementioned rules for selecting the parameters, the appropriate quality parameters for the SLA are highlighted. Prioritization matrix for support quality parameters is depicted in Fig. 7. The parameter QP*i* is the quality parameter with ID *i* as described in Table 2. The prioritization matrix shows the frequency of each parameter and illustrates which parameter is feasible for the SLA.

After specifying the feasible parameters, we employ k-mean clustering method to prioritize them, as depicted in Fig. 8. Since there are three priority levels, we set the number of clustering groups equal to three (i.e., $k=3$). Applying k-mean method to the feasible parameters, three groups mean points are $\mu_1=1.4$, $\mu_2=9$ and $\mu_3=14$. The borders between adjacent groups are half-way between cluster means. By clustering we deduce that one parameter has first priority (P1). This parameter is mandatory for the SLA. Three parameters have second priority (P2), which are recommended to incorporate in the SLA. Five parameters have third priority (P3) which are optional for the SLA. The final list of support parameters is described in Table 3. Note that these support parameters are user-centric and are inherently different from network-centric QoS parameters such as rate, delay and jitter provided in the literature to assess the network performance [51].

We illustrate our proposed method for threshold determination by specifying the threshold interval for the parameter entitled service activation time. This is the parameter with the highest priority within the final list of feasible parameters (see Table 3). The thresholds of service activation time (in terms of days) defined in the international references are gathered in set $\mathbf{S}$, where

$$\mathbf{S} = \{2,3,3,3,3,3,3,3,4,5,5,10,15,30\}.$$

Regarding the definition of outlier data, we realize that 10, 15, 30 are outlier data and should

be removed from the data set. Thus, respect to *Step 2* of the proposed algorithm, we have:

$$\mathbf{S}_f = \{2,3,3,3,3,3,3,3,4,5,5\}.$$

Therefore, after removing the outlier data, μ and σ are equal to 3.363 and 0.924, respectively. Since the threshold limits should lie within the range of valid data (i.e., between 2 and 5), we set N equals one. Also, because the parameter is defined in days, we need to round the boundaries. Consequently, the lower bound and the upper bound of service activation time threshold are 2 days and 4 days, respectively. Here, 2 days is the stringent threshold for service activation time. Thus, the service provider can set this threshold to the customers who reside in the cities with high level of infrastructure deployment or the customers with the highest service level. 4 days is the easiest threshold which can be applied for the customers within rural areas or the customers which receive a low level service.

6.CONCLUSION

In this paper, we proposed a novel step-by-step algorithm for specifying suitable QoS parameters to incorporate in a SLA. Our proposed method prepared a general initial list of parameters including international standards, telecom regulators and telecom operators. This general list is then pruned by performing the feasibility study. At the end, we exploited the *k*-mean algorithm to provide the final prioritized list of QoS parameters. Our proposed method can be applied to any desirable service to extract the most appropriate suitable parameters. We also proposed a statistical approach to determine the threshold value. Our method provided an interval for the parameters thresholds which enables service providers to specify the most suitable threshold according to the conditions or offered service level. Finally, we showed the details of our proposed method via a case study and determined the support QoS parameters for fixed internet service.

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