Conversion of SLA document into Fuzzy Rule base approach and applied in MAPE-K.

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Abstract. A Service Level Agreement (SLA) is the legal catalyst to monitor any contract violation between end users and ISPs and is embedded within a Quality of Service (QoS) framework. It strengthens and advances the quality of control over the user’s application and network resources and can be further stretched to fulfill the QoS terms through negotiation and re-negotiation. Moreover, the present literature does not focus on the combination of rule-based approaches and adaptation together to update the established learning repository. Therefore, this mainstream of this research in the context of SLAs is to fill in this gap by addressing the combination of rule-base uncertainties. The key to this exercise is the conversion of signed SLA document into set of rules in the rule base approach.

Keywords. Service Level Agreements, Quality of Service, Internet Service Provider, MAPE-K and Fuzzy

1. Introduction
This research considers QoS, SLA, ISP and ISP architecture as the elements of the research context, applied in a computer network environment. QoS is the set of service requirements to be fulfilled by the network providers in relation to delivering guaranteed services during network activities. In the recent world, half of the global population [1] are actively connected to the Internet and further initiatives have been made by Facebook, Motorola, Nokia, etc. [2] to capitalise the offline users with equal Internet connectivity through community service responsibility. Social engineering software, Voice Over Internet Protocol (VOIP), Instant Messaging, online shopping, video streaming and robust innovations in communication devices are the major causes of why people heavily connect to the Internet and experience bandwidth issues.

One of the great benefits of QoS is administrative control over the application, as well as, the networks resources in the ISP’s business model [3]. This can be further stretched out by leveraging into ensuring a permitted time in mission-critical applications, a better user experience and lastly, reducing any unwanted costs to do with using the resources efficiently. To secure the services accordingly, SLAs will be a companion to the given service [4]. The success rate of the Internet service depends enormously on the degree of satisfaction between providers and the customers with the measurement in the form of the satisfaction available within the QoS parameters. The major concern fields of this investigation will be the throughput, as well as other elements such as availability, security, response time, reaction time, and reliability [5]. Quality of Experience (QoE) is another argument whereby it is distinguished as the attributes that are based on subjective measurements. Some of these distinguished attributes are usability and reputation. This rating will be valued by the users and will be numerous in relation to the different attributes that belong to QoS.
Although the SLA documents are present in daily executions, available QoS perimeters within that are yet to be extracted into fuzzy rule base approach. Having that, it will ease the ways to measure the correct QoS perimeters agreed by provider.

2. Background

The Internet has been fluctuating robustly within the last ten years. Especially with the introduction of appliances and gadgets. Creative people planned for the modern world. Small devices dynamically change the nature of people using communication via the Internet rather than conventional circuit connectivity. Skype’s current feature allows people to receive a real time translation when communication is engaged with two people with different and distinct native languages. Furthermore, the utmost competition between smart phone makers will rapidly transform peoples' behaviour in adjusting to the technological revolution.

To cater the increasing demand, QoS plays major part in guaranteeing that the services are according to the signed terms and conditions to deliver the complexity of the offered services in the subscribed availability, quality, flexibility, and security. This will then become difficult when dealing with several tiers of software, hardware, and bandwidth providers. Although there is the existence of Software Defined Networking (SDN), it does not resolve the entire connection, from the access router up to the backbone router, when coming from different ISPs providers.

New adaptive management should be present to ensure the ability to control diverse and rapidly growing technologies. This will be a challenge to the research community either from academic standpoint, or an industrial one. With the various advancements of research have been in autonomic computing, since it was announced by IBM [6], several solutions towards the autonomic computing environment have been introduced, such as programming language [7], software-development life cycle [8-14], processing using event [15], profiling approach [16] and the formation of various academic and industrial [17] research groups.

2.1 Quality of Service (QoS)

QoS is the standard setup for measuring quality network performance from one connection to another, whether it is in a local or wide-area connection or not. QoS is built with five principles in mind that are: the integration principle, separation principle, transparency principle, asynchronous network management and lastly, the performance principle.

QoS specification is concerned with capturing the application’s level quality of the service requirements and management policies. The QoS specification is generally different in each system layer and it is used to configure and maintain the QoS mechanism residents in each layer. For example, at the distributed system platform level, the QoS specification is primarily user-oriented rather than system-oriented. Lower level considerations such as tightness, the synchronisation of multiple related flows, the rate and burst size of flows, or the detail of thread scheduling should all be hidden at this level.

2.1.1 Qualities of Traffic

For every successful connection to the Internet or a network, there are three major activities; data, video and audio. Network guys will commonly call this a triple play where there is a combination of three core items. However, when we deal with a larger network, the performance will be a vital role to be sustained as before. In the early days of the Internet, users were granted with best-effort performance and with that agreement, network performance could be varied and there was no guarantee of reliability, delay, jitter, variation in delay and other performance characteristics.

This has been illustrated in Table 2.1. Due to that, a single bandwidth application will result in poor network performance, and no guarantees were given on the consistency of the Internet connection on an hourly or on demand basis. To overcome the uncertainty of this situation, QoS has
been introduced globally to manage bottleneck issues in the computer network. It will ensure that quality is one of the core requirements, either for some applications or to provide different treatment for users with priority who will be treated differently than normal packets.

### Table 2.1 QoS Components

| Network Behaviours | Description |
|--------------------|-------------|
| Bandwidth          | Amount of traffic that is defined by the network environment |
| Latency            | Delay in getting data from source to destination |
| Jitter             | Difference pattern of latency issues |
| Reliability        | Amount of percentage that will be dropped by the router due to data transaction issues |

Urcoubetis [18] reported that sometimes the connectivity between tiers in terms of peering and misuse is among the strategies that are implemented by ISPs to insure their investment. Taking in these exercises, subscribers will proceed to gain greater network performance and better bandwidth connectivity. In a nutshell, this is the business model between the primary ISP and their collaborators to ensure that each of them will gain from the site. It is better known as the free-riding strategy and selective degradation strategy.

#### 2.1.2 Applications

In the network environment, it is a mechanism to guarantee that the connectivity is delivered over the period of established association. There are two outstanding applications that reside in this connectivity, which are: connection-oriented and a connectionless application. Table 2.2 tabulates an example application running on the two associations.

### Table 2.2. Sample Applications Running with QoS Categorisation

| No | TCP (Connection Oriented) | UDP (Connectionless) |
|----|---------------------------|----------------------|
| 1  | Web                       | Tunnelling           |
| 2  | SSH                       | VPN                  |
| 3  | FTP                       | Media Streaming      |
| 4  | Telnet                    | Games                |
| 5  | SMTP                      | Local Broadcast      |
| 6  | IMAP / POP                |                      |

A survey has been performed over the implementation of QoS research on a distributed system platform, operating system, transport and multiple network layers [36]. With huge demands over distributed multimedia applications, it becomes a major issue and fewer researchers finding sufficient solutions in this field. In that, there are three core processes that are involved in these activities such as message passing services, remote invocation and stream services.
For operating systems, some major steps that are focused on, are the communication protocols and scheduling. Nevertheless, the integration among the components from various operating systems is still in a grey area and it will be very beneficial if the results can be built to have one central component that quantifies the integrations.

Lastly, for the transport and network layers, the reasonable research has conversely been on the best-effort method to ensure that the delivery of data is less affected by time lag, jitter, error selection and relative precedence. In the effort of integrating the network layers, the recent research has contributed to the association of four parameters such as packet scheduler, classifier, admission controller and a reservation setup protocol.

2.2 SLA
SLA was introduced back in the 1980s by telecommunication companies. By giving an SLA, the telecommunication providers can spell out their commitment to the customer either it as a best-effort connection or guaranteed connection. Normally, the customer will trust the ISP commitment by saying that their services can do almost everything before the establishment of any agreement.

![Figure 2.1. SLAs Life Cycle](image)

The subscription can either be broadband or a leased line depending upon the needs of the user. Other issues are to do with the IPv4 running out, and some countries have established IPv6 as their pillar. Lots of Internet activities such as Cloud computing and other services have a SLA as a must between subscribers and the providers to ensure that the services are according to their promises.

3. Proposed Research
The broad target of this research is to enable SLA conversion into Fuzzy rule base and it is helpful for the ISPs to manage their resources. To understand their resources, SLA was applied as a (legal) QoS requirement to understand the engagement between ISP and their subscribers. Uncertainties is the key issues in this research. The result of this research is beneficial, as the ISPs can monitor their SLAs and understand the need for any improvements in the resources usage. By understanding these, ISPs are able to cope with challenging business competition, and can be readily available for an active and proactive maintenance plan.

To meet this target, there are **FIVE** (5) objectives that have been established and identified, which include:

1. **Exploring the current research and issues related to QoS, SLA and ISP.** This is here to help understand the current progress and how the remaining progress work can be established in this research. It provides information on the engagement of the connected domains in order for them to be unified, so they are able to be a solid tool for the execution of this study.
II. Investigating the SLA case studies. This is to understand the ability of the adaptive framework and match that is within the available information which is publicly available for ISP case studies on their performance and connectivity.

III. Investigating the fuzzy systems to provide fuzzy rule base approach. This activity is used to understand the exact combination between the fuzzy system and QoS perimeters. The ideal combination can handle the uncertainties.

4. Experiment
This research focuses on the inter-domain of ISP and the current broker architecture. The broker in this research can run as a virtual provider. Table 3.4 tabulates the information of the high-level design and components. The whole blueprint is inspired by the self-healing properties which are the features of autonomic computing.

- **Self-Configuration**
  Initiative following the negotiation process between the application and the service provider.

- **Self-Optimisation**
  A compromise between maximising the use of resources and maintaining an acceptable level of service.

- **Self-Healing**
  Concerned with outright QoS violations or QoS degradations.

- **Self-Protection**
  Linked to policing and monitoring.

- **Self-Awareness**
  Application and middleware can perform adaptations depending on the changing environment.

4.1 MAPE-K Architecture
The architecture is based on the MAPE-K approach. It has two layers; goal management and adaptation model. This is the thorough architecture available in the abstract model. There are four components that form goal management, all stored in the goal model repository. The policy approach is the main connector for the two layers. In this research, there are two scenarios which tally to the architecture. The first scenario is ISP has MAPE-K and a middleman runs as the temporary negotiator before the establishment of the agreement. After engagement, ISP must play their own role to ensure that the relevant penalty will be applied to any violation of the signed agreement. In second scenario, the virtual provider has the MAPE-K framework interact within the environment and the monitoring will be executed until the end of the agreement.

Three simple adaptation rules have been applied for both scenarios:

1. Suitable adaptation rule has been learned
2. The environment has changed the approach of the goal
3. Another rule is applicable

The parameters during the adaptation of these rules with the MAPE-K architecture are the control data and functional components.

4.2 Results
In this assessment, the significant integration between the ISP and their associate business partners will be demonstrated using the early implementation of MAPE-K. This exercise is relevant to the first scenario of the research proposal and the motivation is to have fundamental knowledge of MAPE-K integration between current brokerage approaches.

The framework is based on the MAPE-K approach, invented by IBM. It has five core elements such as monitor, analyse, planning, execute and knowledge base. Each of these elements has its own function and it contributes to a fully autonomic computing environment. In a nutshell, MAPE-K can
be considered as an autonomic element. It has an autonomic manager globally and locally to manage that.

SLA and ISP policies are the main contributions towards this approach. SLA is the set of agreements that are signed between parties once the terms are finalised. This agreement will be the ultimate measurement to ensure the deliverables are as agreed and the mechanism to monitor the violations over the running of the SLA will be an added value.

The ISP, on the other hand, is a company that is making business through internet connectivity through normal or corporate subscribers. In order to sustain their business model, an ISP should have a good business partner with another ISP. With that, it can ensure a productive delivery of their services globally. Since each ISP has its own limitations, such as financial and technical resources, SLA will address the itemised terms during the business engagement. This situation can be addressed with an adaptive approach that is hugely applied in the autonomic computing.

4.3 Objectives

There are four main objectives as to how significant this exercise is to the research activities.

i. To prove that the MAPE-K framework can be applied within ISP using the fuzzy logic approach.

ii. To prove that the MAPE-K framework is able to pick up the inputs and tally with the potential results.

iii. To prove that the fundamentals of the MAPE-K framework can exist within a middleman or broker.

iv. To exhibit a fundamental result that is able to cope with the next scenario of fully autonomic computing between ISPs and the virtual provider which acts as the ISP.

4.4 Experimental Design

The framework can be adapted into a fuzzy system approach with the following components:

a) Inputs

| Table 4.1 Fuzzy Membership Function Inputs (Excerpt) |
|---------------------------------------------------|
| **Performance** | Throughput | Below Satisfactory, Average, Satisfactory, Exceed |
|                   | Uptime     | Below Satisfactory, Average, Satisfactory, Exceed |
|                   | Packet Loss| Low, Average, Critical |
|                   | Latency    | Low, Medium, High |
|                   | Jitter     | High Quality, Acceptable, Poor |
|                   | Grade of Service | Routine, Intermittent, Critical |
|                   | Response Time | Low, Medium, High |

b) Rules

| Table 4.2 Fuzzy Membership Function Rules |
|------------------------------------------|
| Increase Bandwidth | Low, Medium, High |
| Change Package     | Platinum, Gold, Silver, Bronze |
| Service Performance| Low, Medium, High |

MATLAB was the chosen software with embedded fuzzy logic to execute this exercise. The inputs were available in two categories; performance and fault repair. This is a normal practise applied in the SLAs given by ISP to their subscribers. In the performance, there were seven major inputs and the warm-up experiment will focus on the three core inputs which have a strong comparison potential between them. The chosen inputs were packet loss, latency, and jitter.
In the preliminary research progress, to demonstrate fuzzy logic’s ability to handle rules and uncertainty, increased bandwidth was used to meet this purpose. The other rules will proceed gradually within the research progress.

**Table 4.3 Fuzzy logic Rules (Excerpt)**

| Rule | Jitter Logic Operator | Packet Loss Logic Operator | Latency Logic Operator | Increase Bandwidth |
|------|-----------------------|----------------------------|------------------------|--------------------|
| 1    | IF Poor AND Critical AND High Then High |
| 2    | IF Poor OR Critical OR High Then High |
| 3    | IF Poor OR Average OR High Then High |
| 4    | IF Acceptable OR Critical OR High Then High |
| 5    | IF Acceptable OR Average OR High Then High |

The assumption is made through normal practise which is available in the SLA between ISPs. Below are the membership functions that are available in the Matlab tables.

**Table 4.4. Packet Loss Membership Function**

| Membership Function | Packet Loss |
|---------------------|-------------|
| Low MF              | 0           |
| Average MF          | 50          |
| Critical MF         | 100         |

**Table 4.5. Latency Membership Function**

| Membership Function | Latency |
|---------------------|---------|
| Low MF              | 0       |
| Medium MF           | 50      |
| High MF             | 100     |

**Table 4.6. Jitter Membership Function**

| Membership Function | Jitter |
|---------------------|--------|
| HighQuality MF      | 0      |
5. Result
The early results driven from Table 3.5 have produced the expected outcome for increase bandwidth. The results can be read below:

a) Packet Loss vs Jitter
In this scenario, increased bandwidth is not urgent if jitter is high quality and packet loss is low. However, the state of urgency increases when jitter is poor and packet loss is critical. Figure 3.24 shows the outcome of the results.

b) Latency vs Packet Loss
Figure 3.25 illustrates the scenario between packet loss and latency. In this situation, an increase in bandwidth is not necessary when latency is low and packet loss is low. However, the graph increases gradually when both latency and packet loss reach average performance. Lastly, increasing bandwidth reaches the peak demand when there is a logical combination of average and peak performance for both latency and packet loss. Although the resulted output is identical to pyramid shapes, it shows the consistency of the combination of the rules on the defined QoS parameters.

c) Latency vs Jitter
The result is static between latency and jitter. This result is expected because the two factors are interrelated in network performance.
In Figure 3.25, two QoS parameters; Latency and Packet Loss are shown. The output demonstrates that high bandwidth is only applicable if the combination of both parameters are at Medium and gradually increase.

6. Conclusion
The focus of this experiment is based on the ISPs and broker architecture. At this stage, the research has been narrowed down to focus on the rule base within ISP, and the existence of the broker is to justify the perimeters of this study. The MAPE-K framework has been introduced and applied conceptually in this experiment. The self-features are a vital approach in autonomic computing. The renegotiation process within self-adaptive brokerage and fits the assumptions of the research context in the ISP architecture. The connection of MAPE-K framework to the rule base is demonstrated as the goal management layer in the abstract model. A suitable policy within MAPE-K will be iterated to enhance and update according to the current framework.

The Adaptation model layer was introduced with THREE (3) adaptation rules to connect with the other conceptual autonomic elements using control data and functional components as per Figure 3.22 and Figure 3.23. In this approach, the autonomic element refers to ISP. The rules are:

I. Suitable Adaptation rule has been learned
II. The environment changed – another approach to the goal
III. Or another rule is applicable

SLA case studies were presented in this experiment. They carried SIX (6) QoS performance parameters and TWO (2) for the fault repair. The details are available in Table 4.1. In the defined fuzzy rules in Table 4.3, only one rule examined what is the increase bandwidth for different combinations of jitter, Packet Loss and Delay. An example of an “If” statement is below.

IF Jitter is Poor AND Packet Loss is Critical, AND Latency is High, Then Increased Bandwidth is High.

The rule base was applied in the Fuzzy toolbox within MATLAB software with defined Packet Loss, Latency and Jitter membership function. The generated results are based on the static input and
simulation. The first comparison was Packet Loss versus Jitter. The result shows that a state of urgency to increase bandwidth when the fuzzy rules are equal to jitter is poor and that packet loss is critical. On the other hand, the demands for increased bandwidth is less demanding in the event of jitter being high quality and when packet loss is low.

In the second comparison between Latency and Packet Loss, the result was that there was no urgent request for bandwidth increase if latency is low and packet loss is low. The output result match with the rule base defined in Table 4.3, for the continued effects to occur between latency versus packet loss.

The same consistency was applied in the last comparison between Latency versus Jitter. It was a match with the objectives related to using fuzzy logic as the approach to handle uncertainties in the next step in the MAPE-K framework.

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