Selection of IPv6 Attributes for Efficient Cloud Computing Development

Towards Green E-Government in Indonesia

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***Abstract* — This paper introduces a novel idea of achieving efficiency in cloud computing development through IPv6 implementation. Although this approach offers many benefits, it needs extra efforts to make proper selection of particular IPv6 attributes since not all of those attributes might be established at the first phase of cloud computing development. Ternary AHP is applied to tackle the problem of selection process. Finally, the analysis reveals top three IPv6 attributes that should be given priority in mind when deploying Cloud Computing over IPv6 to realize green ICT infrastructure for e-government in Indonesia.**

Keywords - Ternary Analytic Hierarchy Process, IP6, Cloud Computing, Green ICT, E-government

I. Introduction

ICT infrastructures play a vital role in delivering various e-government services to provide better interaction between government and citizens. Inhancing ICT infrastructures by means of adding more hardware is commonly preferred as a simple solution for making better e-government services [1]. Among them, servers and switches are two main devices that usually on top order in government procurement list for improving the ICT infrastructure.

For developed countries, option of buying is commonly accepted since budget is not a serious issue. However, the option is not preferred for developing countries due to financial limitattion of state institutions.

Such situation experienced by Indonesian government. Concern to improve e-government services is often confronted with lack of government funds since to purchase new hardware on the other hand. Therefore, innovation is required to bridge e-government need for enhancing ICT infrastructure and lack of financial support for such improvement.

Cloud computing is a new paradigm in information technology offers a feasible solution to reduce development cost and simplify ICT infrastructures management while enabling green technology simultaneously [3]. Basically Cloud Computing tries to reverse the trend of ICT investment from buying to renting ICT infrastructure and applications [4].

These advantages are very attractive to developing countries such as Indonesia to develop better ICT infrastructures while keeping it affordable for the government's limited budget [4]. This paper also proposes cloud computing as the most attractive option for the realization of eco-friendly ICT infrastructure known as green ICT. In order to make its development more efficient, planning to establish green e-government ICT infrastructure based on cloud computing must be well prepared.

One of progressing research activities in ICT research and development is the so called IPv6 or Internet Protocol version 6. Efforts to develop new protocol were basically driven by many inherent weaknesses addressed to IPv4 which currently still dominates the internet networks that need to be tackled by IPv6 [6].

In general, IPv4 is an earlier standard for internet communication known with many inherent weaknesses such as insecurity, inefficient and many others [7]. These problems have led to the initiation of a new internet protocol called IPv6 with various advanced attributes. Many projects have been done both developed and developing countries to introduce and migrate to IPv6, including in Indonesia through Indonesia IPv6 Taskforce in order to foster migration from IPv4 to IPv6 [8].

In order to achieve better efficiency in realizing green e-government ICT infrastructure, cloud computing must be deployed along with IPv6 migration. There are two main reasons to justify its effectiveness, firstly integration of both technologies could be performed seamlessly and secondly deploying both in the same time will significantly cut time and cost of development of new and green ICT infrastructures.

Fundamentally, IPv6 has many attributes that will bring significant advantages to cloud computing if deployed over it [16]. However, it is time consuming and potentially difficult to implement all of them at the same time. As a result, one to select the most significant and important attributes to be implemented step by step such as in the case of developing cloud computing over IPv6 environment [17].

To deal with the selection process, Ternary Analytic Hierarchy Process is applied in this paper along with the analysis.

II. Leterature Review

A. Cloud Computing

In recent years, cloud computing has been the hot topic discussed and studied by academicians and IT professionals both in universities and industries. Voorsluys et.al [9] present various technical approaches to improve efficiency and quality of cloud computing services which have created intense debate among the experts. On the other hand, in order to obtain the most optimum benefit from business perspectives, many economic models have been tested and improved by experts [10]. However, all of these are based on three main concept of Cloud computing (cloud characteristics, cloud service model, and cloud deployment type) as mentioned below.

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1) Cloud Characteristics

Cloud Computing provides on-demand self-service means that a consumer who demanding particular need at any time may get access into computing resources (storage, CPU, network, software, and others) in an automatic and self-service way without physical interactions with service or resources providers [10].

Resource pooling on the other hand can be understood as cloud service provider's computing resources are "pooled together in an effort to serve multiple consumers using either the multi-tenancy or the virtualization model, "with different physical and virtual resources dynamically assigned and reassigned according to consumer demand [9][10].

Rapid elasticity for consumers, computing resources become immediate rather than persistent, there are no up-front commitment and contract as they can use them to scale up whenever they want, and release them once they finish to scale down. Moreover, resources provisioning appears to be infinite to them, the consumption can rapidly rise in order to meet peak requirement at any time [10].

Measured Service is another feature that able to use appropriate mechanisms to measure the usage of resources for each individual consumer through its metering capabilities, although computing resources are pooled and shared by multiple consumers [9].

2) Cloud Service Model

Essentially cloud computing has three models of service, known as Software as a Service (SaaS), Platform as a Service (PaaS) and Infrastructure as a Service (IaaS) [10][12].

In SaaS model, applications runs on a hosting environment, which can be accessed through networks from various clients (e.g. web browser, PDA, etc.) by application users [12].

Similarly, in PaaS model, cloud consumers are allowed to develop cloud services and applications directly on the PaaS cloud [9]. Unlike SaaS, that only enable users to run applications without access to development platform, PaaS offers a development platform that hosts both completed and in-progress cloud applications. Google AppEngine is an example of PaaS.

Finally, Infrastructure as a Service or IaaS model gives Cloud users directly use various hardware such as storage, networks, and other fundamental computing resources by using virtualization mechanisms [11][12].

3) Cloud Deployment Model

In terms of Cloud deployment, there are three major types of Cloud Computing implementation called Public Cloud, Private Cloud, and Hybrid Cloud.

Public cloud is a term where all Cloud infrastructure, platform and application (software) are developed and owned by Cloud providers. Users who need particular application, platform or even infrastructure do not need to spend money to have them all; instead they only rent as they need from cloud providers [10].

Private cloud is the contrary of Public Cloud. In this type, users develop and operate the whole cloud computing infrastructure within the organization and have full control of the system [9].

Hybrid cloud, on the other hand is the combination of both types mentioned above. For specific reasons, users need to develop particular Private Cloud, but in other case users need Public cloud since it is more efficient in terms of management. This is positioned as a mixture between Private Cloud and Public Cloud [11][12].

B. IP version 6

Since the first Internet era until now, the Internet communication still relies mostly on old Internet protocol known as IP version 4. IPv4 is among the earliest protocols to manage Internet which was designed in a trustworthy environment without concern of security and large amount of users like nowadays. Then in 1980s when the Internet started to experience dramatic growth, the availability of IPv4 address has started to be limited. These are the main reasons for the development and deployment of its successor protocol namely IPv6 [13].

IPv6 was introduced in late 90s with a number of advantages over its predecessor IPv4, as shown in the table below. In recent years, cloud computing has been the hot topic discussed and studied by academicians and IT professionals both in universities and industries. Voorsluys et.al [9] present various technical approaches to improve efficiency and quality of cloud computing services which have created intense debate among the experts. On the other hand, in order to obtain the most optimum benefit from business perspectives, many economic models have been tested and improved by experts [10].

TABLE I. COMPARISON BETWEEN IPV4 AND IPV6

Attribute	IPv4	IPv6
Address	32 bits	128 bits
IP Security	Optional IPSec	Mandatory IPSec
Quality of Service	No QoS identifier	QoS handling in the header
IP to MAC resolution	Done through ARP broadcast	Done through Multicast Neighbour Solicitation
Configuration	Manual with DHCP configuration	Automatic configuration, No DHCP
Packet size	576 byte packet size with fragmentation	1280 packet size without fragmentation

Table I shows how IPv6 attributes outperform IPv4 in many ways such as address bit long, security, etc. Unfortunately, migration efforts from IPv4 to IPv6 in many countries still show relatively slower progress [14] compared with cloud computing adoption [15] particularly in business.

In terms of cloud computing development, IPv6 with its advanced feature will not only benefit in addressing IPv4 limitations but also will potentially make cloud computing development more efficient, powerful and improve its performance [16]. Therefore, features of IPv6 that potentially advancing Cloud computing need to be identified. The following are found to be important features of IPv6 useful for improving Cloud computing infrastructure from three perspectives mentioned below.

1) Security

Security issues are inherent problem in IPv4 that drastically tackled by the new protocol of IPv6. Critical features of IPv6 for cloud computing are address validation, authentication and IP Security [16][17].

Through address validation, IPv6 provides better mechanism in handling address spoofing attacks and strengthen infrastructure from denial of service (DoS) or Distributed DoS [16].

Authentication is applied inherently within IPv6 through authentication header (AH) and encapsulated security payload (ESP). Both AH and ESP are the security mechanisms of IPv6 to provide authentication, integrity and confidentiality security services [16].

IP Security architecture is defined as an integral part of IPv6. Inherently embedded within IPv6 makes users could fully rely on IPSec to guarantee confidentiality, integrity, availability known as CIA, as well as filtering of incoming and outgoing data.

2) Network Management

IPv6 provides better network management through several important features it has namely, mobility, stateless approach and interface identifier [17].

Mobility is a network management feature which is supported in IPv6 as mentioned in RFC 3775 [19]. Ability to choose between multiple IP networks allows a user/device to choose the best network that cheapest, fastest and best coverage.

Stateless approach is IPv6 feature to enable auto configuration without the need of manual activating DHCP. As a result, hosts can auto configure themselves once they are active which simplify network management more efficient [16].

Interface identifier is another IPv6 feature that automatically creates an interface identifier for a host, by using an IEEE-defined format known as the modified Extended Unique Identifier (EUI-64). This element benefits network management in identification of subnet, ISP, and registrant of an IP address [16][17].

3) Performance

IPv6 offers better performance than its predecessor in several ways that could enhance Cloud computing development. These are Quality of Service (QoS), load balancing and efficient broadcast [16][17].

Improved QoS in IPv6 enable to define traffic classes, create and configure traffic policies (policy maps), and then attach those traffic policies to interfaces [19].

Load balancing in IPv6 gives more flexibility to efficiently scaling computer power and distributes traffic load across different segment of networks through neighbour discovery [16].

Efficient broadcast in IPv6 is performed through multicast rather than broadcast. Network bandwidth will be efficiently used, since multicast allows bandwidth-intensive packet flows (like multimedia streams) to be sent to multiple destinations simultaneously [16].

III. METHODOLOGY

Since the nature of problem discussed in this study is a decision making analysis, in the case of selecting the most important attributes of IPv6 for cloud computing, it falls within multi criteria decision making methodology. Among available methods, Ternary Analytic Hierarchy Process (T-AHP) is an innovative decision analysis proposed by Takahashi [20] which simplifies complexity of traditional

AHP scales [21]. Readers who need to get deeper understanding of the mathematical concept behind Ternary AHP may refer to [20] and additional example of its application in [22] and [23].

In short, Ternary AHP method is performed through the following steps [20][22]:

A. Comparing the vector of criteria

After developing decision hierarchy, each factor in all layer of hierarchy should be compare pairwisely in the form of matrix A. The matrix A is a $m\times m$ real matrix, where m is the number of evaluation criteria considered. Each entry a_{jk} of the matrix A represents the importance of the j_{th} criterion relative to the kth criterion. If $a_{jk} > 1$, then the jth criterion is more important than the kth criterion, while if $a_{jk} < 1$, then the jth criterion is less important than the kth criterion. If two criteria have the same importance, then the entry ajk is 1.

Unlike Saaty's AHP which with values of judgment falls within 1 to 9, Takehashi's Ternary AHP only apply three values of 1, θ and $1/\theta$ to represent equally important, more important and its reciprocal [23]. As a result, Ternary AHP requires less judgment choices and also less computation time which makes it efficient for particular environment [22].

B. Comparing the vector of criteria

Once the matrix A is built, it is possible to derive from A the normalized pairwise comparison matrix A_{norm} by making equal to 1 the sum of the entries on each column, i.e. each entry a_{jk} of the matrix A_{norm} is computed as

$$\bar{a}_{jk} = \frac{a_{jk}}{\sum_{l=1}^{m} a_{lk}}. \quad (1)$$

Finally, the criteria weight vector w (that is an m-dimensional column vector) is built by averaging the entries on each row of A_{norm}, as follows

$$w_j = \frac{\sum_{l=1}^{m} \bar{a}_{jl}}{m}. \quad (2)$$

The same processes applied to every matrix at all level and aggregated in matrix S while similar computational processes are performed.

C. Compute final weight

Once the weight vector w and the score matrix S have been computed, the final computation obtains a vector v of global scores by multiplying S and w as follows

$$v = S \cdot w \quad (6)$$

The ith entry v_i of v represents the global score assigned by the AHP to the ith option. Finally, ranking is structured in decreasing order.

Based on the Ternary AHP steps mentioned above, the structure of prioritization problem of IPv6 in Cloud Computing is developed using Expert Choice as the tool.

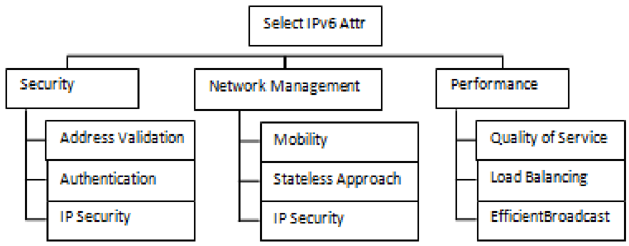

Figure 1. IPv6 selection hierarchy.

The selection hierarchy (see fig. 1) was developed within three levels, all IPv6 attributes derived from related literature as described in section 3.

The first level is goal of IPv6 attributes selection, the second level is criteria consists of three points namely Security, Network Management and Performance, and finally the third level consists of nine alternatives, Address Validation, Authentication, IP Security, Mobility, Stateless Approach, Interface Identifier, Quality of Service, Load Balancing and Efficient Broadcast.

IV. DATA ANALYSIS

Pairwise comparisons are performed at all levels by applying Ternary AHP value of 1, θ and $1/\theta$ [20][23]. The processes begin with performing pairwise comparison between all criteria at every level with respect to the above level until the root level 1.

TABLE II. PAIRWISE COMPARISON OF CRITERIA WITH RESPECT TO GOAL

	S	NM	P
Security (S)	1	*1*	θ
Network Management (NM)	*1*	1	θ
Performance (P)	$1/\theta$	$1/\theta$	1

It is important to note that inconsistency for all pairwise comparisons should be less than 0.1 as recommended by Saaty [21]. In case of more than 0.1, the judgment process should be repeated again. Subsequently, the same procedure applied to the next level to choose the priority among available alternatives.

Table III shows an example of the last pairwise comparison performed to three alternatives (*Quality of*

Service, Load Balancing, and Efficient Broadcast) with respect to Performance as the criteria.

TABLE III. PAIRWISE COMPARISON WITH RESPECT TO CRITERIA

	QoS	LB	EB
Quality of Services (QoS)	1	*1/θ*	*1*
Load Balancing (LB)	*θ*	1	*θ*
Efficient Broadcast (EB)	*1*	*1/θ*	1

At this stage, four tables of pairwise comparison are obtained and collected for the final process called calculation final weight. In addition, overall inconsistency also calculated to identify whether or not inconsistecy occurs during judgment process..

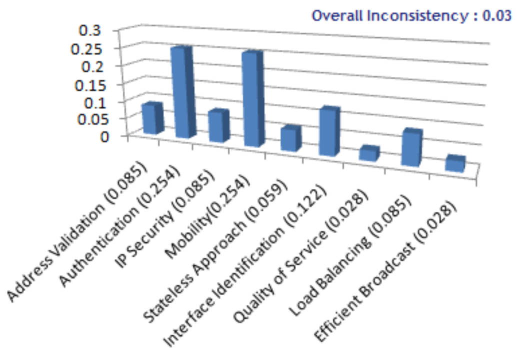

Figure 2. Final result.

Finally, the final result as depicted in figure 2 indicates overall weight of all IPv6 attributes. Top three of them are Authentication, Mobility, and Interface Identification which accounted for 25.4%, 25.4% and 12.2% respectively. In addition, overall inconsistency is 0.03 which means the results are accepted.

Authentication mechanism that inherent in IPv6 through Authentication Header (AH) will greatly helpful for Cloud Computing in improving the level of security that still questionable. It is because authentication in IPv6 improves security of communication and data storage in Cloud Computing environment. Moreover, this feature can also prevent unauthorized access to any Virtual Machines (VM) which is essential in Cloud Computing [16]. As a result, Cloud Computing users will have better security solution with IPv6.

Cloud computing will also benefit from IPv6's feature of mobility which is considered as urgent as authentication (both accounted for 25.4%) in this study. Mobile IPv6 offers a handover system enabling a mobile user to keep connected with the Internet while moving from one to another location. It is urgently needed in Cloud computing particularly in case of moving Virtual Machine (VM) to other servers within the same or different networks [24].

Interface Identifiers of IPv6 which can be generated both manually and automatic are useful for defining a host with unique local address, scope of IPv6 address, subnet, registrant, Internet Service Provider altogether. Gadescu [16] argues that, in addition to Cloud computing, unique local address will streamline Virtual Machine (VM) network management since the traffic might be classified into control and management parts. These approach increase better protection for Cloud computing infrastructure by bounding management services on VM into specific local address which does not affect other cloud infrastructures.

V. SUMMARY AND CONCLUSIONS

Integration of Cloud computing with IPv6 will benefit in making cloud computing development more efficient. This paper proposes the application of Ternary Analytic Hierarchy Process to solve the problem of how to select particular attributes of IPv6 considering enabling all attributus simultaneously is time consuming.

Ternary AHP with its simplicity of only three judgment scales provides simpler decision making process and less calculation complexity.

Finally, it is concluded that *Authentication, Mobility,* and *Interface Identifiers* are the most important ones among all IPv6 attributes to streamline cloud computing development. By appplying selected attributes to cloud infrastructure, green e-government services in Indonesia can be realized in more effective way.

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