Prioritization of IPv6 Features to Improve Efficiency of Cloud Computing Development

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Abstract—Cloud computing is a new paradigm in information technology with features such as reduce development cost and streamline network management while enabling green technology simultaneously. Such benefits are very attractive to government in developing countries to advance ICT infrastructures under low cost budget. On the other hand, IPv6 has been promoted to replace IPv4 that inherently has many limitations. It is argued that instead of deploying Cloud computing and IPv6 separately, it will be more effective and beneficial to deploy them together. By applying Ternary Analytic Hierarchy Process, the study reveals top priority among several features of adopting IPv6 to Cloud Computing.

Keywords: E-Government, Cloud Computing, IPv6, Prioritization, Ternary Analytic Hierarchy Process

I. INTRODUCTION

According to OECD, e-government is defined as the focus of exploiting the best information technology and communications (ICT) facilities to deliver and provide all government functions to public [1]. Through e-government, citizen centric of government services can be provided appropriately to closer government-citizen interaction and provide high level of transparency than traditional public services [2].

Along with increasing demand to e-government services, improvement of ICT infrastructure of e-government is urgent. However, unlike business sector, government particularly in developing countries usually suffers from limited budget available to maintain their ICT infrastructure.

Cloud computing is a new paradigm in information technology beneficial 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]. Such benefits are very attractive to government particularly in developing countries to advance ICT infrastructures under low cost budget [4]. In Indonesia, Cloud computing also becomes an attractive option for the realization of eco-friendly ICT infrastructure known as green ICT. However, security is a great barrier that hinders wide adoption of Cloud computing by government around the world [6].

On the other hand, operations of current ICT infrastructure strongly relies on IPv4 associated with inherent weaknesses such as insecurity, inefficient and many others [7]. This has led to initiation of new internet protocol called IPv6. Many projects have been done in the world to introduce IPv6, including in Indonesia through Indonesia IPv6 Taskforce [8] to foster migration from IPv4 to IPv6.

Features of IPv6 such as improved security, better network management and high performance, if well applied not only will tackle many issues of IPv4 such as address exhausted but also will increase efficiency of Cloud computing development.

Therefore, it is argued that instead of deploying Cloud computing and IPv6 separately, it will be more effective and beneficial to deploy them together. Several researchers have identified several advantages that might be obtained when IPv6 is adopted while moving to Cloud computing environment [16][17].

Application of Ternary Analytic Hierarchy Process in a decision process of adopting IPv6 to Cloud computing development is in the main focus of this study. The decision making process will perform prioritization among selected main benefits under the three levels of decision hierarchy.

The structure of this paper is organized as follows. Section 2 describes related literature of both Cloud computing and IPv6. Then, the methodology to be applied is mentioned in section 3. In addition, prioritization processes based on Ternary AHP are presented in section 4 and eventually the paper ended by discussion of the results in the last section.

II. CLOUD COMPUTING

Cloud computing in recent years, including the most intensive areas discussed by academics and IT professionals. 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.
A. 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].

B. Cloud Service Model

Essentially it has three models of service, called 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].

C. Cloud Deployment Type

In terms of Cloud deployment, there are four major types of Cloud Computing implementation called Public Cloud, Private Cloud, Community 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 since users develop and operate the whole cloud computing infrastructure [9].

A community cloud is cloud computing infrastructure which is maintained and shared by two or more organizations with similar interest and concerns [11].

Hybrid cloud 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].

III. INTERNET PROTOCOL VERSION 6

Until recently, the Internet relies mostly on Internet Protocol version 4 (IPv4). 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 the Internet started to experience dramatic growth leading to IPv4 address exhaustion. 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.

<table>
<thead>
<tr>
<th>Features</th>
<th>Table Head</th>
<th>Table Head</th>
</tr>
</thead>
<tbody>
<tr>
<td>Address</td>
<td>32 bits</td>
<td>128 bits</td>
</tr>
<tr>
<td>IP Security</td>
<td>Optional IPSec</td>
<td>Mandatory IPSec</td>
</tr>
<tr>
<td>Checksum</td>
<td>No header checksum</td>
<td>Header checksum</td>
</tr>
<tr>
<td>Quality of Service</td>
<td>No QoS identifier</td>
<td>QoS handling in the header</td>
</tr>
<tr>
<td>IP to MAC resolution</td>
<td>Done through ARP broadcast</td>
<td>Done through Multicast Neighbour Solicitation</td>
</tr>
<tr>
<td>Configuration</td>
<td>Manual with DHCP configuration</td>
<td>Automatic configuration, No DHCP</td>
</tr>
<tr>
<td>Packet size</td>
<td>576 byte packet size with fragmentation</td>
<td>1280 packet size without fragmentation</td>
</tr>
</tbody>
</table>

Refer to the table above, it can be seen how IPv6 features outperform IPv4 in many ways such as address bit long, security, checksum, 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.

Gadescu [16] justifies that IPv6 with its advanced feature will not only benefit in addressing IPv4 limitations but also has a huge potential to improve the adoption of cloud computing.

In this study, the author argues instead of deploying Cloud computing and IPv6 separately, it will be more effective and beneficial to deploy them together as indicated in current academic literature.

Therefore, features of IPv6 that potentially advancing Cloud computing need to be identified. The following are fundamental features of IPv6 useful for improving Cloud computing infrastructure rather than under IPv4.
A. 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.

B. Network Management

IPv6 provides better network management through several important features 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].

C. 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].

IV. METHODOLOGY

In this study, decision making process to prioritize IPv6 features for Cloud computing is performed through Ternary Analytic Hierarchy Process (T-AHP) [20]. T-AHP is another decision making methodology based on Analytic Hierarchy Process of Saaty [21] which procedures are mostly similar except for the scaling value for judgment [20][22][23].

Similarly, T-AHP 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 $k$th criterion. If $a_{jk} > 1$, then the $j$th criterion is more important than the $k$th criterion, while if $a_{jk} < 1$, then the $j$th criterion is less important than the $k$th criterion. If two criteria have the same importance, then the entry $a_{jk}$ is 1.

Unlike Saaty’s AHP which scaling values of judgment falls within 1 to 9, Takehashi’s Ternary AHP only apply three values of 1, 0 and 1/0 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. Compute weight

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

$$a_{jk} = \frac{a_{jk}}{\sum_{i=1}^{m} a_{ik}}$$

(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

$$w_j = \frac{\sum_{i=1}^{m} a_{ij}}{m}.$$  

(2)

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

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

\[
v = S \cdot w
\]  

The \( i \)th entry \( v_i \) of \( v \) represents the global score assigned by the AHP to the \( i \)th 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.

![Prioritization Model](image)

The prioritization model developed in Expert Choice software which is structured in three levels derived from section 3 above of IPv6. The first level is goal of prioritization, 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 Identification, Quality of Service, Load Balancing and Efficient Broadcast.

V. Analysis

Pairwise comparisons are performed at all levels by applying Ternary AHP value of 1, 0 and 1/0 (in this case 3 is used to represent the value of 0) [20][23]. The process begins with performing pairwise comparison between all criteria with respect to the goal.

<table>
<thead>
<tr>
<th>Security (S)</th>
<th>Network Management (NM)</th>
<th>Performance (P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>( S )</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>NM</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>( P )</td>
<td>1/0</td>
<td>1/0</td>
</tr>
</tbody>
</table>
prevention of 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].

Finally, 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. Gădescu [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.

VII. CONCLUSION

In this paper, it is argued that instead of developing Cloud computing infrastructures on current IPv4, more efficient efforts in terms time and cost will be obtained with new IPv6 technology. However many features of IPv6 for Cloud computing should be selected according to requirement.

The main objective of this paper is to introduce the application of Ternary Analytic Hierarchy Process (T-AHP) to solve the problem on how to prioritize among several beneficial features of IPv6 in order to improve efficiency of Cloud computing development. With its three scales of judgment T-AHP requires little time and resources during the pairwise comparison processes.

Finally, after going through all stages of T-AHP analyses, three features of IPv6 (Authentication, Mobility, and Interface Identifiers) selected as top priorities that will significantly improve efficiency of Cloud computing development.

ACKNOWLEDGMENT

Research reported in this publication is supported by Directorate of Higher Degree, Ministry of Education and Culture Indonesia. In addition, I would like to express my sincere gratitude to all reviewers of my article, especially to Professor David Al-Dabass for his guidance and support.

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