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Developing an IP Address Usage Measurement Index: The Case of South Korea

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Abstract

Background/Objectives: IPv6 adoption index of existing has a limit to survey. Also, the index can't know actual usage because they measure readiness. Therefore, we improved the index to IPv6 usage measurement. **Methods/Statistical Analysis:** The usage measurement methods of IPv6 and case studies in domestic and international were examined. Then using the Delphi method, evaluation and verification of previous IPv6 measurement indices were conducted. **Findings:** The final improved IPv6 usage measurement index is categorized by 'USER' and 'CONTENTS'. The USER indices are indices to measure terminals that are actually using IPv6. The CONTENTS indices are an index that measures whether content service providers support IPv6 for actual use. Meanwhile, infrastructure hierarchy can be the most appropriate measurement points to determine the current state of IPv6 during communication. But accurate measurement is currently not possible in terms of traffic flow. So, the index were deleted. **Application/Improvements:** There is a need to develop an accurate measurement of IoT terminal, mobile application and PC software. Also, developing method to the traffic measurement in infrastructure is needed.

Keywords: Automatic, Index, IPv6, Measurement, Usage

1. Introduction

Along with the widespread use of smartphones and mobile devices and the expansion of the market for Internet of Things (IoT) devices, internet usage is constantly increasing and demand for IP addresses also increases dramatically[1–3]. But because the previous Internet Protocol version 4 (IPv4) system has run out of addresses to allocate, there has been a transition to the newly developed Internet Protocol version 6 (IPv6) system, which solves the shortage of address issue. Korea Internet and Security Agency (KISA) conducts surveys on readiness of equipment and service usability every year to measure the readiness for the introduction of the IPv6 system. But because this is a survey that relies on the sincerity of respondents it has limitations in that it cannot provide real-time information[4].

According to the actual measurements of the Asia Pacific Network Information Center (APNIC), the number of domestic internet users using IPv6 as of March of 2016 is 1.31% of users. This number is significantly lower when compared to that of nations such as Belgium, Switzerland, Portugal, the USA and Greece, which have usage rate of 50.2%, 30.2%, 28.3%, 30.2% and 24.6%, respectively[5]. Organizations such as Akamai, Google and others are also measuring the actual usage rates of IPv6 for each country. But, there is no globally measurement method and these methods differ depending on the organization. Therefore, it is difficult to adopt the measurement methods in Korea[1].

In this research study, the limitations of the previous survey method that is used to measure the readiness of IPv6 introduction in Korea are overcome, and the IPv6 actual usage measurement is attempted to be improved in the form of an automatically measured index appropriate to the needs and situation of Korea. In Section 2, domestic and international research on the actual measurement of IPv6 usage were conducted. In Section 3, the IPv6 actual

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usage measurement index that integrates the domestic and international research was evaluated and verified, and in Section 4, an improved domestic automated IPv6 actual usage measurement index will be presented. Finally in Section 5, the implications and limitations regarding the automated IPv6 usage measurement index will be addressed.

2. Domestic and International IPv6 Measurement Status

The US federal government uses the IPv6 Service Deployment Monitor at the Advanced Network Technologies Division of the NIST (National Institute of Standards and Technology). The introduction state of IPv6 and IPv4 of DNS, e-mail and web services of government organizations, corporations and university websites are monitored on a daily and weekly basis. And the statistical results are displayed on their website[6]. The Ipv6 Consortium of Belgium collects data on the current state of IPv6 introduction by gathering information from ISPs (Internet Service Provider) and other major service providers. Whether or not IPv6 is used for Web servers, email, the DNS server of the major websites for each industry and the prefix information allocated to each service provider and the actual prefix information that is routed are provided[7]. In New Zealand, by benchmarking the IPv6 readiness and introduction indices of other nations, the IPv6 Consortium developed an IPv6 introduction index from the perspective of 'the readiness of the service providers', 'the usability of the contents and services', and 'usage amount'[8]. In[9,10] proposed an IPv6 introduction measurement index by categorizing indices into the categories of 'content provider', 'internet service provider', and 'content consumer'. And by categorizing the main categories of IPv6 into 'the functions of IP' and 'operational characteristics', measurement values for each of the indices were provided.

On the other hand, in order to officially spread global awareness that actual IPv6 based services were being launched, the Internet Society (ISOC) formed the 'World IPv6 Launch' in 2012. The website administrators of 3,002 companies, the network administrators of 76 companies, and 5 home router providers are members of this organization. The participating companies make public site requests from users using IPv6, traffic loads and the measurement methods through the World IPv6 Launch website. For example, Social Network Services (SNS) sites such as Facebook and LinkedIn measure the number of incoming requests from terminals using IPv6. Companies such as Akamai and Yahoo analyze the incoming Content Distribution Network (CDN) traffic from IPv6. Google measures usage based on the Domain Name System (DNS) queries of incoming connections.

In domestic research[1,12] discovered that for various sections of the internet, the values that could be measured differed, and because these values contained different semantical meaning, the research categorized the indices into 'user', 'content' and 'infra'. In[4] developed an index system that included the readiness measurement from a service user perspective in addition to the equipment focused degree of preparation measurement method when measuring the domestic IPv6 introduction readiness. In the process of serving content, the index was categorized by network, or in other words into the 'Internet Exchange (IX) linking hierarchy', 'Internet Exchange (IX) hierarchy', 'Internet Service Provider (ISP) hierarchy', 'Content Service Provider (CSP) hierarchy' and the 'USER hierarchy' according to the internet traffic route[4].

3. Index Evaluation and Verification

3.1 Methods to Evaluation and Verify Indices

Based on previous results of domestic IPv6 usage measurement states, the results of removing duplicate indices and revising and integrating the data can be summarized as shown in Table 1. According to the results of the domestic research the indices were categorized using the method to categorize by the 'USER', 'CONTENTS' and 'INFRA' sections and also by 'IX (Internet Exchange) linking hierarchy', 'IX (Internet Exchange) hierarchy', 'ISP (Internet Service Provider) hierarchy', 'CSP (Content Service Provider) hierarchy' and the 'USER hierarchy'. In this research, by evaluating and verifying each of the indices in Table 1, an attempt was made to improve the index into an automated measuring index. The methods used for evaluation were the library category quality evaluation of Noh and the categories used in the Digital Archive Unified Catalogue Data Quality Evaluation that utilized the method of Choi by Noh were referenced[13,14].

Table 1. Integration of existing domestic IPv6 usage measurement index

Classification		Index name		Definition
USER	USER hierarchy (Man-Machine)	U-1	Usage in USER hierarchy	IPv6 service usage rate among terminals with internet connection
		U-2	IPv6 usage statistics (APNIC)	Ratio of domestic IPv6 using terminals measured by the APINIC which is an internet address management organization
		U-3	Number of terminals using IPv6	Number of terminals communicating using IPv6 among domestic terminals (including IoT smart devices) connected to the Internet
CONTENTS	CSP hierarchy	C-1	Usage in CSP hierarchy	Service ratio actually using IPv6 among internet services
		C-2	Domestic users preferred site TOP 100	Support status of IPv6 for web sites (Measuring the support status about Web/Mail/DNS)
		C-3	Support status of IPv6 services in Country Domain (.kr, .Korea)	Support status of IPv6 for more than 1 million Country Domain (.kr, .Korea) sites
		C-4	Query rate of krDNS (IPv4/IPv6)	Query ratio incoming to the Country Domain, krDNS (IPv4/IPv6)
INFRA	IX linking hierarchy	I-1	Usage in IX linking hierarchy	Circuit number ratio for actual IPv6-enabled state in connections between IXs
	IX hierarchy	I-2	Usage in IX hierarchy	Circuit number ratio for actual IPv6-enabled state in connections between the IX and ISP
		I-3	Daily average usage of international lines	Internet section usage of IPv6 neutrality interworking network (6NGIX: IPv6 Next Generation Internet Exchange) operated by KISA
		I-4	Daily average usage of each institution	Usage of IPv6 neutrality interworking network (6NGIX) for each interlocking institutional
	ISP hierarchy	I-5	Usage in section of ISP and B2C	Ratio of members using actual IPv6 in connection between ISP and B2C
		I-6	Usage in section of ISP and B2B	Ratio of members using actual IPv6 in connection between ISP and B2B
		I-7	IPv6 adoption for each telecommunications company (AS Number)	AS number lists and whether or not advertising of each telecommunications company
		I-8	IPv6 adoption for each telecommunications company (Prefix)	IPv6 Prefix lists and whether or not advertising of each telecommunications company
		I-9	IPv6 adoption for each telecommunications company (Number of terminals)	Number of telecommunication terminals communicating with IPv6 for each telecommunications company
		I-10	Ratio of IPv6 AS number	Application ratio for IPv6 of more than 780 AS numbers used in domestic
		I-11	Usage trend of domestic IPv6 prefix	Network usage (routing) rate of domestically allocated IPv6 address (/32)

Table 2 shows the evaluation categories and evaluation criteria used to evaluate and verify the previous IPv6 indices. Each index was evaluated in the order of coverage, completeness, accuracy and redundancy. Coverage evaluates the appropriateness of the measured range of the index. Completeness evaluates the consistency level between the measurement method and the index (measurement method). Accuracy evaluates the accuracy and timeliness of the collected data and redundancy evaluates the redundancy of meaning and implementation method of indicators. Out of the 4 indices, coverage, completeness and accuracy were evaluated to be high,

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3.2 Evaluation and Verification Results

Based on the results of the evaluation of the indices, out of the total 21 IPv6 usage measurement indices, only 6 indices were maintained or improved upon. Table 3 shows the evaluation and review results for each of the index categories shown in Table 1. The overall evaluation results show that to use a particular internet service, various network sections such as USER terminal, CSP, ISP, and IX etc. can be routed to. Also by measuring based on the network sections, it is easy to subdivide the policy promotion targets related IPv6 introduction in greater detail[4]. By determining that there will be less IPv6 measurement points left out if all of the network sections are included, it was possible to confirmed the appropriateness of classification of the measurement range. In the case where actual measurement methods were already applied, these indices were maintained as indices that measured IPv6 usage. On the other hand even when IPv6 usage could be known, in the case where these measurements depended on outside sources, or for indices with inadequate measurement ranges or definitions and in cases where the index could be improved the index was improved or otherwise the index was deleted. Also indices that just imported the measurement values from other organizations or indices that were not practically related to IPv6 usage were deleted. But in the case of indices that were only measurable through surveys, even though these methods were not compatible with the objective of improving the indices to be automated, because these indices were valuable not as actual measurement but as surveyed indices, they were not deleted and evaluated to be 'not adopted'. The following are the detailed evaluation results.

In the USER hierarchy, with the exception of '(U-3) Number of terminals using IPv6', all indices were either not adopted or deleted. The '(U-3) Number of terminals using IPv6' index measures the number of IPv6 terminals incoming to the content service. The data measurements and results that are provided based on a cooperation with the content provider cannot be trusted for accuracy and because these measurements are not captured in real-time there is a problem with timeliness. Also because the data is only measured in number of terminals so the actual ratio being used cannot be determined. And there is also the

Table 2. Evaluation items and criteria of Index

Evaluation items	Definition	Evaluation criteria
Coverage	Evaluating the appropriateness of the measurement range (the measurement objects) for the index	High: Maintain Medium: Need for Improvement Low: Delete
Completeness	Evaluating the consistency level between the measurement method and the index	
Accuracy	Evaluating the accuracy and timeliness of collected data	
Redundancy	Evaluating the redundancy of meaning and implementation method of indicators	Yes/No: Maintain / Delete / Integrate for existing index

Table 3. Result of the index evaluation and review

Classification	Index name		Coverage	Completeness	Accuracy	Redundancy	Measurement Method	Result of Review
USER	U-1	Usage in USER hierarchy	H	H	L	Y	Survey	Not adopted
	U-2	IPv6 usage statistics (APNIC)					External index	Delete
	U-3	Number of terminals using IPv6	H	M	M/L	Y	CP cooperation	Need for Improvement
CONTENTS	C-1	Usage in CSP hierarchy	H	H	L	Y	Survey	Not adopted
	C-2	Domestic users preferred site TOP 100	M	H	H	Y	actual measurement	Need for Improvement
	C-3	Support status of IPv6 services in Country Domain (.kr, .Korea)	H	M	H	Y	actual measurement	Maintain
	C-4	Query rate of krDNS (IPv4/IPv6)	H	L	L	N	actual measurement	Delete
INFRA	I-1	Usage in IX linking hierarchy	H	H	L	N	Survey	Not adopted
	I-2	Usage in IX hierarchy	H	H	L	N	Survey	Not adopted
	I-3	Daily average usage of international lines	L	H	L	N	actual measurement	Delete
	I-4	Daily average usage of each institution	L	H	L	N	actual measurement	Delete
	I-5	Usage in section of ISP and B2C	H	H	L	N	Survey	Not adopted
	I-6	Usage in section of ISP and B2B	H	H	L	N	Survey	Not adopted
	I-7	IPv6 adoption for each telecommunications company (AS Number)	L	L	L	Y	CP/ISP cooperation	Delete
	I-8	IPv6 adoption for each telecommunications company (Prefix)						Delete
	I-9	IPv6 adoption for each telecommunications company (Number of terminals)						Need for Improvement
	I-10	Ratio of IPv6 AS number	L	L	L	Y	ISP cooperation	Delete
	I-11	Usage trend of domestic IPv6 prefix	M	L	L	N		Delete

issue of redundancy with the '(I-9) IPv6 adoption for each telecommunications company (Number of terminals)' of the INFRA hierarchy. But because it was determined that this index was very appropriate in determining IPv6 usage, which is the goal of this research, through improvement to the internal actual measurement method this index was evaluated as 'need for improvement'.

In the CONTENTS hierarchy, the '(C-3) Support status of IPv6 services in Country Domain (.kr, .Korea)' was evaluated as 'maintain'. And the '(C-2) Domestic users preferred site TOP 100' was evaluated as 'need for improvement'. And the rest were deleted or not adopted. '(C-3) Support status of IPv6 services in Country Domain (.kr, .Korea)' only indicated the simple current status. Because it is inadequate as an index that indicates ratio, in order that the IPv6 service support ratio can be determined there is a need to clarify the index name and definition. For the '(C-2) Domestic users preferred site TOP 100' index, aside from the fact that the measured website list and Country Domain list in 'C-3' had redundancies, there were no problems discovered in the measurement. Therefore it was maintained by just changing the index name.

In the '(C-2) Domestic users preferred site TOP 100' index, the websites of not only domestic content providers, but also overseas content providers were included. In the case of overseas content providers, because they are not appropriate measurement ranges when attempting to measure the IPv6 usage of domestic content providers that is being measured in the content hierarchy of this research, there was a need to distinguish between domestic and overseas sites. Using the WHOIS service of KISA that provides the domain information of IP addresses, this problem can be overcome by distinguishing the country of IPs so this index was evaluated as 'need for improvement'. Also when categorizing domestic sites, because the measurement range decreases, so the number of sites was increased to the TOP 200 user preferred domestic sites instead of 100. And, because there was redundancy with the website list that was measured by the '(C-3) Support status of IPv6 services in Country Domain (.kr, .Korea)' index, a subset of the websites that were measured by the two indices overlapped. But because the meaning differed depending on the index, the measurements were maintained.

From the INFRA hierarchy, with the exception of the '(I-9) IPv6 adoption for each telecommunications company (number of terminals)' index, all indices were either not adopted or deleted. The 'adoption for each telecommunications company' for each of the telecommunications companies had been measured for AS number, Prefix and number of terminals. But all network section and terminals included in the AS number and Prefix were difficult to be regarded as communication using IPv6. Also the results and measuring criteria provided from the ISPs were not exactly reliable. And there was the issue of timeliness because these indices were not measured in real-time. The measurement of number of terminals semantically overlapped with the USER hierarchy '(U-3) Number of terminals using IPv6' index. But it was determined that dividing the ratios of the 'Number of terminals using IPv6' by telecommunication company was a meaningful index. Therefore just the measurement of the number of terminals of the 'IPv6 adoption for each telecommunications company' index was moved to the USER hierarchy and evaluated as "need for improvement'.

4. Improved Automatical Measurement Index

The final improved IPv6 usage measurement index is as shown in Table 4. The indices were categorized by 'USER' and 'CONTENTS'. In order that general user can easily understand the index, rather than using the network hierarchy, which has many professional terms, a general terminology was used for categorization. The deleted infrastructure hierarchy can be the most appropriate measurement points to determine the current state of IPv6 during communication. But there were included indices that were not related to the usage amount of actual IPv6 and for most of the indices, surveys were the best possible measurements. Also in terms of traffic flow, there were many providers related infrastructure between the user and the contents provider. Because accurate measurement is currently not possible in terms of traffic flow, the indices were deleted. For each index name, each of the index values were indicated as ratios in order to show the usage rate (%).

Table 4. Final version of improved IPv6 measurement index

Classification	Index name		Calculation method	Definition
USER	U-a	Ratio of terminals using IPv6	(Unique visitors in IPv6) / (Total number of unique visitors)	Ratio of terminals communicating with IPv6 among domestic terminals connected to the internet
	U-b	Ratio of terminals using IPv6 for each telecommunication company	(Unique visitors in IPv6 corresponding to telecommunication company) / (Unique visitors in IPv6)	Ratio of terminals communicating with IPv6 for each telecommunication company
CONTENTS	C-a	IPv6 support ratio of TOP 200 user preferred domestic sites	(Number of sites to support IPv6 services) / (Total number of sites)	Ratio of IPv6 service support of major domains of businesses including web services mobile application S/W
	C-b	IPv6 support ratio of mobile application providers' official site	(Number of mobile application providers supporting IPv6 services) / (Total number of mobile application providers)	
	C-c	IPv6 support ratio of S/W providers' official site	(Number of S/W providers supporting IPv6 services) / (Total number of S/W providers)	
	C-d	IPv6 support ratio of Country Domain (.kr, .Korea)	(Number of Country Domains(.kr, .Korea) supporting IPv6 services) / (Total number of Country Domains(.kr, .Korea))	IPv6 support ratio of more than 1 million sites in Country Domain(.kr, .Korea)

The USER indices are indices to measure terminals that are actually using IPv6. In relation to the total number of terminals, by calculating the number of terminals using IPv6, the '(U-a) Ratio of terminals using IPv6' and the '(U-b) Ratio of terminals using IPv6 for each telecommunication company' to view each of the main telecommunication companies separately were measured. The '(U-a) Ratio of terminals using IPv6' index was improved from an index that was measured using information provided through the cooperation of a content service provider to a direct automated measurement method. The '(U-b) Ratio of terminals using IPv6 for each telecommunication company' index was in the form of receiving information from a cooperation of ISP providers. But because this is an index regarding terminals, by moving this index to a USER index, this index was improved to be measured together with the '(U-a) Ratio of terminals using IPv6' index.

The CONTENTS indices are an index that measures whether content service providers support IPv6 for actual use. This index measures '(C-a) IPv6 support ratio of TOP 200 user preferred domestic sites', '(C-b) IPv6 support ratio of mobile application providers' official site', '(C-c) IPv6 support ratio of S/W providers' official site' and '(C-d) IPv6 support ratio of Country Domain (.kr, .Korea)'. In the case of '(C-a) IPv6 support ratio of TOP 200 user preferred domestic sites', by expanding the measurement range from the TOP 100 user preferred domestic sites to the TOP 200 user preferred domestic sites, the coverage of the measurement range was improved upon. The TOP 200 user preferred domestic sites provided by the domestic market research organization Rankey.com included both domestic and overseas sites, and to select only domestic sites, the WHOIS[15] service of KISA was used to confirm the country information. Meanwhile, for current Korean internet use patterns, it was determined that not only website visitation but also mobile application use and PC S/W usage took up a large portion. Therefore, '(C-b) Support rate of IPv6 in mobile application services' and '(C-c) Support rate of IPv6 in major domestic PC S/W' were added to actual measurement methods. But there is no current method to distinguish the mobile applications or PC S/Ws as can be done for domain addresses and IP address of web sites. So, automatic measurement is not possible. However, because domestic mobile application usage and PC S/W usage are not intended to be overlooked, an alternative was considered. As a result, it was determined that the IPv6 support ratio would be measured using the official websites of each of the providers. Therefore, it was possible to know the current status of whether IPv6 was actually supported through the official sites, albeit using an indirect method.

5. Conclusion

In this research, by evaluating and selecting previous IPv6 usage measurement indices based on previous research, the index was improved to design an automated usage measurement index appropriate for Korea. The measurement results based on this index were able to provide more accurate measurements than those provided by overseas organizations. And this index will influence the usage expansion of IPv6 by domestic content service providers. Also, this index is more trustworthy in terms of accuracy, than the survey method, which relies on the sincerity of the respondent. Meanwhile, the followings are improvement requirement for the limitations that cannot be accurately measured using this index.

First, it is not possible to measure distinct IoT terminals, which are the biggest reason that there is an urgent need to transfer to IPv6. IoT will be applied for automotive[16], home, industrial. So usage and demand of IoT increases in the future. But because there is no current clear definition for the range of IoT in Korea, while there are terminals that are registered with telecommunication companies before use, there are also terminals that only use WiFi without being registered with a telecommunications company etc., making the devices to be measured unclear. Also in the case where sensor organizations assign a unique identifier and in the case where service providers assign a random identifying number, while the readiness can be indirectly determined through the number of IoT sensor devices domestically shipped and also through the registration rate with the telecommunication company service, actual measurement will still be difficult.

Second, the accurate actual measurement of mobile application and PC software is not possible. This research proposed an indirect method of measurement using the official websites of these services, but there is a concern of lack of accuracy.

Third, for the traffic flow according to the network hierarchy, it is not possible to measure the infrastructure section. If it would be possible to measure all traffic that occurs between the infrastructures sections, the accuracy for the IPv6 usage actual measurement results will increase dramatically. But actual measurement is not currently possible and there are also limitations in obtaining the cooperation of related organizations and companies. In follow up research there is a need to appropriately improve on these three limitations and to provide alternatives.

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