Development of A System and Tools for Unified Internet Addressing with Public ENUM

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ABSTRACT

With the spectacular growth of both the Internet and Mobile networks, there are more and more people benefiting from the fruits of networking technology. As these networks continue to grow, applications and services are being introduced that have the capability to provide new and exciting uses. However, this growth is threatened by the increasing complexity of today's data networks. One of the reasons for this increase in complexity is the increase in the number of different and incompatible addressing schemes. The problem is that there are now too many addresses to keep track of and remember.

In order to remedy this issue, a universal addressing scheme was introduced. A universal addressing scheme hopes to reduce this complexity by allowing the use of a single address for multiple services. This project discusses the use of ENUM-based addressing (E.164) as a possible candidate universal addressing system. In order to demonstrate the possible use as such, an ENUM system was extended to support Instant Messaging addressing. Since there are no instant messaging clients that support ENUM today, ENUM resolution support was integrated into the GAIM Instant messaging client. By extending the use of ENUM to support instant messaging, the project demonstrates that it is possible to use the same system for other services and applications.

Keywords

Internet Addressing, ENUM, E.164, RFC 2822, DNS

1. INTRODUCTION

The Internet has shown significant growth in terms of network size and number of users in the past few years. This growth has been relentless in the past decade. As of June 30 2006, the world has now over 1 billion Internet users. Of this 1 billion users there are approximately 90 million Broadband (DSL, Cable, Fixed Wireless) Internet users. This represents approximately 16% of the world's population which represents over a 11% growth in just 10 years[11]. With this growth in number of Internet users, there is also a growth in the number of applications available on the Internet. In the beginning, only a few applications such as electronic mail and file transfer systems were available. Later, web browsing was introduced. This sparked the first major growth in the Internet (also the first dotcom boom and bust).

Today, traditional Internet applications such as Web browsing and electronic mail usage are still continuing to pick-up. Inspite of this, new Internet applications are gaining popularity everyday. One of the most important and fastest growing applications is Voice-over-IP (VoIP). Ever since the idea of routing voice calls over a data network was discovered in the 1970s[4].The next important application is Instant Messaging (IM). IM promises to deliver timely and relevant messages as opposed to electronic mail's current store and forward system. However, another form of Instant Messaging that is also making a bigger impact in the world today and that is the Short Messaging Service (SMS) on mobile networks.

In another technology space, another major technological development in the last few decades is the proliferation of the cellular mobile phone technology. The GSM Association (GSMA) alone represents 690 GMS operators in 214 territories that account for 80% of all mobile phone users in the world. The current figure for GSMA mobile phones subscribers is at 2 billion[18]. This is twice the number of Internet users and this number is growing. Here we can see the proliferation of many many different services and applications that all use the Internet (and sooner than we think: the mobile phone). Additionally, we also see that more network-enabled applications are moving towards the other forms of networks.

As all these applications and networks begin to converge, new products and services can be introduced into the market. This will drive usage and increase its acceptance amongst users (and increase revenues for network operators). As more and more users utilize these services, the core components must be constantly scrutinized and optimized. A number of issues begin to emerge. One of these important issues is **addressing**.

Right now, each user is required to have many different addresses. They are expected to have at least one different address for each service. In the past, we could print a calling card with just a phone, fax, mobile number and email address. Right now, imagine having to add a website address, various IM account addresses, SIP addresses (for every VoIP network) and many others. It is either we increase the size of our calling cards or reduce the number of addresses. *A solution must be devised or consumers will be flooded with a deluge of different addresses stunting the growth of these networks and slowing down the introduction of more services and applications.*

2. STATEMENT OF THE PROBLEM AND OBJECTIVES

This project suggests a strategy for implementing a unified addressing scheme for a number of Internet applications and services. The ENUM system currently used by VoIP was extended to support other applications and services. This research was focus on discussions between end-user or gateway-based approaches to address translation. This research aims to answer the following question: "How and what is the best way to implement unified addressing for both current and future applications and networks?". In the course of the study, a number of tools were implemented to support this strategy.

3. SIGNIFICANCE OF THE STUDY

By providing the necessary technologies that allow universal addressing, this will enable people to utilize a single address to refer to the different services that the user is subscribed to. This, in turn, allows the greater proliferation of new applications and services. Here are some of the other benefits of Universal Addressing.

- **Consolidation**. A universal address provides people with an option to consolidate all their different addresses into a single unified address. This eliminates the need to memorize and carry around different addresses for different services and applications. This also provides the community a system for ease of identification. Potentially, this can be used as a future universal identification system. It would also be easy to keep communications channels open between individuals if such a scheme where maintained for multiple communications methods.

- **Portability**. Another problem with current systems is that when people move away from a particular service or address such as mobile phone service in the Philippines, the user is forced to change his or her mobile phone number. The user is forced to inform all his or her contacts of the change in their mobile phone number. This can prove a costly and cumbersome exercise. A universal addressing system can provide a way for the end-user to be able to change the details of the particular service without having to change their universal address. One identity to be carried around regardless of provider, application or service.

- **Interoperability**. By providing a system for universal addressing for multiple applications and services, this can potentially provide a channel in which these services and applications to interact. There are applications and services that traditionally do not interact such as IM and VoIP that can be easily integrated by using a universal address. This gives us the possibility of offering combinational services into the market place.

There are numerous other benefits to a universal addressing scheme. Universal addressing and the existing global DNS hierarchy provides the users with the ability to consolidate their numerous addresses into a single universal address. This can also be potentially offered as a Value-Added Service similar to the current domain name assignment system operated by the International Consortium for Applied Names and Numbers (ICANN) and domain registrars like Network Solutions, dotPH and others.

4. SCOPE AND LIMITATION OF THE STUDY

The study focuses on two (2) major competing ideas for universal addressing: the End User-based and Gateway-based ENUM resolution approaches which will be defined in this paper. This paper covers universal addressing for a fixed number of services particularly in Voice-over-IP (VoIP) and Instant Messaging (IM). VoIP was chosen because it is currently the most important application that ENUM can be used for today. IM was chosen because it is potentially the next logical addressing problem with the possible of convergence of fixed IM networks and mobile SMS networks. We did not attempt to go into all possible applications and services. However, ENUM can still be used for other applications such as web and electronic mail. The objective was to define the general framework with a handful of services. Future research can be done to extend this system to other services. Some security issues and recommendations are also discussed. However, they were not the focus of this research because they concern a different aspect of implementation.

5. REVIEW OF RELATED LITERATURE

Addressing is one of the most important components of any network whether it is for voice, data or multimedia. It is an essential component of any form inter-network interoperation[22][12][20]. The ability to determine where information is from and should go to is very important. Without proper addressing, no communication may occur. Therefore, we first discussed the different forms of addressing used in the telecommunications world today and then proceed to the current solutions taken to address internetwork addressing.

5.1 PSTN Addressing with E.164

The Public Switched Telephone Network (PSTN) is the oldest, still existing and operating, telecommunications network in the entire world today. However, it has significantly evolved throughout the years into the form and shape it currently has today. The governance of the PSTN is typically done by the Telecommunications Standardization Sector of the International Telecommunications Union (ITU-T) and national authorities of each respective client. The ITU-T defines standards, protocols and procedures for interconnecting different elements controlled by different national authorities[1].

The current PSTN uses a common international numbering plan. It is also used by some data networks especially those that provide System Signaling 7 (SS7) signaling. It was defined by the Telecommunications Standardization Sector of the ITU[1]. The aim of this numbering plan is to provide a numbering system in which all telephones (and other PSTN addressable devices) around the world can be reached. E.164 is not a fixed digit numbering plan but has a 15 digit maximum length. This standard allows different countries to define variations for own numbering plans. However, the ITU-T defines the first few digits as a standard and allows different territories to the define the rest of the numbering plan.

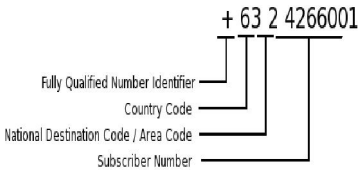

Figure 1: E.164 Numbering Format

It is generally divided into three (3) major parts as shown in Figure 1. The E.164 numbering plan is composed of a Country Code (CC), National Destination Code (NDC) and Subscriber Number (SN). An E.164 number is primarily based on geo-political divisions such as country, territory, area, region and others. E.164 addressing has a number of limitations including shared country codes, limited address space and variable number of digits and divisions. However, it is good to note that inspite of these limitations the current E.164 numbering plan works very well. It is also flexible enough to adjust to the growth in the number of telecommunications subscribers. Unlike the current problems faced by the current generation of Internet addressing such as IP version 4 addresses which are now experiencing a shortage.

5.2 IP Addressing and the Domain Name System

The Internet Protocol (IP) is a packet-based protocol that provides best effort service that does not guarantee delivery, correctness and order of data. A number of higher layer protocols such as TCP and UDP run on top of it. The main purpose of IP is to address and route packets in a TCP/IP network[17]. The definition of how addressing is done in today's Internet is described in section 2.3 of IETF RFC 791. There are two (2) versions of Internet addressing today. One is called IP version 4 (IPv4) and the other one is called IP version 6 (IPv6). Both of these addressess are composed of a fixed number of bits (32 and 128 bits) respectively. IP addresses uniquely identify a network element in a computer network.

However, IP addresses are not easy for humans to recall. This is unlike E.164 numbers that are geo-politically blocked. Therefore, the Internet community had to create a way of referring to machines without having to use their IP addresses. This human-readable name is called a *fully qualified domain name (FQDN)* or just *domain name*. A means to translate between domain names to IP addresses and vice versa is now necessary. The solution was to introduce the Domain Name System (DNS). DNS is an extensible and distributed IP protocol created to perform network translation tasks. Its most important use today is for domain name to IP address mapping and vice versa[15].

However, this only provides information about a single network element and not the users in it. Current, network technology allows many users to share a single host for their Internet services. Hence, DNS resolution only provides host information and not user information. This makes plain IP addressing or the use of domain names inadequate for end-user addressing.

5.3 Internet Addressing with URI/URLs

The Uniform Resource Identifier (URI) and Uniform Resource Location (URL) are two (2) other ways of addressing resources in the Internet. These are commonly used when identifying websites in the World Wide Web (WWW). By definition, it is a simple and extensible way of using a compact sequence of characters (subject to special encoding rules) to identify an abstract or real resource as described in the fairly recently updated RFC 3986[3]. URI's can be used to determine the exact resource in a particular host in the Internet. However, the URI format is more suitable for identifying resources such as multimedia and webpages, as opposed to identifying people.

5.4 Internet Addressing with RFC 2822

With the introduction of Electronic Mail, the Internet community devices created an addressing format that was designed for its use and defined by RFC 2822. This format is called the Internet Message Format[19]. Everything before the '@' sign is part of the username name. It is typically an alphanumeric string (including the period symbol) that identifies an user account in the system. If this is an electronic mail system it will identify the electronic mail user. Everything after the '@' sign is part of the domain name. This domain name can be used to determine which mail server will handle this particular service.

RFC 2822 addressing is commonly used in Electronic Mail and Session Initiation Protocol (SIP) systems. However, the major drawback with RFC 2822 addressing is that it delegates the control of user identification and handling to the host identified by the domain name. This means that the user databases are managed by each and every host. Another problem is the inability to use RFC 2822 addresses in legacy telephony devices.

5.5 E.164 Number Mapping - ENUM

IP addressing is definitely the world's most popular Internet addressing protocol and is being used in a growing number of Internet-connected devices. While, E.164 is the world's most commonly-used Public Switched Telephone Network addressing protocol. E.164 numbers are easier to remember than IP addresses.

Fortunately, the Voice-over-IP community was faced with this problem and a solution was devised in the form of the E.164 number mapping or ENUM[9] by using the best of both Internet and PSTN addressing. ENUM was originally designed to be used to provide address mappings from

E.164 numbers into any other form of address that can be defined by a URI. The designers of ENUM defined it in such a way that it can be used with many forms of Uniform Resource Identifier (URI) to support multiple applications. In this particular case, E.164 numbers where mapped to SIP or H.323 addresses used in Voice-over-IP. Today, some members of the global VoIP community have adopted it to allow the use of the E.164 number format to map to SIP/H.323/PSTN addresses in a VoIP network[16]. This is particularly true for US VoIP and Cable operators. The beauty of the E.164 number is that it follows the current numbering format in today's Public Switched Telephone Network (PSTN) which is what most people are familiar with.

```
$ORIGIN 6.1.3.7.3.6.e164.arpa.
0.0.0.9 IN NAPTR 100 10 "u" "E2U+sip" "!^.*$!9000@asterix.ateneo.net!" .
0.0.0.9 IN NAPTR 101 10 "u" "E2U+tel" "!^.*$!tel:+6324266001!" .
0.0.0.9 IN NAPTR 102 10 "u" "E2U+fax" "!^.*$!tel:+6324266126!" .
0.0.0.9 IN NAPTR 103 10 "u" "E2U+email" "!^.*$!mailto:wyu@ateneo.edu!" .
0.0.0.9 IN NAPTR 104 10 "u" "E2U+im" "!^.*$!xmpp:william.yu@novare.com.hk!" .
0.0.0.9 IN NAPTR 105 10 "u" "E2U+web" "!^.*$!http://hip2b2.yutivo.org/!" .
```

Figure 2: Sample ENUM Configuration

A sample ENUM configuration can be seen in Figure 2. This figure shows a number of possible address mappings that can be done. In this particular example, you can see a mapping for a SIP address, telephone or fax number, electronic mail address, website address and even instant messaging identification.

ENUM is a system for using the Domain Name System for storing E.164 addresses and identifying available services defined for that E.164 addresses[9]. ENUM uses a system called Dynamic Delegation Discovery System (DDDS)[14]. DDDS allows the arbitrary definition of translated address from any other address. For example, an E.164 can be mapped to an URI defining a RFC 2822 email address, SIP address, telephone number, Website URL, IM address and many other service specific addresses. RFC 3761 is the standard that defines ENUM for use in the Public Internet. However, it is possible to deploy ENUM for private dialing plans or private networks. Being a public DNS-based service there are now alternative ENUM trees that can be used such as e164.edu, e164.org and others. An organization can even define an ENUM tree of their own to serve as a private dialing plan.

6. SYSTEM OVERVIEW

This project built a system and some supplementary tools to enable Universal Internet Addressing using ENUM. Figure 3 presents a high level user point of view of the system architecture to be used. In this diagrams, the user is equipped with an ENUM-aware User Agent that does a ENUM DNS query. After getting the proper address and service, the User Agent then accesses the proper server hosting the service based on the information provided by the ENUM DNS query.

It should be noted that this system is primarily client-driven

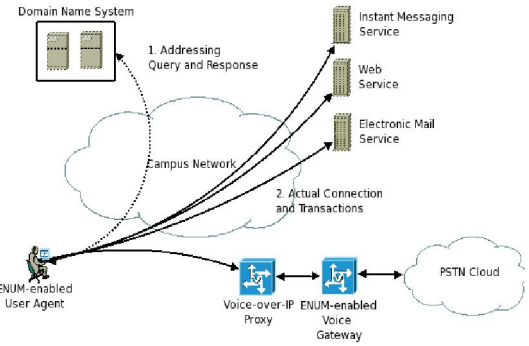

Figure 3: High Level System Diagram

which is also true in the case of the current DNS system. This means that a significant amount of client modifications must be made (an ENUM client must be integrated into the actual client or client application software). Most of these modifications can be done on the application-side of things. However, there are some servers and gateways that have ENUM resolution done in them instead of the client. In this diagram, this is the case for VoIP hard phones.

7. KEY TECHNOLOGY COMPONENTS

This ENUM system has a number of key components. The most important component of the system is the Domain Name Service (DNS). This system is the primary database for the ENUM to service-specific address mapping. The next major component is ENUM-support in the end-user client software. Then lastly, the actual implementation of ENUM on the services that were addressed in this research was done.

7.1 Address Space

The ENUM addressing space used for this project was the **e164.arpa** address space. This is the official IETF sanctioned ENUM address space. There are also other address spaces used by different organizations and for different purposes such as **e164.edu** and **e164.net**. For this project, the Ateneo de Manila University was assigned a trial numbering block on the **e164.arpa** address space. The address block is **6.1.3.7.3.6.e164.arpa** was temporarily assigned to the university for this project. The equivalent E.164 numbers for this block was **+63 (73) 16XXXX**.

As an example, the address assigned to myself is **+63 (73) 169000** which translates into **0.0.0.9.6.1.3.7.3.6.e164.arpa** for an ENUM query. The results of an ENUM query on this number can be found in Figure2. You will notice that there are seven (7) service-specific addresses returned in this query. Two (2) are SIP URLs which are in RFC 2822 format. There is a web URL. The email address and generic instant messaging addresses are also defined in RFC 2822. There is an E.164 PSTN number and finally a proprietary Yahoo Instant Messenger address. So instead of memorizing these seven (7) addresses, it is possible to just memorize one E.164 number.

7.2 Domain Name System

The Domain Name System or DNS is one of the key components of this system. It provides a distributed, scalable and reliable system for performing address translation. Address translation is very important as without it other services would not be able to function. The failure of this service would cause address translation to fail and thus addressing in general to fail. This is similar to the original role of the DNS in host name and web host address resolution. Since DNS has proven itself a reliable addressing translation technology for domain names, it should be safe for us to use the same technology for ENUM address translation.

The DNS system to be used for this project is the Open Source Internet Software Consortium's (ISC) Berkeley Internet Name Domain (BIND) DNS server. ISC BIND is an implemention of the IETF DNS-related protocols[2]. It is also the reference implementation for most DNS-related features. Any DNS system should be usable for this project as long as it supports NAPTR and DDDS. All Linux distributions contain a DNS server. The current project's ENUM-related DNS entries are hosted by the Ateneo Campus Network Group. For this project, the primary DNS server is **dns.ateneo.net**.

7.3 Service-specific Servers

There are a number of services that are used for this trial. Each service is provided by its own server. Initially, voice-over-IP and instant messaging are services that can be easily tested with sandboxed systems.

7.3.1 Voice-over-IP

The experimental campus Voice-over-IP solution is being used for this project. It is also the service being deployed for the National ENUM trails in country jointly administered by DOST-ASTI, Ateneo de Manila and other participating network operators and Internet Service Providers. This Voice-over-IP server routes calls to VoIP locals within the campus. The current VoIP system is power by the Asterisk Open Source PBX software[21]. The current VoIP server is **asterix.ateneo.net**. This VoIP server currently allows user registration and authentication, call completion and proxying, and Private Branch Exchange (PBX) functionality (voice mail, call forward, call waiting and others).

Some end-user client VoIP software solutions natively support ENUM already. However, an easier way to provide ENUM support to VoIP is with the use of VoIP proxies and gateways that support ENUM lookups. The Asterisk open source PBX was then configured to perform ENUM address resolution and can be configured to do so on behalf of the end-user VoIP client.

7.3.2 Instant Messaging

A number of instant messaging systems can be used for this project since ENUM resolution can be translated to any of the supported protocols of the GAIM instant messaging client. ENUM support was integrated into this client for this research project. Details of the client will follow in the next sub-section. The supported protocols by the GAIM client are AIM, MSN, Yahoo!, Jabber, ICQ, IRC, SILC, SIP/SIMPLE, Novell GroupWise, Lotus Sametime, Bonjour, Zephyr, Gadu-Gadu, and QQ. For the purposes of this project, we chose the public Yahoo! Instant Messaging service and a Jabber-based system.

Yahoo! Instant Messenger uses a closed proprietary protocol developed by Yahoo! This protocol is closed but a number of developers were able to reverse engineer it and integrate it into a number of open source software products like the GAIM Instant Messenger. For this project, the DDDS defined service for this will be **E2U+yahoo**.

A prototype Jabber Instant Messaging and Presence system was deployed as a test instant messaging system. Jabber is a set of streaming XML protocols and technologies that enable any two entities on the Internet to exchange messages, presence, and other structured information in close to real time[6]. The Jabber protocol is also known as Extensible Messaging and Presence Protocol (XMPP).

The Jabber server used for this project is called Wildfire XMPP Server. Wildfire XMPP is an enterprise instant messaging (EIM) server dual-licensed under the Open Source GPL and a commercial license. The Wildfire XMPP server is incredibly easy to setup and administer, but offers rock-solid security and performance[7]. This Wildfire XMPP server does not support ENUM by default. So, client ENUM resolution must be used. For this project, the DDDS defined service for this is **E2U+im** and the protocol specified in the URI is **xmpp**.

7.4 ENUM clients

There are a number of services that already support ENUM. However, it is currently used mainly for VoIP. For this project ENUM is integrated into the Asterisk Open Source SoftPBX system to allow hard VoIP phones to benefit from ENUM resolution without having to modify the phone's firmware. A graphical representation of the process is shown in Figure 4. In the case of software VoIP phones, a good number of them already support ENUM addressing. However, these phones can also be configured to depend on their VoIP servers for ENUM resolution even if they can do it themselves.

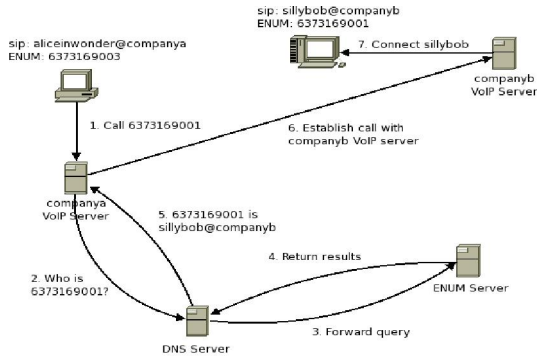

Figure 4: VoIP ENUM Process Flow

However, there is currently no instant messaging solution that supports ENUM resolution. In order to create a proof-of-concept for this, the GAIM open source Instant Messaging client was used as a platform to support ENUM reso-

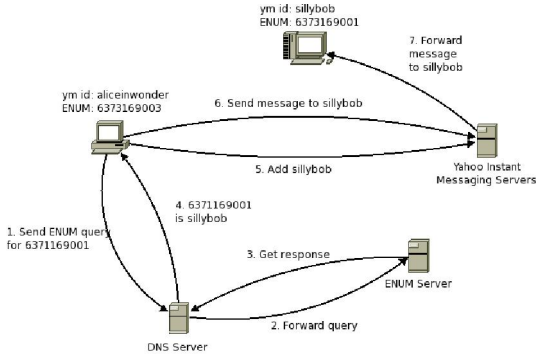

Figure 5: Instant Messaging ENUM Process Flow

lution. GAIM is a popular and modular messaging client capable of using AIM, MSN, Yahoo!, Jabber, ICQ, IRC, SILC, SIP/SIMPLE, Novell GroupWise, Lotus Sametime, Bonjour, Zephyr, Gadu-Gadu, and QQ all at once. It is written using GTK+.[5]. An ENUM resolution client waembeddeded into GAIM for this project. The client was integrated into the add account interface. So whenever a user wants to add a new account into the GAIM client, he or she will simply have to type the ENUM address of that user. The embedded ENUM resolution code will then look up the address from the server, get the service-specific address and then use the service-specific address to interface with the IM service provider. This solution does not require any changes on the IM service provider's infrastructure. Refer to figure 5 for a graphical representation of the process.

8. RESULTS AND DISCUSSION

This use of ENUM for Universal Addressing has been demonstrated to be possible with both user-based or gateway-based addressing. It was demonstrated that the ENUM can be used with our services aside from just voice-over-IP. In this particular project, it was demonstrated that the same ENUM system configured for use in voice-over-IP is also usable when used for Instant Messaging.

ENUM resolution was integrated into the **asterix.ateneo.net** voice-over-IP gateway and proxy server. When making a voice call that requires ENUM resolution on VoIP hard and soft phones, the user simply dials the fully qualified E.164 number (including the '+'). So, if the user wants to call me, he or she simply has to dial **+6373169000**. The number is then sent to the voice-over-IP proxy that does ENUM resolution, determines that the SIP URL of the called party which is **9000@asterix.ateneo.net** and routes the call appropriately.

The Yahoo! Instant Messaging and Presence server does not support ENUM resolution. Therefore, it was necessary to add ENUM resolution an instant messaging client that supports the Yahoo! Instant Messenging protocol. In this case, ENUM resolution was integrated into the GAIM Instant Messaging client that supports the Yahoo! Instant Messenging protocol. A patch was written to integrate ENUM resolution into GAIM. ENUM resolution is performed in the client when a user is added to the buddy list for the first time. Here, the GAIM Instant Messaging client does an ENUM look-up to determine the actual address of buddy that needs to be added. So, if a user uses GAIM to add a buddy with the following E.164 address - **+6373169000**. A look-up on the **E2U+yahoo** field will yield **hbogbindero** (which is my Yahoo! id). After obtaining the actual protocol specific address, it is then processed to be added to the GAIM buddy list.

8.1 Analysis of Gateway-based Addressing versus Client-based Addressing

There are two (2) major possibilities for the implementation of universal addressing using ENUM. The gateway-based and client-based approach. Each approach have their own merits.

8.1.1 Gateway-based Addressing

This strategy allows client software to directly connect to a gateway device that is responsible for performing ENUM-to-address resolutions. Therefore, the client uses their native addressing schemes. The gateway is responsible for all translation. In the case of VoIP, only local telephone addressing is used. In the case of instant messaging, only the IM-specific IM identification is used.

8.1.2 Client-based Addressing

This strategy requires that the client software is capable of doing ENUM-to-address resolution itself. This strategy does not require a gateway device to support ENUM. This way clients make ENUM queries directly. This eliminates the additional load on the DNS system. However, this requires the inclusion of ENUM resolution support on the client software.

Both methodologies have their own set of benefits and issues. The gateway-based approach being centralized benefits by having all queries relating to address resolution converge to it. This also allows end clients to be used as is and run unmodified. This saves on development effort and having to replace clients already being used in the Internet. This because a gateway-based approach shields the Internet client from having to understand the mechanics of the address resolution. Therefore, each client is operated with the assumption that it is running on its own network with its own network technology. The major disadvantage of this approach is that this requires additional intelligence on the part of the network gateways. As more and more services are offered, these gateways become more complex.

On the other hand, a client-based approach benefits from being distributed similar to the current domain name system. Each systems connected to the Internet today has a small DNS client on it. Everytime a user needs to access a website or an Internet server, it first lets its DNS client query the necessary DNS servers to obtain the IP address of the website or Internet server they want to visit. Only after this is the target site accessed[15]. This method is cleaner to implement because all clients simply need to support ENUM. With the proper support, the client can intelligently get the proper address by doing an ENUM query. Gateways and servers can simply operate as they have. The main disadvantage of this approach is that embedded ENUM clients

must be deployed on all clients.

In the near term, gateway-based solutions will probably be used. In our setup, we used the ENUM support on the Asterisk SoftPBX system to provide the ENUM translation service. Clients connected to the Asterisk SoftPBX simply access it as a regular VoIP service and are unaware of ENUM. However, in the same setup, our IM solution was implemented using client-based ENUM. This is because it would be impossible to ask Yahoo to support ENUM on their servers. Therefore, the solution was to embed an ENUM-client into the Gaim Instant Messaging software. So on the near term, gateway-based approaches are the easiest to implement. But, in the long term, an embed client-approach will win out. The ideal client solution would be one embedded into the operating system similar to how DNS is integrated today.

8.2 Analysis of ENUM versus RFC 2822 addresses

ENUM addressing has a number of benefits over RFC 2822 addressing. These differences will be the primary driver for the use of ENUM instead of RFC 2822. Here are the primary benefits of using E.164 addresses instead of RFC 2822 addresses.

8.2.1 Stability, Scalability and Reliability

The use of tried and tested existing DNS infrastructure and technology for addressing has been powering the Internet for the last few decades and still continues to do so until today[2]. The ENUM system takes advantage of DNS infrastructure and technology. Therefore, ENUM inherits all the benefits of DNS. Its most important benefits are stability, scalability and reliability. Since, this system is being proposed as the universal addressing translation system, it is important that maximum availability is provided. RFC 2822, on the other hand, only uses the DNS service to identify the host part of the address. The username part of the address is handled by individual hosts who may or may not be configured to be reliable.

8.2.2 Extensible and Compatible

ENUM and DDDS provides the ability to map multiple services to one ENUM address. This allows people to consolidate all their contacts and addresses into a single ENUM address. So the next time one prints a calling card, it can contain at least two (2) entries: the person's name and ENUM address. With the growth in the number of services available in the world today, calling card real estate is growing short. Even, the use of electronic calling cards become cumbersome with too many addresses. ENUM addressing provides a way to consolidate this. However, RFC 2822 cannot be used to map telephone numbers. While, E.164 is supported by the existing public switched telephone systems (PSTN). RFC 2822 cannot be supported by such legacy systems. Although RFC 2822 also defines a SIP address used in VoIP, it is still more natural for most people to use an E.164 number for making telephone calls. One major benefit of RFC 2822 address is that they are easier to remember than fully qualified E.164 numbers. However, with the advent of sophisticated address book software, it should no longer be difficult to keep E.164 numbers.

8.2.3 Geo-Political Ordering

The geo-political make-up of ENUM makes it easier to remember. The E.164 number is broken down into typically three (3) parts. By looking at the first few digits it is easy to tell that the E.164 number is located in a particular region or country. This is untrue of RFC 2822 addresses that can be located anywhere in the world. Of course, this geo-political ordering is beginning to be loosely implemented. There are VoIP providers than actually move these numbers from one country to another. However, it is safe to assume that these ported numbers are still registered in the original country.

8.2.4 Portability

The number of countries implementing number portability (NP) has been steadily increasing. This is primarily brought about by its ability (when implemented properly) to bring equitable competition in the telephony space[10]. In this year alone, we have witnessed a number of nations from Japan to Brazil that have implemented mobile number portability (MNP). Also portability does not have to restricted to be telephone numbers. This can also be applied to electronic mail, SIP and instant messaging addresses. ENUM potentially provides the ability to put all these addresses under it and provides end users with the ability to customize their entries. This provides greater portability for users of any of these systems. ENUM is also cheaper to implement than current LNP/MNP directory-based technologies[13]. On the other hand, RFC 2822 addressing cannot be supported by our current PSTN and thus cannot be used for number portability.

8.2.5 Security and Privacy

One of the current concerns with the current state of Voice-over-IP is its vulnerability to a certain type of security attack called Phishing. By using E.164 numbers and having them hosted using secure DNS techniques[8], the results of the address resolution can be obtained from trusted and secured ENUM servers. The same cannot be said for RFC 2822 whose username component is not controlled by the DNS system but is handled by the hosts themselves. Also a RFC 2822 volunteers more information in the address than a E.164 number.

8.3 Other Addressing Options

Aside from RFC 2822, there are also currently some debates about the use of E.212 numbers (the ones used as mobile phone IMSI) instead of E.164 numbers. The main reasons is that E.212 numbers are more standardly defined regionally and internationally. Unlike E.164, which is inconsistently defined around the world. The major reason against this is that people are already familiar with E.164 numbers and changing it to another number scheme would just add complexity and confusion.

Finally, E.164 addressing with ENUM appears to be the most readily deployable and mature solution for Universal Addressing as summarized in Table 1. It currently has more support that other competing addressing schemes such as RFC 2822 and plain URLs. It should also be noted that ENUM support is not difficult to add to existing applications and services that still do not have it. In the future, it is possible for addresses to be simplified even further and there

Service	ENUM	RFC 2822	URL	Proprietary
Voice-over-IP	X	X		
Instant Messaging	X	X		
Electronic Mail	X	X		
World Wide Web	X		X	
Peer-to-Peer Systems				X
Electronic Commerce				X

Table 1: Application and Service ENUM Support

will come a time when E.164 addressing will be rendered obsolete. This can definitely happen. However, it is clear that there are benefits to having a unified addressing scheme for all Internet services. As the Internet continues to grow, the number of services available to end users also increase. This is the most important case for universal addressing.

9. CONCLUSION

The growth of both mobile networks and the Internet has created an environment where multiple services and applications can be introduced. Because of this growth in applications and services, there is also a growth in the number of user indentifiers or addresses that have to be used. This growth in the different address types have the potential to increase the complexity of operating both mobile networks and the Internet. This additional complexity make these networks harder to maintain for operators and difficult to use for end users. It is therefore critical that steps towards the development of a universal addressing be taken.

The ENUM-based approach for universal addressing, discussed in this paper, provides network managers and operators with a system, built using the robust and reliable Internet DNS infrastructure, that can consolidate multiple different services and application addresses into one. This one address, which is an E.164 number, can be used to map into different addresses. The flexibility of such a system allows network operators to add and remove support for different services and applications easily. This provides a modular approach to supporting universal addressing with minimal impact to the existing Internet and mobile network infrastructure.

Acknowledgment

The authors would like to Ceejay Dideles of the DOST's Advance Science and Technology Institute, for the necessary collaboration on setting up the Voice-over-IP ENUM trial that served as the base for this project. Patrick Medina and Ton Dolor of the Ateneo Campus Network Group, for providing support and access to all the resources necessary for the implementation of this project in the campus network. Dr. Palmes, Dr. Libatique, Dr. Manalastas, Engr. Pineda, Paolo Villaflor, Nash Sevillo for stimulating discussions on the future of networking and telecommunications that helped shape this project. Dr. Reena Estuar for assisting in the editorial requirements of this project and providing valuable advice on the writing of this paper.

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