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The Economics of ENUM Over Cable Broadband Access Networks

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Abstract:

Entry of cable companies into the local telephony market has not been easy due to various technical and regulatory barriers. One of the main technical-regulatory constraints on cable companies is the issue of numbering systems supporting public PSTN services, especially with two-way call setup. This project investigates how the newly-standardized ENUM (RFC2916) protocols can be adapted to broadband cable networks to overcome the technical hurdles associated with the bundling of telephony services with cable company broadband access and subscription TV services. The development of ENUM is one of the efforts to promote network convergence by providing number-to-address mapping mechanisms to close the gap between PSTN and other types of networks. Accordingly, it increases the market opportunity for cable access providers in the converged telecommunication service market. The study develops cost models that can be used to compare the numbering service costs of cable telephony systems with and without the ENUM-based numbering system. The main objective of this research is to find out whether an integrated numbering system provides cable companies with a cost-effective migration path to a converged market structure. This research provides empirical evidence to help answer this general but important question. The results of this project provide the industry, regulators, and researchers with a clearer understanding of the future of cable telephony and its ENUM-enabled numbering system.

Keywords: Cable telephony, ENUM protocol, Network economics, Telephone Numbering, Internet identifiers, Internet telephony, VoIP.

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A. Introduction and Overview

Digital convergence is making it possible for cable companies to compete with telephone companies in a variety of markets. Many regulators and consumers are viewing cable companies as the alternative infrastructure that can provide competition with incumbent local exchange carriers (ILECs). Cable companies have already made major incursions into the broadband Internet access market, where cable modems have outpaced DSL by 70 percent to 30 percent. Voice telephony, however, is still the largest revenue generator and remains the stronghold of the telephone operating companies. While their presence in the telephone market is growing, the cable companies have been reluctant to wholeheartedly enter this market due to a combination of technical, business, and regulatory uncertainties. Cable companies are divided as to whether voice over Internet protocol (VoIP) or traditional circuit-switched methods are best. If VoIP methods are adopted, cable operators face a number of technical and regulatory constraints on addressing and interconnection. Internet telephony, while cost-efficient and powerful, must interoperate seamlessly with the public switched telephone network (PSTN), which is based on a different technology.

One new protocol, ENUM (RFC 2916), may help cable companies enter this market effectively. ENUM uses the Internet's DNS protocol to map standard telephone numbers to identifiers that work on the Internet. It is described in greater detail in Section C below. Some advocates believe that the ENUM protocol may serve as an effective bridge between the PSTN and Internet telephony systems. It may also help to achieve cost savings and increase revenues by lowering interconnection-related expenses and providing messaging-related value-added services.

This research performs an economic analysis of a cable system deployment of the ENUM protocol in connection with an IP telephony service offering. We develop an architectural model of how the ENUM protocol can be implemented over cable access networks. Our implementation model is based on the architecture specified by CableLab's PacketCable project. We develop cost models that compare an ENUM-based IP telephony implementation with an IP telephony solution that relies on traditional methods of interconnection, such as SS7 signaling and gateways. The objective of this research is to find out whether ENUM provides cable companies with a more cost-effective method of offering IP-based telephone service. The results will provide the industry, regulators, and researchers with a clearer understanding of the future of ENUM-based cable telephony.

I. Findings

To briefly summarize our findings, we discovered that for our baseline scenario, the signaling cost difference between ENUM and SS7 will be insignificant for early implementers. Initial implementations will have to rely on *both* SS7 and ENUM and hence will incur some duplicative costs. This rough equivalence of signaling costs is actually good news for ENUM, however, because deployment of ENUM could also result in major per-line savings in access charges. The protocol could be used to locate IP-only routes that could bypass origination and/or termination charges. Some of the most significant cost savings from ENUM come from this.

The cost savings of ENUM improve significantly as customer migration to VoIP and ENUM proceeds. ENUM seems to have significant signaling economies of scale; i.e., the signaling cost per line decreases as the number of subscribers using ENUM in a given market increases (over a certain range). Due to the pricing structure proposed by ENUM vendors, which relies on the greater of a monthly flat rate or a per-query charge, ENUM is not cost-effective for small (<10,000 line) exchanges, unless vendors reduce the flat rate for smaller exchanges significantly. The analysis also shows that ENUM is more economical for high-volume users. Our models also show that the cost of ENUM is more sensitive to per-query charges than to changes in the flat rate.

ENUM might also create new revenue opportunities. The protocol could be used to offer advanced messaging capabilities. This study, however, does not take the revenue side into consideration but concentrates on the cost side exclusively. It finds that even without additional revenue generation, ENUM is worth exploring.

B. Cable Telephony, Numbering and Interconnection

Internet telephony puts into play about $250 billion of annual revenues in the United States alone. Entities contending for the services market include:

- Incumbent Local Exchange Carriers (ILECs). They control the lion’s share of local services and must contend with entry of CLECs and IXCs into their market. They also want to enter the long distance (IXC) market and are beginning to succeed in penetrating that market.
- Competitive Local Exchange Carriers (CLECs). Some are attempting to be mini- or specialized ILECs; some are integrated with long distance carriers.

- Interexchange Carriers (IXCs). These firms control the lion's share of long distance services. Their revenue streams are threatened by continuing downward pressure on prices, the entry of ILECs into long distance, and by bundling of long distance minutes into wireless service.
- Retail VoIP providers, usually Value-Added Resellers (VARs)
- Wholesale VoIP providers (Application Service Providers or ASPs)

Cable operators are in a much stronger position to capture significant parts of the voice telephony revenue stream at profitable levels than other competitors. Unlike ILECs, VoIP augments rather than cannibalizes current revenue streams. Unlike CLECs and IXCs, cable companies control their own origination network. They need not be dependent upon ILECs for facilities provisioning, and do not have to pay out access fees on the originating end or engage in low-margin resale. Unlike VARs, cable companies have years of experience as direct service providers to consumers, sometimes on a large scale. Unlike wholesale ASPs, they have a direct relationship to their customers.

CLEC market share rose gradually in the late 1990s. But CLECs have appealed primarily to large and medium-sized business customers rather than households. Whereas 79 percent of a typical ILEC's customers are households and small businesses, only 40 percent of a typical CLEC's customer base are in those categories. Cable Television companies are in a much stronger position to compete with ILECs for the household and small home office telephony market.

The $108 billion long distance market is highly competitive. In 1999, 738 companies reported to the FCC that long distance service was their primary business, and another 1,777 reported long distance revenues without it being their primary lines of business. Interexchange carriers typically originate and terminate most of their traffic via Local Exchange Carriers (LEC), generating approximately $11 billion in annual access charge revenues. Voice over IP revenues are a very small but rapidly growing segment of that market.

The once hard and fast line between local and long distance service is eroding. Increasingly, telephony providers strive to offer attractively priced bundles of local and long distance minutes. This is true not only of CLECs, but also of long distance providers attempting to get into the local services market, and of wireless carriers, who now offer packages of minutes that do not distinguish between local and long distance. VARs also engage in such bundling.

The most promising point of entry for cable operators is to offer Voice over IP (VoIP) as a second-line service. That is, cable-based VoIP would be competing for the market of telephone subscribers who already subscribe to one telephone system, have been assigned an E-164 number as part of that service, and want to purchase an additional line. The additional line might be used for a variety of purposes: fax machines, Internet access, giving household members their own access line, etc.

Many cable operators have identified the second-line market as a more technically feasible way to enter IP voice service provision. The QoS, backup power and scaling problems associated with offering the first telephone line into the home are much more formidable than many cable operators want to face.[1]

Moreover, a subscriber who already has telephone service from the PSTN has an assigned E-164 number. Subscribers who discontinue their service from the telephone company would have to give up their E-164 number. Subscribers who continue their service but add a second line, on the other hand, can keep the number and, with the help of ENUM, use it for multiple purposes. For a cable operator, the customer's retention of an E-164 number has some important consequences. In order to qualify for assignment of blocks of E-164 numbers, cable operators would have to obtain certification from state regulators as a Local Exchange Carrier (LEC). The advantage of such certification is that customers can port their number to certified LECs. If cable operators offer a second-line service they do not need to be certified as LECs.

The second-line market is a substantial and attractive market for cable operators attempting to establish a presence in telephony. At the end of 1999 there were 28.6 million households with additional residential lines. This is nearly 30 percent of all households with telephone service. The percentage of households with additional lines has grown by double-

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[1] See "Special Report: The US Cable Industry," released at the Chicago NCTA convention June 11-13, 2001. The section on "Voice over IP and telephone" discusses the division in the industry between those (AT&T and Cox) who favor deploying circuit-based technology for voice over cable as a first-line alternative, and those (AOL-Time Warner, Comcast) who favor limited deployment of VoIP as a second-line substitute. In Sounding Board Magazine, (July 2001 p. 22) Comcast Sr. Vice President Mark Coblitz acknowledges the technical and operational challenges of offering a "lifeline" or first-line voice service using IP: "To scale to hundreds of thousands or millions of customers, you have to have some really extraordinary stuff going on in the back room."

digit percentages since the mid-1990s. From 1998 to 1999 the growth rate was thirty percent.[2] (Since 1999, wireless carriers have provided an increasingly attractive second-line alternative, so that growth rate may have slowed.) Federal regulations regarding subscriber line charges (SLC) impose a significant handicap on traditional telephone companies who offer second-line service to their customers. The regulatory discrimination between the first and second line creates a market opportunity. The SLC is a flat monthly fee designed to recover the non-traffic sensitive costs of the local loop. For initial telephone lines the SLC is frozen at $3.50 per month. For political reasons, the SLC for second lines is much higher than for the initial telephone line into a home. Residential users pay $7 per month in SLC charges *in addition to* the actual subscription charge, and multi-line businesses can pay up to $9.20 per month in SLC charges.

C. What is ENUM?

ENUM is a protocol for mapping standard telephone numbers to Internet identifiers.[3] It converts a telephone number into a domain name and then uses the global domain name system (DNS) to retrieve records that associate the number with an identifier that works on the Internet. The identifier could be an Internet Protocol (IP) address, a SIP identifier,[4] or a web site URL. ENUM was developed by the Network Working Group of the Internet Engineering Task Force (IETF). The protocol relies on the E.164 telephone numbering standard of the International Telecommunication Union as an assumed structure for all telephone numbers.[5]

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[2] Trends in Telephone Service. U.S. Federal Communications Commission, Common Carrier Bureau, Idustry Analysis Division. August 2001.

[3] Faltstrom, P., “E.164 number and DNS ,” RFC 2916, September 2000. The ENUM protocol makes extensive use of the Naming Authority Pointer Record (NATPR) to identify different services for, or methods of, contacting a user associated with a telephone number. NAPTR is a new type of DNS resource record. See Mealling, M. and R. Daniel, "The Naming Authority Pointer (NAPTR) DNS Resource Record", RFC 2915, September 2000.

[4] Session Initiation Protocol (SIP) is defined in RFC xxxx

[5] International Telecommunication Union, ITU-T Recommendation E.164 , ITU-T Recommendation E.164, “The International Public Telecommunications Numbering Plan,” 1997.

ENUM has generated interest because a growing portion of voice or data traffic may originate or terminate on an IP network. For many years to come, however, a significant amount of telecommunication traffic will remain on traditional circuit-switched, time-division multiplexed networks. These two types of networks use different signaling and routing systems. Interconnecting them requires a fast and efficient method of finding out which type of network a called party is on and what address it is using. The ENUM protocol is intended to solve this problem. It uses DNS queries to allow telecom service providers to discover whether a dialed E.164 number is associated with a telephone company switch, an IP-based network, or something else.

ENUM could prove to be a powerful capability for two reasons. First, it may provide a simpler and less expensive method of interconnecting telecommunication carriers. ENUM services can act as a substitute for Signaling System 7 (SS7) capabilities and the trunk group administration and tandem switching hierarchy used by the PSTN to interconnect service providers. It can act as a bridge between traditional interconnection methods and Internet Protocol-based networks, providing carriers with a migration path between a Time-Division Multiplexing (TDM) and SS7-dominated environment and an IP-dominated world.

Second, ENUM provides “intelligent network” capabilities that allow both Internet users and telephone network users to benefit from Internet-based applications. The ENUM protocol will allow telephone numbers to be used to identify many different types of end terminals and associated services, such as cable telephone service, cable fax, and teleconferencing over cable access networks in addition to existing broadband services. Just as SS7 made it possible for voice telephone service to become enhanced with features such as caller ID, distinctive ringing, and the like, so ENUM makes it possible for voice and data services to be linked to a wide variety of multimedia Internet applications that can add functionality to voice and data services. Unified messaging and “follow-me” forwarding services are examples of the types of capabilities that might be enabled by ENUM.

I. Public vs. Private ENUM

A great deal of policy debate has swirled around the definition of models for ENUM implementation.[6] In particular, debate has focused on which domain would serve as the root of the DNS resolution hierarchy for ENUM queries, who will control that root, and who or what process will determine the delegation of E.164 country codes to particular ENUM registries. The struggle for control of the naming hierarchy is a product of the attempt by some participants in the standards process to ensure that the standard is implemented in a way that forces everyone into global compatibility. Under this top-down implementation model, all the world's governments, telecommunication and Internet standards bodies, prospective registries, service providers and customers must agree on a single root, a single provisioning scheme, and a variety of related policies regarding control and transfer of records regarding E.164 numbers before any real implementation begins. We term this option "public ENUM."

While global compatibility is a Good Thing, the political costs and barriers associated with achieving such widespread agreement are formidable. Even if agreement is eventually reached, the process may take so long and raise the cost of deployment so much that the relevance of ENUM in the marketplace could be eclipsed by other technologies. There are numerous historical examples of standards that foundered on the politics of global compatibility, such as the development of Open Systems Interconnection (OSI), and ISDN in the United States.

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[6] See followings for details: Rutkowski, the ENUM Golden Tree: the quest for a universal communications identifier, 3 Info 97 (No. 2, April 2001); ITU web site on ENUM (http://www.itu.int/osg/spu/enum/); Craig McTaggart, E PLURIBUS ENUM: Unifying International Telecommunications Networks and Governance , The 29th Telecommunications Policy Research Conference 2001, October 27-29, 2001, Alexandria, VA, USA; Hwang, Junseok, Mueller, Milton, Yoon, Gunyoung, and Kim Joonmin "Analyzing ENUM Service and Administration from the Bottom Up: The addressing system for IP telephony and beyond", The 29th Telecommunications Policy Research Conference 2001, October 27-29, 2001, Alexandria, VA, USA; Robert Cannon, ENUM: The Collision of Telephony and DNS Policy, The 29th Telecommunications Policy Research Conference 2001, October 27-29, 2001, Alexandria, VA, USA; Ranalli, D. "Is e164.arpa the only answer for Tier 1 registry services?", (http://www.itu.int/osg/spu/enum/workshopusafeb12-13/ranalli-doc.html); ENUM FORUM (www.enum-forum.org).

An alternative to public ENUM is a private implementation of ENUM. Private ENUM uses a private domain as the root of their ENUM resolution tree. It can use more secure virtual private networks to transport queries, and can develop proprietary software applications to enhance queries. The US company NetNumber is one example of a company that has pursued the private ENUM option.

For a cable TV system operator, the choice between public and private ENUM boils down to a choice between an open standard and a proprietary standard. Private ENUM rewards entrepreneurs and service developers who respond appropriately to the market, but may create higher switching costs for customers in the long term. Public ENUM would ensure global compatibility and uniformity, but raises the risk that ENUM will never happen or that it will be implemented badly. Public ENUM invokes slow-moving, contentious political processes and creates a major risk that exclusive registry contracts will be awarded to companies that are not responsive to the market, potentially excluding the entrepreneurs who are most capable of developing the service at the outset.

II. Market Structure

Industry working groups such as Study Group A in the United States have gone to great lengths to define various ENUM provisioning models.[7] Most have proposed complex structures that contain defined roles for registries, registrars, Application Service Providers (ASPs), and telecommunication service providers.

That discussion is not terribly relevant to this study, however. First, market structures cannot be predicted or planned in advance; they will emerge over time in response to real forces of supply economics, entrepreneurship, demand, competition from alternative technologies, politics and regulation. Second, this study assumes that the cable telecommunication service provider will outsource its ENUM service to another firm. We do not care (and suspect that most cable companies will not care, either) whether that firm is an integrated registry-registrar offering a proprietary ENUM service, or part of a

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[7] Hwang, Junseok, Mueller, Milton, Yoon, Gunyoung, and Kim Joonmin “Analyzing ENUM Service and Administration from the Bottom Up: The addressing system for IP telephony and beyond”, The 29th Telecommunications Policy Research Conference 2001, October 27-29, 2001, Alexandria, VA, USA

horizontally disintegrated market structure based on the public ENUM model. What matters for the purposes of this cost study is the price of the service to the cable operator.

D. Cost Modeling and Analysis

In this section, we present cost models for the signaling and numbering services for two major architectures of cable telephony service providers: PacketCable with SS7 signaling and PacketCable with ENUM. The cost modeling is based on previous studies and a signaling flow analysis for the different architectures. The data for the cost analysis are obtained from industry sources,[8] previous studies,[9] or estimates based on empirical assumptions and analysis. We calculated the signaling costs and the estimated access charge reductions for the two architectures. We did not estimate the costs of building and operating signaling and numbering systems. Instead, we assumed that the signaling and numbering services will be outsourced to existing signaling network service and access providers (both for SS7 and ENUM).

I. General Assumptions

The comparison is based on the following assumptions. On the demand side, we assumed that a cable telephony service provider will support the model market with 100,000 subscriber lines with 0.1 Erlang and 3 minute average call time during a normal weekday busy hour. This translates into 200,000 calls per hour generated by the cable telephony service provider. We then calculated the signaling traffic that would be generated based on those assumptions, and compared the costs of handling the signaling using the SS7 and ENUM-based architectures.[10]

Table D.1 - Baseline Demand Model Assumptions

Variables	Value	Unit
Subscriber	100,000	lines
Busy hour usage	0.1	erlangs
Call duration	3	Minute
Average number of calls per line per day	15	calls/day

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[8] We have used data from various SS7 service providers (Illuminet, Verizon, Qwest), and an ENUM service provider (NetNumber: www.netnumber.com).

[9] Sicker, Douglas C. and Martin B.H. Weiss, "Cost and Policy Implications of AIN-Based Local Number Portability Implementations." Conference on Telecommunications Systems, Nashville TN, March 1998.

[10] The assumption can be changed depending on how many calls are destined to outgoing networks.

Different switching point assumptions result in different signaling cost estimates. In the PacketCable signaling architecture, we assumed that all calls require only ISUP messages for call setup through direct SS7 SSP switching points. In other words, in the original PacketCable architecture all of the call setup will be completed through ISUP queries to the SS7 network. In the ENUM-based signaling architecture, we assumed that some of the call setups will require ISUP queries to an SS7 network, while others will require ENUM queries. ISUP queries will be needed when the call originates with the cable telephony provider and terminates on the PSTN. ENUM queries are required when the call terminates to another ENUM subscriber. That method requires us to make assumptions about how calls originated on the cable telephony network will be distributed. In the baseline call scenario, we assumed that 70% of calls involve PSTN call connection to and from the cable telephony service provider. The remaining 30% would be IP – to IP calls, including calls internal to the cable telephone service provider's network. We considered this assumption reasonable since 30% is conditional probability of IP calls (for IP telephony provider) when both IP telephony and ENUM service are available in the market. We think a reasonable timeframe for such an assumption will be in two years or later. See Table D.2 below for a summary of those assumptions.

II. PacketCable with SS7 Signaling Network Cost Model

To develop the cost model for a SS7 based Packet Cable signaling network, we surveyed and calculated certain input parameters. Also, we identified key signaling network cost drivers for the baseline cost model.

Those input variables include;

- Per STP port monthly cost
- STP link (A and D links) translation charge
- Per message cost
- Testing setup charge (A and D links)

In our model, major cost signaling drivers include;

- Number of ISUP messages
- Number of STP pairs
- Number of STP ports
- Number of exchange codes
- Number of switches used

The specific values of the input variables and the calculations for the baseline cost model for SS7 are presented in Appendix 1. To calculate the STP link capacity required, we specified the ISUP message size at 25 bytes and the TCAP message size at 100 bytes. In the model, we assumed that 80% of all calls generate ISUP messages. For the base line model, we assumed 200,000 calls are completed during the busy hours of normal weekdays. To calculate the number of ISUP messages, we assumed that 70% of the calls are completed and 30% of calls are not completed. A completed call is assumed to generate 6 ISUP messages and a not-completed call is assumed to generate 2 messages. To calculate the access charges associated with each call, we assumed that the originating and terminating access charges are 1.5 cents per minute each, producing an average 3 cents per minute of access charge for the call. We selected such average access charge number of PSTN as about 1/4 of average long distance rate. Detailed descriptions of the cost components and the calculations can be found in Appendix 1.

Table D.2 below summarizes the call flow assumptions of PacketCable network in our baseline cost model analysis.

Table D.2 – Baseline Call Pattern Matrix of PacketCable

Calls From	Calls To	% of Calls
PacketCable	PacketCable	10%
PacketCable	Other IP Networks	10%
PacketCable	PSTN	35%
Other IP Networks	PacketCable	10%
PSTN	PacketCable	35%
Total		100%

III. PacketCable-ENUM Signaling Cost Model

The PacketCable-ENUM signaling network cost model is composed of three cost categories: a flat-rate monthly fee for ENUM service, a fee for successful ENUM queries, and gateway SS7 charges. Depending on the origin and destination of the call and assumptions about ENUM subscription levels, some calls will be charged for successful ENUM queries and some calls will be charged for both ENUM queries and SS7 signaling charges. Based on the initial pricing models proposed by the ENUM industry, we assume that cable service providers using an ENUM service will receive ENUM service for a flat monthly fee between $20,000 and $50,000, depending on the number of users. In addition, ENUM vendors will set a query fee that will be applied to each successful query. If the sum of the query fees exceeds the flat monthly rate, customers will be charged the per-query fee. If the sum of the query fees is lower than the flat rate customers will just pay the flat rate. (Some pricing models may set different prices for “external” and “internal” queries; i.e., external queries being for records provisioned by ENUM service providers *other* than their own. We did model this price structure but did not include it in this report.)[11] In addition, the PacketCable ENUM operator will still have to pay SS7 service costs for the calls involved in PSTN interconnection. In addition to the SS7 cost drivers, the number of successful ENUM queries and monthly flat charge are the major cost drivers of the PacketCable-ENUM signaling network architecture.

We assumed that the price for ENUM queries was 0.15 cents per query.[12] We used the same call distribution assumptions as in the PacketCable SS7 scenario, but posited that 20% of the calls are between ENUM subscribers. The detailed call pattern is summarized in Table D.3. The call matrix shows that 11.1% of outgoing calls are to other ENUM subscribers. Since this assumption can vary depending on ENUM service penetration, we conducted sensitivity analysis on ENUM user penetration. We assumed that ENUM-supported IP telephony calls will be charged an average 1 cent per minute in access charges using the information from the IP-telephony service providers. We assumed a lower average access charge for ENUM-enabled calls because the ENUM protocol can provide cable telephony service providers with media gateway information for each call that incurs the lowest possible termination cost. Description of cost components and detailed calculations for ENUM query costs can be found in Appendix 2. Table D.3 is the baseline call flow matrix used for PacketCable-ENUM signaling cost calculation.

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[11] This is called the “external query pricing model” for ENUM service. It has been suggested by several ENUM service providers, such as NetNumber and Verisign. The successful query types will include protocol, service and interconnection (such as media gateway). “Minimum flat ENUM service fee will be charged to the service providers. And, successful query fees are applied against the minimum fee for the service providers to recoup full minimum fee payments.” These fees include all the validation and security costs with respect to the management of the ENUM service.

[12] As a proxy, 800 number or SCP database query costs range from 0.15 cents to 33 cents when the pricing was first discussed. It is now about 0.12-14 per query. From the industry interview, we found current 0.2 cents per query can become a ceiling rate for future ENUM query services.

Table D.3: Baseline Call Pattern Matrix of PacketCable-ENUM

Call Pattern	Call Percent	ENUM	Non-ENUM
PacketCable-ENUM to PacketCable-ENUM	10.0%	10.0%	
PacketCable-ENUM to Other IP Networks	10.0%	1.11%	8.89%
PacketCable-ENUM to PSTN	35.0%	3.888500%	31.11%
Other IP Networks to PacketCable-ENUM	10.0%	1.11%	8.89%
PSTN to PacketCable-ENUM	35.0%	3.888500%	31.11%
Total	100.0%	20.0%	80.0%

IV. Comparative Signaling Cost Analysis

This section discusses the results of the cost model described in the previous sections. The output variables from the cost models are used to estimate per line per month signaling costs for various input variables and scenarios. The key output variables include:

- Number of ISUP message generated
- Number of ENUM queries
- Required number of STP port pairs and links

We first present a baseline scenario cost analysis, and then move on to perform sensitivity analysis on various input variables such as ENUM subscriber percentage, VOIP call percentage, number of subscribers, daily usage pattern, number of ENUM providers and ENUM flat charging plan.

Baseline Analysis

Using the baseline cost model assumptions, we calculated key output variables and estimated per-line-per-month costs for both PacketCable and PacketCable-ENUM scenarios. In addition, we estimated the amount of access charges that would have to be paid using the different architectures. Table D.4 summarizes the cost comparison of the baseline scenario. In both scenarios, the actual signaling costs are shown to be insignificant (less than 1 cents per line per month). There are, however, major differences in access charge costs (about 1 dollar per line per month). In the baseline PacketCable-ENUM scenario, the sum of all per query charges was still lower than the flat service charge ($20,000). This means that ENUM usage could grow significantly without increasing costs. On the other hand, SS7 costs are dominated by per message charges, so that as usage increases costs will increase, too.

Table D.4 – Baseline Signaling Cost Comparison

	PacketCable One 100,000 line switch	PacketCable Two 50,000 line switches	PacketCable-ENUM
CCS	1,505.60	3,011.20	752.80
Links	127.88	255.76	63.94
Signaling	42,120.00	42,120.00	29,484.00
Other Nonrecurring Charge	10,888.50	10,888.50	5,467.75
SS7 Subtotal (Recurring)	**43,752.48**	**45,386.96**	**30,300.74**
ENUM flat rate	0.00	0.00	**20,000.00**
Signaling Total	54,641.98	56,275.46	55,768.49
Access Charges	1,242,000.00	1,242,000.00	1,158,008.40
TOTAL	**1,296,641.98**	**1,298,275.46**	**1,213,776.89**

The above table is our baseline scenario. In the next sections, we alter the assumptions of the baseline scenario and perform sensitivity analysis on some key cost variables.

Variable 1: Cost Sensitivity to Percentage of Calls to other ENUM users

We are assuming that all of the subscribers of the cable telephone system operator will have ENUM records associated with their telephone numbers. The costs of ENUM signaling are strongly affected by whether the parties called by these ENUM users are also ENUM users or not. To analyze the effect of ENUM penetration in the IP telephony market, we performed a sensitivity analysis on the ENUM user's call percentages. In our baseline scenario, 20% of all calls involve ENUM subscribers communicating with PacketCable-ENUM network users. As the number of terminations to other ENUM users increases, the per line signaling costs increase because of the larger number of ENUM queries, but the amount of access charges decreases substantially. The ENUM flat pricing plan allowed substantial extra query margin (up to almost 80%) for the increase of ENUM users. In the extreme scenario (100 % ENUM user scenario), 12% of per-line-per-month cost increase (about 6 cents) is shown. On the extreme scenario, the potential cost saving was more than 50% ($6.72) of original baseline access charge cost.

Table D.5: Cost Sensitivity to % of Calls to ENUM Users

% of ENUM users	**SS7 Sig.**	**ENUM Sig.**	ENUM SS7	ENUM Query	**SS7 Access**	**ENUM Access**	**SS7 Total**	**ENUM Total**
10%	0.4375	0.5030	0.3030	0.2000	12.4200	12.4200	12.8575	12.9230
20%	**0.4375**	**0.5030**	**0.3030**	0.2000	**12.4200**	**11.5801**	**12.8575**	**12.0831**
25%	0.4375	0.5030	0.3030	0.2000	12.4200	11.1597	12.8575	11.6628
50%	0.4375	0.5030	0.3030	0.2000	12.4200	9.0603	12.8575	9.5633
75%	0.4375	0.5468	0.3030	0.2438	12.4200	6.9602	12.8575	7.5070
100%	0.4375	0.6186	0.3030	0.3156	12.4200	4.8600	12.8575	5.4786

Figure D.1: Signaling Cost (Variable 1 – Percentage of Calls to ENUM Users)

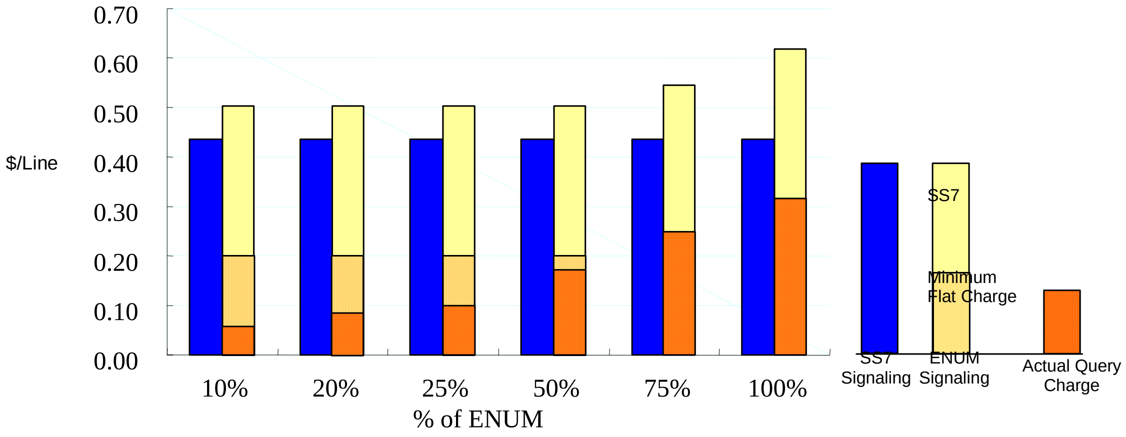
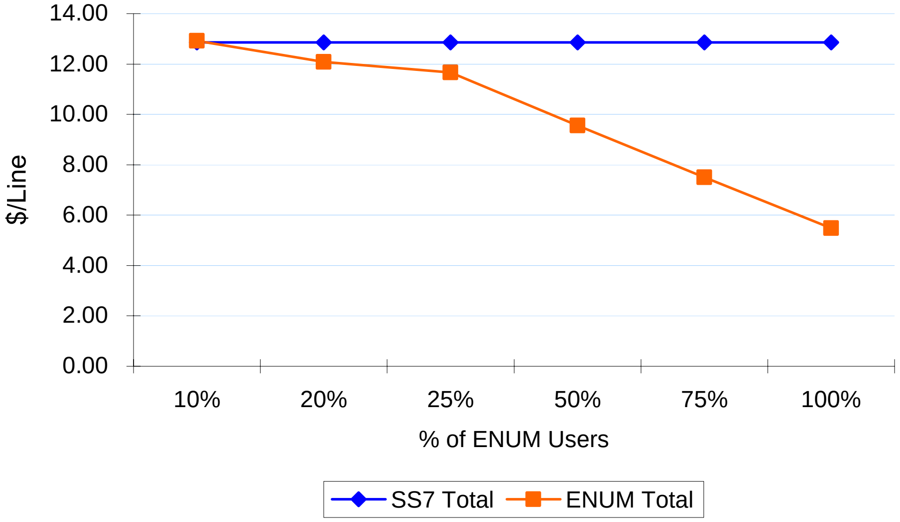


Figure D.2: Total Costs (Sum of Signaling Costs and Access Charges)



Variable 2: VOIP Call Penetration

In the baseline scenario, we assumed that 30% of the calls are IP-to-IP calls.[13] This percentage will increase when there are more VOIP users in the telephony market. For different scenarios of VOIP market penetration, we estimated PacketCable-ENUM signaling charges in comparison with PacketCable SS7 architecture. With a high penetration of VOIP calls, we observed substantial savings both on signaling and access charge costs for ENUM implementations.

Table D.6 Cost Sensitivity to Percentage of IP Calls

% of IP calls	**SS7 Sig.**	**ENUM Sig.**	ENUM SS7	ENUM Query	**SS7 Access**	**ENUM Access**	**SS7 Total**	**ENUM Total**
100%	0.4375	0.2082	0.0082	0.2000	4.8600	4.8600	5.2975	5.0682
70%	0.4375	0.3345	0.1345	0.2000	8.1000	7.7400	8.5375	8.0746
50%	0.4375	0.4188	0.2188	0.2000	10.2600	9.6601	10.6975	10.0788
30%	**0.4375**	**0.5030**	**0.3030**	**0.2000**	**12.4200**	**11.5801**	**12.8575**	**12.0831**
10%	0.4375	0.5954	0.3954	0.2000	14.5800	13.5001	15.0175	14.0955

---

[13] We considered this assumption reasonable since 30% is conditional probability of IP calls (for an IP telephony provider) when both IP telephony and ENUM service are available in the market. Additionally, we performed a sensitivity analysis for this IP telephony call percentage.

Figure D.3: Signaling Costs (Variable 2 – Percentage of VoIP calls)

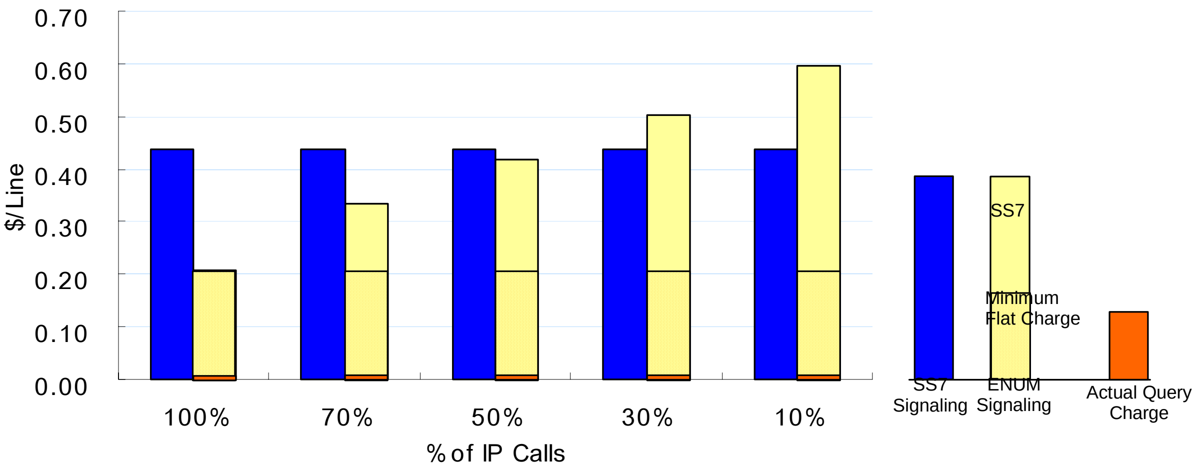
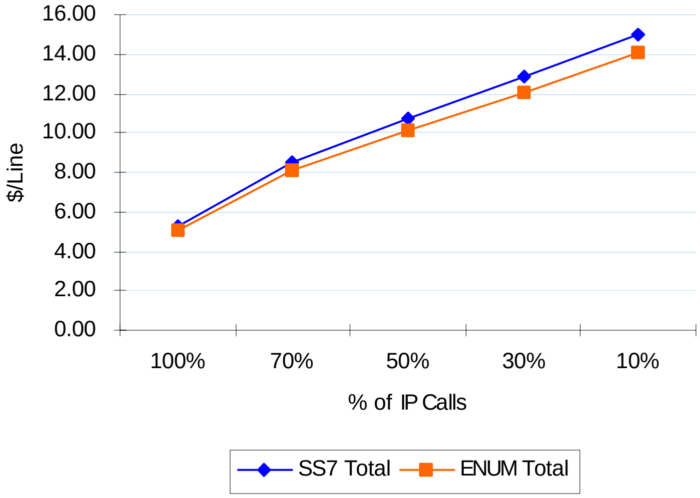


Figure D.4: Total Costs (Sum of Signaling Costs and Access Charges)



Variable 3: Number of Line Subscribers

The cost model is sensitive to the number of customers. There are significant economies of scale in signaling costs between 10,000 and 500,000 subscribers. This suggests that IP telephony providers could benefit from aggregating signaling network services.

Table D.7 – Cost Sensitivity to Number of Lines

# of lines	**SS7 Sig.**	**ENUM Sig.**	ENUM SS7	ENUM Query	**SS7 Access**	**ENUM Access**	**SS7 Total**	**ENUM Total**
10000	0.4294	2.3030	0.3030	2.0000	12.4200	11.5801	12.8494	13.8831
100000	**0.4375**	**0.5030**	**0.3030**	**0.2000**	**12.4200**	**11.5801**	**12.8575**	**12.0831**
500000	0.4702	0.4217	0.3357	0.0861	12.4200	11.5801	12.8902	12.0018
1000000	0.5192	0.4544	0.3683	0.0861	12.4200	11.5801	12.9392	12.0345
2000000	0.6172	0.5197	0.4337	0.0861	12.4200	11.5801	13.0372	12.0998

Figure D.5: Signaling Costs (Variable 3 – Number of lines)

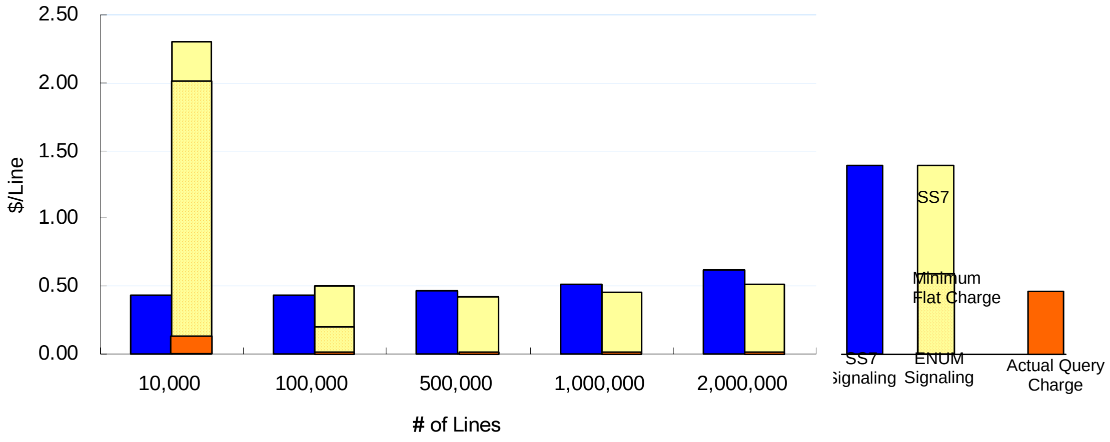
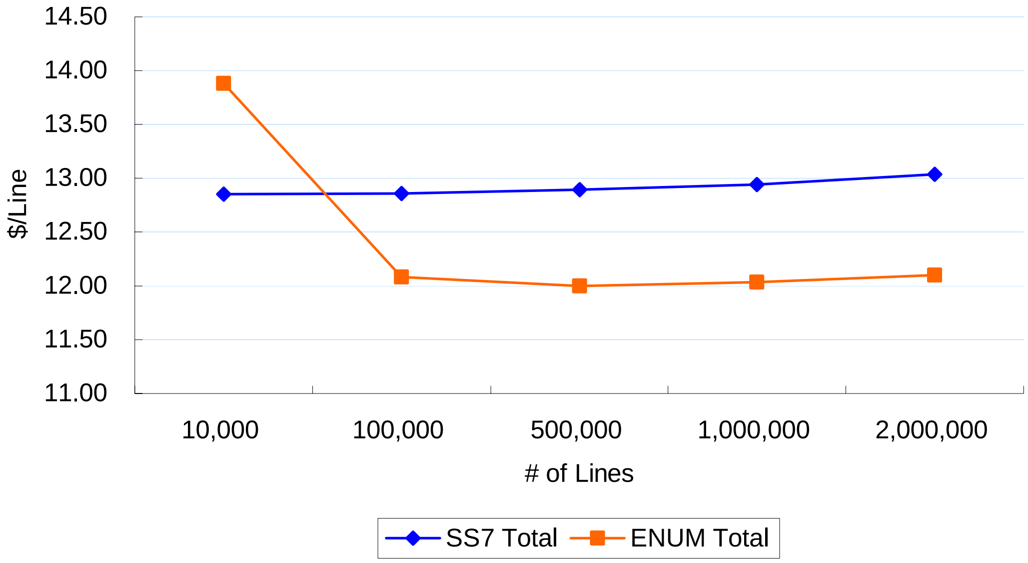


Figure D.6: Total Costs (Sum of Signaling Costs and Access Charges)



Variable 4: Calls per line per day

Call usage patterns will be different for different types of users. We increased the usage pattern from the baseline scenario and observed the per-line-per-month signaling and access charge implication. The results shows that higher volume customers (such as business line customers) will benefit more from ENUM signaling and PacketCable-ENUM's access charge saving.

Table D.8 – Cost Sensitivity to Number of Calls per Line per Day

# of calls per day	**SS7 Sig.**	**ENUM Sig.**	ENUM SS7	ENUM Query	**SS7 Access**	**ENUM Access**	**SS7 Total**	**ENUM Total**
15	**0.4375**	**0.5030**	**0.3030**	**0.2000**	**12.4200**	**11.5801**	**12.8575**	**12.0831**
30	0.8587	0.7978	0.5978	0.2000	24.8400	23.1602	25.6987	23.9580
50	1.4203	1.2778	0.9910	0.2869	41.4000	38.6003	42.8203	39.8781
75	2.1223	1.9127	1.4824	0.4303	62.1000	57.9004	64.2223	59.8131
100	2.8243	2.5475	1.9738	0.5737	82.8000	77.2006	85.6243	79.7481

Figure D.7: Signaling Costs (Variable 4: Calls per line per day)

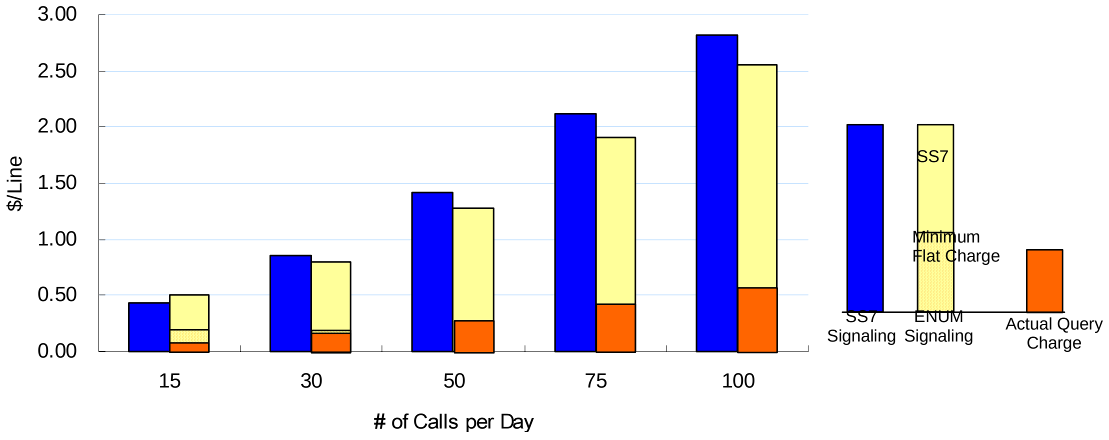
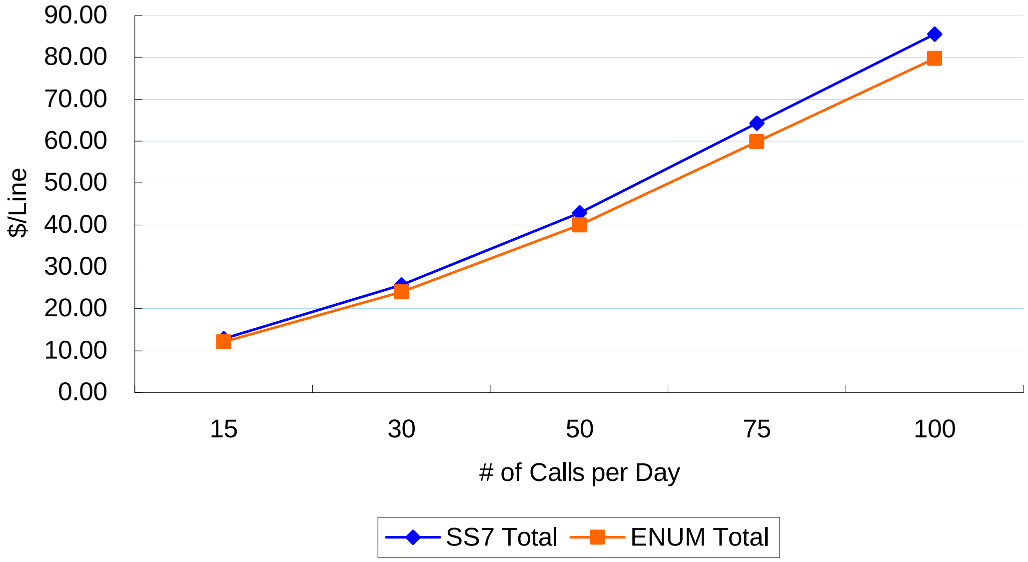


Figure D.8: Total Costs (Sum of Signaling Costs and Access Charges)



Variable 5: Charge per query

The following table and graphs show the potential cost increase caused by increasing the charge per query. Overall ENUM costs are quite sensitive to the charge per query, because of the pricing model in which customers are charged the greater of the sum or the queries or the flat fee. One factor that might increase query charges would be a more fragmented industry, which would increase the number of external queries among ENUM providers. This would increase the providers' cost of queries, unless there is a peering agreement among ENUM providers. Signaling cost sensitivity is shown only after the sum of the per-query charge exceeds the flat service fee (in this case, after the per query charge goes up to $0.006).

Table D.9 – Sensitivity to Charge per Query

Charge per Query	**SS7 Sig.**	**ENUM Sig.**	ENUM SS7	ENUM Query	**SS7 Access**	**ENUM Access**	**SS7 Total**	**ENUM Total**
$0.0015	**0.4375**	**0.5030**	**0.3030**	**0.2000**	**12.4200**	**11.5801**	**12.8575**	**12.0831**
$0.0030	0.4375	0.5030	0.3030	0.2000	12.4200	11.5801	12.8575	12.0831
$0.0060	0.4375	0.6472	0.3030	0.3442	12.4200	11.5801	12.8575	12.2273
$0.0120	0.4375	0.9915	0.3030	0.6885	12.4200	11.5801	12.8575	12.5716

Figure D.9: Signaling Costs (Variable 5: Charge per query)

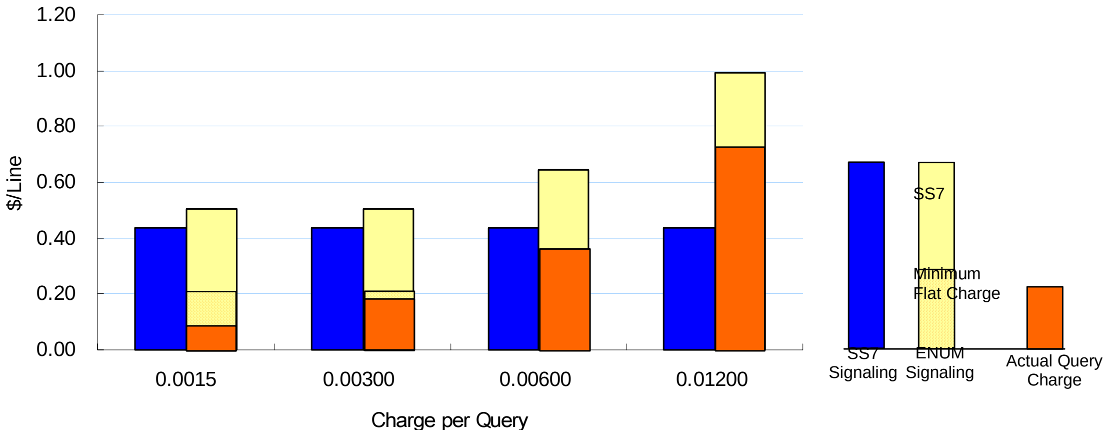
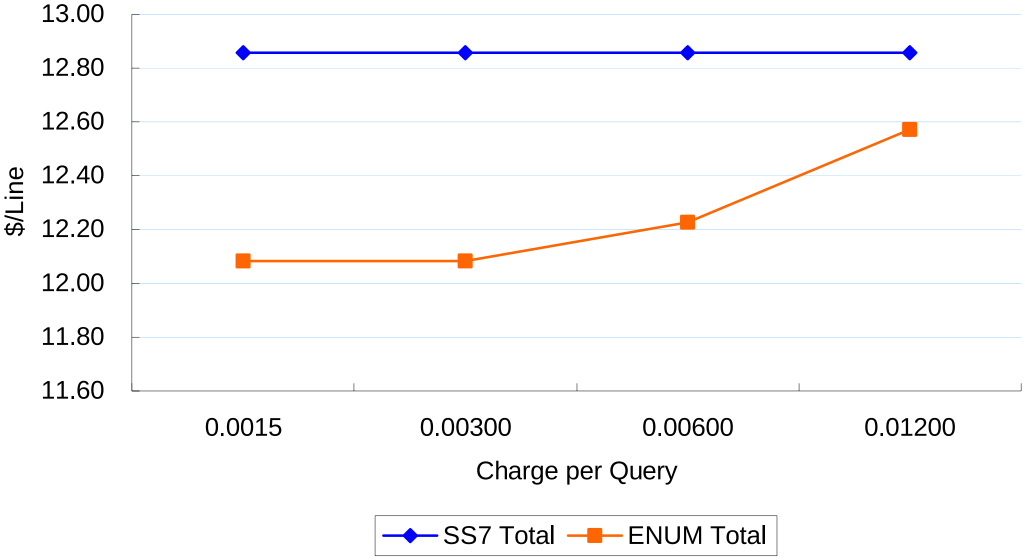


Figure D.10: Total Costs (Sum of Signaling Costs and Access Charges)



Variable 6: Minimum Flat charge

The cost differences between SS7 and ENUM are sensitive to the selection of a flat monthly rate by the ENUM provider, although slightly less so than the per query fee. In Table D.10 below, we show that the signaling costs per line per month can range from 39 cents to 80 cents depending on the selection of different service plan, whereas the flat charges for SS7 are constant.

D.10 – Sensitivity to Minimum Flat Charge

Flat Charge Cost	**SS7 Sig.**	**ENUM Sig.**	ENUM SS7	ENUM Query	**SS7 Access**	**ENUM Access**	**SS7 Total**	**ENUM Total**
$5,000	0.4375	0.3891	0.3030	0.0861	12.4200	11.5801	12.8575	11.9692
$10,000	0.4375	0.4030	0.3030	0.1000	12.4200	11.5801	12.8575	11.9831
$15,000	0.4375	0.4530	0.3030	0.1500	12.4200	11.5801	12.8575	12.0331
$20,000	**0.4375**	**0.5030**	**0.3030**	**0.2000**	**12.4200**	**11.5801**	**12.8575**	**12.0831**
$30,000	0.4375	0.6030	0.3030	0.3000	12.4200	11.5801	12.8575	12.1831
$50,000	0.4375	0.8030	0.3030	0.5000	12.4200	11.5801	12.8575	12.3831

Figure D.11: Signaling Costs (Variable 6: ENUM minimum flat charge)

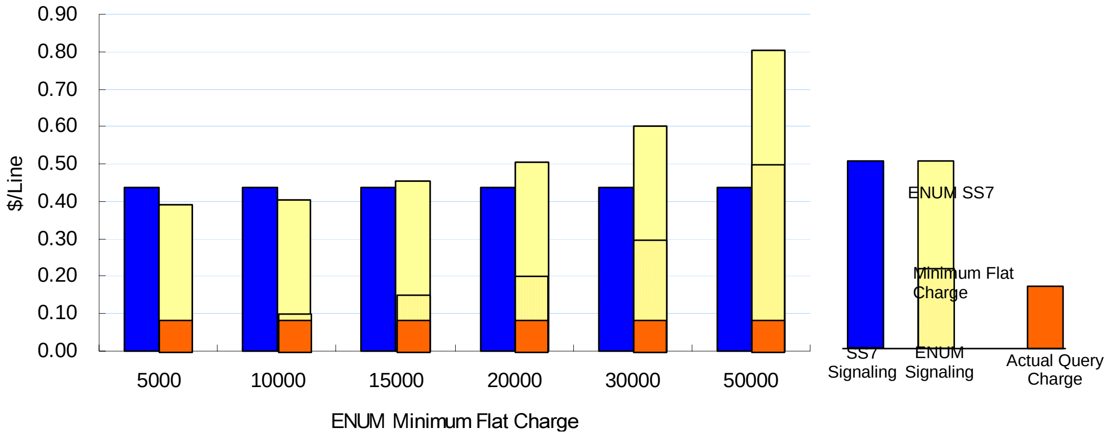
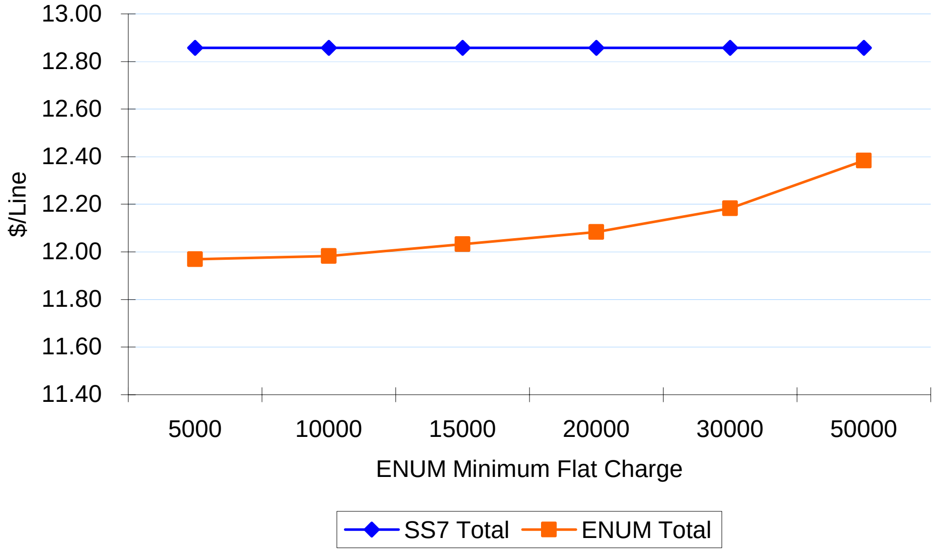


Figure D.12: Total Costs (Sum of Signaling Costs and Access Charges)



E. Market Implications and Concluding Remarks

In this report, economic implications of ENUM service deployment have been examined. We evaluated ENUM deployment in the PacketCable architecture for cable telephony service providers. Technical feasibility has been examined through architectural design and call flow analysis (Detail technical analysis is presented in Appendix 3). Our economic modeling and analysis focuses on the signaling and access charge costs associated with various ENUM deployment and market scenarios. In our baseline scenario, no fundamental signaling cost difference is found between traditional SS7 architecture and ENUM enabled signaling architecture. If there is a major migration to ENUM and to IP telephony among telephone users, on the other hand, ENUM becomes less expensive, especially when high-volume users are involved. In addition, major access charge cost reductions using ENUM signaling can be achieved using ENUM. In addition to the benefits of access charge cost reductions, some other major market implication can be drawn from ENUM service development in telephony and other information service market. There have been several technical development and market formation for IN and signaling services over the Internet. One of those is SS7 over IP technology that allows the SS7 based service through IP platform. In addition to such development, ENUM can extend more IN services through the IP network. This development will allow CLECs like cable telephony operators to expand their customer base through enhanced dialing capability (E.164-IP address), AIN and other information service (such as UMS) support. Moving on to the second generation IP telephony, more of IN and other convergence services will have ubiquitous service platform over IP networks as well as PSTN through convergence signaling service like ENUM. As a follow-on project, we plan to engage in additional economic analysis of the economics of major IN services using ENUM.

For cable companies, using ENUM to interconnect their telephone service offerings to the PSTN may prove to be less contentious and more efficient than traditional methods.

Appendix 1: Detailed PacketCable SS7 Cost Model

A. SS7 Signaling Cost Input Variables

Basic Recurring Cost

Common Channel Signaling

2 ports * (# of STP pairs) * (# of switches)	$752.80	Port/Month

Links

2 A Links (dedicated DS0 circuits)	$31.97	per DS0 per month
number of links	2	
Link Cost =		
($/Dso) * (# of links) * (# of STP pairs) * (# of switches) =	$63.94	per month

Signaling

ISUP message	$0.000195	per message
number of messages per month =	2160	messages
Cost of ISUP for 100,000 lines per month=	$42,120.00	per month

Non Recurring Cost

STP Translation Charges: A-Links

Per Pair Charges	$940.00	per STP Pair
NPA/NXX Input Charge	$23.50	Per 10 Codes

STP Translation Charges: D-Links

Per Pair Charges	$1,222.00	per STP Pair
NPA/NXX Input Charge	$23.50	Per 10 Codes

Testing Set-Up A Link

	$1,306.20	per TC Switch & Telco STP Pair

Testing Set-UP D Link

	$1,952.55	per TC Switch & Telco STP Pair

B. Baseline Cost Model and Cost Driver

Recurring Cost

Lines per Switch			**2 x 50,000**	**1 x 100,000**
CCS Port			4 port	2 port
	$752.80	Port/Month	**$3,011.20**	**$1,505.60**
Links				
number of links	2		4	2
Link Cost =	$31.97	per month	**$255.76**	**$127.88**
Signaling				
#of messages per month =	2160			
Cost of ISUP for 100,000 lines per month=			**$42,120.00**	**$42,120.00**
Total Monthly Cost			**$45,386.96**	**$43,753.48**

Non Recurring Cost

STP TC: A-Links				
Per Pair Charges	$940.00	per STP Pair	**$1,880.00**	**$1,880.00**
NPA/NXX Input		Per 10 Codes	**$23.5**	**$23.50**
STP TC: D-Links				
Per Pair Charges	$1,222.00	per STP Pair	**$2,444.00**	**$2,444.00**
NPA/NXX Input Charge		Per 10 Codes	**$23.50**	**$23.50**
Testing: A-link	$1,306.20	per TC Switch & STP Pair	**$2,612.40**	**$2,612.40**
Testing: D-link	$1,952.55	per TC Switch & STP Pair	**$3,905.10**	**$3,905.10**

C. SS7 Major Cost Components

Common Channel Signaling

STP Port	$752.00		
Service Access Charge	$0.60		
Assumed Usage	$0.200000		
		$752.80	Port/Month
Signaling Usage Rate	$0.000195		
		$0.000195	per Message

STP Translation Charges: A-Links

Basic ISUP	$141.00		
ISUP + TCAP	$188.00		
800 DB Quries	$94.00		
LIDB Queries	$94.00		
Calss Features	$94.00		
Calling Name	$94.00		
AIN Queries (Verizon)	$94.00		
TC to TC (Telephone Carrier)	$141.00		
		$940.00	per STP Pair
NPA/NXX Input Charge	$23.50		
		$23.50	Per 10 Codes

STP Translation Charges: D-Links

Basic ISUP	$235.00		
ISUP + TCAP	$329.00		
800 DB Quries	$94.00		
LIDB Queries	$94.00		
Calss Features	$94.00		
Calling Name	$94.00		
AIN Queries (Verizon)	$141.00		
TC to TC (Telephone Carrier)	$141.00		
		$1,222.00	per STP Pair
NPA/NXX Input Charge	$23.50		
		$23.50	Per 10 Codes

Testing : A Link

MTP: Levels 2 & 3	$522.48		
ISUP	$522.48		
800 DB Queries	$65.31		
LIDB Queries	$65.31		
Class Features	$65.31		
Calling Name	$65.31		
		$1,306.20	per TC Switch & STP Pair

Testing: D Link

MTP: Levels 2 & 3	$694.24		
ISUP	$1,041.36		
800 DB Queries	$86.78		
LIDB Queries	$43.39		
Class Features	$43.39		
Calling Name	$43.39		
		$1,952.55	per TC Switch & STP Pair

D. STP Pair Calculation

Number of SSP-STP pairs

Variables	Assumptions	
Subscriber	100,000	lines
Usage	0.1	Erlangs
Call duration	3	minute
trunk traffic	80	%
line traffic	60	%
SS7 messages /call/direction	3	
TCAP size	100	byte
ISUP size	25	byte

Call Rate = Usage (Elang) / Call Duration
= 2 calls/Hr
BHCC = Subscriber * Call Rate
= 200,000 calls/Hr

Traffic Load = ISUP OCTETS + TCAP OCTETS
= (bhcc * Trunk Traffic * ISUP size * number of ISUP messages) + (bhcc * Line Traffic * Tcap size)
= 24,000,000 O/BHCC
= 6,666.67 O/s

Number of SSP-STP pair = Load / Link Rate (5,600 O/s)
= 1.19 pairs
= 2 pairs

E. SS7 Message Calculation

Number of ISUP messages

	AVG Number of Calls per line per day	Number of Messages per Call
Completed Call (70%)	10.5	6
Uncompleted Call (30%)	4.5	2

Number of Messages per line per day

= 72

Number of Messages per line per month

= Number of Messages per line per day x 30

= 2160

F. **PacketCable Call Scenario and Access Charge**

Access Charge

Total Calls (per Line / Day): 15

	Calls From	**Calls To**	**% of Calls**	**Total Calls (per Line per Day)**	**Calls Completed (70%)**	**Calls Uncomp. (30%)**	**Call Duration (minutes)**	**Access Charge**
1	PacketCable	PacketCable	10%	1.5	1.05	0.45	3.6	
2	PacketCable	IP	10%	1.5	1.05	0.45	3.6	0.036
3	PacketCable	PSTN	35%	5.25	3.675	1.575	12.6	0.378
4	IP	PacketCable	10%	1.5	1.05	0.45	3.6	
5	PSTN	PacketCable	35%	5.25	3.675	1.575	12.6	
	Total		100%	15	10.5	4.5		**0.414**

Notes
1. 3 minutes for completed & 1 minute for uncompleted calls
2. $0.03 per minute

Appendix 2: Detailed PacketCable ENUM Cost Model

A. PacketCable-ENUM Signaling Cost Driver

ENUM Cost Model

Charge per Query	$0.00150	per query
# of Query	1	query per call
Minimum Charge/month	$20,000	per month
Subscriber	100,000	lines

1. ENUM Cost	=	Successful Query	x	Charge per Query	x	30 day/mo.	x	Subscriber
	=	1.91243625	x	$0.0015	x	30	x	100,000
	=	$8,606	per month		OR	$20,000	whichever is greater	
	=	**$20,000**						
2. SS7 Cost	=	**$30,301**						
3. Access Charge	=	**$1,158,008**						
4. Extra Traffic Cost	=							
<u>Total ENUM Cost:</u>		**<u>$1,208,309</u>**						

B. SS7 Hybrid Signaling Network Cost Model

Number of Switches	**50,000 lines**		**2 x 50,000**	**1 x 100,000**
Number of STP Pairs =	**1**	) (# of pairs)		
Common Channel Signaling				
	$752.80	Port/Month	**$1,505.60**	**$752.80**
Links				
2 A Links (dedicated DS0 circuits)	$31.97			
number of links	2		4	2
Link Cost =				
	$63.94	per month	**$127.88**	**$63.94**
Signaling				
SUP message	$0.000195	per message		
number of messages per month =	1512			
Cost of ISUP for 100,000 lines per month=	$0.29	per month	**$29,484.00**	**$29,484.00**
TOTAL Monthly Cost			**$31,117.48**	**$30,300.74**

STP Translation Charges: A-Links				
Per Pair Charges	$940.00	per STP Pair	**$940.00**	**$940.00**
NPA/NXX Input Charge	$23.50	Per 10 Codes	**$23.50**	**$23.50**
STP Translation Charges: D-Links				
Per Pair Charges	$1,222.00	per STP Pair	**$1,222.00**	**$1,222.00**
NPA/NXX Input Charge	$23.50	Per 10 Codes	**$23.50**	**$23.50**
Testing: A link				
	$1,306.20		**$1,306.20**	**$1,306.20**
Testing: D link				
	$1,952.55		**$1,952.55**	**$1,952.55**

C: ENUM Query Calculation

	Calls From	**Calls To**	**% of Calls**	**Total Calls (per Line per Day)**	**Calls Completed (70%)**	**Successful Query 1**	**Calls Uncomp. (30%)**	**Successful Query 2**
1	PacketCableENUM	PacketCableENUM	10.0%	1.5	1.05	1.05	0.45	0.225
2	PacketCableENUM	ENUM-IP	1.1%	0.16665	0.116655	0.116655	0.049995	0.0249975
3	PacketCableENUM	Non-ENUM-IP	8.9%	1.33335	0.933345		0.400005	
4	PacketCableENUM	PSTN	35.0%	5.25	3.675	0.4082925	1.575	0.08749125
5	ENUM-IP	PacketCableENUM	1.1%	0.16665	0.116655		0.049995	
6	Non-ENUM-IP	PacketCableENUM	8.9%	1.33335	0.933345		0.400005	
7	PSTN	PacketCableENUM	35.0%	5.25	3.675		1.575	
	Total		100%	15	10.5	**1.5749475**	4.5	**0.33748875**

Notes

1. 100% of Completed Calls will generate successful query
2. 50% of not-completed calls will generate successful query
3. Assumption of 80% of MG information is ENUM database

D. PacketCable-ENUM Access Charge Calculation

Total Access Charges for Call Termination

Total Calls (per Line per Day): 15

Calls From	**Calls To**	**% of Calls**	**Total Calls (per Line per Day)**	**Calls Completed (70%)**	**Calls Uncomp. (30%)**	**Call Duration (minutes) 1**	**Access Charge 2**
PacketPacketCable-Enum	PacketPacketCable-Enum	10.0%	1.5	1.05	0.45	3.6	
PacketPacketCable-Enum	Enum-IP	1.1%	0.16665	0.11666	0.049995	0.39996	0.0039996
PacketPacketCable-Enum	Non-Enum-IP	8.9%	1.33335	0.93335	0.400005	3.20004	0.0320004
PacketPacketCable-Enum	PSTN	35.0%	5.25	3.675	1.575	12.6	0.3500028
Enum-IP	PacketPacketCable-Enum	1.1%	0.16665	0.11666	0.049995	0.39996	
Non-Enum-IP	PacketPacketCable-Enum	8.9%	1.33335	0.93335	0.400005	3.20004	
PSTN	PacketPacketCable-Enum	35.0%	5.25	3.675	1.575	12.6	
Total		100%	15	10.5	4.5		**0.3860028**

Notes
1. 3 minutes for completed & 1 minute for uncompleted calls
2. $0.03 for SS7 & $0.01 for Enum generated calls

D. ENUM Signaling Traffic Calculation

Average Traffic Load generated by ENUM

Variables	Assumptions	
Subscriber	100,000	lines
Usage	0.1	Elangs
Call duration	3	minute
Query size	80	byte
		(DNS query 40 + TCP 20 or UDP 8 + IP minimum 20)
% of Calls generating ENUM Query	4%	(Successful Outgoing Query/ # of Calls per day)

Call Rate = Usage (Elang) / Call Duration

= 2 calls/Hr

BHCC = Subscriber * Call Rate

= 200,000 calls/Hr

Traffic Load of ENUM queries = bhcc x Query Size x % of Calls generating ENUM Query

= **433,413 Octets/bhcc**

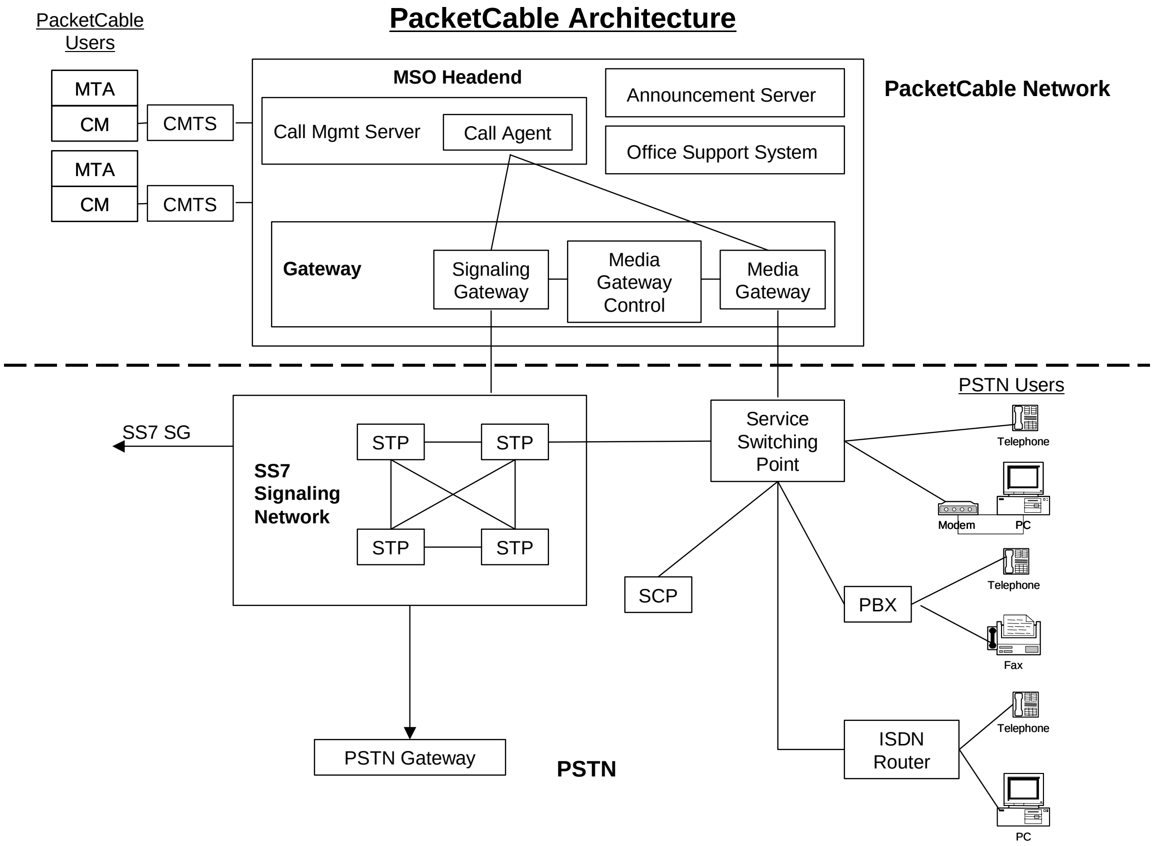
Load = **120.39 O/s**

963.14 bps

Appendix 3: Architecture and Signaling Analysis

I. Packet Cable Architecture

Figure 4. System Architecture for Packet Cable



There are three different networks involved in cable telephony service network:

- The cable access network
- The Public Switched Telephone Networks with SS7
- The Internet.

With PacketCable architecture, the voice traffic is managed exclusively inside Managed IP network (a network provisioned for only VOIP traffic) and interoperates with PSTN. In Packet Cable Telephony network, an MSO provides packet telephony services through their own network that is specific to the telephony traffics. It consists of Customer

Premises, Hybrid Fiber Coax, and the MSO Headend. Functional components of each of the sub-networks are as specified by PacketCable specification, as follows.

- Customer Premises
- Multimedia Terminal Adapter (MTA)
- Cable Modem (CM)
- HFC Access Network
- Cable Modem Termination System (CMTS)
- Headend
- Call Management Server (CMS)
- Call Agent (CA)
- PSTN Gateway
- Media Gateway Controller (MGC)
- Signaling Gateway (SG)
- Media Gateway (MG)
- OSS and other network components
- TGS
- Dynamic Host Configuration Protocol Server (DHCP)
- Domain Name System Server (DNS)
- Announcement Server (ANS)

An **MTA (Multimedia Terminal Adapter)** is a PacketCable client device that contains a subscriber-side interface to the subscriber's CPE (e.g., telephone) and a network-side signaling interface to call control elements in the network. An MTA provides codecs and all signaling and encapsulation functions required for media transport and call signaling.

The **CM (Cable Modem)** is a modulator/demodulator residing on the customer premise that provides data transmission over the cable network using the DOCSIS protocol. In PacketCable, the CM plays a key role in handling the media stream and provides services such as classification of traffic into service flows, rate shaping, and prioritized queuing.

PacketCable-based services are carried over the Hybrid Fiber/Coax (HFC) access network. The access network is a bi-directional, shared-media system that consists of the Cable Modem (CM), the Cable Modem Termination System (CMTS), and the DOCSIS MAC and PHY access layers. The **CMTS** provides data connectivity and complimentary functionality to cable modems over the HFC access network (DOCSIS). It also provides connectivity to wide area networks. The CMTS is located at the cable television system head-end or distribution hub.

In the **Headend** of the Cable networks, the **Call Management Server (CMS)** provides call control and signaling related services for the MTA, CMTS, and PSTN gateways in the PacketCable network. The CMS is a trusted network element that resides on the managed IP portion of the PacketCable network. **Call Agent (CA)** refers to the control component of the CMS that is responsible for providing signaling services using the NCS protocol to the MTA. Other than CMS, the headend needs to be equipped with OSS network Components such as TGS, DHCP, DNS Servers and ANS announcement servers .

PacketCable allows MTA's to inter-operate with the current PSTN through the use of PSTN Gateways. In order to enable operators to minimize cost and optimize their PSTN interconnection arrangements, the PSTN Gateway is decomposed into three functional components; MGC (Medial gateway Controller), SG (Signaling Gateway) and MG (Media Gateway). The **Media Gateway Controller (MGC)** receives and mediates call-signaling information between the PacketCable network and the PSTN. It maintains and controls the overall call state for calls requiring PSTN interconnection. The MGC controls the MG by instructing it to create, modify, and delete connections that support the media stream over the IP network. The MGC also instructs the MG to detect and generate events and signals such as continuity test tones for ISUP trunks, or MF signaling for MF trunks. Each trunk is represented as an endpoint. Functions performed by the Media Gateway Controller include: Call Control Function, PacketCable Signaling, MG Control, and so on. The **Signaling Gateway (SG) –** provides a signaling interconnection function between the PSTN SS7 signaling network and the IP network. For PacketCable 1.0, the signaling gateway function only supports non-facility associated signaling in the form of SS7. Facility associated signaling in the form of MF is supported by the MG function directly.

The **Media Gateway (MG**) terminates the bearer paths and transcodes media between the PSTN and IP network.

II. PacketCable Architecture with ENUM

With ENUM-based networks, cable modem access networks transmits both data and voice packets over the general data network. We assume appropriate QoS technologies are implemented to support VOIP quality within the general IP networks. ENUM provides the numbering functions throughout the data network and PSTN, hence enabling larger interoperability. In this case, MSOs provide ordinary data traffic services, eliminating the need for PSTN gateways inside their network. Instead, the gateways reside on the border between PSTN and the data network, mainly the Internet, provided as needed by independent gateway service providers, TSPs, or some of the MSOs that have large networks. Other components such as CMS, AS, and OSS are still necessary for voice traffic transmission, billing information, and so on. To initiate a call, however, SIP server sets up the call instead of Call Agent in Packet Cable network. For the calls that were originated from PSTN, the gateways set up the calls. ENUM registries, registrars, and ASPs are managed separately, providing numbering functions and database look-ups. Any MSO that would provide ENUM service, in other words, that would act as an ENUM ASP, would need additional components such as SIP proxy server, interfaces and software for customers and ENUM administrations. Address look up is a function of DNS server in OSS Back Office network; hence it is necessary to embed the ENUM look-up function and interfaces to the OSS. Other components will be managed separately by different parties in different networks such as PSTN and Internet, as necessary.

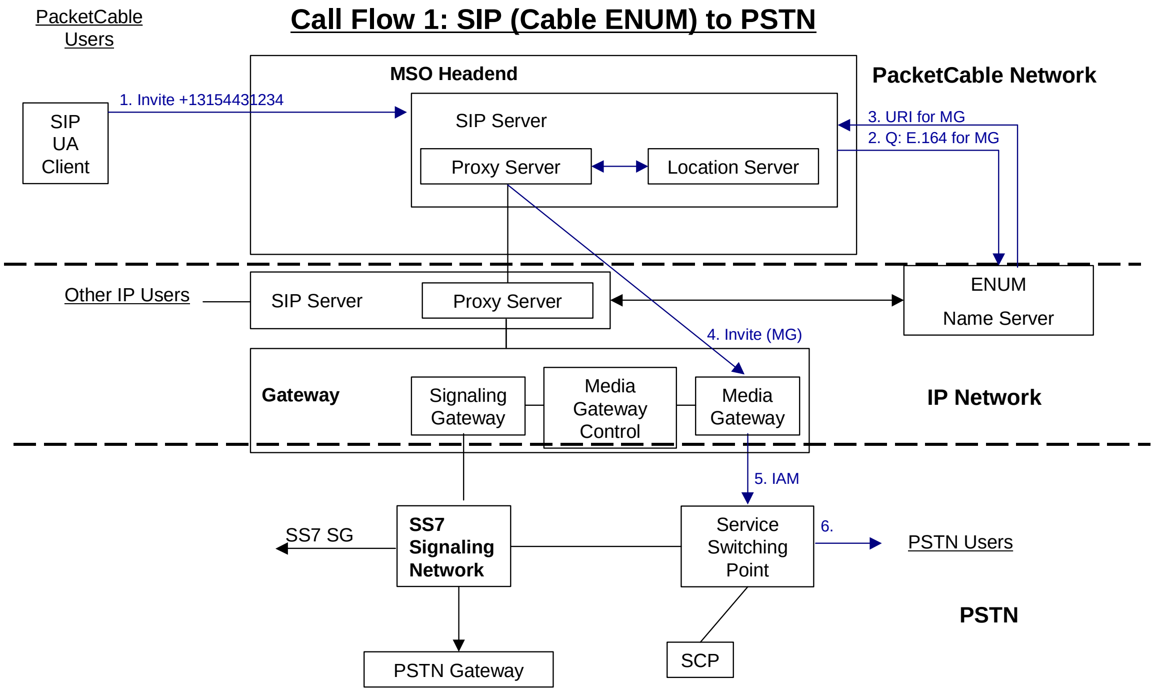
III. Signaling and Call Flow Analysis

With the proposed architectures, customers are divided into three different groups in accordance with the three types of the networks: Packet Cable subscribers, Data network subscribers (other IP users), and PSTN subscribers.

- Packet Cable subscribers are connected to the cable data network via cable modem. Packet telephony is available through the Internet and ENUM, available to call all the other users in different networks.

- Other IP users may use various technologies to be connected to the IP network, including a typical Internet connection via 56k modem or ISDN through PSTN, DSL, and so on. Users in this category may also use ENUM enabled services.
- PSTN subscribers are typical telephony service subscribers within PSTN network. It is essential for the packet telephony services to interoperate with PSTN because it has a large number of subscribers and will remain as basic telecommunication services.

IV. Call Flow 1: SIP (Cable ENUM) to PSTN telephone.



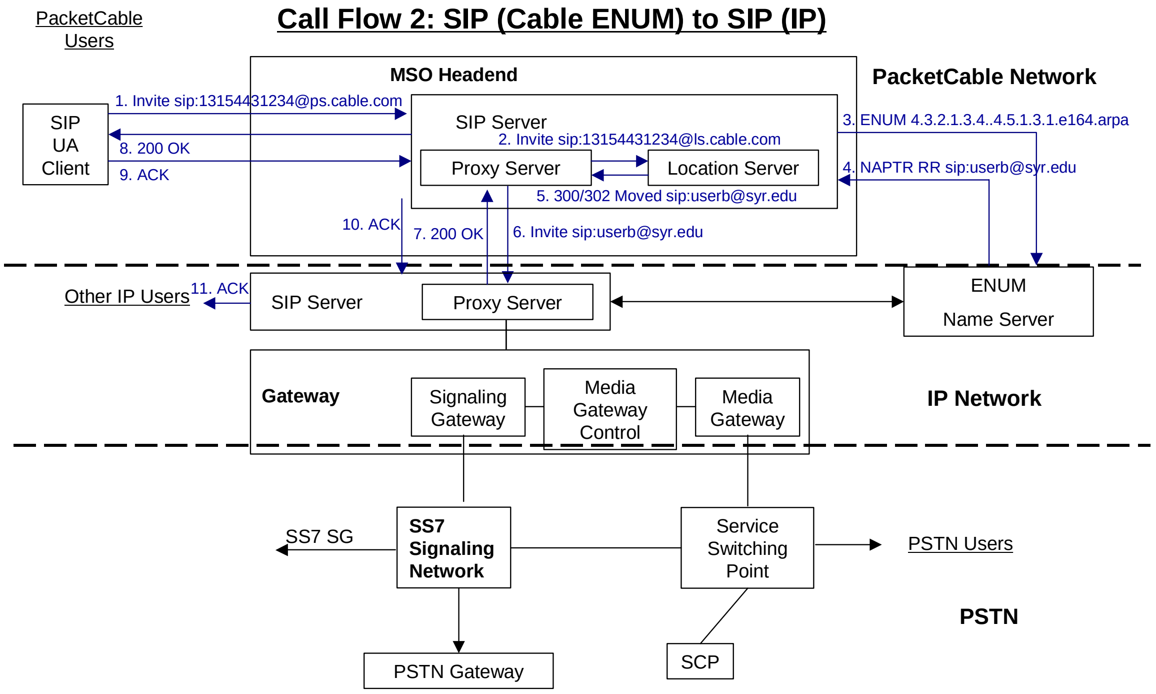
In this scenario, the calling party is a subscriber of the Cable Telephony and ENUM ASP and the called party does not have to be an ENUM subscriber. This call flow is possible if the MG's mapping information is registered in the ENUM. ENUM may not be necessary for the completion of IP-originated (e.g., SIP) to PSTN calls in that there are alternatives for gateway selection such as Telephony Routing over IP (TRIP), being developed by the IPTEL working group in IETF. TRIP servers maintain and exchange information on what gateways are available to establish calls to ranges of telephone numbers.

1. A packet cable subscriber (user A), using a SIP phone, dials global E.164 number for the called party in PSTN (user B).
2. Local Proxy Server for User A queries ENUM Server to determine which Media Gateway to signal.
3. The ENUM Server returns the address of the Media Gateway.
4. Proxy server forwards invite to the Media Gateway.
5. The Media Gateway sends Initial Address Message (IAM) to the Service Switching Point (SSP).
6. SSP signals User B's telephone.
7. If User B accepts the call, then a two-way voice path is established between the Media Gateway and the User B. A two-way Real-Time Protocol (RTP) path is also established between the Media Gateway and the User A. At this point User A is able to communicate with User B as indicated by the dashed line.

From Packet Cable:

1. CMS queries a database with the destination phone number and determines that the call must be routed to the PSTN via a particular PSTN gateway.
2. The call is passed to the MGC, which may be responsible for controlling more than one MG, and determines the correct MG.
3. MGC decides to route the call through a specific MG.
4. The first message: RQNT and CRCX from MGC to MG.
5. MGC sends an SS7 message via SG to the switch at the far end of the trunk.
6. The switch responds to MG, which transmits message.
7. The MGC informs the switch and the network is opened a one-way path from the destination party to the originating party. The caller hears announcements or other audio signal.
8. The MGC will receive a message via the SG that the destination party is being alerted.
9. Destination party goes off-hook, the MGC receives a signal to that effect via the SG.
10. The MGC now modifies the connection so that it shifts into full-duplex mode.

V. Call Flow 2: SIP (Cable ENUM) to SIP (other IP).



There are two possible ways to call from a Cable ENUM network to any other SIP phone in the IP network. One is querying an E.164 number to ENUM service, and the other is using SIP URI directly to find the proxy server of the called party. In the latter case, however, the proxies need to share the mapping information, through some kind of clearinghouses if they are in different networks. If they are listed in ENUM, then they have to use the E.164 number, which is the former case. When using ENUM, both the calling and the called parties must be registered in ENUM service. It is assumed that the calling party is charged for the query and the called party would incur the registration cost to be listed in the ENUM service. It will depend on the ENUM provisioning model how to charge for each service. Therefore, user B is assumed to have an ENUM listing with one of the resource records being a SIP address sip:userb@syr.edu.

User A does not know the specific SIP address or SIP URI to contact User B at. So User A inputs a known E.164 number +1-315-443-1234 of User B into the SIP Phone. The SIP Phone subsequently issues an INVITE message to the phone number that was entered and addressed to the pre-configured SIP Proxy server.

This SIP Proxy directs the call to a location server to get the appropriate SIP Address.

The location server does not have that particular E.164 number listed in any of it's local database look-ups and issues and ENUM query to the public ENUM listing "e164.arpa".

Since the E.164 number was listed in the e164.arpa domain the appropriate NAPTR Resource Records are returned. One such resource record includes a listing for the SIP address of User B, "sip:userb@syr.edu".

The Location Server translates the data from the NAPTR Resource Record as a contact field in a 300 or 302 "Moved" message that is sent back to the SIP Proxy.

The SIP Proxy translated the contact field from the 300/302 message into the SIP URI of the INVITE message that is then sent on to the IP Phone of User B directly.

The SIP Phone of User B received the SIP INVITE and issues the 200 OK message back to the Proxy indicating that User B has picked up the phone physically.

The Proxy issues the 200 OK back to User A's SIP Phone

User A's SIP phone issues an acknowledgement "ACK" back to the SIP Proxy indicating it is ready to send & Receive RTP media streams.

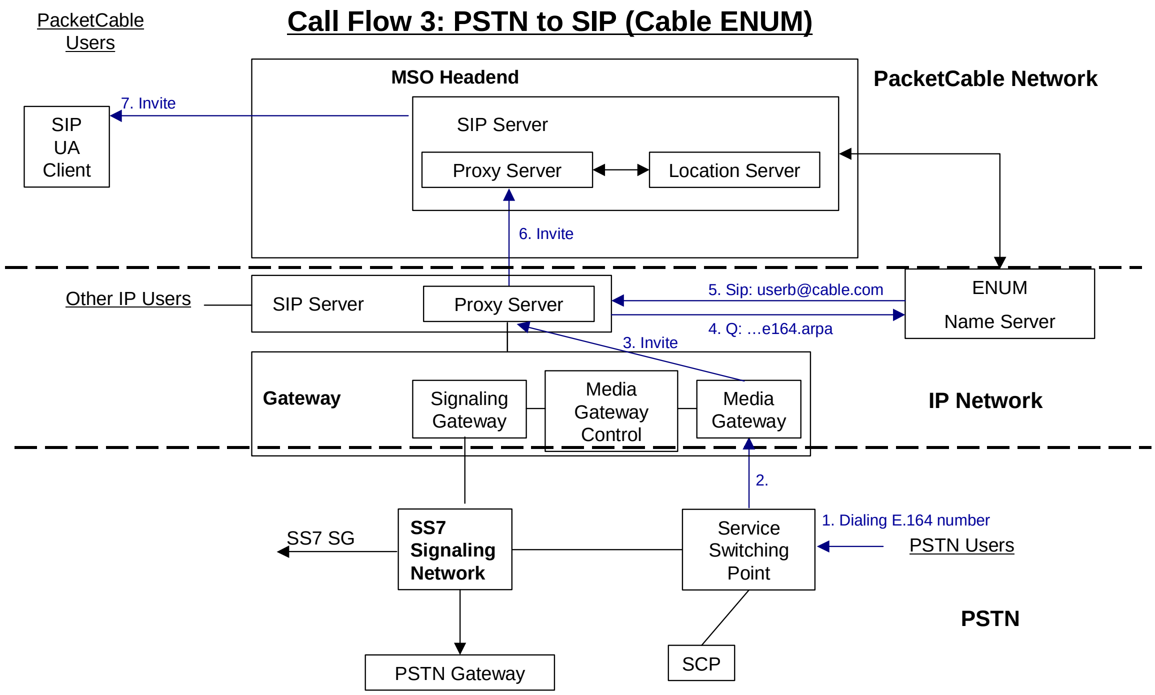
The Proxy Server passes the ACK on to User B's SIP phone.

Two-Way RTP over UDP (User Datagram Protocol) media sessions are established and the two parties can talk to each other.

From PacketCable

1. A calls B: MTAa places the address of its local CMS -> CMTSa
2. CMTSa forwards (routes) info to CMSa.
3. CMSa checks caller's authentication and lookup the database for CMSb.
4. CMSa contacts CMSb, and sends message to CMTSa to reserve bandwith.
5. CMTSa reserves bandwidth between the caller and CMTSa. CMTSb receives incoming call signaling fro CMSa.
6. CMSb contacts CMTSb and instructs it to reserve bandwidth.
7. CMTSb informs CMSb that the resources are reserved and the bandwidth is available.
8. CMSb sends a signal to B's MTAb via CMTSb.
9. From this point on, both end can place each other;s IP address in the destinatin fields. The network will route the packets directly between the MTAs instead of facing the packets to travel through the CMSes.

VI. Call Flow 3: PSTN to SIP (Cable ENUM)



In this scenario, only the called party in the Cable ENUM network needs to subscribe to the ENUM service.

User A dials the global E.164 number for User B.

1. The SSP sends an IAM message via SS7, including a signaling gateway, to the Media Gateway.
2. The Media Gateway sends an invite message to the nearest Proxy Server.
3. Proxy Server A does not know User B address; therefore it contacts an ENUM Server.
4. The ENUM Server returns the SIP address of User B.
5. Proxy Server A sends an invite message to User B’s Proxy Server B.
6. Proxy Server B passes the invite to User B
8. If User B accepts the call, there is a two-way RTP path established between User B and Proxy Server B and Proxy Server A and the Media Gateway. A two-way path is also established between the Media Gateway and User A. At this point User A is able to communicate with User B as indicated by the dashed line.

To PacketCable

Assumption:

1. The calling user should be able to select a particular carrier/ service provider that provides the usual telephone service in PSTN by dialing the CAC or with pre-subscription, that carrier/ service provider sets the path to the network of called user. Or the routing systems in PSTN intend to set the path through PSTN until they find out that the dialed number is for a call to the user in the Internet, in which case, they access the gateway.
2. To set the path to the called user, the carrier/ service provider selected by the calling user must have the interconnection with the PacketCable MSO providing the termination service for the called user.

Appendix 4: Glossary

AIN	Advanced Intelligent Network
ANS	Announcement Server
ASP	Application Service Provider
BHCC	Busy Hour Call Completion
CA	Call Agent
CAC	Call Admission Control
CLEC	Competitive Local Exchange Carrier
CM	Cable Modem
CMS	Call Management Server
CMTS	Cable Modem Termination System
CRCX	Create Connection Command
DHCP	Dynamic Host Configuration Protocol Server
DNS	Domain Name System Server
DOCSIS	Data Over Cable Service Interface Specification
DSL	Digital Subscriber Line
HFC	Hybrid Fiber-Coax
IAM	Initial Address Message
IETF	Internet Engineering Task Force
ILEC	Incumbent Local Exchange Carrier
ISDN	Integrated Subscriber Digital Network
ISUP	ISDN User Part
IXC	Inter Exchange Carrier
MF	Multi Frequency
MG	Media Gateway
MGC	Media Gateway Controller
MSO	Multi-System Operators
MTA	Multimedia Terminal Adapter
NCS	Network-based Call Signaling
OSI	Open System Interconnection
OSS	Operation Support System
PSTN	Public Switched Telephone Network

RQNT	Request Notification Message
RTP	Real Time Protocol
SG	Signaling Gateway
SIP	Session Initiation Protocol
SLC	Subscriber Line Charge
SS7	Signaling System 7
SSP	Service Switching Point
STP	Signal Transfer Point
TCAP	Transaction Capabilities Application Part
TDM	Time Division Multiplexing
TGS	Ticket Granting Server
TRIP	Telephony Routing over Internet Protocol
TSP	Telephone Service Provider
UDP	User Datagram Protocol
UMS	Unified Messaging Service
VAR	Value Added Reseller
VOIP	Voice Over Internet Protocol