VoIP Availability and Reliability Model for the PacketCable™ Architecture

Technical Report

PKT-TR-VoIPAR-V01-001128

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1 SCOPE

1.1 Introduction

The advent of the Internet age and the wide spread use of the Internet Protocol (IP) has brought with it new network technologies and new applications, as well as new-world approaches to old-world technologies.

One of the most well known old-world technologies is the transmission of voice over a Public Switched Telephone Network (PSTN) circuit-switched path. The PSTN is known for its performance and availability. It is important that the new-world applications such as Voice over IP achieve an equivalent level of performance and availability.

This technical report directly addresses the issue of availability. It presents detailed end-to-end network models for both the PacketCable and PSTN environments. The end-to-end availability objective of the PSTN network, based upon Telcordia[1] documents, is 99.94%, with individual elements having the more well known value of 99.99%.

The same end-to-end availability objective of 99.94% was set for the end-to-end PacketCable network. The vendor and MSO membership within the PacketCable community analyzed, negotiated, and assigned parts of the availability budget to each vendor's equipment within the model. The result is that the end-to-end engineering goal of 99.94% was achieved. This Technical Report provides the details of both the PacketCable and PSTN models. It includes end-to-end long distance models as well as various local calling models, including homogeneous configurations (on-net to on-net) and various hybrid configurations (on-net to off-net).

Of major significance is that with an end-to-end IP PacketCable network, an MSO can indeed provide the same high-availability service as the LECs. This analysis has resulted in the documentation and understanding of availability requirements for each element of the network to achieve this goal. This report provides the availability requirements for individual network elements which will allow vendors to independently develop equipment for the PacketCable Primary Line environment, and thus allow the MSO to offer a consistently reliable service. Although this report specifically targeted the PSTN voice environment, the resulting PacketCable availability model is extensible to data and video over IP applications as well.

[1] Telcordia Technologies, formerly known as Bellcore, was created during the divestiture of the Bell System in 1984 to serve the Bell operating companies. www.telcordia.com

1.2 Purpose

The purpose of this Technical Report is to describe the availability and reliability requirements for a residential VoIP service. This is done at a system level in order to provide sufficient detail to vendors that are building VoIP products according to the PacketCable Architecture Framework. [1] This document describes availability and reliability concepts, requirements, and models for a residential Voice over Internet Protocol (VoIP) service that is based upon the PacketCable architecture. Further, the purpose of this Technical Report is to provide a high level reference framework that identifies the functional components and describes the scenarios necessary to implement the defined availabilities in a PacketCable network.

This document covers definitions, models, and scenarios necessary to serve as a technical reference in the design and implementation of availability and reliability for a PacketCable network. This is not a Specification but rather a Technical Report and as such there is not any imperative language such as "must", "should, "recommended", etc. Its scope is the identification of the functional components (e.g., subscriber access) that comprise end to end bearer path call completion within a PacketCable network as well as to and from the PSTN. Reference models for both PacketCable and the PSTN are presented with associated definitions. PacketCable availability is compared along side PSTN availability for on-net to on-net (homogeneous) call scenarios.

From time to time this document refers to the voice communications capabilities of a PacketCable network in terms of "IP Telephony." The legal/regulatory classification of IP-based voice communications provided over cable networks and otherwise, and the legal/regulatory obligations, if any, borne by providers of such voice communications, are not yet fully defined by appropriate legal and regulatory authorities. Nothing in this specification is addressed to, or intended to affect, those issues. In particular, while this document uses standard terms such as "call," "call signaling," "telephony," etc., it should be recalled that, while a PacketCable network performs activities analogous to these PSTN functions, the manner by which it does so differs considerably from the manner in which they are performed in the PSTN by telecommunications carriers, and that these differences may be significant for legal/regulatory purposes. Moreover, while reference is made here to "IP Telephony," it should be recognized that this term embraces a number of different technologies and network architecture, each with different potential associated legal/regulatory obligations. No particular legal/regulatory consequences are assumed or implied by the use of this term.

1.3 Organization of Document

This Technical Report describes Availability for PacketCable 1.0 architecture. It is expected that the principles of this Technical Report will also apply to future releases of PacketCable architecture. The document is structured as follows:

- Section 1 – General introductory and organizational information.
- Section 2 – References
- Section 3 – Abbreviations and Acronyms used in the report.
- Section 4 – Availability and Reliability: Availability definitions, end-to-end calculations, repair budgets, and service metrics are outlined.
- Section 5 – Availability Models: Reference models for the PSTN and PacketCable and their associated definitions.
- Section 6 – Scenarios: Visuals of homogenous (on-net to on-net) and heterogeneous (on-net to off-net) call scenarios and their computed unavailability and corresponding availability percentages.

2 REFERENCES

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3 ABBREVIATIONS AND ACRONYMS

This recommendation uses the following abbreviations and acronyms.

ABSBH	Average Busy Season Busy Hour load: The three months out of a year with the highest average traffic in the busy hour is the busy season. The busy hour traffic averaged across the busy season is the ABSBH load.
A/D	Analog to Digital converter.
AN	Access Network. PSTN term representing the network providing connectivity between individual subscribers and a central office.
BER	Bit Error Rate.
CM	Cable Modem.
CM/MTA	Term used in this document generically representing the CM and MTA combination. This could be an embedded MTA or a standalone MTA.
CMCI	Cable Modem Customer premises Interface.
CMS	Call Management Server.
CMTS	Cable Modem Termination System. DOCSIS cable modem headend equipment.
CMTS-NSI	CMTS- Network Side Interface.
CPE	Customer Premise Equipment. Usage of CPE within this specification generically refers to the cable modem and MTA device that reside at the subscriber home, as well as any customer telephony equipment (telephones, answering machines, fax machines, etc.). Typically, CPE would refer to equipment that is beyond the service provider network interface, such as a telephone or personal computer. However, since the cable modem/MTA represent the service provider network interface device at the subscriber home, it is commonly referred to as CPE.
DOCSIS	Data Over Cable System Interface Specification.
DHCP	Dynamic Host Configuration Protocol.
DNS	Domain Name Server.
DQoS	Dynamic Quality of Service.
DS1	PSTN signal representing 24 time slots, running at a rate of 1.544 MHz.
DS3	PSTN signal representing 28 DS1s, running at a rate of 44.736 MHz.
FITL	Fiber In The Loop. A PSTN architecture consisting of a fiber optic access network.
HDBH	High Day Busy Hour load: The highest traffic load day of the year.
HDT	Host Digital Terminal. PSTN term for headend equipment providing access network distribution.
HFC	Hybrid Fiber Coax. Access network architecture consisting of fiber optic feeders from the headend to nodes, at which point coaxial cable is used for the final distribution to the subscribers.
IP	Internet Protocol. A network layer protocol.
IPSec	Internet Protocol Security, a collection of Internet standards for protecting IP packets with encryption and authentication.
LAN	Local Area Network.

LATA, intra/inter	Local Access and Transport Area. A PSTN term for a serving area.
LE	Local Exchange. A PSTN central office switch.
LEC, ILEC, CLEC	Local Exchange Carrier. Incumbent LEC and Competitive LEC. A PSTN service provider.
MAC	Media Access Control. A data link layer protocol.
MGC	Media Gateway Controller. The control element of a PSTN gateway.
MG	Media Gateway. The PSTN gateway element handling media transport and translation.
MSO	Multi-System Operator, a cable company that operates many head-end locations in several cities.
MTA, MTA-1	Multimedia Terminal Adapter. An MTA-1 is a PacketCable client that can be attached to a CM (standalone) or integrated with a CM (embedded) that supports POTS.
MTBF	Mean Time Between Failure. A reliability term denoting the average expected time between failures. By definition, includes the time required to restore a system after a failure. However, MTBF is commonly used interchangeably with MTTF.
MTTF	Mean Time To Fail. A reliability term denoting the average expected time to fail. By definition, does not include the time required to restore a system after a failure.
MTTR	Mean Time To Restore. A reliability term denoting the average expected time to restore a system after a failure.
NCS	Network Call Signaling. The PacketCable MGCP profile used for controlling calls.
NE	Network Element. A generic term referring to any element residing on a network.
NI, NID	Network Interface or Network Interface Device. A common PSTN term, also used by PacketCable, that refers to the subscriber’s interface point to the network. In this document, the CM/MTA is considered the NI or NID.
OA&M, OAM&P	Operations, Administration, & Management or Operations, Administration, Management, & Provisioning.
ONU	Optical Network Unit. Equivalent to a CM/MTA in the FITL architecture.
OSS	Operations Support System.
PHY	Term referring to the PHYsical layer of a network.
POTS	Plain Old Telephone Service.
PSTN	Public Switched Telephone Network.
PSTN GW	Generic PacketCable term referring to the combination of the MGC, MGW, and SGW.
QoS	Quality of Service.
RKS	Record Keeping Server.
RTP	Real Time Protocol, a protocol defined in RFC 1889 for encapsulating encoded voice and video streams.
SCTE	Society of Cable Telecommunications Engineers.
SG	Signaling Gateway. The PSTN gateway element handling signaling transport

	and translation.
SNMP	Simple Network Management Protocol.
SS7	Signaling System 7.
Telcordia (Bellcore)	PSTN research/standards organization.
TFTP	Trivial File Transfer Protocol.
THDBH	Ten High Day Busy Hour load: The ten highest traffic load days of the year. The ten day average is the THDBH load.
ToD	Time of Day. A network element that maintains and distributes the current time.
UPS	Uninterruptible Power Supply. A power supply including a battery for backup power when AC input power fails.

4 AVAILABILITY AND RELIABILITY

4.1 Availability Definitions

The availability of a PacketCable network is defined in terms of uptime, downtime, availability, and unavailability. These terms will define appropriate parameters that permit modeling of availability and offer the means to present numerous call scenarios.

4.1.1 Uptime

The uptime of any system is the average time the system is in its operational state. The uptime is typically specified in units of hours, e.g. uptime = 40,000 hours.

In different applications of reliability calculations, the uptime is often synonymous with the term MTBF (mean time between failures).

4.1.2 Downtime

The downtime of any system is the average time the system is not operational. The downtime is typically specified in units of hours, e.g. downtime = 4 hours.

The downtime is synonymous with the term MTTR (mean time to repair)[2].

4.1.3 Availability

The availability of any system is the *proportion* of time the system is in its operational state. The availability will be denoted as **A**.

In relation to uptime and downtime, availability can be calculated as:

A = uptime / (uptime + downtime)

In relation to MTBF and MTTR, availability can be calculated as:

Availability = MTBF / (MTBF + MTTR)

4.1.4 Unavailability

The unavailability of any system is the *proportion* of time the system is not operational. The unavailability will be denoted as **U**.

In relation to uptime and downtime, unavailability can be calculated as:

U = downtime / (uptime + downtime)

In relation to MTBF and MTTR, unavailability can be calculated as:

Unavailability = MTTR / (MTBF + MTTR)

[2] There is no dispute between the Telecordia definition and industry usage with MTTR = downtime.

Note that the proportion of time a system is down (unavailability) plus the proportion of time a system is up (availability) is equal to 1 (i.e., 100% of the time).

A + U = 1

4.2 End-to-End Availability Calculation

This section defines the methods for calculating the end-to-end availability when referencing the availability models defined below in Section 5. The proper method to utilize will be referred to as the "multiplication" method. A second method, referred to as the "addition" method may be utilized to calculate an approximation of the end-to-end availability. Detailed discussion concerning this subject can be found in [15]. For the purposes of this report, the “addition” method for availability analysis will be used, as explained in Section 4.2.2

4.2.1 Multiply the Availabilities

The proper method to calculate the end-to-end availability (AE2E) of the system is to multiply the availabilities of the individual network elements.

AE2E = A1 * A2 *...*An

4.2.2 Add the Unavailabilities

An approximation method to calculate the end-to-end availability of the system is to add the unavailabilities of the individual network elements.

AE2E ≈ 1 – (U1 + U2 + U3)

This method is only effective for extremely high availability values, as in those we are considering in this analysis. The error in this approximation will become significant if relatively low values are used.

4.2.2.1 Example 1: High Availability Calculation Comparison

(Multiply): AE2E = 0.9999 * 0.9999 = 0.99980001

(Add): AE2E ≈ 1 – (0.0001 + 0.0001) = 0.9998

(Comparison): 0.99980001 – 0.9998

= 0.00000001 / 0.99980001 = **0.000001% error**

4.2.2.2 Example 2: Low Availability Calculation Comparison

(Multiply): AE2E = 0.75 * 0.65 = 0.4875

(Add): AE2E ≈ 1 – (0.25 + 0.35) = 0.4

(Comparison): 0.4875 – 0.4 = 0.0875 / 0.4875 = **17.9% error**

4.3 Mean Time To Repair

In order to calculate the availability of a piece of equipment, both the Mean Time Before Failure (MTBF), and the Mean Time To Repair (MTTR) must be known. The MTBF is a function of how the piece of equipment has been designed. The MTTR is much more related to the time it takes the MSO service personal to get to the piece of equipment for service.

To ensure that vendors who have the same MTBF values calculate and specify the same availability numbers, this Technical Report defines a common set of MTTR numbers for equipment in typical MSO facilities. Any vendor-generated availability data are expected to use the MTTR numbers below, indicating which locations are assumed.

4.3.1 Staffed Headend Equipment

MTTR = 2 hours.

Equipment such as the CMTS (Cable Modem Termination System), CMS (Call Management Server), OSS (Operational Support System), etc., that reside within a headend that is staffed with on-site technicians.

4.3.2 Unstaffed Headend Equipment

MTTR = 4 hours.

Equipment such as the CMTS, CMS, OSS, etc., that reside within headends, hubs, etc., that are not staffed with on-site technicians.

4.3.3 Outside Hybrid Fiber Coax Plant

MTTR = 4 hours.

Outside Hybrid Fiber Coax (HFC) plant includes all fiber optic and coax cables, amplifiers, power taps, fiber nodes, etc., between the headend/hub and the CM/MTA (Cable Modem/Multimedia Terminal Adapter). Note that it is assumed that service technicians have direct access to all outside plant and that since most failures will affect many subscribers such failures will be repaired quickly.

4.3.4 Direct Access CM/MTA

MTTR = 4 hours.

A direct access CM/MTA is one that a service technician can access without any obstructions. For example, a CM/MTA mounted on the outside of a residence.

4.3.5 No Direct Access CM/MTA

MTTR = 24 hours.

A CM/MTA with no direct access has obstructions, which prevent a service technician from accessing the device without subscriber help. For example, an inside-the-home CM/MTA or an outside CM/MTA inside a gated community.

4.4 Service Metrics

This group of metrics, unlike the earlier sections of this document, address availability measurements that are dependant on subscriber call rates in addition to the reliability of the functional pieces of the network. Unavailability of equipment and network elements will be tracked and addressed by the MSO whether the consumer perceives the outage or not. The metrics addressed in this section attempt to discourage any avoidable outages during peak calling periods, delaying them until such time as network traffic is at a minimum.

4.4.1 Cutoff Calls

The objective for cut-off calls is adapted from Telcordia specification GR-512-CORE [9] and TR-TSY-000511 [11].

A cutoff call occurs when a stable call is terminated for some reason other than customer-initiated termination (i.e., either party going on-hook). For PacketCable, this means the call signaling is complete for call setup and the RTP media streams between the endpoints have been established. Thus, a cutoff call is unlikely to occur due to a signaling abnormality (e.g., a CMS failure). However, the network elements participating in the RTP media stream transport could cause a cutoff. The RTP media stream path, which is used for the VoIP bearer path, is illustrated in Figure 1, showing the network elements that could contribute to a cutoff call.

The objective for the probability of cutoff calls appears in Telcordia TR-TSY-000511. Section 11.5.3 [11] of the document states that for all causes within the system, the probability that a stable call is cut off should not exceed 0.000125, or one cutoff call in 8,000 calls. In addition, this metric is affected by the length of the call, since a call that lasts several hours will be more likely to be cutoff than one that lasts only a few minutes. The typical call length associated with this requirement, and the one that will be used for PacketCable, is three (3) minutes.

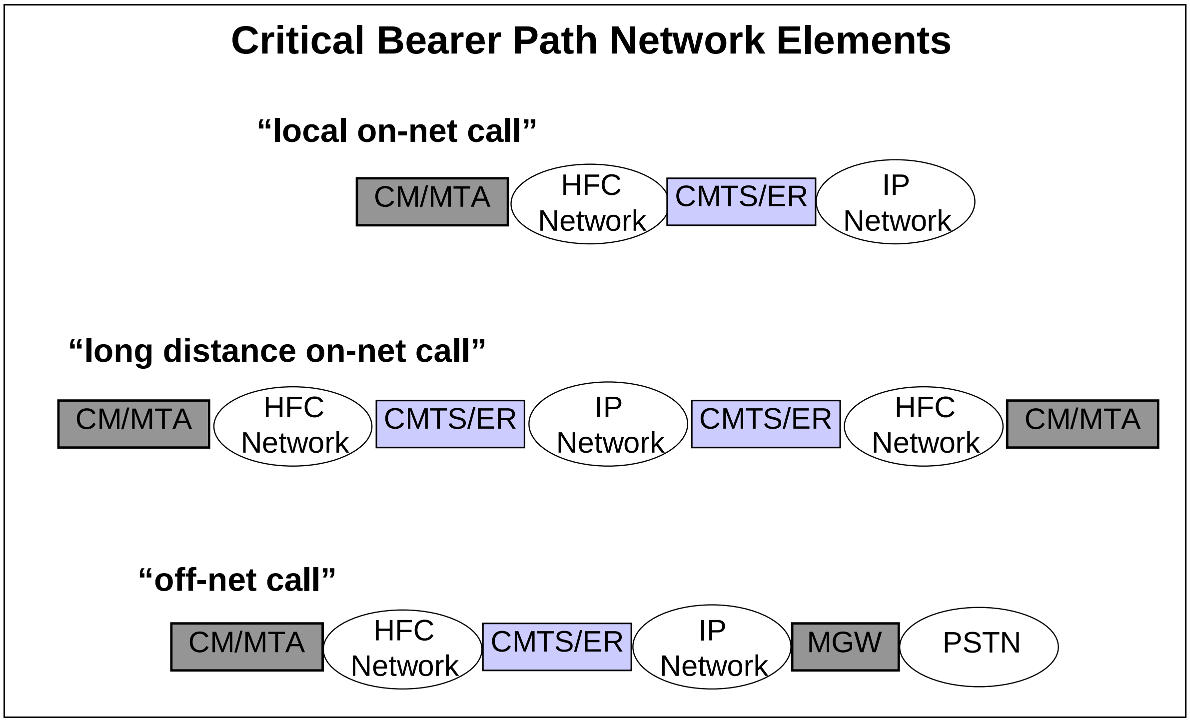

Figure 1. Critical Bearer Path Network Elements

4.4.2 Ineffective Attempts

The objective for ineffective attempts is adapted from Telcordia specifications GR-512-CORE [9] and TR-TSY-000511 [11].

For PacketCable, an ineffective attempt occurs when any valid bid for service does not complete because of a fault condition (e.g., hardware or software failure). A valid bid for service is any originating or incoming call attempt that delivers the expected signaling information to the system. Misdials or incomplete dialing by the customer are not included.

A fault condition then, can be directly equated to the downtime or unavailability of a network element. The distinguishing factor between unavailability and ineffective attempts is that the latter are tied to the number of customers affected, while the former is a long-range target for the average customer. Putting a requirement on ineffective attempts discourages downtime at the busiest times. An example of this might be planned downtime. An MSO could conceivably plan a service-affecting upgrade during business hours, affecting far more customers than if that upgrade was done at 3 a.m., yet still meet the average annual availability target. In this example, the upgrade performed during business hours would yield far more ineffective attempts than the one done at night.

The objective is a long-term average ineffective attempt rate not to exceed 0.0005 ineffective attempts per call attempt, or five (5) ineffective attempts per 10,000 call attempts. This equates to an average system availability of 99.95%, or roughly the availability of an end-to-end local "on-net" call.

In Telcordia GR-512-CORE [9], the definition of ineffective attempts also includes those due to traffic congestion, also known as blocked calls. The blocked call rate is affected by the engineering of the system (i.e., the concentration used across the elements), and will be implemented at the discretion of the MSOs. PacketCable sees blocked calls as primarily a service metric, not an availability metric, and therefore blocked calls are not included in our definition of ineffective attempts.

For PacketCable, an ineffective attempt means that some portion of call setup fails, implying a signaling failure. Therefore, the network elements participating in call setup may cause an ineffective attempt when a failure occurs. The signaling path is illustrated in Figure 2, showing the network elements that could contribute to an ineffective attempt.

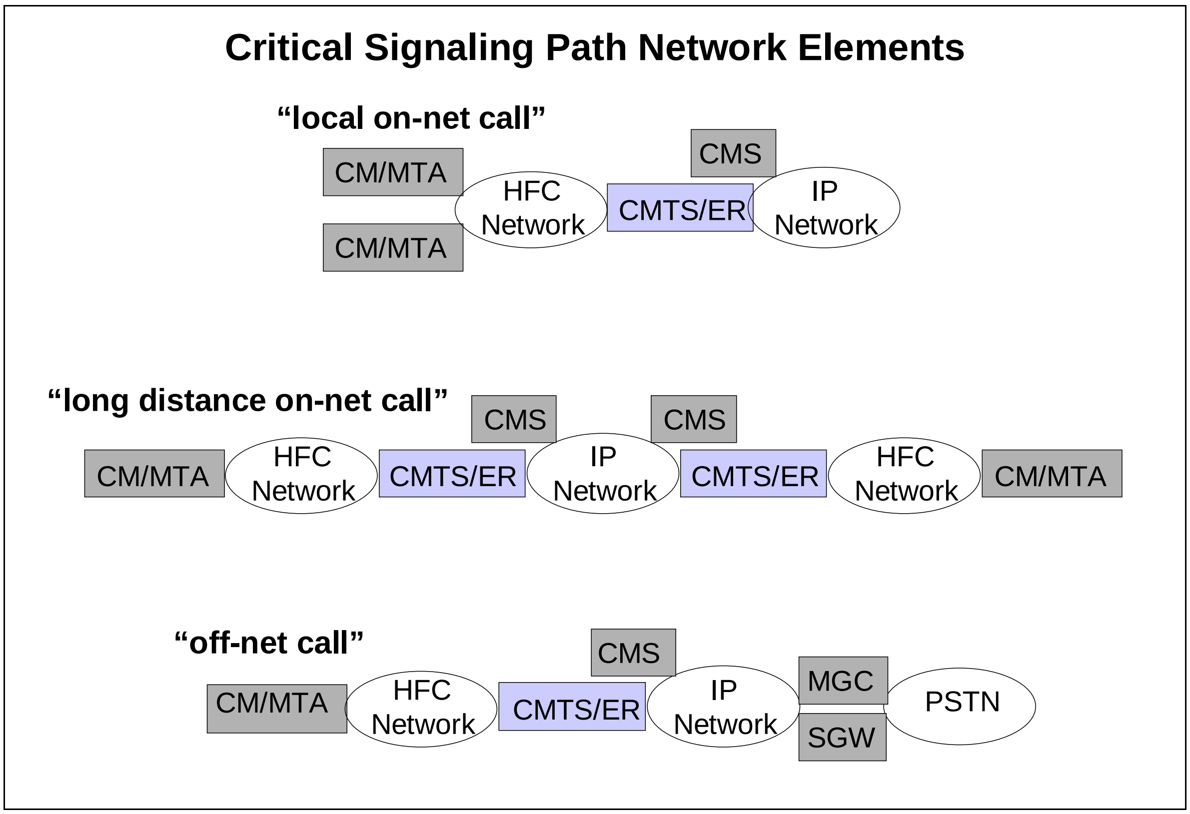

Figure 2. Critical Signaling Path Network Elements

5 AVAILABILITY MODELS

The end-to-end availability model for the PacketCable system is derived from the classic PSTN end-to-end availability model. The purpose of this model is to illustrate the conditions under which there will be equivalent availability for voice-grade PSTN service and PacketCable VoIP service. Additionally, the PacketCable model identifies what are considered to be the critical network elements necessary to provide the intended service.

Within the PSTN, the access network is the subsystem that provides individual subscriber *access* i.e., connectivity to the local circuit switch. The classic availability objective for the local loop is to provide 99.99% availability. The inverse of this, 0.01% unavailability, equates to approximately 53 minutes of downtime per year. This objective applies to the access network (AN) portion of the PSTN system, and is therefore not the end-to-end objective of the PSTN (which is calculated to be 99.94%).

The availability model developed for PacketCable defines the downtime budget from the point of view of a single subscriber. That is, the availability objectives apply to individual, end-to-end voice connections across the PacketCable network (the PacketCable network includes connectivity to the PSTN).

5.1 PSTN Reference Model

This PSTN reference model is intended to depict the elements that a typical end-to-end, long-distance call would pass through between one user and another. The details of this model can be found in the cited references, but at a high level, we will review the functional components here.

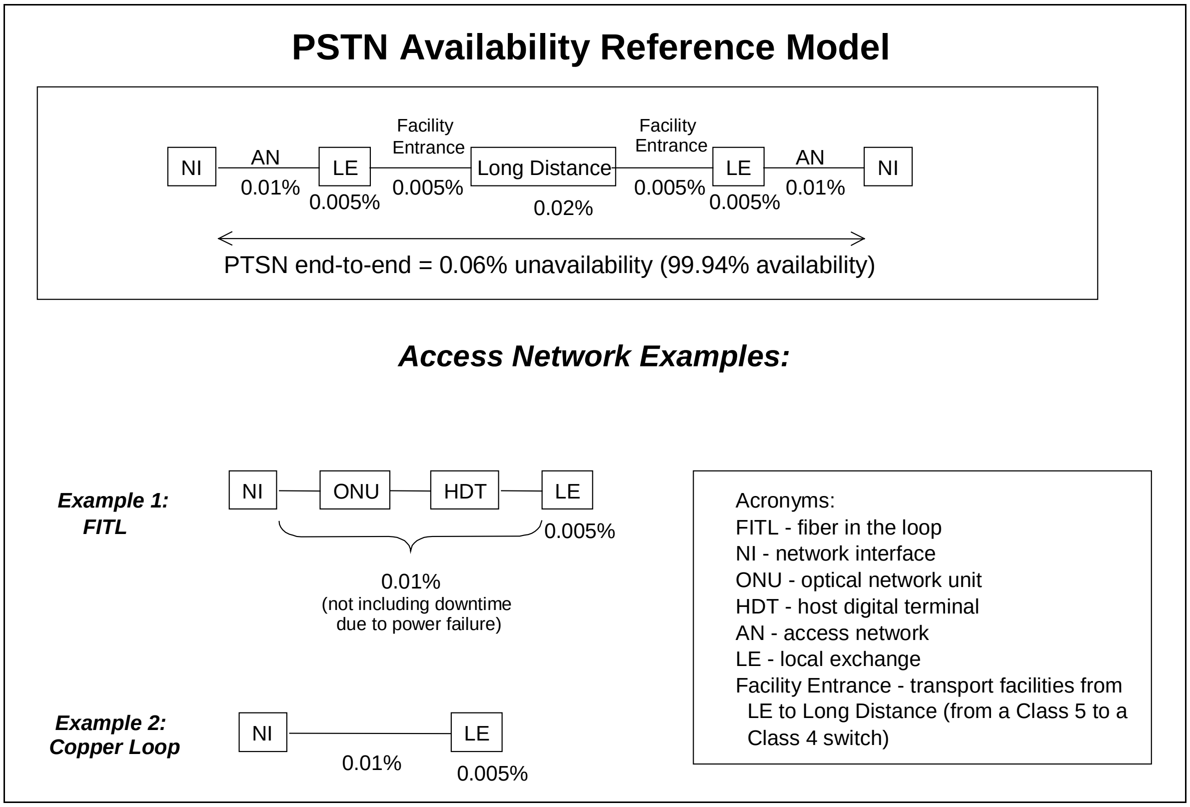

Figure 3. PSTN Reference Model

The Network Interface (NI) is a passive device that is typically installed on the outside of a subscriber's home. It serves as the demarcation point between the LEC network and the subscriber's inside-wiring. The ILEC typically does not control the subscriber's inside wiring (although much telephone inside wiring is covered by ILEC wire maintenance plans). Outages that occur on the customer side of the NI are not included in the model and are not tracked by the LEC.

The Access Network is the plant that connects the NI to the Local Exchange (LE) (a.k.a. Central Office or CO). Historically, the AN consisted simply of a twisted pair of copper wires, dedicated to a single phone number which terminated in the CO on the local Class 5 switch. This configuration still likely represents the majority of lines, particularly for residential customers. Increasingly, however, there are other configurations of the AN which may include Digital Loop Carrier (DLC) systems or Fiber In The Loop (FITL), which add additional active elements to the LEC's AN. Interestingly enough, there are no specific powering requirements for these types of active devices in the AN. The Telcordia requirements speak only to hardware reliability when they are used, and ignore downtime due to power. The lack of powering requirements implies that there should not be any downtime due to a power outage in these elements, but since most are backed up by batteries in the field, 100% reliability is unlikely.

The Local Exchange (LE) is meant to represent a local Class 5 switch. It is the place where all local loops are terminated, and where the originating call can be switched either to another user on the same Class 5 switch, or to a distant user somewhere else in the PSTN. In the latter case, the call is connected via a trunk to another Class 5 switch. Our reference model depicts this user as being connected to the Long Distance (LD) network. The trunk that connects the two is shown as the Facility Entrance.

The LD network can be made up of one or more LD switches, and is represented in the model as a single box. This is because the LD carrier needs to meet the availability target no matter how many switches it decides to use.

At the terminating end of the call, we see the reverse of the originating side. The call exits the LD network, is trunked through another facility entrance, is switched through another LE, is passed through the AN, and finally arrives at the terminating NI.

Obviously, there are many different scenarios that one could build using this reference model. For instance, today, most ILECs use the concept of "Tandem Switching" for connection to LD networks. A tandem switch is an additional local switch (e.g., a Lucent 5ESS or a Nortel DMS 100) where all of the LD carriers terminate on one side, and many of the ILEC's LEs terminate on the other side. Some LD carriers establish direct connections to some or most ILEC LEs, but they also connect to tandems to handle overflow traffic. Other LD carriers may connect only to the ILEC tandem for connectivity to all LEs subtending that tandem. In general the tandem concept saves terminations and trunking to every single LE in the network, but adds another active element in series. Thus, our reference model provides us with the appropriate pieces to depict this scenario, should we desire to.

This model is derived from separate Telecordia specifications as follows:

1. GR-499-CORE O2-16 [10] specifies the subscriber line availability as 99.99%. This specifies the AN unavailability objective of 0.01%. The AN objective covers up to the service provider's network interface (NI) which is typically the point at the side of the house where the network ends and the subscriber home wiring begins.
2. GR-499-CORE O2-3 [10] specifies the interoffice transport availability as 99.98%. This specifies the Long Distance unavailability objective of 0.02%. The Long Distance objective is assumed to include the Class 4 switch.
3. GR-499-CORE O2-13 [10] specifies an 80-mile DS3 level facility unavailability as 26 minutes/year. This specifies the Facility Entrance unavailability objective of 0.005%.
4. GR-512-CORE [9] Section 5 specifies the unavailability of the switching system as 28 minutes/year. This specifies the LE unavailability objective of 0.005%. The LE is equivalent to the local Class 5 switch.

It should be reinforced that neither the PSTN reference model nor the PacketCable reference model takes into consideration their respective signaling networks. Only elements within the bearer path are included in the availability calculations. The signaling paths covered by the previous metrics are given a separate unavailability budget. A signaling path outage can also be reflected in the metrics for Cutoff Calls and Ineffective Attempts. An example of the PSTN signaling system would be the Signaling System 7 (SS7) network. An example of the PacketCable signaling system would be the NCS CMS message exchanges.

5.2 PacketCable Reference Model

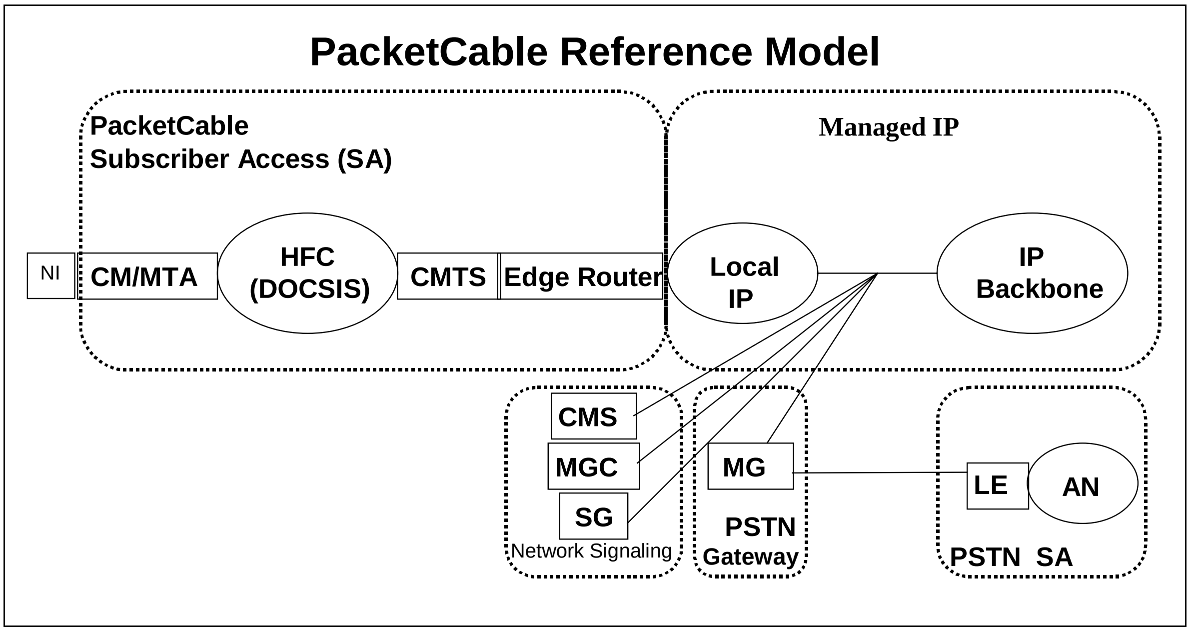

Figure 4. PacketCable Reference Model

The intention of this model is to map the PacketCable network elements that are critical to providing the intended voice service as closely as possible to the PSTN model. By assigning unavailability objectives to these critical network elements, two results are obtained. First, end-to-end call scenarios can be derived and compared to the PSTN equivalent scenario to see how the PacketCable services relate to the PSTN. And second, equipment vendors have a tool to support the design their equipment to meet the reliability objectives without PacketCable having to specify the actual design.

5.3 Model Definitions

The PacketCable Reference Model maps to the PSTN Reference Model with the following PacketCable functional components: Subscriber Access, Managed IP, Network Signaling, PSTN Gateway, and the PSTN itself.

5.3.1 Subscriber Access

The PSTN and PacketCable models differ in the technology used in the local loop. The PSTN has a clearly defined Access Network (AN) consisting of a passive copper plant, followed by a Local Exchange (LE), which this Technical Report defines as the electronics required to manage the local loop. The combination of the AN and the LE constitutes the PSTN Subscriber Access (SA).

The PacketCable model distributes the electronics for call control between distributed network equipment and the subscriber location. To manage a comparison between the two networks, this Technical Report defines the PacketCable Subscriber Access as the combination of the CM/MTA, HFC, and CMTS/ER. This is therefore functionally equivalent to the PSTN Access Network and the Local Exchange.

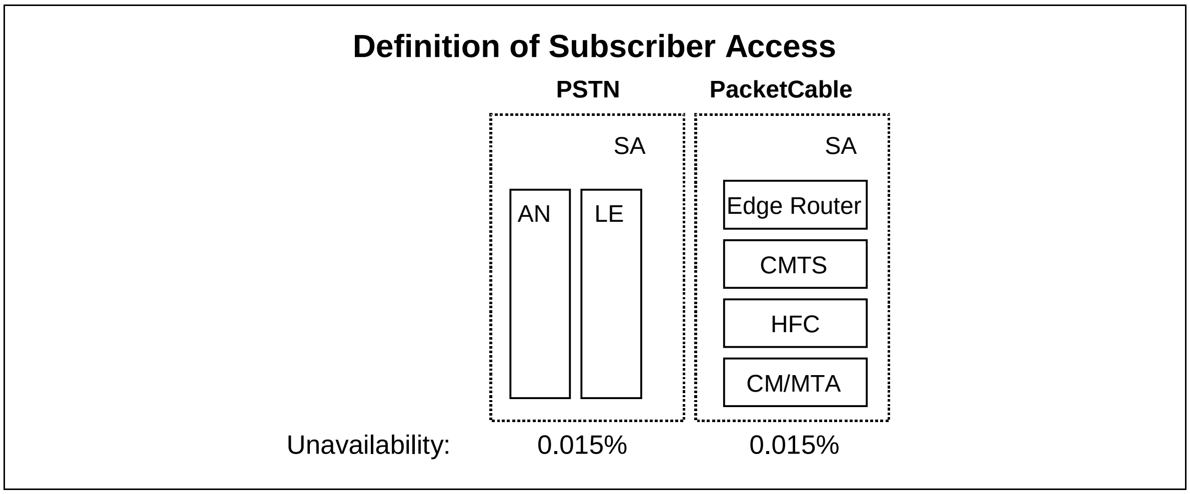

Figure 5. Definition of Subscriber Access

The PacketCable subscriber access is in some respects similar to the PSTN Fiber in the Loop (FITL) access network example. Note that both FITL and PacketCable place the POTS analog interface (i.e. the analog-to-digital conversion point) at the far end. The far end for PacketCable is the MTA and the far end for FITL is the Optical Network Unit (ONU). Thus, both PacketCable/DOCSIS and FITL are digital transport technologies. In contrast, the traditional PSTN copper loop example represents an analog transport technology in which the analog interface is at the near end (i.e., headend).

5.3.1.1 Cable Modem/Multimedia Terminal Adapter

The cable modem (CM) is a network element that is defined in the DOCSIS (Data Over Cable System Interface Specification) [7], [8]. The CM 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.

The Multimedia Terminal Adapter (MTA) may be embedded within the CM [6] or exist as a separate entity. The MTA performs the voice CODEC functions [3], and is responsible for interfacing between the POTS analog phone and the DOCSIS packet network.

5.3.1.2 HFC

PacketCable-based services are carried over the Hybrid Fiber/Coax (HFC) plant. The HFC plant 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.

As with the PSTN reference model, downtime of the power systems for the active elements within the HFC plant are not included in the availability numbers for this section of the network.

5.3.1.3 CMTS

The Cable Modem Termination System (CMTS) [7] provides data connectivity to the Cable Modems through the use of the DOCSIS protocol over the HFC plant. It also provides connectivity to IP networks. The CMTS is located at the cable television system head-end or distribution hub.

5.3.1.4 Edge Router

It is assumed that each CMTS will have a routing capability between it and the managed IP network. It is also realized that not every CMTS will have router functionality integrated into it. Thus, we have allocated a reasonable budget for the CMTS/EM (Edge Router) and have divided the budget appropriately amongst the two functional components. It can be noted that the CMTS resembles the PSTN HDT (host digital terminal, part of FITL AN, see Figure 3 3) and the downtime associated with each is the same.

5.3.2 Managed IP

Managed IP is decomposed into two functional components: Local IP and IP backbone.

5.3.2.1 Local IP

The local IP network is the "cloud" nearest the CMTS/ER which contains all the other PacketCable network elements/servers that are required. These servers, with respect to the architecture framework, are lumped into the category of OSS back office or media servers. Not all servers, at this time, are considered critical to provide a primary line service. However, from a failure recovery or operations standpoint, these servers are required. In other words, DHCP and TFTP are not only required to bring new CMs online but also to recover CMs in the event of a failure. Also included are the network elements that actually create the cloud (routers, switches, and hubs) and the facilities that connect them. These servers consist of: TFTP, RKS, DHCP, ToD, DNS, Media Servers (e.g. announcement servers, conference mixing bridges).

The Local IP network can extend across an entire metropolitan area.

5.3.2.2 IP Backbone

The IP Backbone network provides wide area coverage and interconnection between PacketCable domains.

5.3.3 Network Signaling

Network signaling is a functional component containing those elements responsible for call set-up, call supervision, and call teardown.

5.3.3.1 CMS

Call Management Server (CMS) is a term that is often used interchangeably with Call Agent (CA), especially in the protocol MGCP (Media Gateway Control Protocol). In PacketCable, the Call Agent refers to the control component of the CMS that is responsible for providing signaling services using the NCS protocol to the MTA [2].

5.3.3.2 Media Gateway Controller

The Media Gateway Controller (MGC) maintains the call state and controls the overall behavior of the PSTN gateway. This is similar to the role played by the CMS. The difference between the MGC and the CMS is that the MGC also manages the signaling to the PSTN SS7 network. [2] [5]

5.3.3.3 Signaling Gateway

The Signaling Gateway (SG) provides signaling interconnection functionality between the PSTN SS7 signaling network and PacketCable signaling network. [4]

5.3.4 PSTN Gateway

The PSTN gateway is considered very critical, at least initially, since most voice communications involving PacketCable subscribers will likely be to stations on the PSTN, as opposed to other PacketCable subscribers. The PSTN Gateway provides the bearer path connectivity between the PacketCable and the PSTN once Network Signaling has established a connection.

5.3.4.1 Media Gateway

The Media Gateway (MG) terminates the bearer paths and transcodes media between the circuit switched PSTN and the packet switched IP network. [2]

5.3.5 PSTN

The PSTN is a circuit switched network maintained by Incumbent or Competitive Local Exchange Carriers (ILECs or CLECs respectively) and LD carriers.

5.3.5.1 Local Exchange

The Local Exchange (LE) or Central Office (CO) includes all of the elements that terminate dedicated subscriber loops from outside plant in order to process and switch calls to their called destinations. For an *intra*switch call, the LE is also the terminating switch, but for an *inter*switch call, connectivity is required to another LE or to a long distance (LD) network.

5.3.5.2 Access Network

The Access Network (AN) is that portion of the PSTN from the LE to the NI at the subscriber's premises. The AN may be a passive copper loop or may include Fiber in the Loop (FITL).

5.4 PacketCable Availability Model

Now that the components of both PacketCable and the PSTN have been presented it is possible to look at the PacketCable Reference Model with attached availability numbers. This yields the PacketCable Availability Reference Model; Figure 6 6. The scenarios in Section 5 are obtained by choosing the appropriate bearer path elements and mathematically combining their unavailability numbers. The PSTN model used in this Technical Report does not include SS7 signaling. For a fair comparison, the scenarios in the Section 5.5 also do not include the PacketCable signaling path elements; CMS, MGC, or SG.

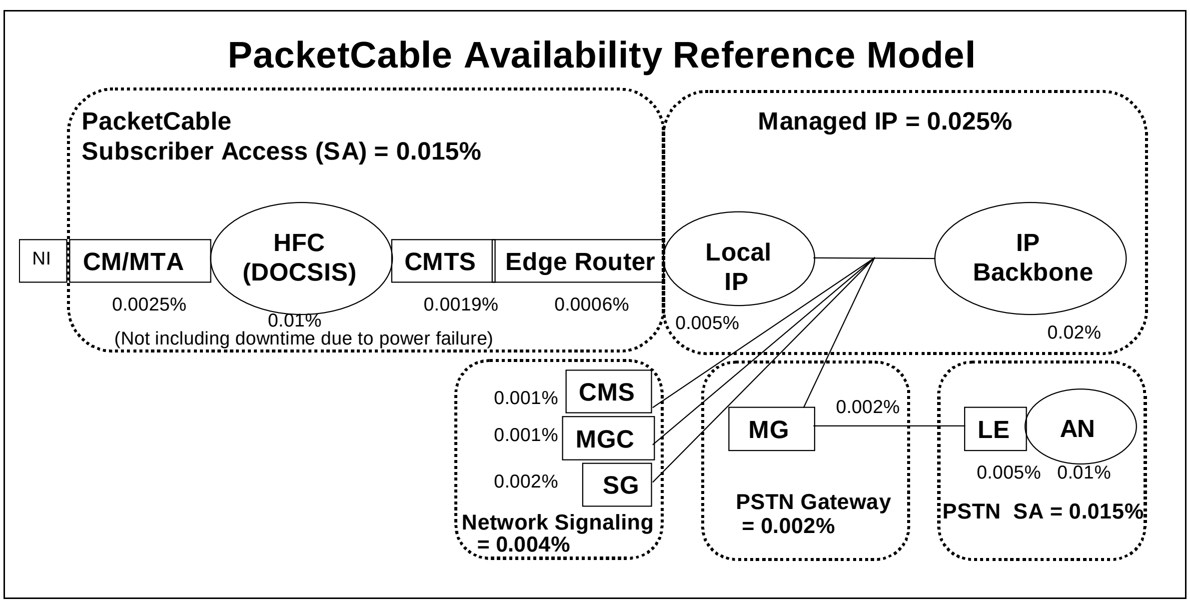

Figure 6. PacketCable Availability Model

5.5 PacketCable End-To-End Reference Model

With all of the respective PacketCable and PSTN components identified in the previous sections, a comparison of the two Reference Models can be now be made. Figure 7 below illustrates the two Reference Models using the generally accepted end-to-end availability objective of the PSTN. Each model is used to show the simple construction of an end-to-end on-net long distance call. An on-net call is defined as a communication between two endpoints or subscribers on the same network. For PacketCable, "on-net" means that the call is established end-to-end on the IP network without traversing the PSTN network at any time.

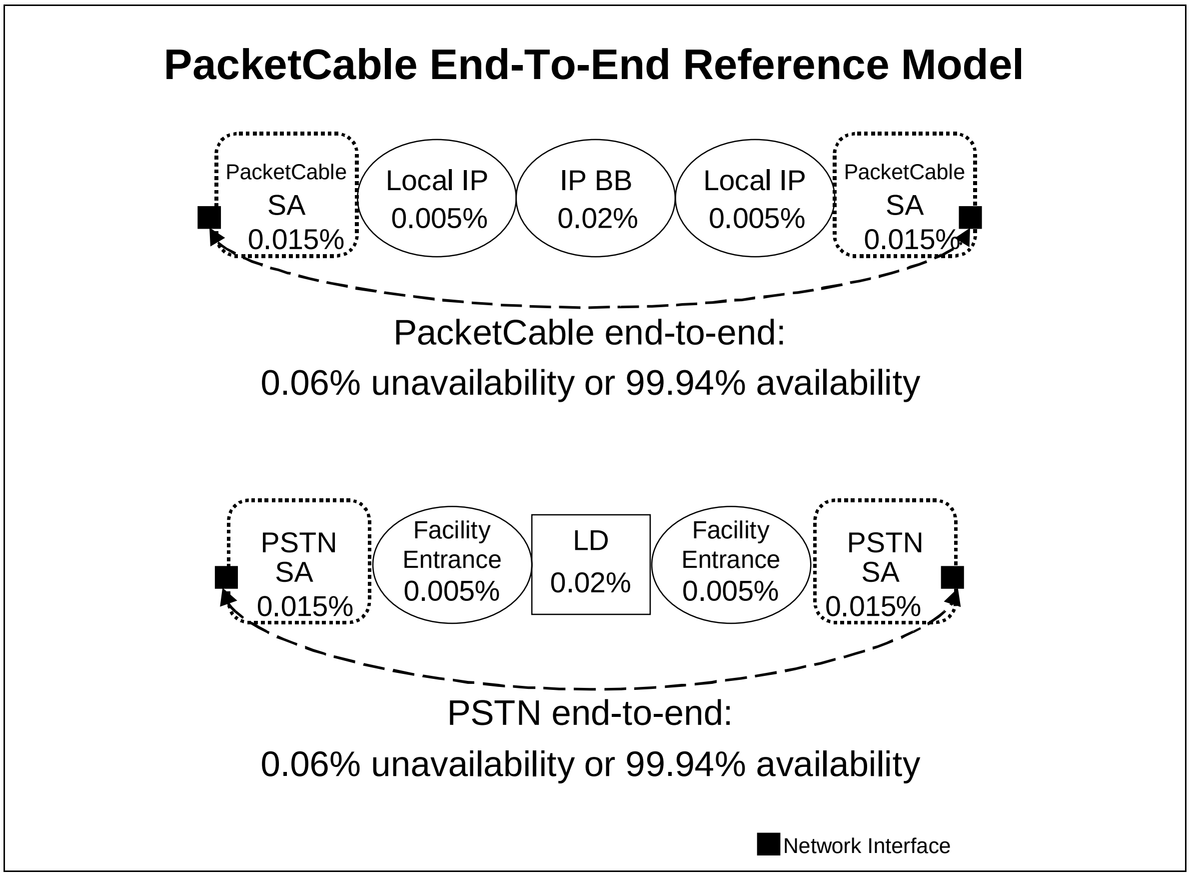

Figure 7. PacketCable End-To-End Reference Model

6 SCENARIOS

Some reasonable scenarios, from a bearer path reliability perspective, are provided below to illustrate how the model can be utilized to predict the end-to-end availability of the system under various call constructions. These scenarios show end-to-end call completion within a PacketCable network as well as to and from the PSTN.

6.1 On-Net Calls

In this section, the PacketCable availability model is applied to two common on-net call scenarios: local on-net call – Single-zone, and local on-net call – Multi-Zone.

A PacketCable Zone is defined as the set of customer premise equipment controlled by a single CMS.

6.1.1 Scenario 1: Local On-net – Single Zone

Scenario 1 illustrates a local on-net call between two subscribers serviced by the same Call Management Server (CMS) (e.g., a call between two neighbors). A Single Zone on-net call is analogous to the PSTN local intra-switch call where both subscribers are served by the same Class 5 switch.

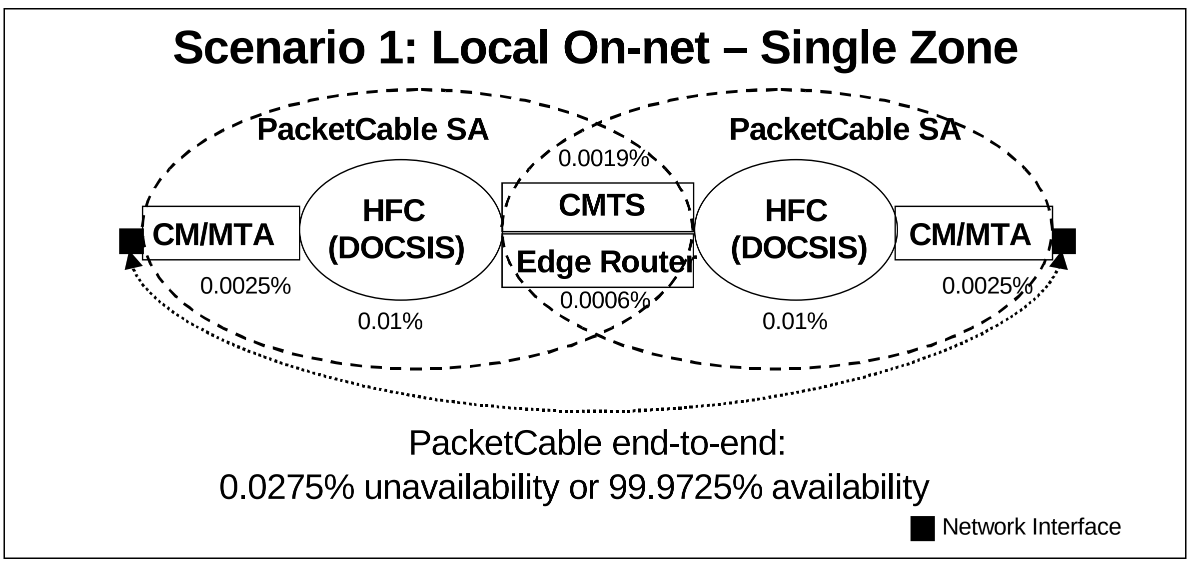

Figure 8. Scenario 1: Local On-net Single Zone Availability

6.1.2 Scenario 2: Local On-net Call – Multi-zone

This scenario illustrates a local on-net call between two subscribers serviced by different Call Management Servers. A Multi-zone on-net call is analogous to the

PSTN local inter-switch call where each subscriber is serviced by a separate Class 5 switch.

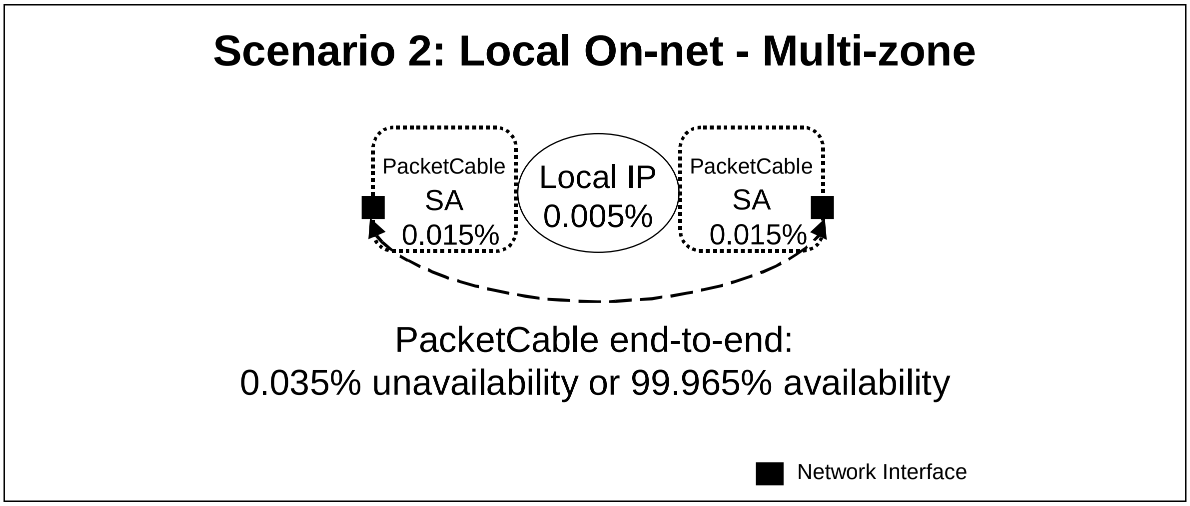

Figure 9. Scenario 2: Local On-net Multi-zone Availability

6.2 Off-Net Calls

This section presents three off-net call scenarios. An off-net call is defined as a call between an endpoint on a PacketCable network and an endpoint on the PSTN.

6.2.1 Scenario 3: Local Off-net Call

This scenario illustrates a local call in which one subscriber is a PacketCable customer and the other subscriber is a PSTN customer. The scenario illustrates a call where the calling and called parties are served by a single CMS and Class 5 switch.

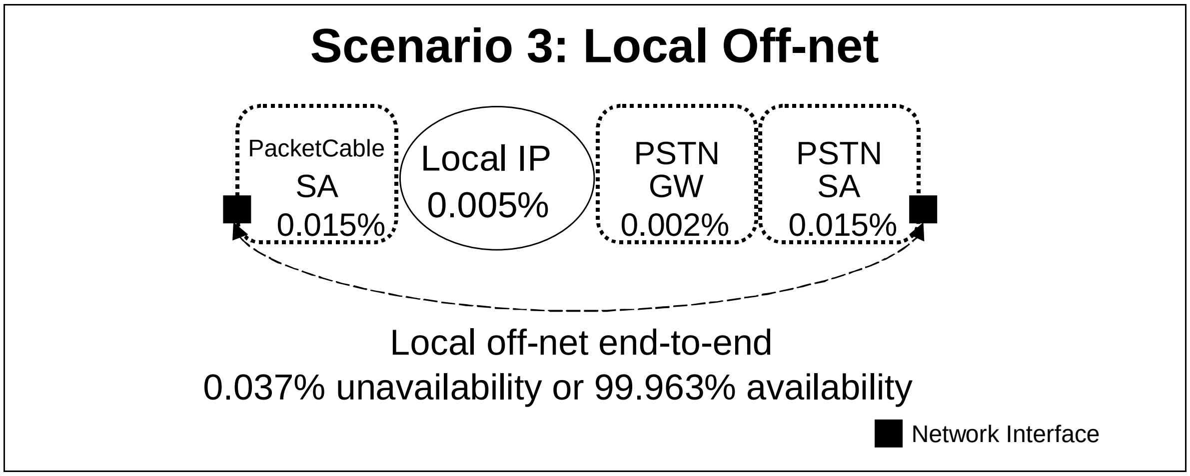

Figure 10. Scenario 3: Local Off-net Availability

6.2.2 Scenario 4: Long Distance Off-net Call – IP Transport

This scenario illustrates a typical long distance call from a PacketCable endpoint to a PSTN endpoint. For this scenario, long-distance transport is provided by the IP backbone network. It is assumed that the PSTN gateway is served by a local CMS which is separate from the originating CMS.

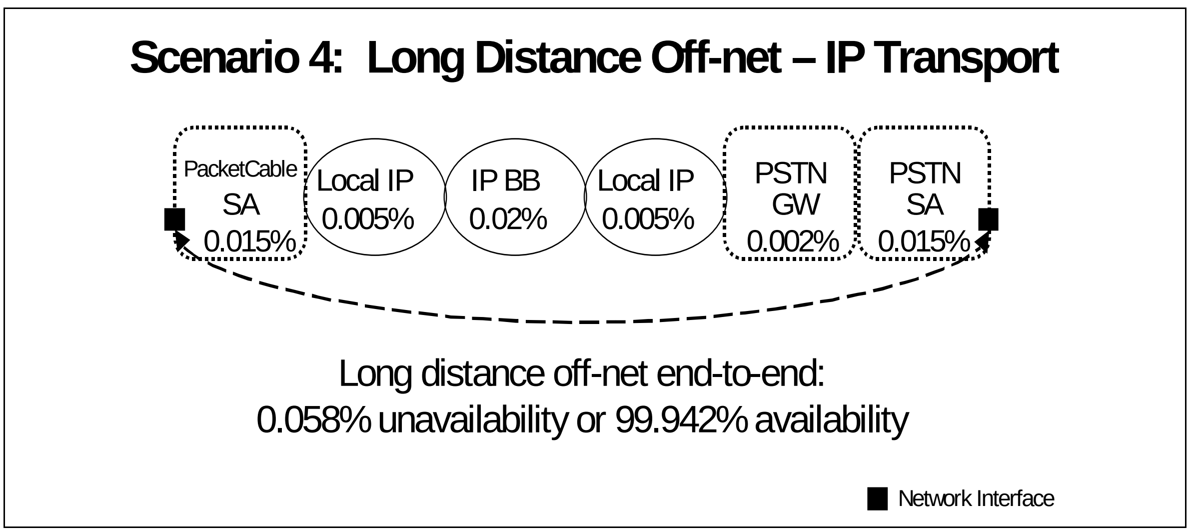

Figure 11. Scenario 4: Long Distance Off-net Availability – IP Transport

6.2.3 Scenario 5: Long Distance Off-net Call – PSTN Transport

This scenario also illustrates a typical long distance call from a PacketCable endpoint to a PSTN endpoint. This scenario differs from Scenario 4 in that the long distance transport is now provided by the PSTN long distance network as opposed to an IP backbone.

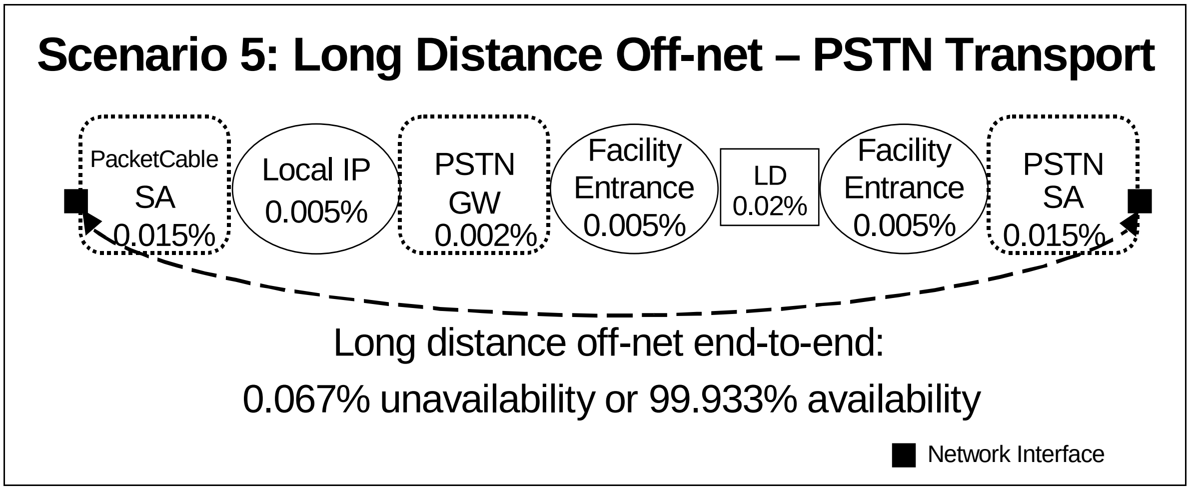

Figure 12. Scenario 5: Long Distance Off-net Availability – PSTN Transport

APPENDIX A. Acknowledgements

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