Comments on the Technical Ability to Implement Open Access Provisioning via High-Speed Data over Hybrid Fiber-Coaxial Cable Television Systems in the United States

Prepared for the White House National Economic Council

by

Mark Laubach
Mountain View, CA 94040
laubach@ricochet.net

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1 Introduction

This white paper addresses the technical aspects of the question: *What would be the level of pain felt by the United States cable industry if the government were to mandate open access for high-speed data broadband residential access cable television networks?*. In this context *pain* is directly related to actual or perceived lost money, revenues, or resources needed to implement open access given the state of today's broadband cable modem deployments.

This paper attempts to stay close to technical viewpoints surrounding broadband residential access systems in general, with specific focus on cable television networks. It is not the intent of this paper to recommend policy, nor will it do diligence in assessing direct impact to the economics or business models of broadband access service providers or cable modem vendors. Any cost discussions are related to technical deployment and/or support costs.

2 Executive Summary

The U.S. Cable Industry, the DOCSIS standards it produced, and the compliant products produced by vendors, are not prepared to implement open access provisioning for high-speed data broadband access over cable television networks.

After securing cable industry commitment, at most three years lead time is needed to produce open access ready DOCSIS-based cable modem products due to standards enhancement, vendor development, and successful certification of multiple vendors' products. For example, if U.S. policy were established that mandated open access provisioning by early year 2003, the U.S. cable industry would need to motivated and commit to begin standards enhancement in early year 2000.

To deploy and enable open access provisioning, there would be substantial technical costs associated with updating and/or replacing previously deployed subscriber cable modems, updating or replacing CATV head-end high-speed data equipment, and enhancing cable operator backend networks and support services for multiple service provider access.

This white paper presents a technical summary only and needs to be substantiated by a business and financial impact study.

3 Overview

- Open access provisioning is technically possible in all high-speed data broadband residential and commercial access networks:
  - Cable television is not enabled and open access is difficult due to historical issues.
  - Digital Subscriber Loop is enabled and exploiting open access provisioning now.
  - Metropolitan Area Wireless services (e.g. MMDS) have no standard at this time and without guidance will repeat cable television issues.
  - Broadband satellite systems have some open access capabilities.
- An open access mandate aimed at short-term (less than three years) availability would generate great technical pain for the U.S. cable industry.
- To date, CableLabs and its member cable operators have not viewed open access as necessary, hence there is no vendor support planned in customer premise or head end equipment in the foreseeable future.
- The initial release of the North American Data Over Cable Service Interface Specification (DOCSIS) Radio Frequency Interface (RFI) (Version 1.0) specification for cable modems does not directly support open access. The subsequent release (DOCSIS RFI Version 1.1) does provide lower layer protocol enhancements that can be used for a version of open access provisioning, however no attention has been paid to open access provisioning in the development of the specifications.
- Due to the delays in achieving widespread DOCSIS RFI Version 1.0 roll out, the industry will move rapidly to deploy Version 1.1. It is expected that the majority of the deployments towards at the end of 1999 and early 2000 will be either Version 1.1 certified or Version 1.0 certified with capability of being software upgraded to Version 1.1. Non-upgradeable Version 1.0 cable modems would continue to operate in Version 1.0 mode.
- The facilities provided by DOCSIS RFI Version 1.1 could be used to implement ideal open access provisioning for cable television networks. However, implementation requirements contained with the RFI specification and other DOCSIS specifications would need to be appropriately updated to document which facilities should be engaged for the open access system: e.g. choice of IEEE 802.1p versus ATM. Previously deployed Version 1.0 cable modems could not participate and would need to be replaced, where open access is needed. Previously deployed Version 1.1 cable modems may lack software or hardware capabilities needed to achieve open access provisioning with a software upgrade hence, they would need to be replaced where open access is needed. It is also likely that head end Cable Modem Termination Systems (CMTS's) would need to undergo partial hardware upgrade or complete replacement where open access is needed, even to support one open access provisioned cable modem. It would be possible for an Open Access CMTS to support Open Access modems as well as legacy non-open access modems.

4 Ideal Open Access Definition

For the purposes of this white paper, ideal open access provisioning for high-speed data broadband access networks is defined by a set of ideal technical requirements. For these requirements, *subscriber* refers to the residential or commercial end user who is receiving a *service* (e.g. Internet service, IP dial tone service, packet voice service, packet video service, etc.) which is delivered over the broadband access network; *service provider* refers to the organization or business which is supplying one or more services to the subscriber; and *broadband access provider* is the owner or operator of the broadband access network *last mile* facilities to which subscribers are connected and through which services are exchanged between the subscriber and the service provider. The broadband last mile facilities could be a Digital Subscriber Loop (DSL), a CATV plant (concentric pair), a Fiber-To-The-Curb (FTTC) plant, a wireless network, a satellite network, and in some cases combinations of these access methods.

The requirements are labeled as R1 through R12 for reference later in the paper:

- R1:*Provider Selection*: In the United States, the technical delivery of a high-speed data broadband access facility to a residential home or commercial site allows the subscriber to be provisioned to the service provider of their choice, selected from a set of service providers. For example: high-speed data (i.e. Internet) access and potentially separately for packet voice service provider(s) access. The number of service providers in this set may be from several to upwards of several hundred.
- R2:*Multiple Providers*: Extends R1a to support multiple service providers selected from a set of service providers and the broadband access device (e.g. cable modem) and facility would allow a subscriber to be served by multiple providers. For example, the work IP service provider for in home telecommuting, simultaneously with an Internet service provider for private non-work related Internet access, and a packet voice provider for voice services, with potential of a different service provider for each enabled phone service.
- R3: *Ability to Provide*: A service provider is technically able to offer service to their customer via any high-speed data broadband access network that reaches that customer. Actual delivery of services will be dependent on a number of factors including backend network access, access network physical deployment issues, tariffs, quality of service needs, franchise rights, settlement fees, etc.
- R4: *Bandwidth Allocation*: The broadband access network should support service contracts and provide reserved individual or aggregate data rate to a subscriber or service provider. The allocated bandwidth may be statically provisioned or changed dynamically through signaling with the subscriber or service provider. The broadband access network system should support a range of data rate allocations that may be *contracted* between the service provider and the subscriber. For example, Internet data access may offer a *best effort* service with contracted minimum and maximum data rate delivery and/or delay agreements: e.g. 386 Kbps or 1.5 Mbps full duplex Internet data service with or without a Committed Information Rate (CIR)
- R5: *Quality of Service*: The broadband access network should support specific Quality of Service (QoS) attributes for specific services (e.g. delay, jitter, and error rate) which meet the subscriber's needs of that service. For example, a 64 Kbps constant bit rate with low delay and jitter per *off hook* packet voice connection while the call is in progress, etc. The Quality of Service required could be statically provisioned or may be changed and negotiated dynamically through signaling with the subscriber or service provider.
- R6: *Subscriber Containment*: The broadband access network must contain and limit abusive subscribers: a subscriber in one service should not be able to abuse their services so as to interfere with the services being provided to another subscriber in the same or different ser-

vice; e.g., a large file transfer by one cable modem user should not interfere with the voice call from another cable modem user.

- R7: *Provider Containment*: The broadband access network must contain and limit abusive service providers; a service provider should not be able to abuse their services so as to interfere with other services or subscribers of other services.
- R8: *Link Privacy*: In the case of shared media or publicly propagated media, high-speed broadband access networks (e.g. cable television, wireless), communications over that media exchanged between the subscriber premise equipment and the head-end, must employ cryptographic techniques at the data link layer to provide a high degree of privacy for individual subscriber communications. Note this is link privacy only to dissuade promiscuous observation by other parties connected to the same shared media, this is not an end-to-end cryptographic solution.
- R9:User *Content Preservation*: User information contained in packets and packet headers exchanged between the subscriber's premise and the service provider are not altered by the broadband access network or the back end network, except as defined by protocol standards and standards of operation of Internet gateways and routers.
- R10: *Provider Address Management*: The addresses used by the service (e.g. IP addresses for Internet, phone numbers for packet voice, etc.) are managed by the service provider and not by the broadband access network provider.
- R11: *Provider Subscriber Management*: The service provider is able to manage their service to the demarcation point associated with the customer premise equipment. For example, the Internet Service Provider (ISP) can manage their service delivery through the broadband access network to the cable modem and be able to troubleshoot to the cable modem Ethernet interface; or a Competitive Local Exchange Carrier (CLEC) can manage a voice over cable service to the RJ11 jack in the cable modem.
- R12:*IP Dial Tone Service*: The subscriber has the option of obtaining unblocked unrestricted IP packet exchange for any packet submitted to and/or received from the access network according to IP protocol standards and Internet standards for routers and gateways. That is, broadband access network and broadband service provider will not block and/or alter IP packets except according to IP routing standards. The subscriber may be subject to contracted bandwidth allocation restrictions and admission control policies for Quality of Service. It should be noted that most subscribers will want to take advantage of the services and content provided by the cable operator and/or their ISP; e.g. residential subscribers seeking turn key email, web based content, etc. However, some subscribers will want a plain IP connection (IP Dial Tone) without additional services and features; e.g. sophisticated subscribers, small businesses, larger commercial establishments, etc.

Note that it is possible to run versions of open access provisioning with less than this ideal set of requirements.

These ideal requirements do not represent a consensus of definitions used by today's open access providers, nor are they meant to convey an official definition in use by the government or any regulatory agency. They are used here to illuminate and support comparisons of different open access provisioning methods that are discussed within this paper.

5 Summaries of Broadband Access Technologies

5.1 Digital Subscriber Line

The varieties of broadband access via Digital Subscriber Line (ADSL, SDSL, G.lite ADSL, etc.) all technically support close to if not the ideal open access system. Today's DSL deployments are more or less following the specifications set forth by the ADSL Forum; that is, they are following a standard. The basis for DSL open access support is Asynchronous Transfer Mode (ATM) networking between the subscriber premises equipment and the service provider. ATM virtual circuits are straightforwardly provisioned from the ADSL modem via the broadband access network provider, through the central office and the access network and backend networks, to the service provider. The architecture of DSL and developed technology supports open access from initial deployment.

5.2 Fiber to the Curb

Over the past decade there has been significant development of Fiber-To-The-Curb (FTTC) technologies for the delivery of voice, video, and data services to subscribers. Deployment of this broadband access technology has slowed from initial predictions. It is likely that efforts will renew after deployment of DSL has reach sufficient penetration. Motivation for moving to FTTC solutions include the timely replacement of aging twister pair copper plant, and the need to push more last-mile access bandwidth closer to the subscriber. FTTC architectures are capable of support ideal open access provisioning.

5.3 Metropolitan Area Wireless

The deployment of high-speed data for Internet access over wireless systems (e.g. MMDS) has been undergoing a substantial amount of churn in the past several years. At this time, both the market demands, service providers, and the technology appear to be better aligned for the next attempt to grow the market. The high-speed data over broadband wireless access network environment has no standard at this point in time. There are rumors that several companies will enter the market in the near future with adapted systems using the DOCSIS RFI Media Access Control (MAC) protocol. In contrast, Com21 is investigating entering the market with a wireless version of its CommUNITY ATM based system. Hybrid Networks has been in the market for a several years, has ridden the ups and downs, but does not appear to have an ideal open access solution. In the absence of public or defacto standards and policy, the politics may select a DOCSIS based system thereby inheriting the same lack of support for open access provisioning as the cable television specification. There is short and shrinking window in which to persuade the wireless market to adopt a more ideal open access posture.

5.4 Broadband Satellite

The deployment of high-speed Internet services via satellite transmission systems has some active deployments to date. It is expected that there will be an increasing number of satellite based deployments over the next several years, including changes in deployment architectures. DirectPC is an example of a satellite-based Internet service for personal computers. Initial satellite deployments provide chiefly and high-speed one-way downstream service (provider to subscriber), using a terrestrial return path. Newer deployments will make use of two-way transmissions. Due to propagation delays and bandwidth per transponder, there will be varying degrees of scale. It may be possible for satellite systems to support ideal open access provisioning, however more study is needed in this area.

5.5 Cable Television

Today's DOCSIS specifications come from a project which was initiated from a group called MCNS: Multimedia Cable Network System Partners Limited: TCI, Time Warner, Cox, Comcast, with addition partners: Continental, Rogers, and CableLabs helping out. They set forth to rapidly develop the Data Over Cable Service Interface Specification: (DOCSIS) project, on behalf of the North American cable industry, the necessary set of communications and operations support interface specifications for cable modems and associated equipment. The specifications are intended to be non-vendor-specific, allowing cross-manufacturer compatibility for high-speed data communications services over two-way hybrid fiber-coax (HFC) cable television systems.

MCNS/DOCSIS was triggered by John Malone in December, 1995 in response to broadband access competition, vendor postures, and lack of progress in public standards process taking place in the IEEE 802 LAN/MAN committee. The DOCSIS specification was born out of an initially very closed development effort by the MCNS six cable companies and selected vendors (BayNetworks/LANCity - now Nortel, GI, Broadcom) with CableLabs helping in the process management. Many vendors are participating now in a Non-Disclosure Agreement (NDA) fashion. Once completed, DOCSIS specifications are made publicly available via www.cablemodem.com. CableLabs maintains a strict revision and control process for updates to the specifications.

The DOCSIS project is actually a family of coordinated specifications dealing with many aspects of a cable modem access system. The most well known specification is the Radio Frequency Interface (RFI) specification. The RFI specification is usually referred to as the DOCSIS Specification, DOCSIS Version 1.0 or DOCSIS Version 1.1. DOCSIS RFI Version 1.0 was adopted by the Society of Cable Telecommunications Engineers (SCTE) Data Standards Subcommittee (DSS) as their standard in July 1997. Subsequently, the SCTE selection was adopted as the U.S. position into the ITU J.112 recommendation starting in the fall of 1997.

The DOCSIS RFI specification is based technically on an evolved LANCity based protocol with the target having the qualities of: residential, low-cost, off the shelf, Internet access, interoperable (base functions) with vendor differentiation. The architecture of the DOCSIS system is a single large Ethernet-based bridged LAN. DOCSIS has a single ISP service provider architecture. Version 1.0 is primarily a *best effort* Internet access system. Version 1.1 adds protocol support and sufficient operation detail to provide dynamic Quality of Service facilities for packet voice services in addition to packet data services. There are other enhancements such as base line privacy, multicast support, etc. In addition, Version 1.1 has packet recognition support for IEEE 802.1p tagged Ethernet frames. The tagging supports both Priority tagging as well as Virtual LAN (VLAN) tagging.

Today, CableLabs is running an impressive vendor certification process for cable modems. The current focus is on DOCSIS V1.0. Several vendors have just been recently certified. The acceptance of DOCSIS in the cable operator community is predicated on sufficient vendors being certified and product being available. DOCSIS V1.0 was originally predicted to begin large roll out in Fall 1998, however delays with vendors and the certification process itself has pushed that out at least nine months. Summer 1999 should see the beginning of wide spread roll out in North America of Version 1.0 modems. The first release of the DOCSIS Version 1.1 specification became available in March 1999. It is expected that vendors will move rapidly to DOCSIS Version 1.1

capable hardware and software. DOCSIS Version 1.1 certification is dependent on CableLabs's efforts. Note that DOCSIS Version 1.1 certification requires DOCSIS Version 1.0 certification; Version 1.1 is in addition to Version 1.0 operation, not a replacement for Version 1.0 operation. Version 1.1 is fully backward compatible to Version 1.0. Subscribers who purchase Version 1.1 cable modems can enjoy DOCSIS service anywhere provided, with Version 1.1 services supported only on those systems which are enable for Version 1.1.

There is another DOCSIS RFI project effort underway called Version 1.2, which adds the support for high performance upstream physical RF channels. Version 1.2 is being developed in conjunction with the efforts of the IEEE 802.14 Hi Performance Physical working group. Version 1.2 cable modems will need to be separately certified for Version 1.0, Version 1.1 and Version 1.2 operation. As Version 1.2 is only a physical RF channel improvement addition to Version 1.1; all issues relating to open access provisioning for Version 1.1 will apply equally to Version 1.2.

NOTE: prior to DOCSIS being widely available, there are a number of proprietary cable modem systems being deployed in the United States. The vendors include 3Com, ADC, Com21, Hybrid Networks, LANCity (became Bay Networks, now Nortel), Motorola, Phasecom, Terayon, Zenith, and others. Of these, Motorola, LANCity (now Nortel), Com21, and Terayon are the most deployed. The number of cable modems deployed in North America is on the order of several hundred thousand. Of these vendors, the Com21 system is the only one that directly supports open access provisioning by use of direct Layer 2 Virtual LAN support and ATM networking (similar to DSL), which more or less gets close to providing the ideal open access system. At this time, there are cable *overbuilders* (e.g. Knology, south east U.S.) who are using Layer 3 approaches (enumerated later in this paper) to provide less than ideal, but workable, open access provisioning.

6 Focus on DOCSIS RFI

This section discusses open access provisioning techniques using DOCSIS RFI based cable modem systems. The arrangement of this section is based on the ISO networking layer, starting with the physical RF layer up through applications.

6.1 Open Access: Layer 1 - Physical

In the DOCSIS RFI world, the physical layer of the networking stack is provided using RF channels that operate within the RF spectral bandwidth of a cable television network.

In the downstream direction (head end transmitter to subscriber receiver) the RF channels are compatible with existing analog modulated television channels. The high-speed data channels are digitally modulated, are 6 MHz wide, and have a raw data carry capacity of approximately 30 Mbps using 64 Quadrature Area Modulation (64 QAM) (with an option to use 40 Mbps using 256 QAM modulation in CATV plants that have a cleaner downstream noise environment). A high-speed digital data channel uses the same digital modulation standard as used for digital television; i.e. MPEG encoding. However, the lower layer of MPEG, called the MPEG Transport Stream allows for the digital data to be typed; video has one type, DOCSIS data has another type. The amount of available downstream RF spectrum available to all services (analog video, digital video, data, and others) varies from system to system and cable operator to cable operator. There is no one standard configuration or topology that is followed. In modern systems, we typically see new deployments and upgraded system support roughly 750 MHz to 860 MHz of downstream spectrum, which in turn is subdivided into 6 MHz television channels. Some cable plants are already at capacity for television distribution, leaving at most one channel available for digital data. In the best cases, one or two digital data channels can live in the *roll off* region at the high end of the plant's operating bandwidth. Digital data is less sensitive in the roll off and can provide viable service. However, there is precious little available room on *at capacity* plants. Some cable operators have many tens of MHz available in the downstream and could potentially support multiple downstream high-speed data RF channels however, this ability is not universal.

In the upstream direction (subscriber transmitter to head-end receiver), the allocated spectrum is from 5 MHz to 42 MHz (sometimes less than 42 MHz). The selection of 5 to 42 MHz is fraught with many problems due to ingress noise impairments from outside of the cable plant. Unfortunately, this RF spectrum is *dirty* noise wise, and presents a somewhat arduous environment for digitally modulated signals. As such, a little less than 1/2 the band is mostly unusable (except on very clean cable plants), leaving about 15-18 MHz of spectrum for signals. Due to the inherent noise environment, the type of modulation used for upstream communications is *less dense* for robustness reasons. In addition, RF channels are smaller in spectral width. In DOCSIS, an upstream data channel RF spectral width can be anywhere from 200 kHz to 3.2 MHz depending on configuration. This configuration is done at deployment time. In terms of data carrying capacity, a DOCSIS Version 1.0 and Version 1.1 channel will operate at approximately either 2.5 Mbps raw or 5.0 Mbps raw on most plants. In "cleaner" plants, the upstream capacity can be doubled per channel with a maximum of 10 Mbps in 3.2 MHz.

Note that the available RF spectrum in cable plants is highly asymmetric, with potentially up to ten times more bandwidth in the downstream direction. This has the unfortunate effect of running out of upstream bandwidth for high-speed data services before exhausting potential downstream bandwidth for high-speed data channels.

When a DOCSIS Cable Modem Termination System (CMTS) is installed in a head-end, one downstream channel is configured, along with one or more upstream channels. Specific configurations, number of channels, and placement of RF channels is done at installation time.

Open access at Layer 1 means that for each service provider wanting access to the cable network, a separate CMTS and set of downstream and upstream RF channels must be allocated to that service provider. This approach does not work because: 1) there is insufficient RF bandwidth downstream or upstream to create a single high-speed data service let alone multiple, for varying numbers of providers; 2) by FCC regulations cable operators must control (operate) and manage all RF transmitters attached to the cable plant so that the plant does not inadvertently radiate unwanted signals into the community. This means that all CMTS devices must be managed and operated by the cable operator. The CMTS design and requirements do not easily permit the CMTS's operation to be completely divorced from the service provider using the equipment.

Observation:

- Open access at Layer 1 is not workable.

6.2 Open Access: Layer 2 - Data Link / Media Access Control Protocol

Layer 2 is called the Data Link layer and supports a variety of data link protocols: Ethernet and the DOCSIS MAC are in this layer[1]. In DOCSIS RFI Version 1.0 this layer provides an Ethernet frame based access protocol, mediated by the DOCSIS MAC. The architectural approach used

1. In comparison, in DSL services ATM also lives at this layer.

between the CMTS and all the cable modems is that of a single large Ethernet based LAN. That is a switched/bridged large Ethernet address space supporting a single broadcast domain. In addition, the bandwidth management practice of DOCSIS Version 1.0 systems is that of a best effort system. There is little to no bandwidth allocation management, except by vendor initiative. There is no real QoS management to differentiate services; e.g. packet data from packet voice.

DOCSIS Version 1.1 adds several important elements which can be used as foundations for open access (although open access did not drive their existence): packet classification, QoS support, multiple queues/services per cable modem, better support for multicast, and recognition of IEEE 802.1/p frame tagging: Virtual LAN (VLAN) tag and a priority tag. DOCSIS V1.1 efforts are focused on supporting packet voice with packet data services.

DOCSIS Version 1.0 provides for an ATM cell as a MAC data packet type however, neither V1.0 or V1.1 make use of ATM cells nor is there any requirements presented in the specifications beyond support the packet type flag. The DOCSIS RFI was not designed to support ATM service classes; combinations of bandwidth manager and QoS control (delay, jitter, cell loss). In addition, there is no support for any services over ATM, for example, Ethernet or Point-to-Point Protocol (PPP) over ATM. The use of the ATM packet type and the limited support was left for a placeholder for the future. There is no apparent support by any vendor for ATM.

Review of the ideal open access requirements and their support by the DOCSIS RFI specification:

R1: *Provider Selection*: Multiplexing through the Layer 2 space would allow multiple service providers access via shared downstream and upstream data channels. The multiplexing ability at Layer 2 is limited and can only be accomplished using the IEEE 802.1p VLAN tagging or by exploiting the enhanced multiplexing of ATM. DOCSIS Version 1.1 recognizes the IEEE 802.1p tagging but, omits any specifications or requirements for support the VLAN operations in the cable modem or the CMTS. To date, there has been some interest in exploiting only the priority tag field that is part of IEEE 802.1p to aid in packet classification and QoS support. Therefore, initial DOCSIS V1.1 cable modems will not support VLAN tag processing as a standard. VLAN tagging support would allow an Ethernet frame to be tagged and switched accordingly. This has exploitation potential of creating either a VLAN per service provider, with all common cable modems sharing the same tag, or for creating an ATM virtual circuit equivalent in the Ethernet frame allowing cable modems to directly/receive frames from a single provider. Note that the IEEE 802.1p VLAN tagging support up to 2048 values, which presents aggregation, scaling, provisioning, and labeling challenges when put into practical use. Efficient processing of Ethernet frame tagging may require hardware enhancements for acceptable packet throughput performance. Leveraging DOCSIS ATM cell transport support would remedy the multiplexing scale issue to be equivalent with DSL multiplexing capability. As mentioned, there are no requirements in DOCSIS for any services over ATM transport, leaving it vendor dependent at this time.

R2:*Multiple Providers*: The DOCSIS architecture is a single provider service at Layer 2. With IEEE 802.1p extensions, it would be possible to extend to multiple service providers, but that would likely exhaust the VLAN tagging space quickly. Leveraging DOCSIS ATM cell transport support would remedy this but again, there is no requirements support in DOCSIS for any services over the ATM transport, leaving it vendor dependent at this time.

R3: *Ability to Provide*: The DOCSIS CMTS would need to be able to provision and switch based on a Layer 2 tag between its WAN interface and all the cable modems the CMTS supports (1K to 3K cable modems). Service providers could be connected to individual subscriber cable modems or connected to groups of cable modems within the limits of the IEEE 802.1p tagging. However, given the 2K VLAN tag identifier space, the service providers equipment would need to be collocated near a CMTS if the number of subscribers for that provider gets large. An ATM based approached provides more multiplexing address space and would allow service providers to be connected with individual subscribers in just about any configuration. There have been no requirements for CMTS's to support tagging or ATM for service provider separation.

R4 through R7:*Bandwidth Allocation, Quality of Service, Subscriber Containment, and Provider Containment*: The additional facilities in DOCSIS Version 1.1 support these needs from a Layer 2 protocol and management standpoint. Actual support would vary with different vendor implementations.

R8: *Link Privacy*: DOCSIS supports link encryption.

R9: *Content Preservation*: In DOCSIS RFI V1.0 and V1.1, Ethernet frames (Layer 2 packets) are not altered by the DOCSIS MAC in exchanges between the cable modem and the CMTS. If the cable modem or the CMTS embody a Layer 3 IP routing facility (or similar facility) based on vendor value added the Ethernet frames exchanged will be altered or discarded but the Ethernet data, the user data contained within the Ethernet packet is not altered. This data is typically an IP packet. These operations are normal for Ethernet switches and IP routers. The subscriber data contained within the IP packet is unaltered, however the IP packet header may undergo expected changes as per IP standards and standards for routers and gateways. With the Layer 2 Ethernet tagging approach, IEEE 802.1p allows for Ethernet headers to be extended with tagging information. The operation of inserting, altering, or removing a tag would change the subscribers Ethernet packet, but would do so according to standards. With a Layer 2 ATM approach, the Ethernet packet could be exchanged unaltered between the subscribers cable modem and the service provider. Note that there are many variations of approaches for Layer 2 multiplexing. Some of which would preserve the subscriber's Layer 2 packet completely, others that would modify the packet according to defined standards and procedures. In either scenario with Layer 2 processing, the subscriber's IP packet would remain unaltered.

R10:*Provider Address Management*: For Layer 2 Ethernet addresses, the standards dictate that the vendor build a MAC hardware address into each Ethernet controller. Service providers do not manage or administrate Layer 2 Ethernet addresses. Internet Protocols have been designed for vendor assignment of Layer 2 Ethernet addresses. ATM addresses, e.g. Virtual Path Identifiers (VPI's) and Virtual Circuit Identifiers (VCI's) are managed over each segment of the ATM path; e.g. between ATM switches. ATM addressing does not require that a service provider be in control of all VPI/VCI assignments between it and the subscriber - only that there is an end-to-end connection established between subscriber and provider.

R11:*Provider Subscriber Management*: There are no provisions in the DOCSIS architecture for the cable modem Layer 2 service to be managed by anyone other than the single ISP.

R12:*IP Dial Tone Servic*e: IP dial tone is independent of Layer 2 service.

Observations:

- DOCSIS Version 1.0 cable modems do not provide sufficient support for ideal open access provisioning at Layer 2.
- DOCSIS Version 1.1 does provide additional support that can be exploited for ideal open access at Layer 2 provided that the specification is expanded and enhanced. It is not clear that

Layer 2 Ethernet tagging solutions would scale as needed to support numerous service providers and numerous subscribers. ATM cell transport is the most flexible method, as demonstrated by DSL services, however, while ATM cell transport is provided in DOCSIS, there is no support for ATM networking, defined services, nor specifications and requirements at this time for its use. In addition, DOCSIS was not optimized for ATM networking. The issues at the CMTS are unexplored at this time. Without specification support, specific functions would be vendor dependent.

- DOCSIS Version 1.1 modems deployed prior to open access support may need to be replaced; i.e. they may not be simply software upgrade-able to an open access modem
- It would be possible for an open access Ethernet tag processing CMTS to simultaneously support open access enabled and non-open access modems. The caveat being that the non-enabled modems could continue to interoperate only with the incumbent Layer 2 provider.

6.3 Open Access: Layer 3 - Network: Internet Protocol Techniques

Layer 3 is the called the Networking Layer and supports the Internet Protocol (IP) and the Address Resolution Protocol (ARP). The DOCSIS RFI system has been optimized for the transport of IP packets. DOCSIS is principally a Layer 1 and Layer 2 service. The specifications call for rich assortment of Ethernet, IP, TCP and UDP packet filtering, making the DOCSIS cable modem *aware* of Layer 3 and Layer 4 packets. In DOCSIS RFI V1.0, these filters are used principally to provision a given cable modem for packet *access rights* into the network. DOCSIS RFI V1.1 adds additional filtering, including packet classification filters that are essential for QoS support. The cable operator and/or service provider control these filters in each cable modem.

Said differently, a DOCSIS RFI V1.0 and V1.1 cable modem is a Layer 2 switched Ethernet service with Layer 3 and Layer 4 packet filtering awareness. The specification stops here however, different vendors will augment their cable modem's functionality with one or more Layer 3 services, such as IP routing, specialized routing, tunneling, Virtual Private Networking (VPN), Point to Point Protocol (PPP), and applications services, such as Voice over IP (VoIP).

Recall that the DOCSIS RFI creates a switched Ethernet service supporting a single Ethernet segment at Layer 2 and essentially a single large IP subnetwork at Layer 3 with a single provider administrating IP addresses. There are no facilities in the specifications for providing open access provisioning; i.e. multiple Ethernet segments, multiple IP subnetworks, or multiple address administration. There are Layer 3 open access solutions that have varying degrees of meeting the ideal requirements. Some of these solutions are already being used by a few operators to provide open access support. There are two general classes of Layer 3 solutions: specialized IP routing (forwarding) and tunneling.

Specialized IP routing encompasses known techniques such as source-address based routing, proxy ARP, and others. For source-addressed based routing, the cable operator administrates IP addresses for subscriber's home computing equipment, but also maintains special source based routes for each subscriber, routing packets to/from their assigned home IP address(es) to their designated ISP. Additional home IP address assignments (e.g. for multiple personal computers) are taken from the same service provider address space. A large IP address space is subnetworked into smaller sized IP address space allocations, where each allocation is dedicated to a specific ISP. Backend routing in the service provider's network routes packets from the home to the ISP via the source address, rather than the traditional destination address. Supporting source-addressed based routing in the DOCSIS CMTS and the cable modem is transparent if their vendor has provided a Layer 2 service only - the CMTS doesn't *see* Layer 3 routing. In general, Layer 3 routing techniques are essentially transparent to Layer 2 devices, even with sophisticated DOCSIS packet filtering. If the CMTS or cable modem support any Layer 3 routing intelligence however, then that vendor's products must be either source-addressed base routing aware as shipped, or must be upgraded to be aware. This may or may not involve a hardware upgrade and/or replacement. DOCSIS QoS for subscriber services/applications is possible; QoS can still be achieved over the CATV network. In the cable operator's backend network QoS is determined by vendor support in the varying equipment. Any vendor support for specialized routing is outside the scope of the current DOCSIS specifications. Note that for specialized routing, the cable operator had to design and select appropriate IP routing technology that supports their deployment model. Currently deployed backend technology may not directly support specialized routing for open access. In addition, supporting multiple service providers via the same cable modem is problematic for specialized routing techniques as the cable modem must support multiple IP subnetworks; usually they support one IP subnetwork. It is technically possible to implement support for multiple IP subnetworks in the cable modem, if so required by an updated specification.

Proxy ARP or proxy Address Resolution Protocol, can be used by either the cable modem, CMTS, and/or head end router to preferentially re-route IP packets to a preferred router port (provider) based on Ethernet MAC address, IP source or destination address, or other mechanisms. The effect would be to transparently steer IP and ARP implementations to support semi-intelligent service provider provisioning. Support for this type of provisioning support could impact the cable modem, CMTS, or vendor head end router, dependent on vendor implementation. For example, a cable modem with IP router functionality may be more effected than a cable modem Ethernet bridge. It is not clear that these mechanisms can provide differentiated services for QoS or multiple service provider provisioning in the cable modem. More study is needed in this area to explore capabilities.

Note at this time, there are existence proofs of specialized routing being used to provide access from a subscriber to a single ISP of their choice. Knology (www.knology.com) is exploiting source-address based routing techniques (and likely other supplemental techniques) to connect subscribers with either Mindspring or other ISP's. Sufficient details on the Knology solution were not obtained in time for completing this white paper, however the system operates with specialized routers at the head end and possibly with customized software in the cable modems. It is believed their source-addressed based routing approach can be *wrapped* around any cable modem system to produce a workable, but less than the ideal, open access provisioning system. Their solution may be transportable to other cable operators.

Tunneling, as used in this paper, is a mechanism to tunnel IP packets through another protocol such as IP, PPP[1], Point-to-Point Tunneling Protocol (PPTP), Layer 2 Tunneling Protocol (L2TP), or IP Security (IPSEC) for Virtual Private Networking (VPN) support. With the general form of tunneling, the IP address of the end of the tunnel within the DOCSIS cable modem is administrated by the cable service provider, while the IP addresses that flow through the tunnel are administrated by the service provider. This model assumes that for each service, the cable modem would create a tunnel between itself and a remote access server maintained by the service provider. This tunnel would run transparently through the CMTS and any intervening routing and switching

1. I'm including PPP and PPP/Ethernet in the tunneling discussion due to functional similarities.

equipment until reaching the service provider. The cable modem would be aware of what IP addresses assigned should be moved through which tunnel. Technically, it is possible for a single cable modem to support multiple tunnel endpoints by leveraging an extension of its DOCSIS packet classification filters. This also allows voice traffic to be segregated into a different tunnel than other QoS traffic, for example. There are several different tunneling protocols, each with their own distinctions. Tunneling has the one undesirable effect of forcing all tunneled packets to have the same QoS, requiring different tunnels to be established for different QoS needs even if the end points of the tunnels are to the same service provider. DOCSIS does not specify any requirements for tunneling in the cable modem, leaving everything to vendor value added support. The best implementation would be for the cable modem to be the endpoint of the tunnels because the cable modem has direct knowledge of QoS requirements and packet classifications to support QoS. In addition, tunneling itself and tunneling with encryption require more processing power in the cable modem than with the base DOCSIS system suggesting that the cable modem would have to be replaced to support multiple service provider provisioning via tunnels.

Use of VPN technology is becoming increasingly more popular for telecommuting scenarios as a work at home employee can benefit from high-speed access over to Internet to their corporate VPN firewall. In these cases, corporate MIS departments manage the any security configurations (cryptographic keys, logins, passwords) and local IP address assignments. If exploited beyond corporate telecommuting, VPN and/or other cryptographic authorization techniques can be used for access to service providers. This enhanced level of exploitation would require software and hardware processing beyond that of the DOCSIS specification. Note at this time that VPN facilities are often being deployed with software in the personal computing equipment or via specialized appliances that are placed between the subscriber computing equipment and the cable modem. It is nature in the future for external VPN support to migrate into the broadband access mediation device, e.g. the cable modem.

At this time, there is no mandatory or suggested implementation of a Layer 3 IP signaling protocol that could be used to communicate with the DOCSIS system. Hence, QoS interaction between the DOCSIS system elements (CMTS and cable modem) and other routers in the network is, at best, left up to individual vendors. The other CableLabs' project PacketCable is focusing on packet voice and video over cable data systems, with specific focus on DOCSIS RFI Version 1.1 implementations. The PacketCable effort is driving for QoS signaling protocols for use in voice call set up and tear down. It is possible, this can be exploited in the future for Layer 3 open access provisioning implementations. There is also the belief that some vendors will be implementing the IETF Reservation Protocol (RSVP) in their CMTS, allowing QoS signaling exchanges with other RSVP aware routers. It is too soon to tell precisely where all the efforts are headed however, there will be some signaling protocol available in the future to interconnect the CMTS with the backend network in a meaningful QoS manner. Note that requirements for signaling will likely emerge first from a PacketCable specification requirement and not directly from a future DOCSIS RFI requirement.

Reviewing Layer 3 Service Provider Provisioning against the ideals:

R1:*Service Provide Selection*: Both source-address based and tunneling mechanisms provide a method of allowing the subscriber to be connected to a service provider of their choice. DOCSIS does not specify either mechanism.

R2:*Multiple Providers*: With the current DOCSIS specification, source-addressed based routing appears to suited to provisioning to a single service provider. Software and hardware enhancements would likely be needed to support multiple service providers via a single cable modem. Tunneling could support multiple providers and ability to differentiate/route different services to difference providers; e.g. packet voice to a voice provider, Internet access to an ISP. Tunneling must be done via vendor software or hardware cable modem extensions or external box(es).

R3:*Ability to Provide*: Source-address based routing must be done in conjunction with cable operator and/or service provider administrating IP addresses for the cable network. Tunneling approaches without QoS support are independent of cable data IP address administration. QoS aware tunneling must be done in conjunction with the cable operator, CMTS, and cable modem management. Technically, either solution is workable to different degrees of meeting the ideal.

R4:*Bandwidth Allocation*: This feature falls out directly when dynamic QoS and signaling are universally supported and coupled to the DOCSIS Layer 2 facilities. Before that time, any bandwidth allocation support, dynamic or static, will need to come from vendor value added implementations.

R5:*Quality of Service*: Without QoS signaling, Layer 3 approaches require static QoS provisioning of the CMTS and/or cable modem as required and as provided for by individual vendors. At some point in the future, QoS signaling will be available for IP and will likely be implemented in CMTS and/or cable modems as a requirement for PacketCable packet voice services. At that time, QoS signaling support would be in place for open access provisioning. In some cases, different vendors may have provided sufficient management and control capability to allow some QoS to be statically provisioned.

R6:*Subscriber Containment*: Relies directly on DOCSIS RFI Layer 2 facilities and the CMTS's ability to manage cable modem bandwidth appropriately for a subscriber's access to the network.

R7:*Provider Containment*: At Layer 3, either the CMTS will need to be upgraded both with software and possible new hardware to manage downstream and/or upstream bandwidth per service provider. In absence or in addition to CMTS functionality, provider containment would be performed where the service provider connects with the cable operator's backend network.

R8:*Link Encryption*: Not an issue at Layer 3; except to mention that Layer 3 packets will be transparently encrypted on a per cable modem basis over the DOCSIS RF channels.

R9:*Content Preservation*: Specialized routing technique will alter the headers of IP packets that traverse the cable operators network between the cable modem and the service provider. Tunneling approaches preserve the IP packet header that was placed into the tunnel at the cable modem. When open access is provided at Layer 2, subscriber data contained within the IP packet is unaltered, however the IP packet header may undergo expected changes as per IP standards and standards for routers and gateways.

R10:*Provider Address Management*: Specialized routing techniques require that the cable operator and the ISP managing the CMTS and cable modems control the IP address space for cable modems and subscriber's personal computer equipment. For tunneling techniques, the subscriber side tunnel endpoint address is in a space administrated by cable operator and/or associated cable ISP, the actually addresses that flow through the tunnel are management by the service provider to which the tunnel is connected on the backend side of the network.

R11:*Provider Subscriber Management*: There are no provisions in the DOCSIS architecture for the cable modem Layer 3 service to be managed by anyone other than the single ISP.

R12:*IP Dial Tone Servic*e: There are no provisions in the DOCSIS RFI specifications for altering IP packets in general. However, QoS requirements and packet classification at the CMTS and cable modem may require that certain fields of the IP header might be altered due to results of certain packet classification rules and subsequent processing.

Observations:

- DOCSIS RFI specifications at Layer 3 do not support ideal open access, due to the single provider architecture of the DOCSIS system and Layer 3 and Layer 2.
- DOCSIS RFI V1.1 does provide facilities that can be exploited for ideal open access solutions however, additional design work and requirements must be developed for ideal open access to be supported by the DOCSIS standard.
- There are specialized routing and tunneling techniques that support workable, but less than ideal open access solutions. These techniques could be exploited further, for more workable solutions however, additional enhancements are needed at Layer 2 for ideal open access.

7 Technical Observations

It is not the argument that cable system cannot technically support ideal open access provisioning. Rather, there is an existence proof that open access is possible over cable because the Com21 CommUNITY cable modem system is a working near ideal open access system. It is the case however, that the DOCSIS standards that are developed by the North American cable operators does not support ideal open access. Re-engineering ideal open access into the DOCSIS system at Layer 2 and Layer 3 is possible, but not in the short-term. As such, DOCSIS compliant products being shipped, and subsequently widely deployed in the latter half of this year, will not be capable of providing ideal open access provisioning within the DOCSIS system itself.

In the short-term, there are techniques such as specialized routing and tunneling that can be used to augment a DOCSIS system to allow a broadband access provider to provision IP addresses to a subscriber that preferentially route packets to and from a subscriber selected service provider. The system is workable, but not an ideal open access system. Further developments in IP signaling for bandwidth allocation and Quality of Service support will improve as vendors implement standard Layer 3 signaling - when available.

In the longer term, the DOCSIS RFI Version 1.1 specification does provide fundamental facilities necessary for providing ideal open access provision. However, these need to be developed, implemented, and tested. Due to short-term focus and the availability of less than ideal solutions, there is not sufficient motivation within the cable operator community to actively pursue enhancement of the specifications to achieve an ideal open access system. However, it could be mandated, for example, that in three to five years high-speed data over cable systems must support ideal open access provisioning. Updating the entire DOCSIS family of specifications would be necessary and one or more technical solutions must be adopted. Selection of IEEE 802.1p VLAN tagging support is useful, but does not have as large a scaling potential as ATM. DOCSIS could make use of its ATM cell transport capability, and achieve the same scale and level of ideal open access as DSL solution, but the DOCSIS system was not designed to optimally handle ATM, hence there would be a drop in data channel efficiency.

Augmenting the DOCSIS specifications to support ideal open access would be a substantial effort and take approximately a year from the time that the cable industry is motivated to direct Cable-

Labs to update the specifications. Following an approved specification it would take approximately 18 months to have multiple certified vendors in the market place. Even if the motivation were to happen today, it would be mid 2002 before DOCSIS based open access cable modems and CMTS's were available. Between now and that approximate example time, there would be close to several million cable modems deployed, some being DOCSIS Version 1.0, most being DOCSIS Version 1.1, and some being DOCSIS Version 1.2 (the balance between DOCSIS V1.1 and V1.2 will be determined when it is settled if Version 1.2 is optional or mandatory).

If open access were mandated to start, for example, sometime in later 2002 or early 2003, there would be several million cable modems and some tens of thousands of CMTS's deployed. The subscriber will own the cable modem, therefore if they desire open access facilities, the cable modem would need to be replaced. In cable plants, where open access has been enabled, the CMTS's would need to be upgraded and/or replaced. The backend networks would need to be expanded and improved, at significant additional cost, to support exchanges between multiple service providers and their subscribers. Note in competitive contrast, that such a backend network would be in place for DSL access networks in that time frame.

Subscribers who have legacy DOCSIS cable modems who don't desire open access, can co-exist on the same CMTS and RF channels as DOCSIS cable modems that do support open access provisioning. In this case, the CMTS must support open access provisioning. Non-open access cable modems would get service from either a default service provider, or if specialized routing or tunneling is employed a service provider of their choice. Subscribers who require the features of a cable modem that supports ideal open access provisioning would need to replace their legacy cable modem with a new one. This would be similar to buying a feature enhanced cellular phone for use with the same cellular provider.

Providing separate downstream RF channels in the cable plant to different service providers is not workable, as discussed previously, due to the lack of availability of sufficient downstream or upstream channels. However, it is possible to reserve a future channel for open access capable systems or perhaps convert a local must-carry video channel for use as a local must-carry open access channel for operation of cable modem equipment that does support ideal open access. In this case, multiple subscribers and providers could adequately use that equipment up to the limits of performance offered by that equipment and the configured downstream and upstream channels. In practice however, this will not be possible on all cable systems due local plant capacity issues in either the downstream or upstream spectrum. Technically, it would be possible to convert a must-carry local television channel to a must carry open access cable modem channel in the downstream direction. The upstream spectrum may still not be available. It will be observed that the cable industry is rapidly moving towards digital video distribution. For example, TCI has made great headway turning up new digital TV services. Digital video is contained in a digital video channel that is 6 MHz wide which is the same as analog. The difference is that a digitized 6 MHz channel contains multiple video programs. Said differently, if you convert analog channels to digital channels, you will take up between one quarter to one sixth the RF spectrum as the same number of analog TV channels. The number of TV channels supported per digital RF channel is variable, depending on quality of delivered video, and delivered format. Upcoming HDTV systems will likely have one video program per digital RF channel, while NTSC formats may have from four to six or more video programs. Converting from analog to video may release downstream RF spectrum for other uses. This is not strictly true in all cases, hence might not be subject to universal mandate. More study should be done here to understand if in the future, downstream

RF space for open access channels could be provided. Upstream RF channel allocation is still problematic(!). If the space is available, then technically it is possible to operate multiple CMTS's in the same cable plant, allowing open access cable modems to be provisioned on the RF channels associated with open access CMTS's while one or more legacy CMTS's (non-open access cable) support legacy cable modems.

This paper assumes that open access provisioning would leverage the existing DOCSIS Version 1.1 specification and subsequent follow on specification(s). Technically speaking, if another specification or standard were selected for ideal open access support, then the preceding observation regarding multiple CMTS's would become practice on cable plants. Where one or more CMTS's would be present to provide legacy DOCSIS support, and the other non-DOCSIS CMTS's would be supporting open access to non-DOCSIS open access cable modems. This notion however, has not been developed in this paper, and is therefore for future study.

7.1 Technical Cost Considerations

Internet architecture in general has always been open access in that it allows any subscriber (client) to connect to any service provider (server) via the Internet Protocol (IP) and the other higher layer Internet protocols (e.g. TCP, UDP, etc.) Supporting numerous subscribers, there are numerous ISP's. These service providers have deployed large server farms and backend networks to support their customers. Subscribers today, chiefly use dial-up modems over legacy Plain Old Telephone Service (POTS) with the subscriber bearing the cost of the phone call. The service provider, bearing the cost of providing dial-up access within a local call of the subscriber. The phone system provides the individual connection between subscriber and service provider. The telephone company gains revenues by calls made by subscribers and by revenues gained from ISP's connections to remote access servers, e.g. primary rate ISDN, T1, T3, etc. Subscribers can select their ISP and simply have to call a different phone number, after authorization has been set up.

In the DSL model, the technical architecture is open access from the start, and has moved service provider equipment directly into the local telephone central office (CO) or directly connected to a CO, e.g. via an ATM network. Access to the copper local loop requires an exchange of payment (settlement), either from the subscriber to the local phone company with a separate payment for ISP access, or a single payment to an ISP, where the ISP pays revenues back to the local phone operator, in part, for rent of the subscriber's copper pair carrying the high-speed signals. The revenue model changes somewhat from the dial-up POTS network, but the local wire provider gains revenue from the additional high-speed data services. The revenues are used for expansion, upgrade, and maintenance of their twisted pair plant and other distribution technology in support of high-speed services.

In the cable environment, cable operators have begun to deploy high-speed data over cable equipment (CMTS's or equivalents and cable modems) and to construct servers and backend networks. In most cases, the size of the servers and the capacity of the backend networks have been balanced for deploying a single ISP service for the subscribers. Cable operators have stated that their revenue models are leaner than other broadband access solutions, and are carefully balanced based on both cost of capital technology and cost to support that technology and customers. Mandating open access for cable operators would require them to install additional new and/or upgraded open access capable routers, support for multiple high-speed interconnections to connect a headend with each service provider desiring access, and the local maintenance needed to support the additional equipment and high-speed interconnects. In addition, there are technical limitations to how many service providers can be connected through a given head-end. Practical limits may top out at several dozen to several hundred ISP's. In contrast, there are several thousand ISP's in the U.S. The costs associated with technical upgrades and support would roughly scale with the number of ISP's connecting through the head-end; i.e. open access provision for high-speed data over cable services does not come for free. A short-term mandate for open access would have severe costs implications for existing high-speed data over cable services with respect to a cable operator readjusting itself with new technology and new support, let alone the costs associated with upgrading subscriber's cable modems. If open access were mandated to happen in the future, say three to five years, vendors would likely be motivated to have open access support in future generations of technology. As discussed previously, it would take about two and a half to three years after being motivated for technology improvements to be in widespread place. In addition, the longer time space would allow operators to gradually enhance and deploy required technology. However, any upgrade of technology or its support still requires a revenue stream to support the enhancement and deployment. Therefore it is apparent, that a revenue exchange similar to DSL would be needed where service providers pay their way for connection to a head-end and for support of subscribers.

Specifics of any business models for future open access economics require further study. Such models are beyond the scope of this paper.

8 Summary

A definition for ideal open access provisioning was presented. A high level review was performed discussing the technical abilities of the current DOCSIS cable modem specifications to meet the ideal open access requirements in the U.S. Cable TV Broadband Access environment. Various approaches and alternatives were discussed.

A short-term mandate for open access provisioning over cable systems would cause immediate technical and cost pain for U.S. cable operators: the existing and upcoming DOCSIS RFI specifications do not support open access directly, however DOCSIS RFI Version 1.1 does provide fundamental facilities that would be exploited for open access. Most cable operators' high-speed data over cable and backend servers and networks have been designed and optimized for a single ISP. Forcing these systems to support open access provisioning would incur unforeseen technical costs for new capital equipment and support

There are techniques being used by some cable operators to provide workable but, less than ideal open access provisioning, via specialized routing and tunneling techniques. Some of the capability needed for this support may rely on customized software from select vendors and may not be generally available. These techniques are being applied to cable modem systems and are independent of the cable modem system, e.g. DOCSIS versus proprietary. In some cases, a vendor's cable modem may need a software or hardware update to work. Tunneling techniques also have merit, but impact the cable modem directly, and will take time to put into place. Either solution can be developed to better couple with upcoming bandwidth allocation and QoS abilities of DOCSIS V1.1 systems.

A longer-term mandate, such as three to five years, should give sufficient time for the U.S. cable industry and associated vendors to develop and upgrade the DOCSIS specifications and products to support ideal open access. However, all cable modem systems deployed between now and that would not support ideal open access. There is significant cost associated with the manner in which legacy technology is upgraded to desired technology. However, given sufficient planning, open access capable cable modems could be deployed on the same upgraded CMTS's that support legacy cable modems. The cost impact is beyond the scope of this paper.

There are other broadband access network methods being used in the U.S., with some methods in place today: (e.g. DSL) and some under development or just beginning deployment: wireless, satellite, FTTC. The wireless and satellite methods are lacking open access provisioning requirements and standards. It is observed that all broadband access systems could potentially share the same ideal open access provisioning goals, thereby providing a consistent service offering potential to subscribers, regardless of broadband access method.

9 About the Author

MARK LAUBACH holds a Bachelors of Electrical Engineering and a Master of Science in Computer Science from the University of Delaware (thesis advisor is David J. Farber). He currently is an independent consultant. He is a co-founder and past Vice President and Chief Technology Officer at Com21, Inc. in Milpitas, California where he was responsible from 1994 to 1999 for directing the end-to-end systems architecture, protocol design, performance, and technology of the Com21 ATM-based cable TV network telecommunications products. He has participated in many cable TV standards activities (IEEE, IETF, ATM Forum, SCTE, and CableLabs' DOCSIS). He has made numerous presentations at Cable TV industry conferences and events. He is an instructor for cable modem systems and protocols at Networld+Interop. He is a principle co-inventor of a patent with Paul Baran, and a principle co-inventor on several additional patent filings with Com21 and other companies. Prior to Com21, he was with the Hewlett-Packard Company for 14.5 years. Mark is past chair of the IP-over-ATM Working Group. He is the author of the RFC1577/2225 Classical IP and ARP Over ATM (IPOA) standard. He is a past member of the CSNET Executive Committee. He is a senior member of IEEE (Institute for Electrical and Electronic Engineers), a member of ACM (Association for Computing Machinery), and a member of SCTE (Society of Cable Telecommunications Engineers).

Mark Laubach
PO Box 4065
Mountain View, CA 94040
650-961-1041 (direct)
650-961-1185 (voice mail)
650-961-9774 (fax)
laubach@ricochet.net and laubach@matmos.com