White Paper

Cisco Packet Telephony Center: A Novel Approach for the Management of Open Packet Telephony Networks

Abstract

Open packet telephony (OPT) networks based on H.323, Session Initiation Protocol (SIP), or the Media Gateway Control Protocol (MGCP) or Megaco/H.248 control protocols present an excellent value proposition for service providers. Management of such networks, whose architecture significantly departs from that of traditional time-division multiplexing (TDM) networks, poses new challenges, such as dealing with functional distribution, a very high degree of openness, and the adaptation of existing operations support infrastructure. This paper explores these challenges in detail and presents a management solution that centers on the Cisco Packet Telephony Center (PTC), a system designed specifically to address those challenges. One of its key features is the introduction of virtual management entities that hide much of the complexity in dealing with the distributed nature of OPT networks.

Introduction

Open packet telephony (OPT) networks[1] based on voice-over-packet (VoP) technology are making inroads into voice carriers' infrastructure. They present a great opportunity for service providers to cost-effectively offer telephony integrated with other services. Different types of such architectures exist, many of which share the same basic principles. One common theme is the separation and distribution of voice functionality into different planes:[2] the bearer plane deals with transport of the payload, whereas the control plane deals with the voice specifics, such as signaling and call control. This decoupling enables sharing of network devices with other services, which might be controlled through their own control planes but utilize the same transport infrastructure. The result is a single, converged network that needs to be operated and maintained. The same principle also allows for flexibility in the design of OPT networks and enables integrated services to be provided by different network devices of different vendors. Because of the distribution of

1. Cisco Systems. *An Introduction to Cisco Open Packet Telephony for Service Providers.* White paper, http://www.Cisco.com/warp/public/cc/so/neso/vvda/pctl/opt_wp.pdf, March 2000.

2. McDysan, D. (editor). *System Architecture Implementation Agreement.* Multiservice Switching Forum, MSF-ARCH-001-FINAL IA, May 2000.

functionality across those different devices, they tend to be individually of lower complexity and wider applicability, a scenario that can translate into significant cost advantages. At the same time, many opportunities for differentiation between service providers exist, because networks can be built in many ways to address different services and service characteristics.

One aspect that has not quite kept up and continues to be less understood concerns network management. The distribution of functionality across separate and heterogeneous components of possibly multiple vendors increases the management complexity of the resulting networks. Likewise, formerly closed and proprietary interfaces within a time-division multiplexing (TDM) switch, mostly invisible to management, are now open and exposed. All this calls for increased effectiveness of management solutions, while at the same time it makes the problem more difficult to solve.

A clear concept for an effective management is required. This generally calls for integration. However, truly effective management solutions can be built only with a thorough understanding of the unique aspects of OPT networks and how they impact management. One of several aspects to consider is the fact that although many of the unique advantages of OPT networks clearly lie in the way in which they differ from traditional TDM networks, from an operations perspective it is desirable to hide many of those very aspects that make them different.[3] To a service provider, any required change in the operations support infrastructure that does not introduce additional value or higher efficiency offsets some of the OPT value proposition, making it less attractive. Of course, because OPT architectures are different, they necessarily have certain unique management requirements. Traditional operations support infrastructures were not designed with those aspects in mind; therefore, the fact that some aspects will need to be managed somewhat differently should come as no surprise.

This paper offers a perspective on these issues and presents the Cisco approach to the development of effective management solutions for large-scale OPT networks. A cornerstone of this approach is the Cisco PTC, an umbrella OPT management system that focuses on configuration management and provisioning. Some key issues that need to be addressed are discussed, along with their resolution. Although this paper uses specific examples, the approach is applicable beyond any one particular network architecture.

The following section gives an overview of OPT technology as Cisco customers are deploying it today. Then the paper builds on this background and provides an analysis of the network management problem space and extracts characteristics that are unique to the management of open telephony architectures. The Cisco approach to this problem domain is then presented. Central to it is the Cisco Packet Telephony Center, which realizes the concept of a virtual switch and other virtual entities for management purposes. Resolution of certain key issues is then followed by some conclusions.

It should be noted that this white paper focuses on the technological concepts and ideas that underlie the Cisco PTC. It does not discuss the specific feature set supported by any one Cisco Packet Telephony Center release; any particular features mentioned are for illustrative purposes only. Refer to the Cisco Packet Telephony Center data sheets for specific features, network solutions, and devices that are currently supported.

3. Clemm, A., and P. Bettadapur. *Building Management Solutions for Open Packet Telephony Networks.* 2001 IFIP/IEEE International Symposium on Integrated Network Management (IM 2001), May 2001.

Open Packet Telephony Overview

Telephony is no longer solely the domain of Public Switched Telephone Networks (PSTNs). Software and protocols that allow telephone calls over packet networks such as the Internet have entered the marketplace. They are based on:

- The Media Gateway Control Protocol (MGCP)[4] and related protocols, such as the Simple Gateway Control Protocol (SGCP) and Megaco/ H.248,[5] or
- The Session Initiation Protocol (SIP), or
- H.323

This discussion focuses on MGCP and H.323, which are both supported by the Cisco Packet Telephony Center.

Examples of OPT Networks

Figure 1 depicts an example of an MGCP-based OPT network. (In this discussion, there is no need to distinguish further between the different MGCP derivatives, Megaco, H.248, and SGCP.) The bearer plane is responsible for the transport of the actual payload. Network elements within the bearer plane do not need to be concerned with the specifics of telephony applications. Switches or routers between media gateways at the edge of the OPT network provide for the actual bearer fabric (the "data cloud"), shuffling data packets back and forth. The control plane is responsible for signaling processing and call control; it is here that the actual call-processing intelligence resides. The components in the control plane are commonly referred to as media gateway controllers (MGCs). MGCs control media gateways by instructing them when to set up or tear down connections, requesting notification of specific events for further processing, and so on. They contain all the logic required for telephony applications, including Signaling System 7 (SS7) signaling termination, collection of accounting information, and—very importantly—directory functions and call-level routing based on dial plans. In terms of numbers of devices, there tend to be much fewer MGCs than media gateways, meaning that call intelligence is fairly centralized.

4. Arango, M., A. Dugan, I. Elliott, C. Huitema, and S. Pickett. *Media Gateway Control Protocol (MGCP) Version 1.0.* IETF RFC 2705, October 1999.

5. ITU-T Recommendation H.248: Gateway Control Protocol. June 2000.

Figure 1 Open Packet Telephony Network (example)

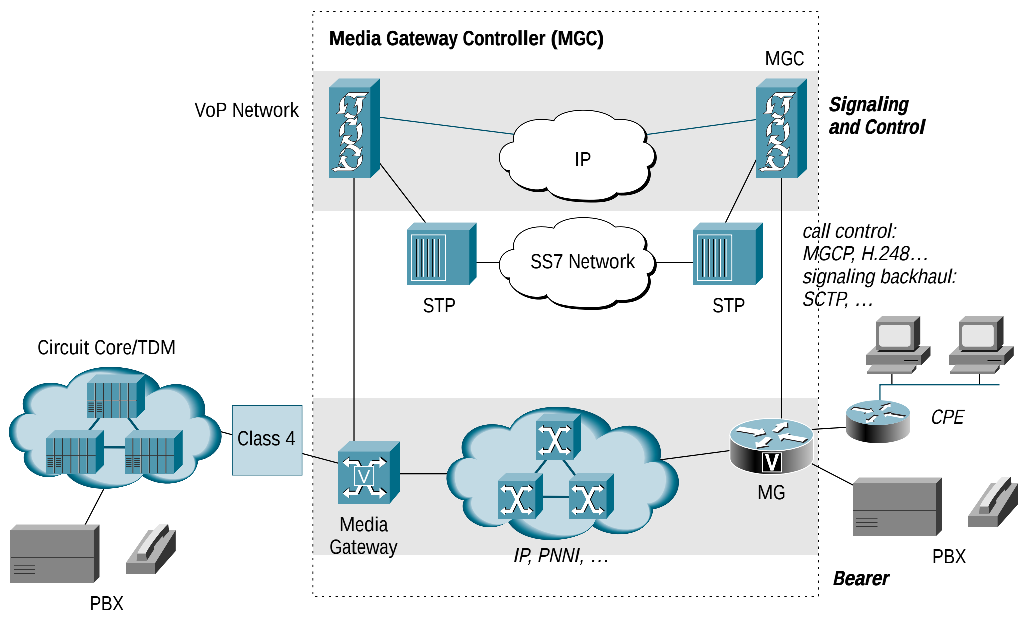
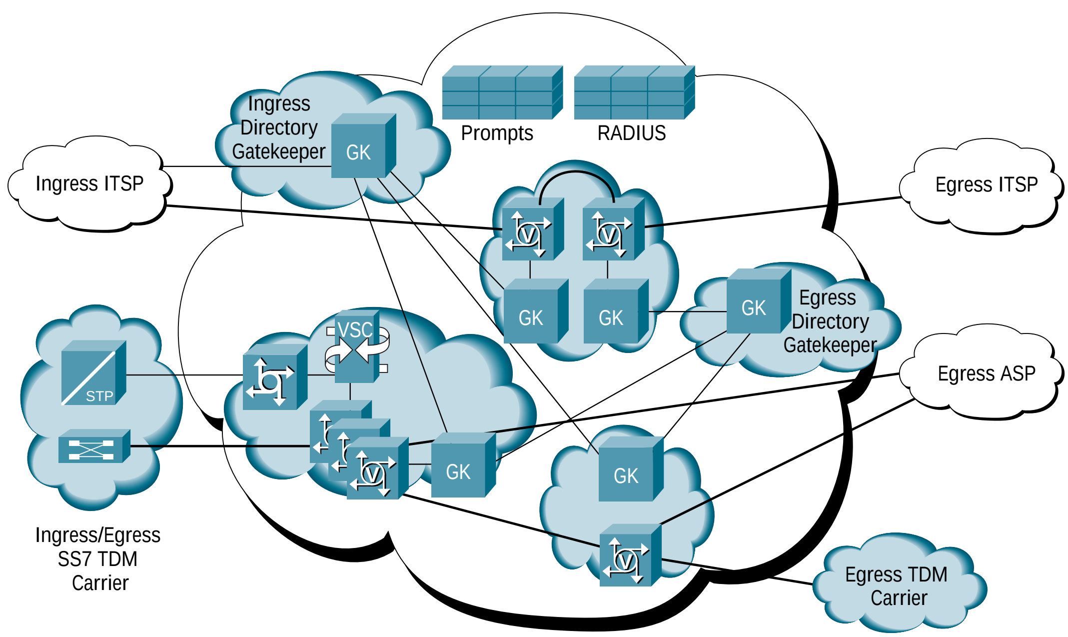


Figure 2 depicts an H.323-based network for a global long-distance application. Again, gateways are at the edge of the network, with routers between them providing for the bearer fabric that shuffles the payload back and forth. In H.323, unlike in MGCP, call intelligence and the ability to process signaling does reside in the H.323 gateways. Intelligence is, therefore, much more distributed, compared with MGCP-based networks. However, call processing is still distributed between gateways and gatekeepers. Gatekeepers are able to make call-level routing decisions based on dial plans. In addition, gatekeeper hierarchies can be deployed, reflecting dial-plan hierarchies, with directory gatekeepers on top of gatekeepers. Likewise, gatekeepers can be supported by route servers in their decisions. If required, SS7 capabilities are provided through signaling converters that mediate and backhaul the signaling information between the gateway and the SS7 Signal Transfer Point.

Figure 2 H.323 Global Long-Distance Network



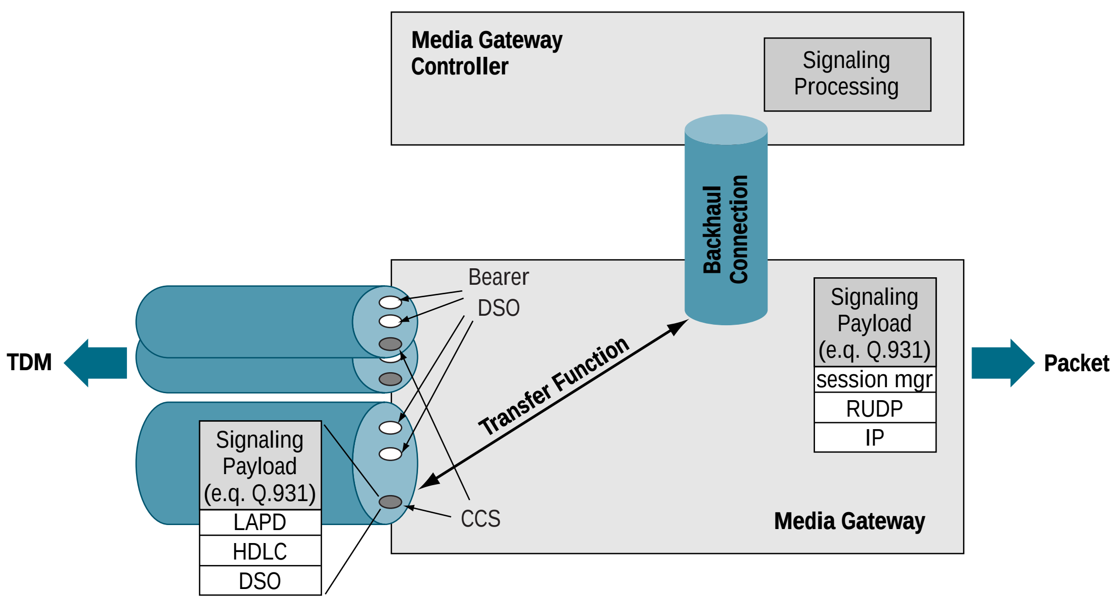
It should be noted that many variations that share the same common set of principles are possible, such as the separation of bearer processing from signaling and control, and the introduction of open interfaces between OPT network components. Collectively, in MGCP-based networks, bearer and control planes provide functionality analogous to that of traditional PSTN switches. Therefore, later in this document a set of associated media gateways and MGCs are referred to as *virtual switches.* (A virtual switch is not to be confused with the term *soft switch*, which is sometimes used synonymously with MGC but does not include the associated media gateways.) Similarly, in H.323 networks, collections of associated gateways and gatekeepers form *virtual zones*, which in essence constitute the H.323 version of a virtual switch. Other virtual entities exist; for instance, signaling controllers that provide signaling conversion (for example, between SS7 and Q.931) for H.323 gateways that are capable of processing signaling, along with the gateways whose capabilities are thus virtually extended to include SS7, form *virtual gateways.* Virtual switches, virtual zones, and virtual gateways are called *virtual entities*. Those concepts are covered in more detail in the Section "Moving beyond Element-Centric Management Approaches."

Open Control Interfaces

Control communication between network elements in OPT networks can be categorized into different functions, including the following:

- Call control—At the core of providing voice services, call control deals with proper allocation of network resources to calls, such as the setting up and tearing down of connections or connection up-speeding for fax calls. It also accounts for the usage of network resources that form the basis for call data records used in billing.
- Signaling backhaul—Signaling is not always physically terminated at the network element where it is processed. This requires the signaling payload to be *backhauled* between the terminating and the processing network elements. Examples are the backhaul of channel-associated signaling (CAS) or Primary Rate Interface (PRI) signaling between media gateways and MGCs in MGCP-based networks, where the line that carries the signaling is physically connected at the gateway (depicted in Figure 3 below), or the backhaul of SS7 signaling converted to Q.931 between a signaling controller and an H.323 gateway.

Figure 3   Signaling Backhaul between Media Gateway and MGC



The interfaces for these functions are provided through one or several control protocols. Examples are MGCP or the H.323 family of protocols (including H.245 and H.225) for call control, and the Session Manager Protocol or the Stream Control Transmission Protocol (SCTP) used for signaling backhaul.[6] The beauty of OPT is that these open protocols are essentially all that is required for network elements to interoperate and collectively provide voice service.

6. Morneault, K., S. Rengasami, M. Kalla, and G. Sidebottom. ISDN Q.921—User Adaptation Layer. IETF RFC 3057, February 2001.

OPT Value Proposition

Through the described principles, OPT networks offer a great value proposition, including:

- Integration of voice and data services—The bearer functions can, in principle, be provided by any packet-based network, allowing the devices used within the data cloud to be effectively service agnostic. The network may, therefore, carry multiple services simultaneously, providing for truly integrated multiservice networks.
- Cost—OPT networks help service providers reduce costs in numerous ways. The separation of functions allows the use of standard components; for example, ordinary IP routers in the bearer plane, at a cost advantage over dedicated PSTN switches. By consolidating voice and other services into one converged network, bandwidth efficiencies may be realized. Also, very importantly, only one converged network has to be operated, as opposed to multiple dedicated ones.
- Flexibility—Open interfaces allow for component-based network architectures that can be engineered in many different ways to address a wide variety of different networking requirements; for example, with respect to the required reliability and availability, scale, cost, the placement of functionality at the core or the edge, and so on. In addition, components of different vendors can be combined to offer service providers greater selection and vendor independence.
- Migration—Gateways that provide traditional TDM interfaces and are able to packetize voice traffic provide an important stepping stone in the transitioning from TDM to packet networks, protecting investment in the core network infrastructure.

Although both traditional and OPT networks will coexist for a long time, over time more and more segments of the traditional networks are expected to be transitioned to OPT. Examples include tandem offload of circuit-switched voice, global long-distance services, and residential services for integrated voice and data access.

The Management Challenge of OPT Networks

Properties that Make OPT Management Challenging

The very properties that make OPT architecture so attractive are among the key factors that make their management a challenge:

Openness—Not only do different components realize functions of what formerly used to be part of the same TDM switch, but they can be realized by widely varying equipment types and can even be from different vendors. There is always a possibility that yet another type of gateway has to be incorporated into the same management solution, compounding the integration problem. Not only does this gateway become part of the same network, it can also effectively become part of the same virtual entity as existing devices. A consistent (ideally, standardized) set of management capabilities across components is imperative to facilitate an integrated management solution.

Flexibility—Networks can be of vastly different architectures. From customer premises equipment (CPE) with few ports to high-end routers, network elements with vastly different characteristics may all participate as gateways in the same virtual entities. The relationship between gateways and gatekeepers, gateways and signaling controllers, and MGCs and media gateways may vary over time; that is, the components of what constitutes a virtual entity can even dynamically change. A particular networking architecture is also called a *network solution or an OPT solution*. Typically, any such solution must abide by certain architectural policies-for instance, whether to use dual homing, trunking or switching, and so on. A management implementation should also be able to enforce such policies of a particular OPT solution while being able to adequately reflect the actual configuration and to flag any violations.

Integration—Boundaries between networks blur. A bearer network may carry services other than voice, which also have to be managed. A component acting as a gateway in a voice network may at the same time be part of a traditional data network. This scenario introduces overlaps and dependencies between management domains, introducing additional complexity. It also increases the need for a truly globally integrated management beyond the boundaries of voice, or any particular service.

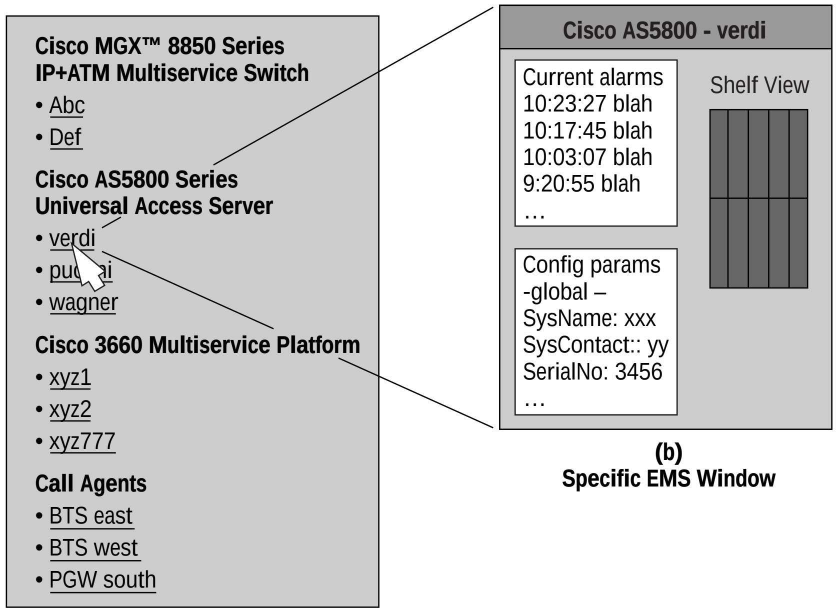
A Simple Management Approach

These challenges can be addressed in different ways. For example, one could try to simplify the problem by limiting the different device types that can participate in a management solution. At an extreme, only one type of gateway or media gateway, one type of gatekeeper or MGC, and one type of signaling controller would be supported. (Taken even further, it might be decided to make those functions all part of the same physical network element and implement each as its own service module that plugs into the same piece of equipment, effectively even removing the aspect of distribution and reducing the OPT network to a voice switch.) Of course, this comes at the expense of severely limiting openness and flexibility of the networks that can be supported, running counter to some of the main motivating factors behind OPT. In general, this would be unacceptable as a prerequisite for the applicability of a management solution.

A simple approach toward OPT management, and one commonly applied today, is to simply integrate the element management systems (EMSs) for the components that happen to be part of the network.[7] Done properly and using a little "glueware," the integration allows for seamless navigation between functions for the management of different elements. For example, a common integration facility might contain a list of the elements in the network that require management. Upon clicking a particular entry, a window with the element management functions for that element opens. The integration facility can be rounded off with a common alarm browser that displays alarms emitted by elements in the network in a consolidated list. A schematic example is depicted in Figure 4.

7. Clemm, A., and P. Bettadapur. *Building Management Solutions for Open Packet Telephony Networks.* 2001 IFIP/IEEE International Symposium on Integrated Network Management (IM 2001), May 2001.

Figure 4 Integrated EMS Navigation



(a)
Common EMS Glueware Explorer Window

This type of approach is perfectly adequate for smaller and trial-type deployments. However, when moving toward larger-scale deployments, the inherent limitations to this approach become quickly apparent. Although all elements in the network may be accessible from a central console, they still need to be managed and configured individually, and independently of each other. This may be acceptable for a handful of elements in the network, but increasingly less so if there are hundreds or even thousands of elements. All responsibility for ensuring data integrity and consistency, coordinating deployment of services through multiple EMSs, making sense of multiple network alarms that are reported by independent systems for the same problem, and much more fall on the network operator. Clearly this results in operational inefficiencies, impeding the rollout of OPT services and negatively impacting total cost of ownership. It may even impact network availability if devices are configured inconsistently and resulting networking problems are difficult and slow to discover and troubleshoot.

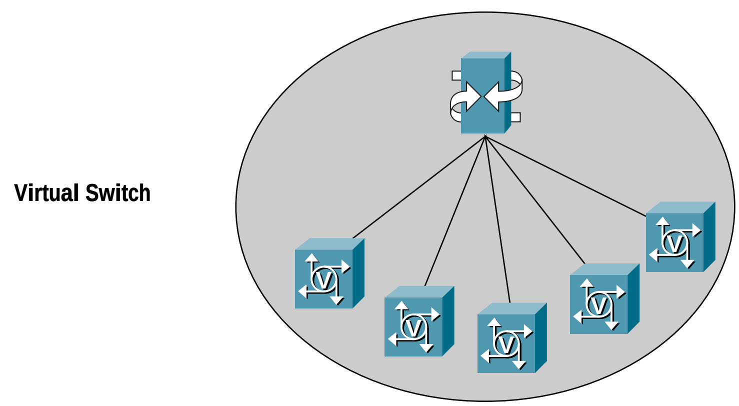
In summary, with such an element-centric approach, complexity that results from the distributed nature of OPT is simply pushed up to the user, requiring highly skilled personnel, or northbound OSS applications. Instead, a more intelligent management solution is desirable, one that takes the unique properties of OPT, its distributed nature, its open interfaces, and its dependencies between network components into account and coordinates their management automatically, hiding network complexity as much as possible from users and keeping management simple.

Moving Beyond Element-Centric Management Approaches

The requirements for a coordinated element management are extensive. For instance, the media gateway and MGC need to be synchronized regarding the voice endpoints. Although the MGC has a concept of trunk, this concept is unknown to the media gateway that has the actual resources (TDM endpoints, ports) that constitute the trunk. Therefore, the knowledge that both the media gateway and the MGC have of the trunk must be managed in a coordinated way. Registration and synchronization of capabilities need to be assured. Beyond element management, failures in voice service, observed at the MGC, need to be correlated with failures in the bearer network. Resources used at the media gateway and controlled by the MGC need to be associated with voice service, which the media gateway has no concept of.

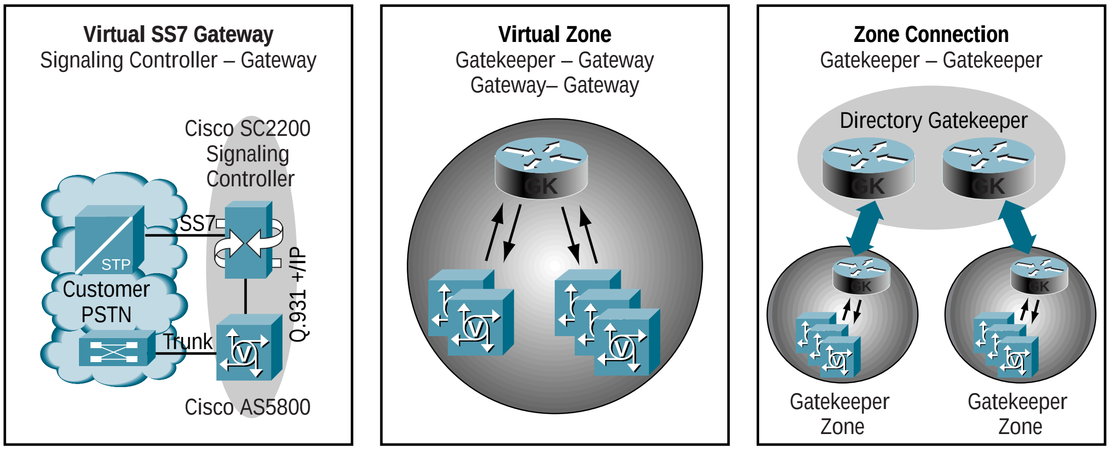
The user will require support for such management coordination. Components in the bearer and control planes operate in conjunction to perform the function of a switch, as far as voice service is concerned. Usually an MGC and a set of media gateways are clearly associated with one another and jointly perform the same function as a TDM switch, thus forming a "virtual switch." This raises the expectation that this virtual switch can, in fact, be managed as a switch, with a management system shielding many of the aspects of the distribution of this virtual entity from the user. This way, the user does not have to be concerned with the peculiarities of setting up control communications between the devices (interfaces that used to be closed); for example, MGCP and signaling backhaul, with the coordination of the configuration of endpoints on the media gateway and of trunks that refer to those endpoints on the MGC and that now collectively simply form virtual trunks of the virtual switch, and so on. Figure 5 depicts the concept of a virtual switch.

Figure 5 A Virtual Switch



Similarly, H.323 gateways and gatekeepers in a zone should be managed as just that, a virtual zone, as if they were one entity. A virtual zone is in essence the H.323 flavor of a virtual switch. Also, gateways and the signaling controller jointly provide the functionality of a "virtual gateway" that has SS7 capabilities. A potent management solution should allow for a holistic management of those entities. Figure 6 depicts the concept of a virtual zone (which deals with dependencies between gateways within a zone, as well as between gateways and gatekeepers), a virtual SS7 gateway (which deals with dependencies between an H.323 gateway and a signaling controller that converts SS7 to Q.931 signaling for the gateway), and a zone connection (which deals with dependencies between gatekeepers, or between gatekeepers and directory gatekeepers).

Figure 6 Other Virtual Entities



Key to the management of OPT networks is, therefore, the concept of virtual entities. The remainder of this white paper revolves around this concept, which is readily supported by the Cisco Packet Telephony Center.

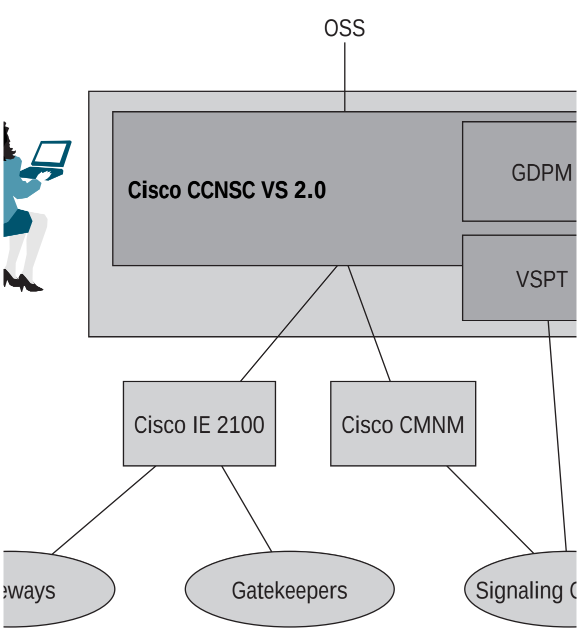
A Management Solution for OPT Networks Based on Cisco Packet Telephony Center

This description of the management solution initially focuses on the configuration management aspect. Other management functional areas, such as fault and performance management, are briefly discussed in a subsection below.

Figure 7 depicts the proposed management solution for OPT networks, as applied to an H.323-based global long-distance network. The key component is the Cisco Packet Telephony Center, which provides for overall configuration management of the OPT network and realizes the virtual entities as discussed. A module within the Cisco Packet Telephony Center, the Generic Dial Plan Manager (GDPM), provides for H.323 dial-plan management. The Cisco Packet Telephony Center enables context-sensitive launching of other management tools, that is, where it makes sense from a navigation standpoint, for an integrated user experience. A pre-integrated application is the Virtual Switch Provisioning Tool (VSPT), which can be used to bulk configure the Cisco PSTN Gateway (PGW) 2200 signaling controller.

To communicate with underlying network devices, the Cisco Packet Telephony Center makes use of underlying EMSs, such as the Cisco Media Gateway Controller Node Manager (Cisco MNM) for the Cisco PGW 2200 signaling controller. EMSs can also be launched as auxiliary tools by the user in case they want to drill down into the device and obtain a graphical device view. In cases where an EMS is not readily available, Cisco PTC can also interface to devices directly or, as in the case of Cisco IOS® devices, utilize the Cisco IE 2100 Series Intelligent Engine. Refer to the Cisco PTC data sheets for the device types and features supported by a particular release. It should be noted that the applicability of the Cisco Packet Telephony Center and its fundamental concepts goes beyond any particular solution and is not limited to support only certain device types; it is expected that essentially any OPT solution can be added.

Figure 7 Management Solution for the Management of OPT Networks



Cisco Packet Telephony Center

A key component of the solution is the Cisco Packet Telephony Center, which operates at the network management layer of the Telecommunications Management Network (TMN) hierarchy[8]. Its most important function is the realization of a virtual entity view, hiding much of the internal complexity of the OPT network and allowing gateways, gatekeepers, and signaling controllers as well as MGCs and the controlled media gateways to be managed as if the virtual zones, virtual gateways, or virtual switches that they form were single entities. These virtual-entity management aspects are the focus of what is described in this paper, specifically configuration management functions, but the focus extends to other management functional areas as well. The Cisco Packet Telephony Center is designed with high scalability in mind, because

8. ITU-T Recommendation M.3010: Principles for a Telecommunication Management Network. May 1996.

it needs to provide a single, overall management entry point into the OPT network, capable of managing large deployments. Accordingly, it offers flow-through interfaces for Operations Support Systems (OSSs) as well as a graphical user interface (GUI) for human users.

Figure 8 shows a Cisco Packet Telephony Center screen shot. The left pane shows the components of the virtual entities and of the network according to a file explorer metaphor. The physical network topology of those components is visualized in the right pane. The remarkable thing to note is that the screen itself is very similar to that of other modern management systems and in that sense at first sight is not remarkable at all. However, unlike other management systems, virtual entities are seamlessly integrated with physical entities, and can be navigated across in exactly the same manner, shielding users from their distributed nature.

Figure 8   Cisco Packet Telephony Center 2 Topology Screen Shot

Provisioning of Virtual Entities

Most voice services and features require coordinated provisioning of the multiple network elements—for instance, in an MGCP-based network typically line parameters on the media gateways, control and routing parameters on the media gateway controllers, interconnection parameters between them, and also some end-to-end connection management parameters within the network. For example, the following may be involved in turning up PRI service for a customer:

1. Add a line with TDM endpoints and a common-channel-signaling (CCS) channel on a media gateway.
2. Instruct the MGC to add a new trunk group and associate it with the customer.
3. Instruct the MGC to add the trunks.
4. Associate them with the associated media gateway endpoint.
5. Verify that a signaling backhaul connection has been set up (also, depending on the OPT solution, primary and secondary connections need to be dealt with separately for reliability purposes).
6. Set up a signaling backhaul connection if required. (This involves adding signaling backhaul terminations at both the media gateway and the MGC, as well as possibly a Layer 2 connection to carry the signaling backhaul connection (for example, an ATM adaption layer 5 [AAL5] permanent virtual circuit [PVC] in voice-over-ATM (VoATM) deployments.)
7. Set up a cross-connect between the common-channel-signaling (CCS) channel and the signaling backhaul connection at the media gateway if required (depending on the type of media gateway).

Similar scenarios apply for H.323 networks, and, for instance, setting up signaling backhaul between a signaling controller connected to an SS7 network and an H.323 gateway. Performing each of these steps manually and in the right sequence is inefficient and error prone. The Cisco Packet Telephony Center instead provides a set of functions that allow operators to operate in the much more meaningful context of a virtual switch (or other virtual entities). This scenario in the above example would allow the operator to simply specify "add PRI service on the specified line for a specified customer." So, instead of requiring tedious individual operations to be performed at each of the network elements, the Cisco Packet Telephony Center offers functions such as the following:

- Turn up/tear down/modify service for subscriber
- Associate or disassociate an H.323 gateway from a virtual zone
- Create/deletes/modify (virtual) trunks, trunk groups, routes, and route lists
- Associate or disassociate a media gateway from a virtual switch
- Associate or disassociate an H.323 gateway from a virtual gateway (that is, a signaling controller)

Through its GDPM dial-plan management module, allows for simple management of dial plans that ensures configuration consistency of the affected network elements, without needing to, for instance, manually configure dial peers.

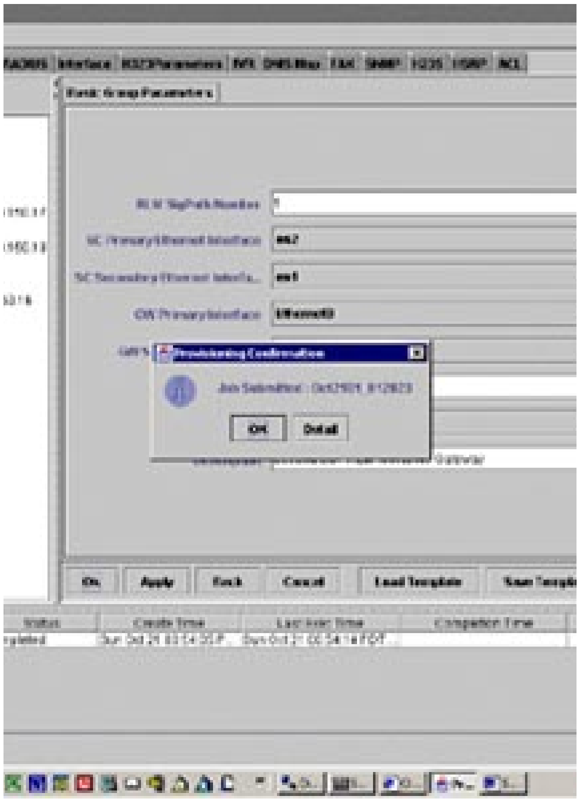
All these functions are provided as if they were single operations, hiding the underlying operational complexity of having to deal with multiple operations across multiple network elements from the user, thus greatly improving operations efficiency and accuracy and making provisioning less error prone.

In addition to virtual entities requiring configuration of multiple network devices in a consistent manner, the Cisco Packet Telephony Center supports configuration operations that can be scoped across the network and its virtual entity. For instance, it allows application of the same configuration of certain gateway parameters across all gateways within a zone, or a region. Although simpler than operations on virtual entities because they lack their stringent transactional requirements, this functionality results nonetheless in a significant gain in operational efficiency.

Provisioning of a virtual entity occurs through a separate screen (Figure 9). To increase user productivity, basic parameters that must be supplied are treated separately from the rest of the parameters whose configuration by the user is optional and for which the system will provide defaults[9]. Wizard-driven screens can be invoked for the configuration of special parameters. Many of the Cisco Packet Telephony Center provisioning operations lead to multiple management requests issued to various EMSs and network elements, resulting internally in network management transactions, or provisioning jobs. The Cisco Packet Telephony Center includes a provisioning job manager to provide a reliable way of managing those transactions. Monitoring of job progress is available through a job-listing tab, allowing display of details of a particular job, as shown in the bottom portion of the screen. This display allows operators to know the actual status at any point in time and to infer what went wrong in cases of failures.

9. Tjong, J., P. Bettadapur, and A. Clemm: *Provisioning Voice over Packet Networks: A Metadata Driven, Service Object Based Approach*. IEEE/IFIP 2001 International Workshop on Distributed Systems: Operations and Management (DSOM 2001), Nancy, France, October 2001. Available on line at http://www.loria.fr/~festor/DSOM2001/proceedings/S2-2.pdf.

Figure 9 A Provisioning Screen

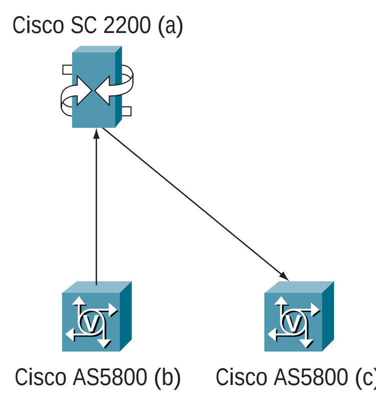


Detection of Configuration Inconsistencies

The notion of virtual entities provides the Cisco Packet Telephony Center with another unique function, namely the ability to detect and flag network level configuration inconsistencies that are otherwise very difficult to troubleshoot. This aspect is one that goes significantly beyond a system that would be content doing only provisioning. For instance, a virtual entity requires its components to be configured in a certain way, for instance to be pointing at each other.

The Cisco Packet Telephony Center provides comprehensive configuration management capabilities. It supports not only provisioning, that is, the generation and delivery of device configurations, but also configuration retrieval to provide an accurate image of the actual network configuration. By validating the current configuration of individual components against the expected virtual entities, users can be alerted of violations of such integrity rules. These violations might be introduced by operating personnel working “around” the Cisco Packet Telephony Center by configuring network devices directly using the command-line interface (CLI), or in cases where the Cisco Packet Telephony Center is added to an already existing deployment. Note that such inconsistent configurations can be very difficult to detect, because typically they are not trapped, and from an element view (such as the one displayed by an EMS) everything appears perfectly legal. Figure 10 depicts one such scenario. A gateway and a signaling controller should be configured to point toward each other. However, because of an erroneous configuration that was performed manually at the devices, instead of gateway (b) pointing at signaling controller (a) and signaling controller (a) pointing back at (b), the signaling controller points at a different gateway, (c). Although the configuration of each network element in isolation is legal, network level configuration integrity is violated, resulting in dysfunctional service at both gateways.

Figure 10 A Misconfiguration Example



Other Management Functions

The current emphasis of the Cisco Packet Telephony Center is on configuration management. However, other management functions are applicable to the management of OPT networks and virtual entities.

Fault management functionality associated with management of virtual entities at the network management layer includes integrated alarm reporting, deduplication, correlation, and impact analysis, in addition to integrated alarm reporting of the various network components. For instance, both the signaling controller and the H.323 gateway in a virtual gateway will report a control connectivity disruption, even if the component at fault is the port of a switch through which all control communications are carried. An advanced fault management application will be able to deduplicate the alarm and indicate the loss of control connectivity as well as loss of service on the affected trunks as the impact/symptoms of the fault. Monitoring is typically performed by a different organizational unit from network provisioning. Hence, a tight integration between configuration and fault management is less necessary. For fault management, the Cisco Packet Telephony Center is accordingly expected to be co-deployed with a dedicated fault-management system, Cisco Info Center, complemented by Cisco Networking Service—Event Engine, a management appliance that precorrelates and preformats alarms and syslog messages from the network.

Performance, accounting, and security management are similar to that of traditional networks and, therefore, are not described here. The Cisco Packet Telephony Center does not carry out performance and accounting management; rather, in a deployment, performance and accounting data collectors such as the data acquisition server (DAS) will complement it. For management security, the Cisco Packet Telephony Center takes advantage of a security server that is shared with other management applications, thus allowing for a common user administration, authorization, and authentication.

There are OPT network management aspects other than those dealing with virtual entites and required control associations. One aspect concerns the management of the transport network that carries the bearer payload traffic, control communications, and potentially the signaling. In many cases, separate network management systems dedicated to the transport network are already in place, such as Cisco WAN Manager for ATM networks in the case of voice-over-IP-over-ATM (VoIPoATM) solutions. Instead of duplicating functionality, the intention of Cisco Packet Telephony Center is to take advantage of those systems. Therefore, Cisco plans for the Cisco Packet Telephony Center to interact with transport network management systems as required to delegate the setup, teardown, and modification of transport connections to carry control or signaling in a way that is transparent to the user.

Element Management

With regard to voice services, comprehensive provisioning and monitoring of gateways, gatekeepers, signaling controllers, media gateways and MGCs as components of their respective virtual entities are supported through the Cisco Packet Telephony Center. Cisco Packet Telephony Center passes through operations to underlying systems as required, so that the operator normally has to interact with only a single management system.

Nevertheless, it should be noted that the Cisco Packet Telephony Center is not intended to replace the respective EMSs of individual network elements. This is important for dealing with the openness property of OPT, because it is impossible to preconceive any component that could possibly be introduced and immediately provide element management for it. Instead, the Cisco Packet Telephony Center takes advantage of EMSs where possible as discussed earlier, allowing users to launch the EMS to perform element-specific tasks such as the downloading of software images. Also, EMSs can make interactions with the network easier, because they generally offer a higher-level abstraction of the network element than the one provided by the network element's Management Information Base (MIB) or CLI. The integration effort with the Cisco Packet Telephony Center can be very small, particularly if EMSs support consistent interfaces based on a canonical in-formation model to minimize any required custom mediation for gateways and gatekeepers, signaling controllers, media gateways, and MGCs. Having said that, the Cisco Packet Telephony Center does not depend on the availability of an EMS, because it can interact with network elements directly when required.

Other Considerations and Solution Summary

In summary, the Cisco OPT management solution addresses the issues raised in the section "The Management Challenge of OPT Networks" as follows:

- Distribution of functionality—This aspect is addressed by the virtual entity concepts, which hide the distribution to a great extent from the user.
- Openness—This issue is addressed by a Cisco Packet Telephony Center architecture that allows EMSs to be easily integrated into the overall solution.
- Flexibility—Again, this aspect is addressed through the virtual entity concepts. Provisioning rules associated with different flavors of the same type of virtual entity (such as different variations of virtual switches) ensure consistency with different OPT network solutions.
- Integration—the Cisco Packet Telephony Center provides a single point of entry for the configuration management of all voice aspects, taking advantage of other tools such as EMSs and transport network management systems as integral parts of the solution. This balances the need for integration from a user perspective with the pragmatics of being able to develop independent management components that can be combined into component-based management solution architecture.

Issues and Challenges Encountered

The following outlines some of the issues and challenges that the Cisco Packet Telephony Center needs to address. Although each warrants a detailed discussion, only key points are delineated.

- Management information model—One question that needs to be resolved is how to represent a virtual switch and its components at the northbound interface. Also, a canonical representation of gateways and gatekeepers, signaling controllers, media gateways, and MGCs on which voice-management applications can be based is required. The same representation would ideally be supported by the EMSs for the individual network elements. This setup would minimize integration and a management information mediation effort. In essence, support of such an interface "Cisco Packet Telephony Center enables" an EMS and the devices it manages. No comprehensive standards exist that specify a management information model specific to OPT networks. Therefore, a model for the management of virtual entities was developed[10]. This model distinguishes different categories of managed object classes (MOCs): virtual entity MOCs provide the abstraction of the virtual entity as a whole and the components and services it provides, typically network management concepts that aggregate management information across components (trunks, trunk groups, control connections, and so on). Device MOCs represent the network elements, that is, the gateways, gatekeepers, signaling controllers, media gateways, and MGCs, respectively, of which virtual switches are composed. Those are essentially the concepts exposed by the EMS that the Cisco Packet Telephony Center mediates toward, representing the individual components in isolation: their physical instantiation (shelf/slot/card), lines, ports, termination endpoints, and so on. The model has been defined to align with M.3100[11]; a common information model (CIM)-based variation (see, for example,[12]) is also available.
- Discovery of virtual entities—Even in the presence of the Cisco management solution, in many cases OPT deployments already exist or operators decide to use other tools such as CLI or craft interfaces to bring up the network. It would greatly compromise user acceptance if virtual entities had to be configured or entered a second time at the Cisco

10. Clemm, A., and P. Leung: *Model-Driven Open Packet Telephony Management.* Accepted at IEEE/IFIP 2002 Network Operations and Management Symposium (NOMS 2002), Florence, Italy, April 2002.

11. ITU-T Recommendation M.3100: Generic Network Information Model. July 1995.

12. Strassner, J. *Directory Enabled Networks.* Macmillan Technical Publishing, Indianapolis, Indiana, 1999.

Packet Telephony Center system. Therefore, discovery not just of the network itself but of virtual entities such as virtual switches and virtual trunks is required.

- Management transactions and rollback—As attractive as it is to hide distribution complexity, this concept comes with an undesirable feature: fallout processing, or the issue of how to handle situations in which problems arise. Of course, as far as possible the system will roll back operations that are part of management transactions if a part of the transaction does not succeed. However, because we are dealing with real resources outside the control of a single management system, it is always possible to encounter a situation that results in an inconsistent state of the network or of a virtual entity. For those cases, the system provides the operator with enough assistance that it is still easy to see where the problem arose, facilitating manual intervention. The present solution provides such support, including the flagging of inconsistencies present in the network (the same concepts applied in autodiscovery described above) as well as the logging of virtual switch operations as management transactions, keeping track of progress of provisioned jobs, and offering functions that allow users to check the status of any provisioning job and the subtasks of which it is composed.

Conclusion

OPT networks provide an excellent value proposition to service providers. Although they reduce complexity of the deployed network elements, arguably some of that complexity is shifted into operations. How to allow for efficient management is, therefore, an important consideration, and it presents interesting technical challenges. This paper has presented a management solution for the aspects that make this problem space particularly unique. The centerpiece is the Cisco Packet Telephony Center, which realizes virtual concepts such as virtual zones, virtual gateways, virtual switches, and virtual trunks that greatly simplify operations by hiding much of the underlying network complexity. The solution thus strikes a balance between the requirement to educate operators on OPT and at the same time minimize disruption compared to traditional management. The feedback so far has been overwhelmingly positive. Challenges going forward include the continuing and ever-increasing need for integration, for instance, the incorporation of additional devices and tighter coupling between fault and configuration management.