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College for Professional Studies Graduate Programs
Final Project/Thesis

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Abstract

Systems Engineering and Application Development (SEAD) Practicum provides opportunities for students to engage in proposing, designing, building and testing various projects related to information technology. There are several ongoing projects designed to upgrade, improve or revamp some aspect of the Academic Research Network, generally referred to as ARNe, and services or applications that are a part of its architecture. Regis University is in the process of replacing their current architecture and equipment that forms the core of ARNe in order to facilitate further upgrades and new projects within various aspects of ARNe. This paper examines and proposes a Cisco-based routing solution utilizing Cisco ISR routing platforms for interconnecting the core WAN, providing a high-performance, scalable, and flexible solution for immediate and future needs.

Acknowledgements

I would, first of all, like to thank God for giving me the strength and endurance to excel in each class and to see this program to completion. I would also like to thank my wife for supporting me all the way and for putting up with all the long hours I spent locked away working on this degree. I would also like to acknowledge my professors for providing me with very insightful information and for enabling me to acquire skills and knowledge that were immediately useful, and that enable me to expand my career.

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Chapter 1: Introduction

Background

Regis University presents a number of opportunities for graduate students within the School of Computing and Information Sciences to gain hands on experience in their program of study. Students seeking to complete their thesis can apply for and be accepted into the Systems Engineering and Application Development (SEAD) Practicum where they engage in proposing, designing, building and testing various projects. A number of projects are ongoing and were designed to upgrade, improve or revamp some aspect of the Academic Research Network, generally referred to as ARNe, and services or applications that are a part of its architecture. According to the SEAD website (http://trackit.arn.regis.edu/sead/new_page1.htm), SEAD's mission is to:

1. Support the SCIS curriculum by providing hands-on experience with software and hardware.
2. Provide a stimulating environment for students to complete their professional project.
3. Encourage and support collaboration between Oracle database administrators and system engineering students.

The SEAD organizational structure is that of an IT company that follows the Information Technology Infrastructure Library (ITIL) framework and is SOA based. ITIL, as defined by the official website, ITIL consists of a series of books that provide guidance on the provisioning of quality IT services and the supporting infrastructure. Additionally, ITIL provides consistent and comprehensive documentation in regards to applying best

practices for IT Service Management. Applying ITIL guidance results in benefits such as reduced costs, improved IT services, improved customer satisfaction, standards and guidance, and improved productivity (ITIL, itil-officialsite.com). The Service Oriented Architecture (SOA) is an architectural style that separates the services or functionality that a system can provide from service consumers. The service consumers are systems that need that functionality. By separating or decoupling the services from service consumers a more flexible architecture is developed and can be easily reconfigured without completely revamping the entire system (McGovern, 2004 p.63). SEAD features operating groups that include Systems, Data, Application Development, Integrated Services and Networking. These groups are responsible for parts of the architecture that consist of server management, security, data storage, application development, and help desk (Regis University, trackit.arn.regis.edu/sead/new_page1.htm).

Regis University is in the process of replacing their current architecture and equipment that forms the core of ARNe. This upgrade in infrastructure and architecture will provide a platform for further upgrades and new projects within various aspects of ARNe. The current core infrastructure does not adequately enable Regis to realize these goals and is not as flexible and scalable to support current and future projects. The core of the WAN will be used to transport packets among the various sites within ARNe. Therefore, the core should facilitate high speed transporting of traffic as well as low-latency packet transmission in order to provide a satisfactory experience for all users. The performance of the core routers is paramount as the quality of routing process and the transmission of packets is highly dependent on the architecture of the router—hardware and software. Also, the type of routing protocol used should be carefully considered as

each protocol has its share of benefits and shortcomings (Cernick, et al, 2000 p.15-18). The proposed routing solution should be flexible and scalable to accommodate current and future project goals and design changes.

Proposed Solution

The proposed solution for this project is Cisco-centric: focuses on Cisco's routing platforms and Cisco's routing protocol. What this means is that, based upon the requirements of the team evaluating ARNe's core infrastructure as well as the network equipment supporting the core, a proposal to replace the said equipment with a Cisco solution was required. This document examines only the core layer and does not venture beyond the perimeter of the network. However, items mentioned such as the routing protocol could also affect the distribution and access layer of the network, depending on the design.

Hardware

- The type of routing platform that should be used in the WAN core.
- The vendor (Cisco) solution that best meets the needs of ARNe. This refers to the series and specific model of router.
- The benefits of using this / these routing platforms. Cisco manufactures a myriad of routers with various purposes. In this case, as it is with any other case, the solution that presents the most benefits, without going overboard is desirable.
- Two models, one each from the Cisco 1800 and 2800 Integrated Series Router platforms are proposed, with one model 2811

(www.cisco.com/en/US/prod/collateral/routers/ps5854/ps5882/product_data_sheet0900aecd8016fa68.pdf) being better suited for the main site and a different model, 1841 (www.cisco.com/en/US/prod/collateral/routers/ps5853/product_data_sheet0900aecd8016a59b.pdf) being more suited for the remote locations. Both platforms are discussed in detail in chapter two and subsequent chapters.

Design and Protocol

- The WAN topology affects performance, redundancy and a number of other issues. The solution proposed in this document favors the star or hub-and-spoke topology.
- One of the benefits of the proposed topology is more simplified network management. Other benefits are discussed subsequently.
- There are several choices for interior routing protocols: RIP (IETF RFC's 1058; 1723; 2453), OSPF (IETF RFC's 1131; 2328), IGRP and EIGRP. Each protocol is examined to determine the best option to be used in conjunction with the Cisco-centric WAN core.

Approach

Research:

In order to provide what this author believes is the best solution, information was gathered on the current WAN infrastructure of ARNe to determine the requirements.

Additional research was done on Cisco's routing platforms, including identifying benefits, concerns and costs. Further research was also done on supporting IP routing protocols as well as ideal WAN topologies that will meet or exceed the needs of the ARNe core.

Selection:

After researching the various routing solutions that Cisco provides, the specific platforms were chosen. Additionally, it is assumed that other network hardware in the form of wan interface cards would be needed to connect each router to the leased circuit at its location. Since the routers will be routing packets between sites, the ideal routing protocol was selected that takes into consideration the hardware platform that is being used, the WAN topology that will be utilized, performance and management.

Design:

The design of ARNe's WAN core features at least seven different sites, including the main site in Denver, CO. The WAN is designed using the proposed WAN topology and diagrammed with links to each remote site and the main site. In an ideal world, each site will connect using private T1 leased lines. But, factors such as cost, availability and bandwidth requirements will eventually determine the type of connectivity at each location. The design not only addresses the logical layout of the WAN, but it also addresses the physical hardware interconnectivity used at each location.

Since this document is, for the most part, a proposal, the actual implementation will be done by another party or group. Having said that, it is understandable that design, as well as other functional aspects may change. There may also be other factors such as cost, individual skill levels, shift in project focus, and other changes that may alter the implementation of this proposal.

Thesis Statement:

To research and propose a Cisco Systems based solution that adequately supports the demands of the Regis ARNe WAN infrastructure at the core layer. ARNe is the Regis Academic Research Network that provides Information Technology students with a platform for gaining hands-on experience in research and development of technology aspects of the Regis University network (http://trackit.arn.regis.edu). This proposed solution takes into consideration the current needs of ARNe and possible future requirements and projects.

Chapter 2: Research

Cisco Router Hardware Platform.

Interconnecting the main site to the remote sites requires routing hardware that connects to the current ISPs at each location. Since this document proposes the Cisco routing platform for interconnecting the WAN, two separate hardware routers should be used. The first router platform for use at the main site in Denver, CO, is the Cisco 2800 series Integrated Services Router. In this case the 2811 modular router.

Cisco 2800 Series Integrated Services Router

Many organizations need to link their remote locations with their main headquarters, to optimize business processes, share data, improve communication and provide better customer support. To supply this demand, several vendors have manufactured and marketed routing platforms. Cisco Systems is one of such companies who have successfully designed several routing platforms, with a vast range of features and functionalities that customers can choose from to meet their needs. The 2800 Series Integrated Series Router (ISR) provides an option for small to medium-sized organizations to enable wide area networking among many locations.

The 2800 ISR consists of four platforms. These include the Cisco 2801, 2811, 2821 and 2851. This series aims to provide similar price points to prior generations of similar Cisco routers while offering major performance (up to fivefold) and security (up to tenfold) improvements, embedded service options, increased slot density and performance and maintains support for over ninety (90) existing modules that are

available for the Cisco 2600, 3700 and 1700 series routers (Cisco 2800 Series Integrated Services Routers, 2008 p.1).

Further, the 2800 series ISR can deliver multiple high-quality services simultaneously and at wire speed to multiple T1 connections. Additionally, they provide embedded encryption, acceleration and built-in voice digital-signal-processor slots. The 2800 series ISRs also feature an intrusion prevention system, firewall functionality, integrated call processing and voicemail support, if necessary, high density interfaces that support a wide range of wireless and wired connectivity options.

Secure Network Connectivity for Data Voice and Video

In order to enhance a network's security posture, the 2800 series ISR features integrated security that facilitates an end-to-end secure delivery of converged services and applications. With the IOS Advanced Security feature set, customers can utilize features such as the software firewall, VPN, intrusion prevention, IPSec, SNMPv3, SSH and advanced application inspection. Also, the 2800 routers offer a range of security and acceleration hardware such as the advanced integration modules (AIM) for encryption (Cisco 2800 Series Integrated Services Routers, 2008, p.2).

Converged IP and Wireless Communications

The 2800 series provides the option to integrate call processing for Cisco IP telephones (wired and cordless) within the IOS in a service called Cisco CallManager Express. Therefore, customers that already have data connectivity implemented who are interested in deploying a converged IP telephony system for up to ninety-six IP phones

can do so using the same platform as their data platform. This is due to the 2800 series' ability to concurrently deliver secured data, voice and IP telephony on a single platform.

The Cisco 2800 series routing platform provides wireless solutions for small to medium-sized businesses. Routers in this series support integrated access points that enable wireless LAN connectivity, wireless infrastructure services for cordless WLAN telephones, as well as land mobile radio over IP for radio users (Cisco 2800 Series Integrated Services Routers, 2008 p.2).

Integrated Services

Because of the integrated functionality of the 2800 series platform, organizations can securely deploy IP communications and IP routing while leaving interface and module slots available for additional advanced services. Customers can integrate standalone network appliance functions and components into the chassis itself. Many of these modules have embedded hard drives and processors that enable them to run largely independently of the router while allowing management from a single interface. This expands the capability and application of the 2800 series ISR beyond traditional routing (Cisco 2800 Series Integrated Services Routers, 2008 p.3).

Table 2 - 1. Architecture features and benefits. (Cisco Systems)

Feature	Benefit
Modular Architecture	• A wide variety of LAN and WAN options are available. Network interfaces can be upgraded in the field to accommodate future technologies. • Several types of slots are available to add connectivity and services in the future on an "integrate-as-you-grow" basis. • The Cisco 2800 supports more than 90 modules, including WICs, VICs, network modules, PVDMs, and AIMs (Note: the Cisco 2801 router does not support network modules).
Embedded Security Hardware Acceleration	• Each of the Cisco 2800 Series routers comes standard with embedded hardware cryptography accelerators, which when combined with an optional Cisco IOS Software upgrade help enable WAN link security and VPN services.
Integrated Dual Fast Ethernet or Gigabit Ethernet Ports	• The Cisco 2800 Series provide two 10/100 on the Cisco 2801 and Cisco 2811 and two 10/100/1000 on the Cisco 2821 and Cisco 2851
Support for Cisco IOS Software	• The Cisco 2800 helps enable end-to-end solutions with full support for the latest Cisco IOS Software-based QoS, bandwidth management, and security features. • Common feature and command set structure across the Cisco 1700, 1800, 2600, 2800, 3700 and 3800 series routers simplifies feature set selection, deployment, management, and training.
Optional Integrated Power Supply for Distribution of Power Over Ethernet (PoE)	• An optional upgrade to the internal power supply provides in-line power (802.3af-compliant Power-over-Ethernet [PoE] and Cisco standard inline power) to optional integrated switch modules.
Optional Integrated Universal DC Power Supply	• On the Cisco 2811, 2821, and 2851 routers an optional DC power supply is available that extends possible deployments environments such as central offices and industrial environments (Note: not available on the Cisco 2801).
Integrated Redundant-Power-Supply (RPS) Connector	• On the Cisco 2811, 2821, and 2851 there is a built in external power-supply connector that eases the addition of external redundant power supply that can be shared with other Cisco products to decrease network downtime by protecting the network components from downtime due to power failures.

Source: Cisco 2800 Series Integrated Services Routers, p.4

Table 2 - 2. Chassis Specifications. (Cisco Systems).

Cisco 2800 Series	Cisco 2801	Cisco 2811	Cisco 2821	Cisco 2851
Product Architecture				
DRAM	• Default: 128 MB • Maximum: 384 MB	• Default: 256 MB • Maximum: 768 MB	• Default: 256 MB • Maximum: 1 GB	
Compact Flash	• Default: 64 MB • Maximum: 128MB	• Default: 64 MB • Maximum: 256 MB		
Fixed USB 1.1 Ports	1	2		
Onboard LAN Ports	2-10/100		2-10/100/1000	
Onboard AIM (Internal) Slot	2			
Interface Card Slots	• 4 slots; 2 slots support HWIC, WIC, VIC, or VWIC type modules • 1 slot supports WIC, VIC, or VWIC type modules • 1 slot supports VIC or VWIC type modules	4 slots, each slot can support HWIC, WIC, VIC, or VWIC type modules		
Network-Module Slot	No	1 slot, supports NM and NME type modules	1 slot, supports NM, NME and NME-X type modules	1 slot, supports NM, NME, NME-X, NMD and NME-XD type modules
Extension Voice Module Slot	0		1	
PVDM (DSP) Slots on Motherboard	2		3	
Integrated Hardware-Based Encryption	Yes			
VPN Hardware Acceleration (on Motherboard)	DES, 3DES, AES 128, AES 192, and AES 256			
Optional Integrated In-Line Power (PoE)	Yes, requires AC-IP power supply			
Console Port (up to 115.2 kbps)	1			
Auxiliary Port (up to 115.2 kbps)	1			

Source: Cisco 2800 Series Integrated Services Routers, p.8

The Cisco 2800 series Integrated Service Platform provides high performance, security, flexibility and scalability that would provide an excellent solution for a corporate headquarters or main site to enable satellite or remote locations to connect to services at its location. However, remote sites may not need all of the functions and features of a 2800 series ISR. To address such cases, Cisco provides a smaller scale, integrated routing platform called the 1800 Series Integrated Services Router.

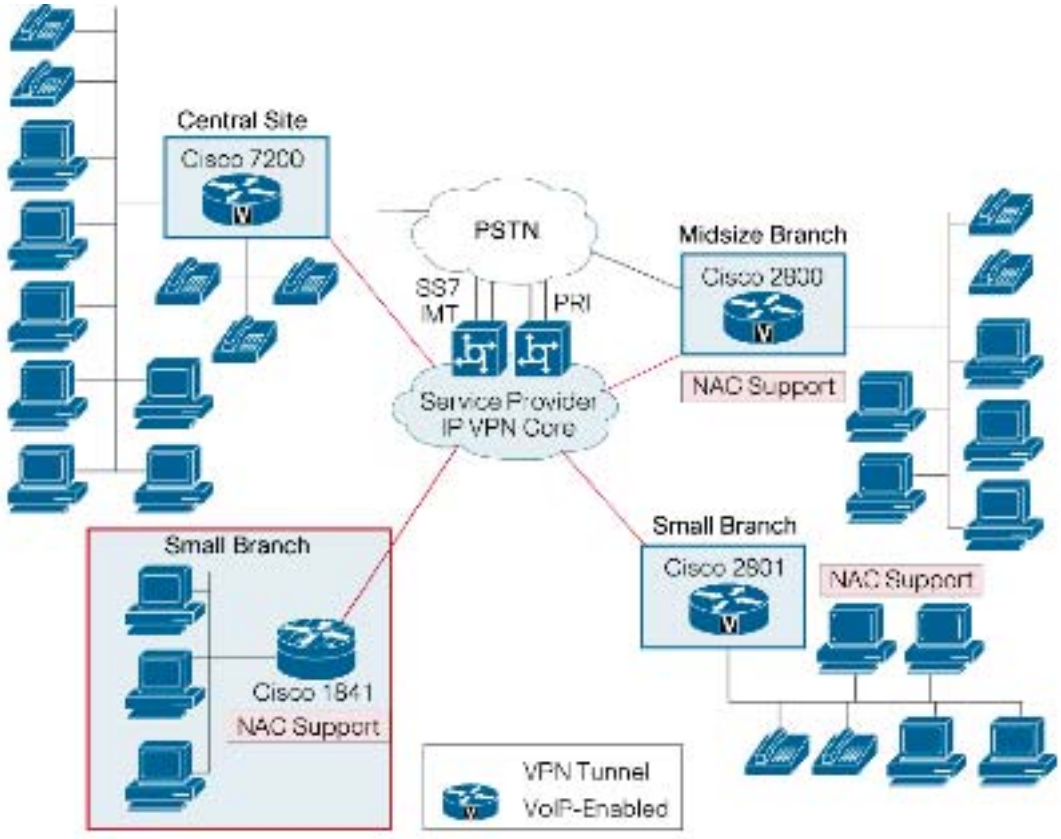
Cisco 1800 Series Integrated Services Router

The Cisco 1800 Series ISRs are produced in two configurations: fixed and modular. However, in order to provide the most flexibility in this platform, the modular configuration option, which is the 1841 router, will be used at each remote location in the ARNe network.

Cisco designed the 1800 Series to be the next evolution of the 1700 Series modular access router. Similarly to the 2800 Series platform, the 1800 Series was designed for secure data connectivity while adding significant performance advantages over the 1700 Series router as well as integrated hardware-based encryption. The 1841 router also maintains support for more than thirty (30) existing WAN interface cards and multiflex trunk cards such as VWICs (Cisco 1800 Series Integrated Services Routers: Cisco 1841 Router, 2008 p.1). By providing support for existing WIC and VWIC cards, Cisco enables customers who have purchased such cards for use on other platforms to protect their investments by not having to purchase new cards exclusively for the 1841 router.

The 1841 router enables fast and high-quality delivery of multiple concurrent services for small and medium-sized businesses. It features optional VPN, intrusion prevention, and firewall functions, thus providing embedded security at the access edge. The 1841 router also provides support for SSH, IPSec, SSL VPN, Network Admissions Control and SNMP in one IOS solution set (Cisco 1800 Series Integrated Services Routers: Cisco 1841 Router, 2008 p.1). Figure 2-1 illustrates how an 1841 router may be used to provide secure network connectivity to other corporate locations.

Figure 2 - 1. Cisco 1841 Router: Secure Network Connectivity. (Cisco Systems).



Source: Cisco 1800 Series Integrated Services Routers: Cisco 1841 Router (modular) p. 2

The high-performance integrated services architecture of the Cisco 1841 router enables businesses to simultaneously deploy services such as data communications along with traditional IP routing at wire-speed. This platform also provides flexibility to integrate a vast array of services, modules and interface cards, making the 1841 a standalone secure data solution (Cisco 1800 Series Integrated Services Routers: Cisco 1841 Router, 2008 p.2-3).

The enhanced modular design of the 1841 router was designed to provide increased bandwidth and performance that can effectively support concurrent secure applications. Specifically designed to meet the needs of small and medium-sized business, the 1841 router along with the 2800 Series Integrated Services Router provide organizations with the broadest range of secure connectivity in addition to availability and reliability features (Cisco 1800 Series Integrated Services Routers: Cisco 1841 Router, 2008 p.3). Table 2-3 below lists architecture feature and benefits of the 1841 router.

Table 2 - 3. Cisco 1841 Router: Architecture Features and Benefits.

Feature	Benefit
High-Performance Processor	• Supports concurrent deployment of high-performance, secure data services with headroom for future applications
Modular Architecture	• Offers wide variety of LAN and WAN options; network interfaces are field-upgradable to accommodate future technologies • Provides many types of slots to add connectivity and services in the future on an "integrate-as-you-grow" basis • Supports more than 30 modules and interface cards, including existing WAN (WIC) and multiflex (VWIC) interface cards (for data support only on the Cisco 1841 router) and advanced integration modules (AIMs)
Integrated Hardware-Based Encryption Acceleration	• Offers cryptography accelerator as standard integrated hardware that can be enabled with an optional Cisco IOS Software for 3DES and AES encryption support • Provides enhanced feature set of security performance through support of optional VPN acceleration card for VPN 3DES or AES encryption
Ample Default Memory	• Provides 32 MB of Flash and 128 MB of synchronous dynamic RAM (SDRAM) memory to support deployment of concurrent services
Integrated Dual High-Speed Ethernet LAN Ports	• Helps enable connectivity speeds up to 100BASE-T Ethernet technology without the need for cards and modules • Allows segmentation of the LAN
Support for Cisco IOS 12.3T, 12.4, 12.4T Feature Sets and Beyond	• Supports the Cisco 1841 router starting with Cisco IOS Software Release 12.3T • Helps enable end-to-end solutions with support for latest Cisco IOS Software-based QoS, bandwidth management, and security features
Integrated Standard Power Supply	• Provides for easier installation and management of the router platform

Source: Cisco 1800 Series Integrated Services Routers: Cisco 1841 Router (modular) p.3

WAN Topology

With each remote site requiring connectivity to ARNe, an appropriate WAN topology needs to be selected that will meet the needs of ARNe and provide the most cost-effective solution. There are several WAN topology options to choose from and each has its own set of benefits and shortcomings. Since the Denver Tech Center is the main site, the other locations are considered smaller branches that require interconnection to the main site. Normally, relatively smaller branches tend to have a single WAN

connection to the headquarters or main site. In this configuration, the smaller sites typically collapse many services into a single networking product such as a Cisco Integrated Services Router (Doherty et. al, 2008 p.114).

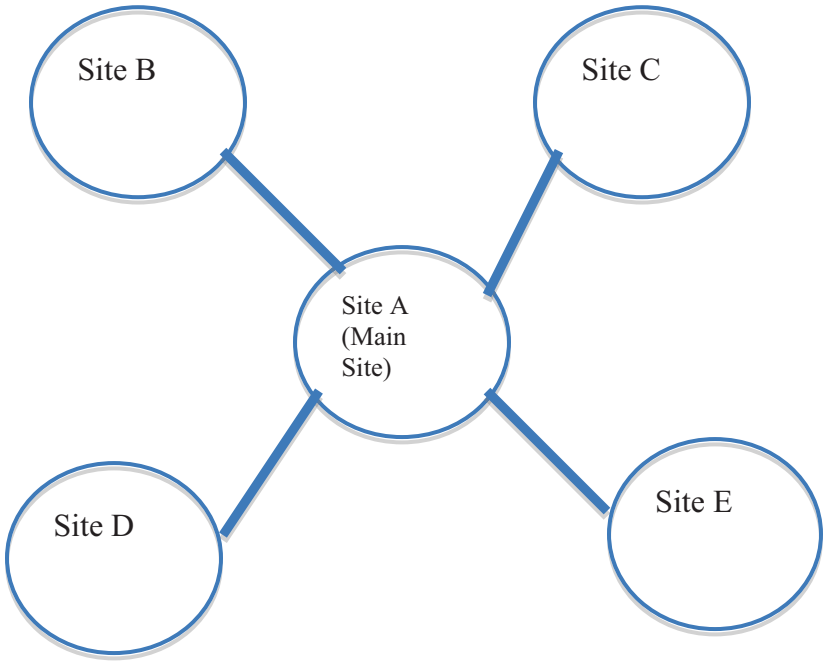
The typical WAN topologies used today are mesh, which includes either full or partial mesh, ring topology and star topology. In a full mesh WAN topology, a separate dedicated link, such as a point-to-point leased line is used at each site to connect to every other site in the WAN. So if you have five offices in different cities, each office has four separate WAN links that connect it to the other offices. While this configuration provides the greatest amount of fault tolerance and network efficiency, it can be very expensive and wasteful, especially if the network does not generate enough traffic between sites to fully utilize all the links (Zacker, 2001 p.280-81). A partial mesh WAN is similar to a full mesh except that it does not interconnect every site to each other. Instead site links are carefully chosen based on the premise that not every site needs to be directly connected to every other site. This means that there are fewer links involved; but cost is also reduced (Zacker, 2001 p.280-81).

A ring topology connects each site to two other sites, for instance. This topology typically uses one more link than a star topology but offers improved fault tolerance. The problem with this configuration is that it introduces a delay by the need for traffic to pass through multiple sites in order to reach to its destination (Zacker, 2001 p.282). A ring is not used as often as the other topologies in this discussion.

The WAN star topology provides interconnectivity by linking all remote sites to the main site or headquarters, usually via a single link at each location. In a star, the core router at the main site serves as the hub for the other WAN connections. Another name

for this configuration is the hub-and-spoke topology. The core router connects to each branch or remote site, and sites can only communicate with each other by passing their traffic through the core router at the main site. Although the star topology is not as fault tolerant as the mesh topology and can present some performance concerns, it does provide the advantage of simplified and centralized WAN topology management as well as reduced costs (Bruno, 2004 p.165). Additionally, in comparison to a partial mesh WAN, each site in the star is never more than two hops away from another site that needs to communicate with it.

Figure 2 - 2. A Star WAN Topology.



Routing Protocol

Routing IP traffic efficiently between sites is necessary to ensure that network performance is as optimal as possible. Routes to each location is contained within the routing tables on each core router and routed protocols such as IP traverses the WAN utilizing the best route to its destination. In order to populate the routing table on a router, administrators can utilize static routes in which the destination's route is hard entered into the router by using the Cisco IOS command "ip route." When only static routes are used, routers can only forward packets to those defined destinations. Defining static routes work well for a small WAN. However, scalability can become an issue since it is difficult to manage with larger networks, as each route will need to be defined on each router.

Dynamic Routing Protocols

Dynamic routing protocols such as OSPF, RIP, IGRP and EIGRP enable the router to dynamically learn or discover routes automatically. The dynamic routes adjust to network topology changes and can forward packets to over any discoverable route. An advantage that dynamic routing protocols have over static routing protocols is that they can automatically adapt to changes in network topologies such as outages; static routing cannot do that (Castelli, 2002 p.685-86).

Any of the above mentioned interior routing protocols can be utilized on a Cisco router. However, both IGRP and EIGRP are exclusive to Cisco and can only be used in a Cisco environment unless route redistribution is used. Route redistribution, according to

McFarlane (2006), pertains to the process of importing routes that were learned from other sources into a particular routing protocol. These sources include static routes, routes from another routing protocol, and directly connected routes (Network routing basics, chpt. 10). Each interior routing protocol can be categorized into either a Distance-vector or a Link-state protocol; with each having its own set of features, benefits and disadvantages. The exception to this is EIGRP, the Cisco proprietary protocol, which is more of a hybrid protocol. Both RIP and IGRP are Distance-vector protocols. Basically, Distance-vector protocols advertise routing information by sending messages that are called routing updates. The updates include information such as the subnet and metric. The metric represents how good the route is; the smaller the number, the better the route is considered to be (Odom, 2003 p. 411). Distance-vector protocols are slow to converge when there is a failure. And RIP, or instance can be very "chatty" as it transmits full routing tables every thirty seconds. It also is limited to a maximum of fifteen hops for its metric.

OSPF is a Link-state protocol. Link-state protocols enable each router to devise a complete map of the network topology by advertising a large amount of topological information, which is processed using the Dijkstra Shortest Path First (SPF) algorithm. OSPF uses cost for its metric; converges very quickly if there is a failure; supports VLSM; uses short Hello messages on a short regular interval instead of full updates—minimizing network traffic; and sends partial updates when a link changes (Odom, 2003 p. 417-8).

Hill (2002) states that the EIGRP protocol is a hybrid interior routing protocol that incorporates the best features of both link-state and distance-vector protocols and

adds some of its own functionality. EIGRP reduces network and router overhead by multicasting routing updates, sending routing updates only when a network change is detected, updating only the routers that need to be aware of the topology change, and sending changes only to the routing table rather than the entire table. EIGRP supports VLSM and CIDR since it includes the subnet mask in routing updates. It also supports discontiguous networks and manual route summarization. The EIGRP protocol is extremely fast at converging in the event of a failure. A typical convergence occurs in a matter of seconds. EIGRP is more complex than IGRP and RIP. However, it is less complex than OSPF to design, implement and support and provides many benefits (p. 810). For these reasons, this document proposes implementing EIGRP as the dynamic routing protocol within the ARNe core.

EIGRP Operational Overview

Routers within an EIGRP topology maintain three tables that hold information. There are the Neighbor table, the Topology table, and the Routing table. Upon boot up, each router actively seeks out its neighbors and adds them to its neighbor table. The router then transfers its entire routing table to the neighboring router(s). EIGRP then adds all downstream routes to the destination routers to its topology table. It then chooses one or more routes as the best routes to the destination from the topology table. When a topology change occurs, the routers closest to the topology change examine their topology table for an alternate route to the destination and update their upstream neighbors on the route change if an alternate route is found. If an alternate route is not found, the router queries its neighbors for a new route. The neighbors will examine their

topology tables for an alternate route and respond to the querying router (Hill, 2002 p. 811).

The Diffusing Update Algorithm (DUAL) performs the internal workings of EIGRP and enables it to be an effective and efficient routing protocol. EIGRP enabled routers use a metric based on bandwidth and delay to select the best route. Additionally, DUAL defines a method for each router to calculate both the best current route to a destination as well as alternate routes to be used if there is a failure. This alternate route is called the feasible successor route (Odom, 2003 p. 419).

Chapter 3: The Problem Approach

The Case for Cisco

With so many organizations operating from multiple locations, it is paramount for data, applications and services to be effectively extended to those remote locations and branch offices. This means that the network at the main branch must be expanded to include remote sites. Organizations such as Regis University are engaged in extending its services to several offsite locations and utilize a wide area network to facilitate the provisioning of information and services. Choosing the right network equipment vendor and solution is important as the decisions made here can affect the quality and the overall satisfaction of the WAN. Several factors influence the decision on which WAN solution and vendor should be used for interconnecting the ARNe network. These factors include flexibility, scalability, performance, management, and cost factors. Since this document focuses on a Cisco-centric solution, it will illustrate how the proposed Cisco networking solution meets these requirements or factors.

Flexibility

In designing the core routing architecture for ARNe, a flexible solution would better serve the needs of a growing and innovative organization such as Regis is. Since ARNe provides many opportunities for students to gain hands-on experience and to work with faculty to research and develop various technologies and projects that further enhance the goals of Regis, flexibility in all aspects of the network build out is necessary. Flexibility, in this, case, suggests that the routing platform should not only meet the current needs or services being used within ARNe but should be able to provide additional services, connectivity options and features whenever the demand arises. For instance, Regis may require additional data, firewall, VPN, IP telephony and wireless solutions eventually. And rather than having to purchase additional equipment outside of the current Cisco hardware, it would be ideal to be able to integrate these features and services within the current hardware inventory.

Cisco provides flexible solutions through its Integrated Service Routers proposed in this document. As mentioned in chapter two, the 2811 and 1841 ISR routers provide

modular platforms that enable Regis to integrate other features besides IP routing. These platforms enable services such as VPN, firewall, intrusion prevention, IP telephony and wireless to be integrated into the ARNe network at any time with minimal cost. With the core routing architecture being the main focus it is expected that IP routing will be the highlighted factor. However, it is good to be aware that the 2811 and 1841 ISR platforms possess the flexibility that is likely to be leveraged at some point in the future.

Scalability

When considering the purchasing or upgrading of networking solutions, the scalability—ability to grow with demand—of the solution is often examined. Rybaczyk (2005) states that a scalable solution facilitates the growth of a business and, over a period of time, it allows for incremental rather than forklift-style upgrades. Further, a scalable network solution allows for increase in the number of users, amount of and type of usage without post-deployment degradation of the network or the need for dramatic upgrades (p. 17).

Again, the modular design of the 2811 and 1841 ISR routers allow them to scale as the need arises. For instance, an increase in users on the ARNe network will increase traffic across the WAN, thus putting more demand on the routing hardware and the bandwidth used across each connection. The Cisco ISRs are already designed to accommodate many users while providing several services simultaneously. However, in the event that there is an increase in usage demand, additional RAM and storage can be added to the router, allowing it to process more requests and services efficiently without degradation. In the case of an increase in bandwidth demand, additional WIC or HWIC modules can be purchased and installed in the router and used to connect additional WAN connections such as point-to-point T1's, frame relay or other solutions. If a VPN is used to connect users to the ARNe network or as an additional site-to-site connection is needed, the ISR router can offload the major processing of VPN traffic to an optional VPN acceleration card. This allows the router to process all traffic without being affected by an increase in VPN traffic.

Performance

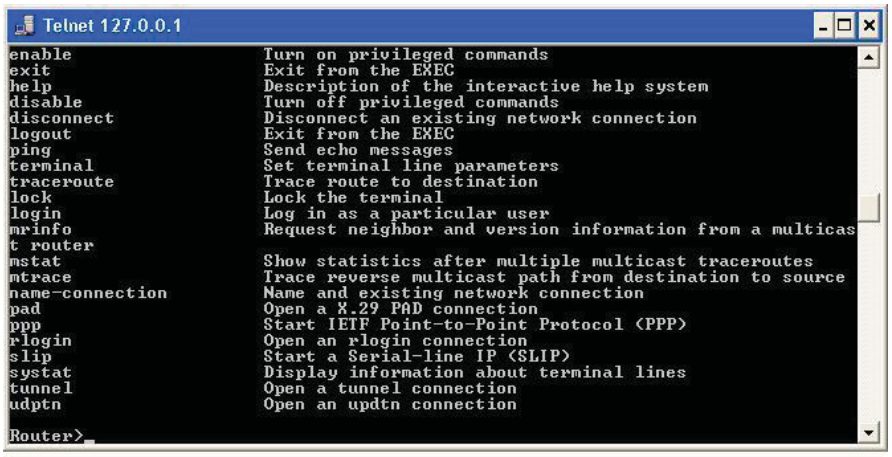
Wide Area Networks are generally more expensive to build and maintain than local area networks, although the WAN bandwidth is much smaller between sites. This means that the core routers at ARNe's perimeter have to receive then process and manage traffic coming from the each LAN before they cue and transmit the packets across the WAN to their destination. There are a number of traffic management and shaping options that can be configured on each Cisco ISR router in order to optimize traffic flow. And while the network administrator can configure the router to create predictable traffic flow patterns, the hardware and software of the 2811 and 1841 platforms are still responsible for routing traffic with optimum performance.

Cisco designed the ISR routers with major performance increases over previous platforms such as the 1700 and 2600 series. In an independent lab study conducted by InfoWorld that evaluated the 1800W and 2811 ISR routers running several services including telephony and wireless, both routers were given a nine out of possible ten points for performance (InfoWorld, 2006). Of course, actual performance may vary in each environment but this study gives an idea of the performance level of these routers.

Configuration and Management

Configuring a router can be a complicated and complex exercise, especially for those who are inexperienced with that particular brand or model of router. Cisco routers are no exception. In fact, the most well known method for configuring and managing a Cisco router is by using the command line interface (CLI) of the IOS. The CLI is similar in appearance and context to the UNIX operating system command shell. Network administrators typically connect to the Cisco router through the console port, serial (AUX) connection or via telnet to access the CLI. Then he or she would type commands at the command prompt in order to configure and manage the router. Figure 3-1 shows the screenshot of a CLI session.

Figure 3 - 1. Cisco Command Line Interface.



The Cisco IOS that is included in the 2811 and 1841 ISR routers has several different modes, with each mode having a unique command prompt, function and list of commands. The User Exec mode, which is the first prompt seen when connecting to the router and passing the login, contains a limited set of commands, such as ping, that are fairly harmless to the router. The Privileged Exec mode, also known as the enable mode, is where the main configuration, observation and control of the router take place. The administrator access the enable mode by typing “enable” from the User Exec mode. There is also the Global Configuration mode where you configure the router and program IOS commands into its active configuration. The Global Configuration mode is accessed by entering “configure terminal” from Privileged Exec mode (Lee, 1999 p.330-4). There are also Interface, Sub-interface, Line and other configuration modes.

The CLI can be intimidating for some users, especially for beginners; and although it provides the most granular control of the router, the CLI can take a while to become proficient in. However, it is a powerful tool for controlling the ISR routers. Incidentally, there is a setup wizard that can help with the initial configuration of the router.

Alternatively, Cisco has provided the Security Device Manager (SDM), which is a built-in GUI that enables administrators to configure the router from a within a web browser—without the need to understand the CLI. The SDM is a Java based management

application that consists of well-laid-out, frames-based configuration dialog and can be launched from a web session directly with the router. Almost all of the configuration options are available through SDM with a few exceptions (Venezia, 2006).

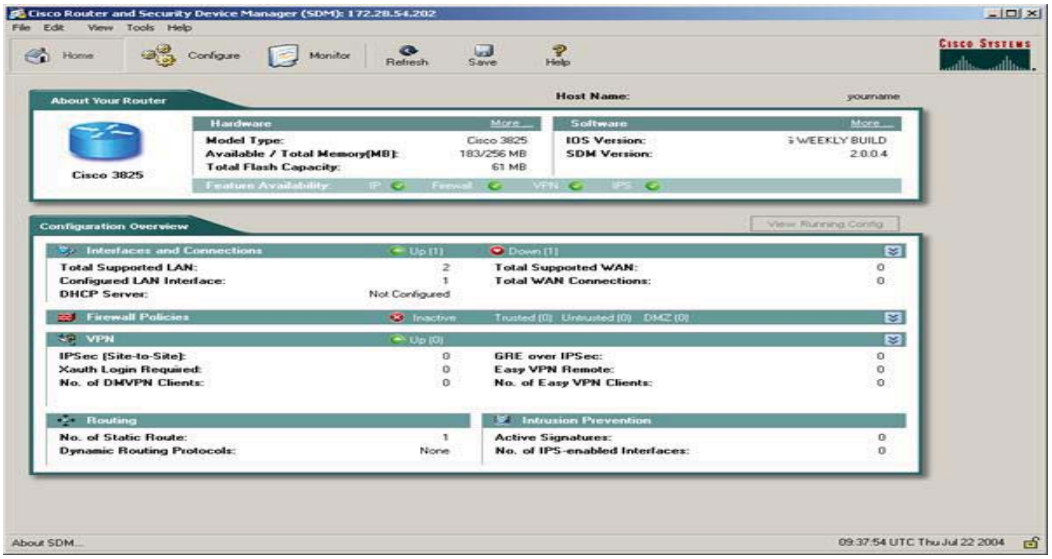
SDM enables organizations to quickly deploy error-free configurations and avoid potential network connectivity issues by "proactively monitoring router performance statistics, system logs, and firewall logs in real time" (Cisco Systems web site).

Additionally,

> Cisco SDM offers smart wizards and advanced configuration support for LAN and WAN interfaces, Network Address Translation (NAT), stateful and application firewall policy, IPS, IPSec VPN, QoS, and NAC policy features. The firewall wizard allows a single-step deployment of high, medium, or low firewall policy settings. Cisco SDM also offers a one-click router lockdown and an innovative security auditing capability to check and recommend changes to router configuration based on ICSA Labs and Cisco TAC recommendations (Cisco Systems web site).

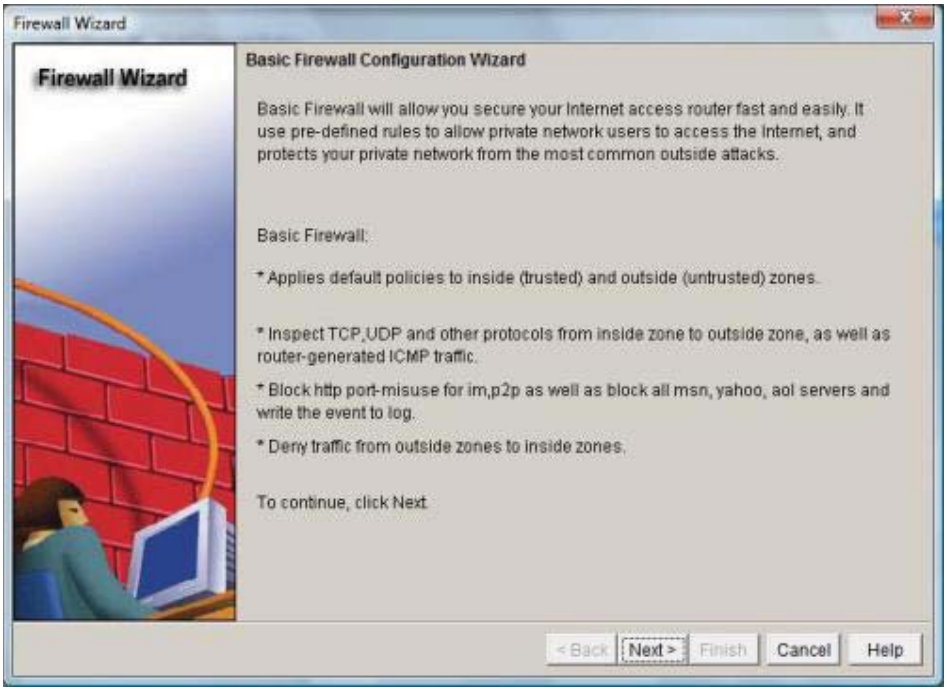
The Cisco Router and Security Device Manager not only allows administrators of the ARNe network to get up to speed quickly on configuring and managing the core routers, but it also enables them to deploy error-free configurations and to be able to monitor and make appropriate changes on a consistent basis without being very proficient on using the CLI. They can then learn the CLI over time while utilizing the SDM. See figure 3-2, 3-3 below for screenshots of SDM in action.

Figure 3 - 2. SDM screen (Cisco Systems).



Source: Cisco (www.cisco.com/en/US/products/sw/secursw/ps5318)

Figure 3 - 3. SDM Firewall configuration wizard (TechRepublic)



Source: Tech Republic (http://techrepublic.com.com/2346-1035_11-91987-2.html)

Cost Factor

Cost is obviously a major factor when considering the purchase of network equipment and support services. Cisco routers are at the higher end of the scale when it comes to cost. There are cheaper options, including an open source alternative called Vyatta (vyatta.org). The problem with Vyatta is that, although the application is free to download, you still have to procure and purchase hardware that is fully compatible with the operating system. Additionally, you may need (and should) purchase support from Vyatta or be prepared for many unproductive hours and erroneous configurations. And, another thing to consider is that the Vyatta OS is not that well known, so expertise will be limited. Other cheaper routers may not provide the robustness, flexibility and scalability of Cisco's ISR routers; which may justify the higher cost of the ISR series. Another aspect to consider is that since the Cisco ISR routers support over ninety existing and new device modules, there is a very high possibility that previously owned interface modules will still work on the 2800 and 1800 platforms, thus protecting your investment.

There are a number of options for purchasing the 2811 and 1841 ISR routers. There are Cisco partners and resellers all around the world. And there is also the choice of purchasing new or used. Another option is the popular eBay. However, there are more risks involved in purchasing equipment through this channel. One reputable and highly recommended reseller is CDW. The prices for the 2811 and 1841 vary depending on the IOS feature set as well as the options they come with. One of the benefits of procuring network equipment (as well as other items) from CDW is that non-profit organizations

can receive discounted prices. The following figures (3-4 to 3-7) are taken from the CDW website (www.cdw.com).

Figure 3 - 4. Cisco 2811 Router (CDW)



Figure 3 - 5. Cisco 1841 Router (CDW)



Figure 3 - 6. Cisco WAN Adapter HWIC-4T (CDW)

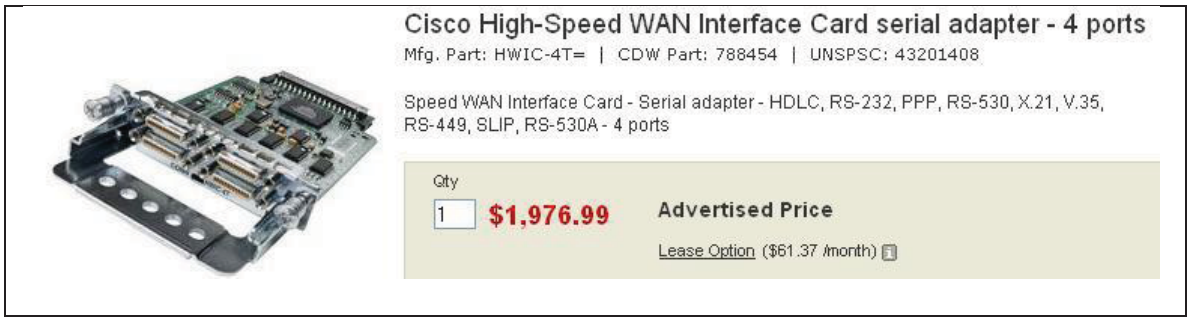


Figure 3 - 7. Cisco WAN Adapter WIC-1DSU-T1-V2 (CDW)



The above CDW prices reflect the currently available pricing for each item and could change at any time. Also, these prices do not include any discounts that Regis University may be eligible for. The two WAN adapters will be discussed later but are recommended.

The Cisco 2800 and 1800 ISR routers provide the most flexibility, scalability, performance that will both meet and exceed the needs for deployment in the ARNe core network. The configuration and management options provide administrators with the choice of using the CLI or SDM so that concerns about complexity can be reduced with the Java-based GUI that SDM provides, as mentioned previously). Cisco routing platforms have permeated the many vertical industries and organizations, which means

that there is a high possibility of locating individuals and companies with Cisco expertise. Numerous Cisco training materials can be easily located and vary in content and cost. Additionally, Cisco provides support contracts if necessary. Understandably, there may be concerns about being locked in to a particular vendor, in this case Cisco. However, this author believes that it is beneficial to develop a standard platform that facilitates easier configuration and management across the entire ARNe network. In the event that routers from other manufacturers need to be used in the WAN, Cisco ISR routers can share and update routing information with them using standard protocols such as OSPF, RIP, BGP (IETF RFC 1654) and IS-IS (IETF RFC 1195). Redistribution can also be used to distribute EIGRP information.

Building the ARNe WAN Core

As previously mentioned, the Cisco 2811 will be used as the core router at the main site in Denver, CO. Meanwhile, the Cisco 1841will be used as the core router at each remote location and will interconnect with the 2811 at the main site to from the core of ARNe.

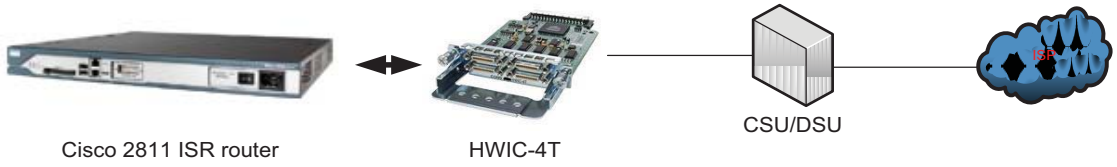
Physical Design Characteristics

In the above sections of this chapter, under the cost factor sub heading, there are two interface modules listed along with the routers from the CDW website. These interface modules will be used to connect the physical router to the CSU / DSU at each location. The CSU / DSU is used by the local ISP to provision the leased point-to-point T1s or fractional T1s, depending on what is available at each location.

The HWIC-4T is a high speed WAN interface card (HWIC) that provides flexible connections to the Cisco 1800 and 2800 ISR series routers. The HWICs enable features such as WAN aggregation, legacy protocol transport, console server, and dial access server and allow customers to tailor solutions to meet their needs. The HWIC-4T provides four high speed synchronous / asynchronous ports that support a maximum of 8Mbps on each port simultaneously. They also support HDLC, SDLC, PPP, Frame Relay, SNA and X.25 protocols (Serial and Asynchronous High-Speed WAN Interface Cards, Cisco Systems, 2008).

The main site (DTC) will be the hub and therefore requires more T1 circuits connected to it. By using the HWIC-4T module, more leased lines can be connected to the 2811 router and will provide the flexibility to scale from fractional T1 speeds up to 8Mbps.

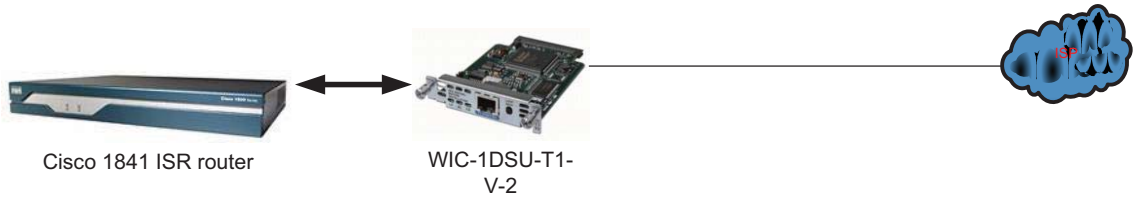
Figure 3 - 8. Denver (DTC) Physical Connection.



The remote sites will currently only need one leased line to the DTC. Therefore, the 1841 ISR routers at each location will utilize the WIC-1DSU-T1-V2 interface module for connecting to the leased circuit. The WIC-1DSU-T1-V2 is a fully integrated and managed CSU / DSU WAN interface card designed for T1 or fractional T1 service. It is a cost-effective, combined DSU/CSU solution that reduces the amount of cabling and devices required for establishing a T1 connection. The CSU/DSU can be configured at

the router using the familiar CLI, eliminating the need for an external CSU/DSU (T1 DSU/CSU WAN interface card (WIC-1DSU-T1-V2) Cisco Systems, 2005 p.2).

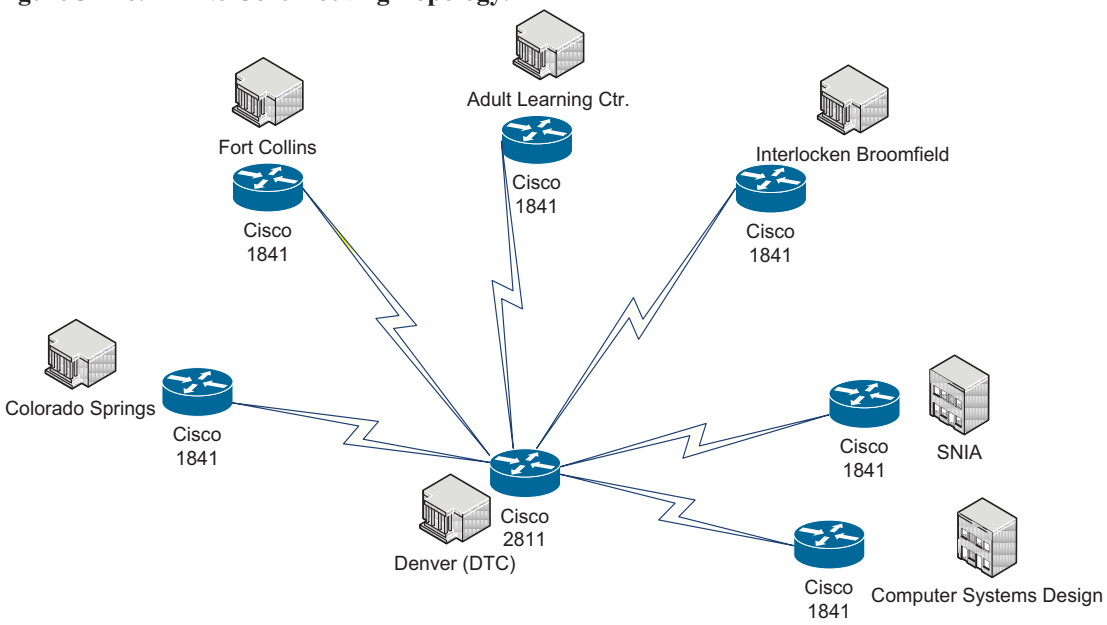
Figure 3 - 9. Remote Sites Physical Connection.



WAN Design Characteristics

The ARNe WAN will be designed in a star or hub and spoke topology. The star, while not as fault tolerant as the full mesh topology, will provide simpler management and reduced costs for the ARNe WAN.

Figure 3 - 10. ARNe Core Routing Topology.



Using this star topology means that all traffic will be routed through the core router to communicate with hosts at the main site or at other locations. This configuration allows administrators to manage the core more efficiently and enables critical issues such as security to be monitored and managed from a centralized location. Network performance can be a concern when dealing with star WAN topologies. The 2811 and 1841 routers are well capable of handling the traffic level that is likely to be experienced on ARN and scale well in the event that network usage level increases.

Core Layer Management and Protocols

The core layer is the high-speed backbone of the network and, in addition to the reliability and scalability requirements, the backbone should be designed for optimal performance. You should use routing features that optimize packet throughput when configuring core layer routers. The core should be optimized for low latency and good

manageability and should have a limited and consistent diameter; this facilitates predictable performance and ease of troubleshooting. Furthermore, external connections to other organizations' networks, such as extranets, or remote sites connection to the Internet should be centralized in the core thus reducing complexity and potential routing problems, as well as reducing security risks. Forcing all external access to pass through the core network essentially means that you would only have one security structure to administer (Oppenheimer, 2004 p.142).

To optimize performance in the core layer, the EIGRP protocol should be enabled for IP routing among core routers. As discussed in chapter two, Cisco's EIGRP protocol is considered a hybrid protocol and combines the best features of distance vector and link state protocols. It reduces network and router overhead by multicasting routing updates, sending routing updates only when a network change is detected, updating only the routers that need to be aware of the topology change, and sending only changes to the routing table rather than the entire table. EIGRP will minimize routing traffic, while ensuring that packets are routed to their destination using the optimal path. Static routing can also be used in combination with EIGRP.

Chapter 4: Conclusion

The Regis Academic Research Network provides interconnection between sites affiliated with Regis University. ARNe enables faculty and students to access data and services from remote locations as well as the main site in Denver, CO. The core network layer of ARNe consists of several different brands of routers that interconnect the WAN and provides transmission of packets to hosts among the sites. This current architecture of the core layer is being evaluated with the intention of replacing elements within the core as well as possibly making topology and configuration changes. Some of these changes are necessitated by the need to begin several projects, to complete others and to prepare for future projects at Regis.

Students in the School of Computing and Information Sciences have the opportunity to work on projects in the Academic Research Network by taking part in a practicum project within the Systems Engineering and Application Development (SEAD) program. This project is as a result of being involved in the SEAD practicum and being assigned into the Network group. There are other projects that being developed that will leverage some aspect of ARNe. Some projects have been put on hold awaiting the completion of routing core upgrades.

During the research of this project, every effort has been made to separate the real facts from the marketing hype found in product brochures. This can be challenging especially when focusing the solution on a particular vendor's product—in this case it was Cisco. By beginning with certain criteria that ideally addresses requirements that this author believes are important to Regis, Cisco's products were carefully examined to determine if they realistically met these requirements. This document does not guarantee flawless performance if the proposed solution is implemented. But this author does

believe that the proposal justifies the implementation of a Cisco-centric solution at ARNe's core layer. If this proposal be accepted, either completely or partially, the persons actually involved in implementing it would obviously have the opportunity to test it and make any modifications necessary that will enable the equipment, protocols and design to align more closely with projects that they are developing.

The Cisco routers in the Integrated Service Router series are ideal solutions for the core layer. They not only provide a routing platform but they would allow Regis to run simultaneous, secured data, voice and IP telephony services on the same platform. The Cisco 1841 and 2811 routers are modular platforms that allow the addition of interface cards that expand the services and features running on each device. This flexibility will benefit an academic organization that is often researching and developing new ideas and projects, and providing innovative connectivity solutions and enhanced learning experiences for students. As more users, services and data requests traverse the WAN, it is reassuring to know that the 1841 and 2811 routers are scalable and will continue to provide additional requests without degradation. Processing and transmission of packets and routing updates are improved over Cisco's previous 2600 platforms, and VPN performance in larger deployments can be further enhanced with the optional VPN acceleration module.

Although the cost and management, in terms of using the CLI can be a hindrance, they, hopefully, should not be obstacles to considering Cisco's 2811 and 1841 ISR routers in this case. These platforms provide many inherent benefits and would be solid, feature-laden "workhorses" within the core layer of the Academic Research Network.

Next Steps:

The proposed solutions should be evaluated initially in a lab-type setting. For instance, in order to test the performance, capabilities, manageability and the overall feasibility of the solutions in this document adequately facilitating the needs of Regis University's and ARNe projects, a lab with both Cisco routing platforms should be set up prior to any rollout plans. The lab should simulate a possible core WAN that will be featured in ARNe a well as scaled down LAN applications that will be used at various sites. For example, a VOIP project with as many IP phones as possible, web servers, application servers and other pc's and network equipment could be connected to the LAN facing interface. Because WANs are usually slower that LAN connections, Cisco serial WICs should be used to interconnect the test core WAN. To further resemble the typical WAN speeds, interface bit rates can be adjusted to more closely evaluate the performance of applications utilizing the WAN. Routing protocols could also be evaluated to determine if EIGRP will meet present and future requirements.

In order to build a reasonable testing environment without major capital investment, Regis should consider renting the equipment before making any major purchases. Companies such as Digital Warehouse (digitalwarehouse.com) and Penn Computer Corporation (penncomputer.com) rent Cisco equipment for various projects. Renting provides flexibility in choosing different routers, hardware and configurations.

During the lab testing phase, Regis University should be in discussion with the ISPs that will be servicing each location to determine the bandwidth requirements as well as circuit and interconnectivity options in order to simulate these conditions as best as possible.

Additional projects could include a more in depth study on the routing process and protocols at the core, with the intent of architecting a new logical scheme that will feature the adoption of the EIGRP protocol. This may involve running EIGRP alongside other routing protocols, if possible, and then completely phasing it in when Cisco routers have been put in place.

Other projects could involve leveraging the IP telephony capabilities of the ISR routers. While there is already a VoIP project developing, it could be extended by rolling out Unified Communication to the other remote sites; streamlining communication and reducing costs.

The ISR routers can provide wireless LAN capability if needed. Depending on the situation at some of the remote sites, projects can be developed to utilize this feature of the routers. By using an integrated wireless function, rather than purchasing external access points, deployment costs can be reduced.

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