

Can the Returning CEO Turnaround the Crisis at Hammerhead?

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Introduction

Rob Keil returned from a Board of Directors' (BOD) meeting and reflected on what brought his company to this major crossroad. Keil reflected on the discussion at the BOD meeting that day:

We are almost out of cash and we have a high burn rate...what do we do?

The BOD decided to appoint Keil as the President and CEO in May 2008 to recoup their almost \$100 million investment spent under the watch of the prior two CEOs. The Board's action was actually a reappointment because Keil served as the first President and CEO of Hammerhead Systems (HS). When Keil was reappointed as CEO, he was given the charge to lead the company in a more successful direction.

Keil and co-founder, John Yu, incubated HS for three months during 2001 as "Entrepreneurs-in-Residence" inside a venture capital (VC) firm and they founded HS in January 2002 to address the future needs of telecommunications (telecom) service providers. Keil secured the initial \$15 million Series A capital in April 2002 from veteran VCs. These investors were familiar with the business environment and challenges of the telecom industry. The veteran BOD and group of industry-savvy top managers hired experienced managers with telecom backgrounds, as well as employed some of the best engineers in the industry to fulfill their vision.

From its inception, Keil had served on the Board of Directors, and as the first CEO he built the core team, hired the first 50 employees, and executed the product development plans. However, from the start, he and key BOD member, Foundation Capital, had actively recruited for the "ideal" go-to-market CEO for HS. Sixteen months after launching the company, they found a person whom they thought was an experienced and well-connected CEO candidate from the telecom industry; someone who ostensibly had the leadership track record that was needed to take the startup company to the next stage. Keil wanted a world class CEO for the company and believed as a first-time CEO he didn't have the track record or senior-level customer contacts to take the company to that level. While Keil believed knowledge, experience, and industry connections were important skills for a CEO, he also saw intangibles like leadership and teamwork as essential skills, and he mentioned to the BOD and prospective CEO recruits:

I believe in the product and market opportunity. I want to help build a market-leading company, and to hire the best talent possible in every role, including the CEO.

Keil remained with Hammerhead as a member of the Board, and he served as VP of Marketing and Business Development after the BOD appointed a telecom industry veteran, Daniel Smith, as President/CEO in April 2003. Smith’s goals were to expand the HS customer base, establish go-to-market channel partners, and grow its operations. Smith had little startup firm experience; however, he had a strong telecom background, successful operational experience with managing larger high growth businesses and had established positive relationships with major telecom carriers. HS secured a major reseller partnership for North America with Fujitsu under Smith’s watch, but this “win” was not influential in landing their first customer orders.

As the HS marketplace opportunities continued to decrease, the BOD replaced Smith with another telecom industry veteran, Grant Fleming, in December 2004. Under Fleming as CEO, HS inked major deals with two large telecommunication carriers, but these major carriers that had been burned by dealing with startups during the dot com bust era now required startups to have partners for financial stability (Austin & Hay, 2009). While Fujitsu served this purpose and even rebranded the HS flagship product (HSX 6000) under an original equipment manufacturer (OEM) arrangement (see Glossary Appendix C), this marketing relationship did not last. Like former President/CEO Smith, CEO Fleming was unable to lead HS past customer “wins” into broad production deployments with the innovative HSX 6000, and he resigned in May 2008. Immediately after the BOD reappointment for his second turn as CEO of HS, Keil reflected on the many changes made by the Board since he co-founded HS (see Table 1). In May 2008, Keil thought he was in the middle of a crisis and time was not on his side to implement a plan to reverse the downward direction.

Table 1. Hammerhead Systems Company Milestones

Dates	Key Events
2001	September-December, Rob Keil and John Yu as Entrepreneurs-in-Residence (EIRs) at Foundation Capital, incubate Hammerhead business plan.
2002	January, Rob Keil as CEO and John Yu as CTO co-found Hammerhead Systems (HS) and develop HSX 6000 framework with niche strategy. April, initial \$15 million Series A funding raised from VCs by Rob Keil.
2003	April, Daniel Smith named President/CEO. November, \$25 million Series B funding from VCs.
2004	December, VCs bring Grant Fleming on-board as President/CEO/Chair of Board.
2005	May, \$10 million extended B round. Bridge financing from VCs.
2006	January, \$30 million Series C funding from VCs. February, Roy Gore named CTO.

2007	August, HSX 6000 product completed lab trial and ready for deployment. August, Series D funding of \$18.4 million raised from VCs. Diablo Management Group (DMG) hired to restructure balance sheet, a senior DMG consultant was hired as advisor to Grant Fleming and BOD, to raise Series D funding, reduce operating cost to help with restructure of the balanced sheet and attract more funding.
2008	May, Rob Keil reappointed President/CEO.

Industry Background

Industry reports revealed the telecom industry experienced a tremendous amount of change throughout the first decade of the 2000s (Appendix A; Hughes, 2008; The Insight Research Corporation Report, 2009). The Industry's turmoil, both global and U.S. recessions, and external forces beyond their control thwarted Hammerhead's competition with the technology giants (Matsumoto, 2009).

Influences on Telecom Industry

Much of the telecom industry turmoil, in the first part of the 2000s decade, was based on widespread memory of recent downturns, as well as current uncertainties in the U.S. and world economies. Experts in the field argued that the telecom industry, in general, was going to reduce profit levels and revenues of at least 22-25 percent due to migration of fixed line customers away from fixed line to a combination of cable Internet access and mobile phone (Vollenweider, Shetty, Khera, Gupta, & Methrothra, 2005). By 2008, experts expected that the telecom sector, offering fixed mobile services, were likely to face a permanent reduction in overall profitability and revenues of at least 22-26 percent due to new technology such as Internet-based phone services. In addition, the Internet solution offered by telecom firms was not going to be able to offset the lost profits (Vollenweider et al., 2005). Keil indicated that as the economy worsened, the prospective buyers became more conservative and risk-averse (Matsumoto, 2009).

Telecom Industry Segments and Characteristics

Lemm (2007) indicated tiers, service areas, and layers segmented the telecommunication industry (Cisco Systems, 2003; Global Crossing, n.d.; SearchEnterpriseWan.com, 1997). Tiers were segmented based on size and scope of the service provider's network. Tier 1 was usually comprised of large size companies and networks with critical reliability, stability, and scalability requirements. Tier 2 was usually comprised of smaller companies and when companies needed quality bandwidth by location. Tier 3 was usually comprised of wholesalers and resellers of tier 1 and tier 2 networks.

From a service area (offerings) perspective, the three corporate data service categories corresponded to: the Internet Protocol Virtual Private Network (IP-VPN), Frame Relay, and Asynchronous transfer mode (ATM) (see Appendix C). Carriers generated the majority of their data services revenues with older Frame Relay and ATM services. In 2003, revenues from legacy Frame Relay and ATM services accounted for \$9.4 billion, while newer IP-VPN services accounted for only \$3 billion of this total. The telecom carriers did not want the added cost to implement the new IP-VPN but they wanted to integrate it with the original, legacy services (Reardon, 2003). Reardon (2003) mentioned that carriers found their older Frame and ATM

services were becoming more profitable, since most of the equipment had already been paid for and they did not feel intimidated by the lowered-priced, newer IP-VPN services. Additionally, Reardon (2003) mentioned that the prices between legacy and Internet services had become very similar. By 2006, the telecom industry was predicted to grow 10.6 percent and projected to slowdown afterwards should the current telecom industry recession last beyond 2008 (Carlson, 2006; Louis, 2008).

In addition to tiers and service offerings, the Open Systems Interconnection (OSI) model, or network communication model was developed by the International Organization for Standardization and became a popular layer method to describe the industry. The OSI model was used to describe the steps to be used to transfer data over a transmission medium from one networked computer to another, which was displayed in seven layers (see Appendix B; Dummies.com, n.d.). The Hammerhead product was positioned between layer 2 and layer 3 (Layer 2.5) of the OSI model and offered a cost-effective solution for major carriers that wanted to maintain legacy systems. This positioning also worked for carriers that wanted to move to newer Internet based products or other hybrid multi-service solutions (see Appendix B).

Hammerhead Systems Market Focus and Product Line

Austin & Hay (2009) indicated the HS co-founders and VCs understood both the supply and demand for telecom services, but the telecom infrastructure was outdated in 2002. Hammerhead was incubated at Foundation Capital VC and developed a new technology approach to help fill that infrastructure niche. The innovative HSX 6000 was a hybrid technical solution in one physical container (box) that allowed carriers to transition, at their own pace, by leveraging the technical and marketing advantages of OSI layers 2 and 3 (see Appendix B). Competitors, such as Cisco that offered a solution in this market space between layers 2 and 3, had more expensive and usually more complex approaches that required multiple discrete hardware platforms. Additionally, Austin & Hay (2009) suggested that “timing” of product delivery and deals were important in this highly changeable environment, and potential customers were excited about the Hammerhead technology. From a global demand perspective, even a strategic OEM partnership signed in 2004 with a name-brand hardware company like Fujitsu North America failed to catapult Hammerhead to instant success and several deals with global players that were agreed upon came undone (Harris, 2009). On the domestic side, Matsumoto (2009) indicated Hammerhead deals, including a prospective Hammerhead negotiation with MCI (Verizon Business) failed, because the carriers wanted Hammerhead to have a large company as a partner. Meanwhile, by early 2007, Fujitsu decided to exit its partnership with HS because Fujitsu had its own financial pressure and was rationalizing its overall product line (Matsumoto, 2009). In addition, HS no longer fit in with Fujitsu’s strategic business model.

Market Sectors

Hammerhead initially focused on the Business Services market segment within the large carrier, tier 1 sector of the industry using a single box technology (Reardon, 2003). HS provided a flexible hybrid multi-service, at a fraction of the cost of legacy services and remained competitive by delivering better performance to their three major markets and eliminating the complexity of a multi-box solution for multi-service applications (Reese, 2009). The low-cost, HSX 6000 single box strategy leveraged the technical advantages of OSI layers 2 and 3 and was simply called Layer 2.5 level aggregation in the telecom industry. As both the company and the

carrier market evolved, HS expanded to target three carrier applications: Business Services, Residential Broadband, and Wireless Backhaul. The key benefit of Hammerhead's technology for their telecom service provider customers was that it enabled the seamless transition of their cash cow revenue streams to a new network infrastructure optimized for the next generation of Internet services. Yet the HSX 6000 could make this transition totally transparent and make a transformational technology user-friendly to their existing customer base. Therefore, HS focused on selling multi-service solutions to major tier 1 telecom carriers. The main purpose was to pool data services traffic for carriers. When VCs provided the Series B round of funding, Kevin Fong, the HS Board member and VC said; "Hammerhead has tapped into this huge market in transition, one that incumbent equipment suppliers have clearly ignored" (PRNewswire, 2004). However, market timing and financial viability were always pressing issues.

The Hammerhead Niche

In absence of Hammerhead's product, additional dedicated hardware was needed to support legacy or new communication protocols. The Hammerhead HSX 6000 software platform combined two elements of the OSI model, the Data Link (Layer 2) and the Network layer (Layer 3) mentioned in Appendix B. Therefore, HS was able to transport legacy Layer 2 services over any network and services were then able to be mapped to multi-service communications on Layer 3 (Wirbel, 2004). This was important because HSX 6000 used a hybrid approach sanctioned by the Internet Engineering Task Force (IETF) to ease the transition of carriers from legacy Frame and ATM networks onto new, Internet-optimized core networks (see Appendix C).

Hammerhead Customers

The HS product focus was on tier 1 service providers, but the HS technology addressed tiers 1, 2, and 3. Hammerhead's technology had attracted "second tier" carriers such as Savvis, Covad Communications, and TelePacific. Additionally, there were growing demands for cloud computing and online software services to which Hammerhead's innovations were well suited (Clavenna, 2005; Matsumoto 2007). In order to adopt the HS technology, each customer usually required about a year of testing and analysis and this could have slowed down market timing. Cisco Systems was the largest competitor for Hammerhead Systems, and Cisco already offered a solution that although significantly more expensive and complex than what HS had to offer, it performed most of the same functions (Carlson, 2006). Cisco had also influenced their customers by directing their new technology to companies of any size. A Cisco disadvantage to some potential customers was the new technology involved a multi-box change from the conventional OSI Layer 2 to Layer 3.

The one thing Hammerhead failed to accomplish in its six years of VC funding was recruiting enough carriers as customers (Ricketts, 2009). This was in addition to the ongoing economic climate which made carriers more risk-averse and uncomfortable dealing with a small, new venture like Hammerhead. Reese (2009) indicated that he believed the possible downfall of companies like Hammerhead meant the potential death of VC funding for young companies with products that could compete against large companies like Cisco. Reese (2009) added:

Large incumbent vendors don't have to do what's best for their customers...they don't

have to buy from a company that has innovated and delivered unique technology that customers want like bandwidth pooling and performance in one box vs. 4 Cisco boxes. So they end up losing when innovative startups like Hammerhead go away. Their only choice ... will be to buy from large incumbents who are more than happy to sell them multiple boxes and who won't worry about customer integration or price performance.

HSX 6000 Product as Disruptive Technology

New products in the form of disruptive technologies have not always resulted in positive outcomes for an industry or company. Customers are required to see the “creative destruction” process as simple, seamless, and low risk to adopt new, disruptive technology (Schumpeter, 1942). Hughes (2008) indicated the telecom industry was ripe for new products in the mid-2000s that were inexpensive, simple to understand and use. Hammerhead viewed the innovative HSX 6000 as a disruptive technology (Reese, 2009). The HSX 6000 design collected data circuits from the carriers’ customers, pooled them, and routed them back to the operators’ core networks (see Appendix C). This process was potentially disruptive, yet customer-friendly and enabled carriers to use much of their aging equipment to keep up with growing data traffic, including Backhaul and Ethernet functionality (see Appendix C). The innovative HSX 6000 framework was designed as a data switching approach that routed information for carriers but, an important dilemma was, the market makes the final decisions about creative destruction. Reese (2009) reported that customers said HS developed exciting technology and had a well-liked product and team.

Company Background, Structure, and Management Team

Goals

Linux (2007) reported the co-founders envisioned Hammerhead Systems as “a company that would be positioned to deliver breakthrough technology that would offer great flexibility and choice to large carriers as they moved to MPLS.” The HS vision statement, “To become the worldwide layer 2.5 market leader for multiservice switching for major service providers,” attempted to make the technical process easy to understand (www.hammerhead.com). HS described its mission as, “The market leader in Layer 2.5 Aggregation, Interworking and Migration solutions to accelerate the profitable delivery of new Ethernet (E-Line, E-LAN, and E-Tree) and existing circuit-based data services at a fraction of the cost and complexity of other solutions” (see Glossary, Appendix C). This vision and mission influenced the market niche where Hammerhead chose “to play on the 2.5 edge” and HS envisioned their marketplace niche as tier 1 providers with Business Services, Residential Broadband, and Wireless Backhaul needs. As previously mentioned, Austin & Hay (2009) indicated that HS was founded as a data switching company and their niche among giant competitors, such as Cisco Systems, was a highly differentiated box that delivered the performance of a router (see Appendix C) and the flexibility, manageability, and price performance of a switch. In 2003, Bill Stensrud, HS Board of Director and Managing Director and General Partner at Enterprise Partners indicated:

Hammerhead’s approach represents the next great leap in the evolution of more agile, efficient and reliable carrier networks, increased service growth and return on assets.

Hammerhead Board of Directors

The first HS Board of Directors (BOD) was comprised of five members, including VCs and the CEO. In 2004, the new President/CEO, Grant Fleming, replaced Smith as CEO and on the BOD. Over the next three years, the BOD expanded with representatives from the company’s newer VC investors, and met regularly to review financial and business plans and results (see Table 2).

Table 2. Year 2008 HS Board of Directors

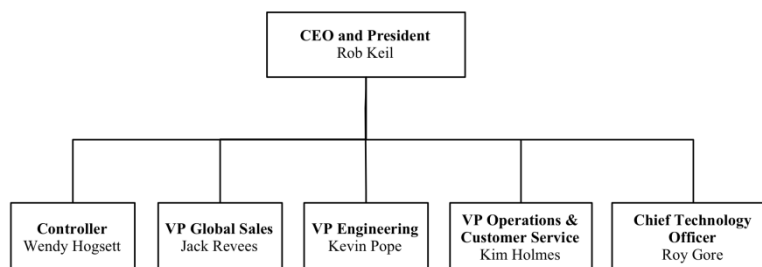
Name	Title	Affiliation
Adam Grosser	Director	VC, Foundation Capital
George Middlemas	Director	VC, Apex Venture Partners
Gregory Rossmann	Director	VC, Pequot
Kevin Fong	Director	VC, Mayfield
Robert Conn	Director	VC, Enterprise Partners
Michael Segrest	Director	VC, Silver Creek Ventures
Rob Keil	Director	Co-Founder, HS

Organizational Structure

When Hammerhead Systems, Inc. was founded in 2002, Rob Keil’s initial role was CEO and John Yu was the Chief Technology Officer (CTO). HS developed a functional organizational structure typical for startup firms with a single product line (www.hammerheadsystems.com).

The HS sales function was broken down further based on location in the world but all other sub-units reporting to these key areas in the organization chart were based on functions. Ricketts (2009) stated, “HS grew quickly as a startup with this structure, starting with thirteen employees in 2002, reaching a peak of one hundred ten employees” (www.hammerheadsystems.com). The 2008 Hammerhead Systems organizational chart is shown in Figure 1.

Figure 1. 2008 Organizational Chart



Top Management Team

Since the VC investors and the co-founders knew that many startups failed due to poor management fit, Keil and the BOD realized HS needed a unique combination of experience,

knowledge, and style in the CEO role to take the company through the anticipated growth stages and industry competition. Keil and the BOD started a search for the ideal CEO when HS was founded in 2002. As CEOs, Keil and Smith had less entrepreneurship experience than Fleming; however, all were telecom industry veterans. The Hammerhead Website (2003) indicated that when Smith was appointed as CEO, Kevin Fong, HS Board Director said:

We're very excited about Daniel joining the team. He combines the best of Silicon Valley entrepreneurial savvy with the management and operational skills gained from scaling and managing high growth businesses. His leadership style and ongoing relationships with tier 1 carriers match Hammerhead's financial and customer objectives.

Positive statements were made about the leadership capabilities and match to Hammerhead when CEO Fleming replaced Smith at the helm (Hammerhead, 2004). The BOD understood that bold leadership was necessary in this time of marketplace transition from legacy systems to Internet based solutions and hybrid methods such as Multiprotocol Label Switching (MPLS) located between layers 2 and 3 of the previously mentioned OSI model (see Appendix B). When Fleming was selected in December 2004, Bill Stensrud, Managing Director and General Partner at Enterprise Partners Venture Capital, and Hammerhead Systems Director said:

We're very pleased to have Grant on board! Service providers are transitioning their networks to MPLS. At the same time they need to accelerate profitable delivery of new Ethernet-based services while maintaining and enhancing the revenue and profits from legacy Frame Relay and ATM services. Grant Fleming understands the economic and technical challenges service providers face as they transition their networks to MPLS. Grant brings additional firepower and trusted relationships with service providers to accelerate Hammerhead's customer traction and broaden distribution channels.

Hammerhead management and BOD did not view the market transition and change in leadership at the top as a crisis in 2004. However, when Keil was reappointed as CEO in May, 2008, "near misses" on past HS goals and both market cycle and leadership items concerned the BOD as signs of growing problems (Collins, 2009; Tinsley, Dillon & Madsen, 2011; Wasserman, 2012).

Financial Backing

Since its start in 2002, Hammerhead Systems managed to raise a total of \$98.4 million from VCs and had spent close to \$97.0 million through May 2008 (see Table 3). These investors were top-flight venture capitalist firms such as Apex Venture Partners, Enterprise Partners Venture Capital, Mayfield Fund, Pequot Capital Management, and Silver Creek Ventures. All of the VC investors had seats on the HS Board (see Tables 1 and 2) with the capability to influence strategic and tactical activities of HS. Table 3 indicated that as HS grew, VC investors provided four rounds of funding; however, the VCs sometimes looked outside HS for expertise in financial management (Business Journal, 2008).

When Hammerhead Systems needed financial expertise in 2007 to restructure its balance sheet and raise additional capital, the BOD hired the Diablo Management Group (DMG) as consultants (Diablo Management Group, 2008). Additionally, DMG was asked to help with reduction of HS

operating cost in order to attract new capital. The CEO and Managing Principal of DMG, was hired as advisor to the CEO (Fleming) and the Board and was selected to serve as Chairman of the Hammerhead Systems Finance Committee. DMG was able to restructure the HS balance sheet and suggested methods to reduce operational costs. HS management and BOD viewed this outside help more as a “near miss” from goals than sign of a major crisis because it allowed the company to successfully raise \$18.4 million in additional VC funding (round D funding).

Table 3. Hammerhead funding by Venture Capitalists

Type of Funding	Amount of Funding \$M	Purpose
Round A	\$15.0 April 2002	Build product development, sales and marketing infrastructure
Round B	\$25.0 November 2003	Working capital
Round C	\$30.0 January 2006	Ramp in sales, customer support and operations
Round D	\$18.4 August 2007	Accelerate product development for anticipated demand for higher bandwidth applications
Other VC Funding and extended B round	\$10.0 May 2005	Equity
Total Raised	\$98.4 May 2008	
Total Spent	\$97.0 May 2008	

The Decision Focus

Wasserman (2012) contended it is difficult for startup founders to change roles as dilemmas occur. Nevertheless, as a co-founder of Hammerhead, Keil felt it was “his baby” and he served the organization in many roles since its founding. In his VP of Marketing and Business Development role, Keil helped Hammerhead Systems make internal and external adjustments as business softened. As the world and U.S. financial environments declined in 2008 and the mature telecom industry waned at the same time, Keil became increasingly concerned about the future of HS. Potential customers became more risk-adverse, less merger activity took place in the industry, the number of outside financial sources was unclear and the BOD became increasingly concerned about the cash burn rate. As a result, the BOD reappointed Keil as President and CEO in May, 2008, to recoup their investment (see Table 3) and achieve a successful new direction for HS (Business Journal, 2008). Keil reflected on the major events since 2002 (see Table 1) and lamented:

In 2002, I looked at the company and believed we had many potential strategic partner options. By 2008, we still haven’t translated our customer wins into mass deployments, and all the hard work we put into the Fujitsu relationship did not pay off. We still had a great value proposition for our customers, and they loved our product and team. But they told us; we needed to have a partner for them to get comfortable to broadly deploy our equipment in their networks, and that left us stuck in a catch-22 situation, since prospective partners had become very conservative and wanted to see customers deploy us before committing to a partnership.

However, Keil had the support of his team and they remained confident that something positive

would happen under his action plan. His May 2008 “action items” to make Hammerhead successful contained several of the same options he had as HS co-founder and CEO in 2002. What options would you place on his list in May 2008 to revive HS and make it successful?

Appendix A

Industry Note

The U.S. telecom industry was comprised of a club of big national and regional companies; however, over the past decade, the industry was swept up in rapid deregulation and innovation (The Industry Handbook: The Telecommunications Industry, n.d.). Broad scale societal acceptance of on-line communications and growth of Internet applications made many industries interdependent. For example, Internet content providers, infrastructure companies, Internet service providers and other providers of dial-up and broadband Internet access services made telecom and the computer industry more interdependent than ever (The Industry Handbook: Telecommunications Industry, n.d.). The dot com bust and decline in the stock market in 2002 affected many Internet companies (Rovenpor, 2003). Some went bankrupt, while others were able to remain in the market after suffering the consequences of the economic downturn.

The telecom industry suffered; more than 500,000 jobs were lost and more than two-dozen publicly held telecom service providers filed for bankruptcy (Burke, 2002; McHugh & Sawyer, 2004). In fact, between 2000-2004, tier 1 providers such as Lucent's R&D budget dropped 60 percent; Ericsson's fell 55 percent, and Nortel's declined by 45 percent. Later, the prospects for mergers and acquisitions in the telecom space rapidly disappeared as the 2008 recession forced companies to lay off employees and hoard cash. In 2008, weak short-term growth and cash flow prospects with unattractive equity valuations and unavailable debt capital made financing a potential acquisition extremely challenging, with the number of acquisitions declining 62 percent from 2007 through 2009 (Ernest & Young, 2011; Freas, Hottovy, & Sekera, 2011; The Insight Research Corporation Report, 2009). Even acquisition oriented companies in the networking industry such as Cisco became less interested in the telecom space. Austin & Hay (2009) reported Cisco was not interested in M&A as "Cisco's business strategy was evolving to include servers and consumer electronics."

The large U.S. telecom industry was highly regulated until the breakup of AT&T by the government in the 1980s to foster more competition (Milestones of AT&T History, n.d.). In 1996, President Clinton signed into law the Telecommunications Act of 1996 or "Act". The Act was designed to foster fundamental and pro-competitive changes throughout the telecommunications industry. For example, the Act limited the ability of a State to prevent competition in telecommunications (Policy Roundtables, 1995). Less regulation attracted more companies until the early 2000s dot com bust era. One industry fallout of the dot com bust era and recession that followed was further market segmentation and the surviving customers and suppliers alike became more price sensitive (The Industry Handbook: The Telecommunications Industry, n.d.). For example, while the number of startups failed to survive the mid-2000s, there were thirteen major equipment vendors in the small but growing multi-service switching sector (Heavy Reading, 2005). This new environment opened the door for price-cutting to survive and development of innovative products that allowed existing companies to maintain profit margins and new, innovative companies to enter (Hughes, 2008; The Industry Handbook: The Telecommunications Industry, n.d.).

Appendix B

Technical Note

Open Systems Interconnection (OSI) model. In telecommunication industry, the Open Systems Interconnection (OSI) model is the framework that is often used to subdivide a communication system into smaller logical layers. The OSI model is displayed in Table 4 and the description of each layer is shown.

Table 4: OSI Model

Layers	Description
7) Application	The end user interacts with this layer. For example, Firefox, Skype, Internet Explorer, Safari.
6) Presentation	The operating system works on this layer.
5) Session	Layer that deals with communication creating a session (bridge) between two computers. For example, when a user goes to a website, the computer at a session layer has to create a session with the web server that the user needs to get information from.
4) Transport	It assesses how much information should be sent at one time among computers.
3) Network Data	It is the layer where routers operate. For example, the IP address is found at the network level. In network communications, different protocols are used to transfer information between different computers; the protocol is analogous to the language used for our inter office mail. The communication protocols (language) operate on Layer 2 or Layer 3 of the OSI stack
2) Data Link	Switches operate from this layer. All the computers in the network are plugged on a switch so they can communicate with each other. The data link formats the bytes (the numbers in the computer 0s and 1s) in a frame, which is a unit of data that goes over the network and contains all the data such as the address of the computer where the user is sending it to and from. It is concerned with delivery of data within a local area network. For example, to send the mail outside the building, you would have to solicit the services of post office, which will represent our next layer. The data link layer is further divided into two sublayers: a) Logical Link Control which handles error control, flow control, framing, and media access control (MAC) sub-layer addressing. It also checks for incoming duplicate signals and fix interferences. MAC address; b) MAC address, which handles access to shared media, such as Ethernet.
1) Physical	It provides the electrical, mechanical and procedural interface for transmission. It describes the shapes and properties of the electric connectors, the frequency to broadcast on, frequency modulation scheme, and error correction of the message. It is all the physical things that connect computers such as wires and cables.

Model adopted from Dummies, n.d.; SearchUnifiedCommunications.com, 2000.

Basically, the OSI model describes how network systems are supposed to communicate with each other. Each layer provides services to its upper layer. The layer 7, Application, represents the layer that is closer to the end user to shooting the information out to the network (lowest number) (Dummies, n.d.). Edge servers connect to physical layer of the OSI interconnection model, and operate on layer 2 (data link) or layer 3 (network) to route communication depending on the protocol type. For example, ATM routing is done on layer 2; most MPLS routing is done on layer 2 and some on layer 3 of the model (SearchEnterpriseWAN.com, 2000). Table 5 is provided to show how the Hammerhead product HSX 6000 and competitor products fit within the OSI model and telecommunications industry.

The Hammerhead product placement. Since the Hammerhead product focused on cost-effective routing and translation between levels 2 and 3, the first three layers of the OSI model are explained below (Table 5). The Hammerhead Edge server implementation has an additional layer that sits between data layer (2) and the network layer (3), called the pseudowire layer or 2.5, since it's between layer 2 and 3. Table 5 summarizes the function of the first three layers of the OSI model, as well as Hammerhead's pseudowire platform. The pseudowire layer is responsible for translating communication protocol (language) from data layer such as legacy ATM and Frame. When possible, pseudowire layer (2.5) either routes the message or it passes it to the above network layer (3) (Wirbil, 2005). The benefit of the pseudowire layer is that, through software updates, it can accommodate for any existing and emerging communication protocols.

Table 5. Edge Server Communication Layers

Physical Layer (1)	Data Link Layer (2)	Pseudowire (2.5)	Network Layer (3)
Provides the electrical, mechanical and interface required for transmission. It describes the shapes and properties of the electric connectors (plugs) and frequencies.	Concerned with delivery of data within a local area network. This is analogous to sending interoffice mail.	Act as a universal translator for different communication protocols from data link layer. Pseudowire either routes the message, or passes it to the next layer for routing.	Responsible of delivery of the messages through routers to different networks; similar to how the post office is responsible for routing and delivery of mail.

Model adopted from Dummies, n.d.; SearchUnifiedCommunications.com, 2000.

In absence of this technology, additional dedicated router hardware is needed to support legacy or new communication protocols. Hammerhead's edge server was differentiated by providing flexibility to accommodate not only the existing legacy communication protocols, but it could also support future protocols without the need of additional hardware.

Appendix C

Glossary

The glossary should help readers who are not familiar with the telecommunication industry, with definitions of key technical terms used in the industry and product concepts used in the case.

- 1. ATM.** In telecommunication, Asynchronous Transfer Mode (ATM) is a switching technique that provides for both end users and communication carriers the capability to transport any type of information such as voice, data, and video by using a common format (Held, 1999; Telecom Dictionary, n.d.).
- 2. Backbone.** A network backbone switch is a switch that receives and forward standard 53 byte ATM packets and is located in the interconnection backbone networks of carriers to interconnect slower switches or edge (network interface) switches (Telecom Dictionary, n.d.).
- 3. Bandwidth Pooling.** It is an optimization technique for using underutilized network interface; thereby maximizing system throughput without additional hardware (PRNewswire, 2004).
- 4. Edge server.** A device used to connect a private or enterprise network to a service provider's network. These devices provide services such as tunneling, authentication, filtering, billing, traffic shaping and rate policing and network address translation. Depending on the service provider, the device may be owned and managed by the service provider or by the customer (Telecom Dictionary, n.d.).
- 5. Ethernet.** Ethernet is a based transmission protocol that is primarily used in LANs (Telecom Dictionary, n.d.).
- 6. Frame Relay.** A sequence of data is grouped or chunked into a logical unit, known as a frame. The older Frame Relay was defined as a telecommunication service designed for cost-efficient data transmission for intermittent traffic between local area networks (LANs) and between endpoints in a wide area network (WAN) (SearchEnterpriseWan.com, 1997).
- 7. IETF.** Internet Engineering Task Force (IETF) is an open international community of network designers, operators, vendors, and researchers concerned with the evolution of the Internet architecture and the smooth operation of the Internet (Internet Task Force, n.d.).
- 8. MPLS.** Multiprotocol Label Switching (MPLS) is the use of label identifiers within the routing information to determine how and where data packets should be routed within a communications network. It lies between Layer 2 (data) and Layer 3 (network) of the OSI model (Protocols.com, n.d.; Telecom Dictionary, n.d.).

9. OEM. Original equipment manufacturer is the usual meaning of the term; however, it is sometimes called value-added reseller in the software industry. This is both a technical and marketing strategy that allows one company to incorporate or resell the product of another company under its own name or brand (Telecom Dictionary, n.d.).

10. Packet Switching. It is a process of connecting two or more points for data transmission in which the data are broken into packets each of which can be routed separately from a source then reassembled in the proper order at the destination. (Telecom Dictionary, n.d.).

11. Pseudowire. In network telecommunication, pseudowire is emulation of data layer (layer 2) of the OSI model (Matsumoto, 2004; Spike, 2007). Hammerhead's pseudowire layer was responsible for translating communication protocol (language) from data layer such as ATM and Frame (Wirbel, 2005).

12. Router. It is a packet switching device that is part of the backbone communications link and serves as the gateway for any communications that come from other devices or systems that are connected to the network (Telecom Dictionary, n.d.).

13. Telecommunication. It is technological transmission of information for communication. This enables one or more users to one or more other user's information of any nature delivered in any usable form such as wire and radio (Interconnect, 2011).

14. VOIP. Voice Over Internet Protocol (VOIP) encompasses a series of technologies that support the transmission of voice and multimedia communications over Internet Protocol. IP-VPN: The newer (IP-VPN) services were defined as a routed link between two or more points across a shared network infrastructure with various degrees of security (Global Crossing, n.d.).

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