MARKET RESEARCH OF MULTIPLE ANTENNA WI-FI WIRELESS TERMINAL AND ITS APPLICATIONS IN PORT ENVIRONMENTS

by

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ABSTRACT

A current research project of the School of Engineering at Simon Fraser University aims to develop smart antenna integrated Wi-Fi network access point technology to address network connectivity loss on the existing Wi-Fi network infrastructure in the Port of Vancouver, to further extend wireless network coverage and to improve the signal quality. This market research project aims to identify and assess any potential market opportunities for commercializing this SFU technology and IP. This project provides a review of the enabling technologies, investigation of the current market structure and dynamics, a study of customers' and competitors' profiles, and competitive environments, a strategic analysis, a SWOT analysis. Utilizing all of this information and analysis, market entry strategic options are presented to assist the technology team to evaluate the market and other environmental factors and choose an appropriate entry strategy. The Balanced Scorecard Method is utilized to choose between the potential strategic options. Findings suggest that the SFU team will face a highly challenging environment with many players competing on technology, standards and distribution channels. As a technology focused team, its key capabilities are not expected to provide competitive advantages in a market where product manufacturing, distribution and marketing efforts will weigh even more on the success than technology alone. In order to leverage its core competencies and capitalize its technological strengths, the technology team is therefore advised to proceed with the option of a forming strategic partnership or alliance with an incumbent equipment manufacturer.

DEDICATION

To my lovely wife, Michelle, and children, Victor, Edward and Sophia, your encouragement and unconditional support are the sources of my inspiration. I thank all of you for helping me succeed by giving me patience and continual encouragement to work hard for all those long nights, weekends and holidays. This research report would not be possible without the loving support of all of you.

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concerns beyond the English language, all that I accomplished during the project would not be possible.

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GLOSSARY

CDMA	Code Division Multiple Access
DVD	Digital Versatile Disc
GPS	Global Positioning System
IEEE	Institute of Electrical and Electronics Engineers
LAN/MAN	Local Area Network/Metropolitan Area Network
MIMO	Multiple In Multiple Out
ODM/OEM	Original Design Manufacturer/Original Equipment Manufacturer
PLC	Programmable Logic Controller
PoE	Power over Ethernet
RFID	Radio Frequency Identification
RTG	Rubber Tired Gantries
SWOT	Strengths, Weaknesses, Opportunities, Threats
TCO	Total Cost of Ownership

TEU	Twenty Foot Equivalent Unit
VoIP	Voice over Internet Protocol
WAP	Wireless Access Point
Wi-Fi	Wireless Fidelity, a wireless networking technology using IEEE 802.11 standards.
WLAN	Wireless Local Area Network

1: INTRODUCTION

The business of transporting and shipping container involves moving goods through the supply chain to locations all over the world. It is a truely global business, as shipping companies from different countries move cargo to and from customers around the world. This business is comprised of a large number of activities and complex interactions among multiple participants and stakeholders.

Global container traffic is growing steadily. Based on *ABIresearch*, more than 20 million shipping containers currently circulate around the world: among them, about 7 million pass through US ports every year (Balog et al., 2005). More than $807 billion worth of goods passed through US seaports in 2003 alone (Haveman et al., 2006). The growth in container traffic has raised the need for effective and efficient methods to track containers and the cargo they transport. Another important issue is container security. Containers need to be secured to prevent theft and pilferage and also to prevent them from being used by terrorists to transport weapons of mass destruction.

Container tracking is an integrated part of container handling practices in port operations. It includes monitoring and positioning of containers in the transportation process and improves operational efficiency and container security. The advantage of container tracking that employs real-time monitoring and auditing is that shippers, receivers and other end-users can know exactly what is exactly happening throughout the entire transportation process.

Although the container tracking market is still in an early stage, there has been significant progress in technology and standards, products and services, as well as increased use of tracking systems over the past few years. With increasing concern for security and more demand from end customers for tracking information, this trend should continue. There are already many initiatives and players in the market, including government and private enterprises. In 2002, the US Department of Transportation and US Customs Service began an $86 million initiative, Operation Safe Commerce, to improve container security through a series of test projects at the three major US port areas, Seattle/Tacoma, Los Angeles/Long Beach, and New York/New Jersey. In April of 2002, the U.S. Customs and Border Patrol (USCBP) introduced the Customs-Trade Partnership Against Terrorism (C-TPAT), a government/business initiative to increase cargo security while improving the flow of trade. In the private sector, during the fall of 2004, General Electric Security, in partnership with Unisys, All Set Marine Security AB, and China International Marine Containers (CIMC) completed the Tamper Evident Secure Container (TESC) initiative (Balog et al, 2005). All of these initiatives and projects involved some type of container tracking capabilities and functions with technologies such as Radio Frequency Identifier (RFID) and Global Positioning System (GPS).

The primary means of tracking containers, or more broadly, vehicles and cargos, are through GPS and RFID and data transfer via Wi-Fi wireless network. GPS and RFID technologies are used to locate and identify containers and track their movement. As data is collected, the tracking system uses Wi-Fi wireless networks to transfer data to a central

processing system, which processes the data and integrates it into related enterprise applications.

The electronic transmitting and receiving terminal is an important component that plays a vital role in the data transfer process. More specifically, the antenna system at the terminals directly affects the effectiveness and efficiency of the data transfer. Due to the limitations and shortcomings of traditional single omnidirectional antennas, more intelligent antenna systems are being developed.

1.1 Background of the Market Research Project

A technology project, led by Dr. Rodney Vaughan of the School of Engineering at Simon Fraser University, is attempting to develop a *Multiple Wi-Fi Antenna Communication Transmitting/Receiving Device* that aims to enhance wireless network coverage by enabling larger coverage areas and higher quality signals in the Wi-Fi based wireless network environment. This technology project is in its early stages. Presently, various development ideas are being generated and screened.

A thorough market research analysis is required to assess the potential market opportunity. This market research will also serve a basis for a more detailed feasibility study to justify future investment in product development. This market research project is sponsored by the Department of Applied Science, Simon Fraser University, jointly with the Segal Graduate School of Business, through the University-Industry Liaison Office as an MBA Applied Research Project for an MBA candidate in the area of Management of Technology (MOT).

Based on information and data collected from other research sources, at this stage, the market research identifies opportunities of adopting this smart antenna technology in port operations and assesses the size of the potential markets as well as identifying customers and competitors. It provides necessary information for further feasibility studies, decision making and general guidance for the product development process. The strategic analysis of market entry options and recommendations are also included in this market research project.

1.2 Overview of Multiple Antenna Technology

Multiple antenna systems are developed to overcome the limitations and shortcomings of traditional single antenna and to improve overall system performance in terms of spectrum efficiency and capacity to achieve high data rate wireless services. Multiple antenna systems use numerous antennas, or an antenna array, at both the transmitter and receiver to offer significantly higher data throughput and link range without requiring additional bandwidth or transmitting power. A multiple antenna system of particular interest is called “smart antenna”. This system combines a physical antenna designed with embedded digital signal processing software.

Early smart antennas were developed for government use in military applications that used directed beams to hide transmissions from enemies. The implementation of smart antennas required very large antenna structures and time-intensive signal processing, and was used in military Radio Detection and Ranging (RADAR) systems. In the early 1990s, smart antennas began to emerge into mobile communications. Co-located with a base station, this smart antenna system combines an antenna array with

digital signal-processing capability to transmit and receive in an adaptive, spatially sensitive manner. This feature of smart antenna system can dramatically increase performance characteristics, such as the capacity of a wireless network, especially in port environments or similar enterprise campuses that are located over a large, disconnected geographic area where there might be buildings, stacks of containers and other objects blocking or changing the signal paths and directions.

1.3 Objective and Scope of the Market Research

The objective of this paper is to analyze the overall application of multiple antenna systems in port environments. By analyzing and evaluating the market, including potential customers and competitors and other players in the supply chain, various environmental factors affecting the opportunity, including entry and future sustainability, in this market are assessed. Furthermore, the opportunity of penetrating into the market as an independent business entity is further investigated and explored based on the analysis of product and business competencies.

This paper focuses on the application of multiple antenna technology in port environments because of the mandate of the existing research team. As one of the technology project team members pointed out, the purpose of their research is to explore this niche market, starting with addressing the technical issues encountered in the Port of Vancouver, and possibly expanding to other ports in North America, especially on the west coast. The long term goal is to expand to major seaports around the world.

Following the introduction, Chapter 2 presents an overview of related technology and products, including the IEEE 802.11x Wi-Fi standards, GPS and RFID, and their

applications, especially in port operations. Chapter 3 focuses on the market analysis. New product attributes and competency in relation to the market are analyzed. Chapter 4 gives detailed information about the major market players. Potential customers, suppliers, vendors and competitors are thoroughly analyzed. In Chapter 5, a strategic analysis using industry analysis, SWOT profiling, business model and value chain analysis, and the balanced scorecard (BSC) method is used to further analyze and assess the possible options and the range of strategic decisions that may emerge. Chapter 6 discusses options and recommendations. Finally, a summary and conclusions are presented in Chapter 7.

1.4 Operational Improvements Required by the Port of Vancouver

The primary concern with the current implementation of container tracking system in the Port of Vancouver is the Wi-Fi network's poor coverage. In particular, the connectivity is typically lost when a vehicle passes into large stacks of containers. In this situation, both the local wireless link and the GPS link are lost. The operators are supposed to make an entry into the online system from the laptop on the vehicle when placing or moving a container so that the location of the vehicle and containers will show up in the control centre in real time mode. This is problematic, because the lost connectivity leads to disappearance of the equipment on the central control system. Furthermore, the onboard Programmable Logic Controllers (PLCs) on the heavy machinery can be polled and reprogrammed remotely via this wireless network link. Therefore, the wireless link is critical and the connectivity problem will significantly affect overall operations activities.

1.5 Development of a New Wireless Access Point Device

Improving the range of wireless coverage and signal quality will rely on the characteristics of IEEE 802.11x technology being adopted (see section 2.2.3 and Figure 2.1 for an overview of IEEE 802.11x technology). In addition, the quality of the access point devices, or base stations, needs to be improved. One of the methods is using smart antenna technology. The technology research team in the Department of Engineering, Simon Fraser University is considering developing a new wireless access point device with a smart antenna array system, integrated with innovative embedded signal processing software, to resolve the current problem and achieve higher performance with lower Total Cost of Ownership (TCO).

As this new product is still in the very early stage of idea generation, the current research focuses on the investigation and review of similar products in the market with emphasis on technical architecture, technology standards and software integration. The technology research team would like the market research project to collect and analyze current market information, including market sizes, trends, potential customers and competitors, to help make decisions for any further actions, and to conduct further feasibility studies if necessary. Based on both the technical and market research results, the critical product attributes can be developed to enable a competitive advantage.

While working with the IT team at the Port of Vancouver to identify the area of problem and provide solutions, the technology research team is also exploring an opportunity to enter this market with its own start-up business entity. Therefore, the team is also interested in understanding competitors' business models. Of particular interest are marketing efforts, competitive strategies and general positive or negative lessons learned.

In addition to basic customer and competition analysis, this market research attempts to provide more information and guidance to business strategies and product development.

2: TECHNOLOGIES AND PRODUCTS

This chapter initially describes container tracking systems and their technology components. Technological reviews of the three core technologies used in sophisticated container tracking systems are presented thereafter. Finally, the problems and issues surrounding container tracking in the Port of Vancouver will be addressed.

2.1 Container Tracking Systems Overview

The continuing growth of container traffic makes an automated and interactive container tracking system that will identify and track containers as they enter and exit the port increasingly important to port operations. Such a system relies on three core technologies: Radio Frequency Identifier (RFID), Global Positioning System (GPS) and Wi-Fi wireless network infrastructure. Each of these plays a number of different roles in the tracking system. Their roles are discussed here and the three core technologies are reviewed in section 2.2.

RFID tags are attached to containers and contain data, such as size, weight and content, for a particular container. Essentially, an RFID tag is an extremely small microchip combined with a transponder and a transmission antenna. The data stored on the RFID tag is transmitted to an RFID reader, which is a combination of an RFID transceiver and a radio scanning antenna. Once information from the RFID tags is read and collected, it is organized and stored on a computer, usually a laptop, running a data processing software application. The computer is located on a pick-up vehicle.

Information about container processing and handling can be entered into the laptop, which is equipped with GPS. This provides real time location information for the truck and the containers. The software application transfers the data to the central processing system for entry into the enterprise database via a Wi-Fi wireless network. Eventually the container information stored in the central data center will be made available to the end users. This process is depicted in Figure 2.1.

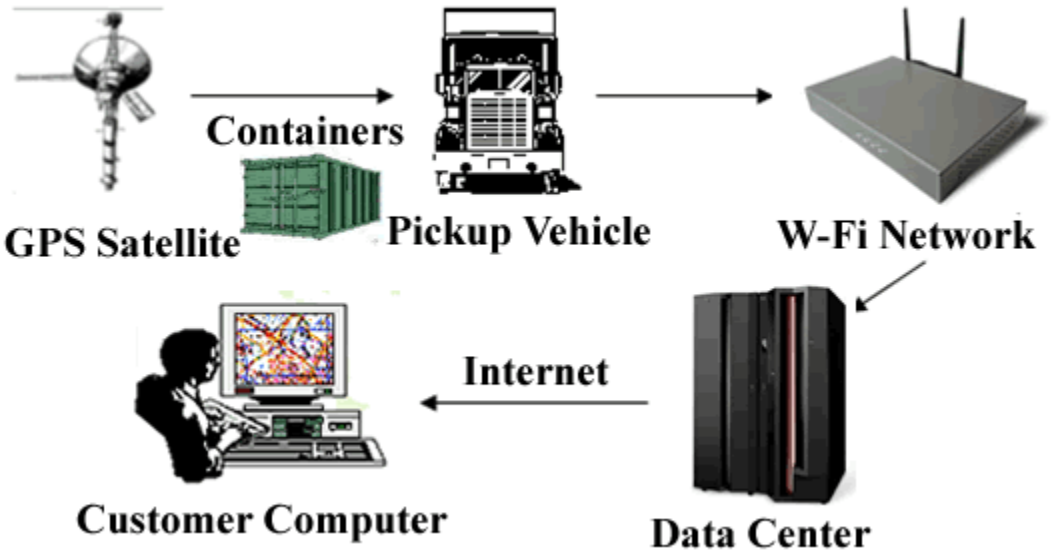

Figure 2-1 Container Tracking Systems (Adapted from US Department of Transportation)

In the system illustrated in Figure 2.1, the GPS locates the pickup vehicle and containers equipped with an RFID system; and all the data, including locations of the containers and pickup vehicles, and contents of the containers, is transferred via wireless network link to the central data center for processing. Using web technology, the

enterprise system delivers the processed real time tracking data to management for operation and control. The end customers, for example, shippers and receivers, or other vendors, can also track and monitor the process from their computers over the Internet.

2.2 Overview of RFID, GPS and Wireless Access Technologies

Multiple technologies are used in container tracking systems, specifically RFID, GPS and Broadband Wireless Access. These technologies are briefly reviewed below.

2.2.1 Radio Frequency Identification (RFID)

Radio Frequency Identification (RFID) is an automatic identification method used to store, retrieve and transmit an object's identity data through a (Wi-Fi) wireless network using radio waves. It consists of three components: a transponder, or tag, that stores data, a transceiver, or reader, with a scanning antenna and decoder to retrieve the data, and a data processing subsystem (computer) that processes and transfers data.

With RFID, electromagnetic or electrostatic coupling in the radio frequency (RF) portion of the electromagnetic spectrum is used to transmit signals. The antenna on a RFID reader receives radio wave signals, scans and reads the information stored on a RF transponder, or tag, and transfers the data to the RF reader, which acts as a processing device. The RF reader converts the radio waves transmitted from the RFID tag into digital information that can then be passed on to computers for analysis (Figure 2.2).

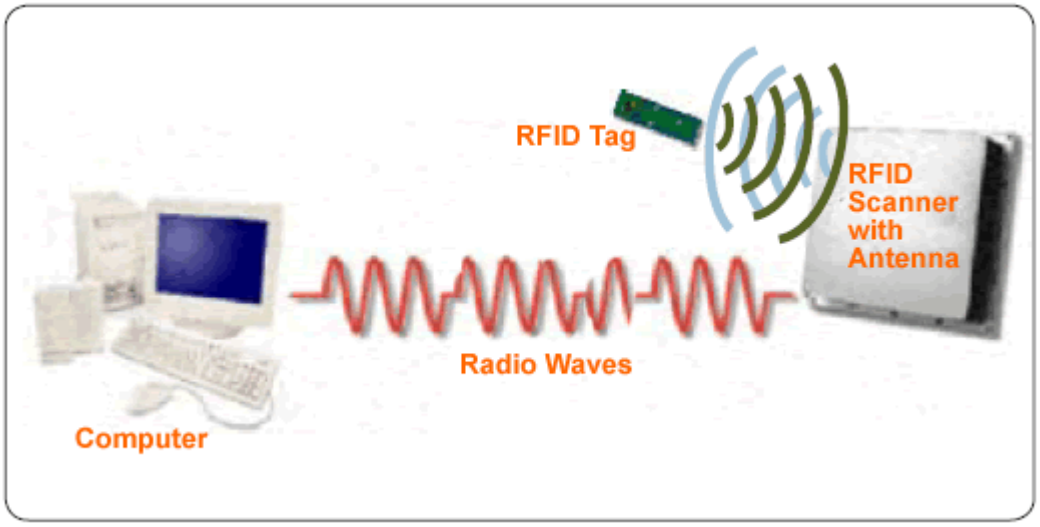

Figure 2-2 How RFID Works (Adapted from *Intermec*)

RFID tags can be active or passive. Active tags are more sophisticated and have an on-board battery for additional power that allows them to transmit their data signal over a greater distance. The passive tags, in contrast, have no internal power supply and rely on the electric current supplied by the incoming radio waves from the reader to transmit their signal. RFID systems can also be differentiated based on the frequency range they use. The common ranges are Low-Frequency (LF: 125 - 134.2 kHz and 140 - 148.5 kHz), High-Frequency (HF: 13.56 MHz) and Ultra-High-Frequency (UHF: 868 MHz - 928 MHz). The frequency range selected is determined by where and how the RFID tag will be used, as shown in Figure 2.3.

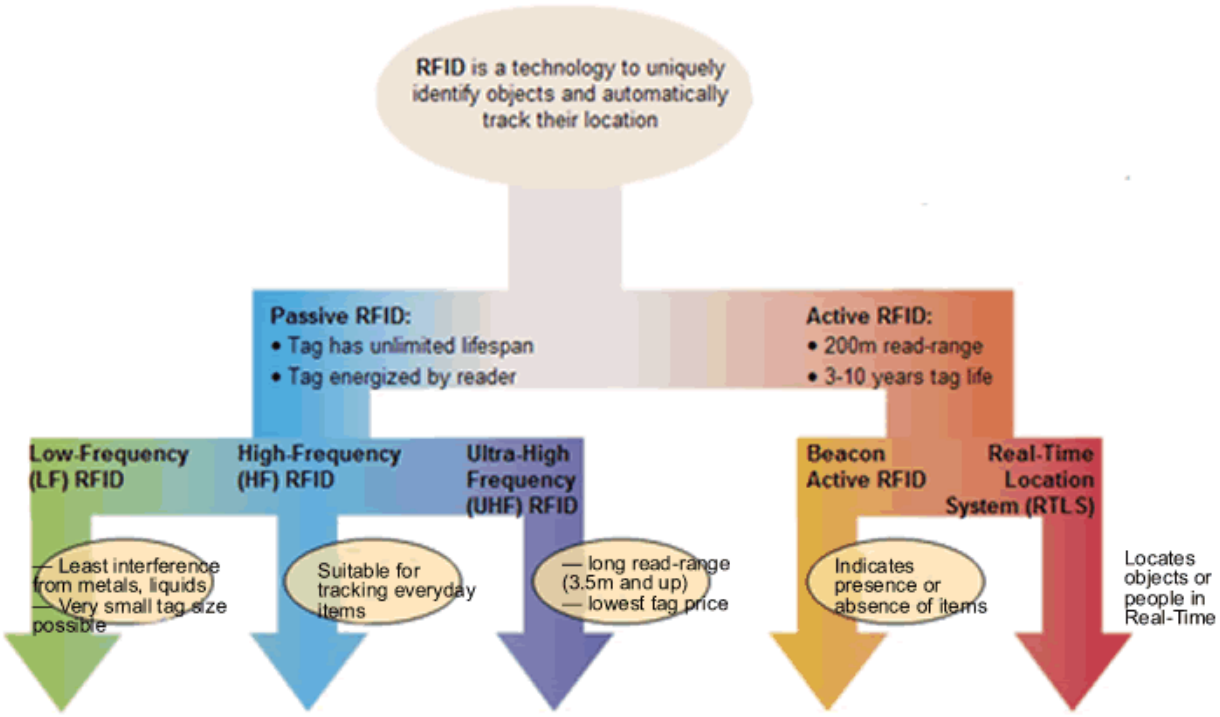

Figure 2-3 RFID Applications Integrated with GPS (Adapted from *NJE Consulting*)

RFID systems can be used just about anywhere. Most are used in enterprise supply chain management for consumer and industrial goods, replacing traditional bar code systems and improving inventory tracking efficiency and management. In a broader scope, RFID is a promising method for Asset Tracking systems and applications, which are used in Supply Chain Management system (SCM) to track and locate enterprises-wide assets.

2.2.2 GPS

Developed and operated by the U.S. Department of Defense, the Global Positioning System (GPS) is a satellite-based navigational system made up of a network

of 24 satellites around the Earth. Originally intended for military use, and available for civilian use in 1980s, GPS provides reliable and free positioning, navigation and timing services on a continuous worldwide basis.

The GPS is comprised of three elements: the satellites constellation, ground stations and user receivers. Each GPS satellite transmits data that indicates its location and the current time. All GPS satellites synchronize operations so that these repeating signals are transmitted simultaneously. The signals, moving at the speed of light, will be picked up by a GPS receiver at slightly different times due to the different distances of the satellites from the receiver. The distance from the receiver to the GPS satellites can then be determined by measuring the amount of time it takes for their signals to reach the receiver. When the receiver estimates the distance to at least three GPS satellites, enabling triangulation, using the location of the satellites, it can calculate its position in three dimensions (Figure 2.4). The ground stations maintain and control the satellites to ensure they are in their correct orbital positions and monitor system health and status.

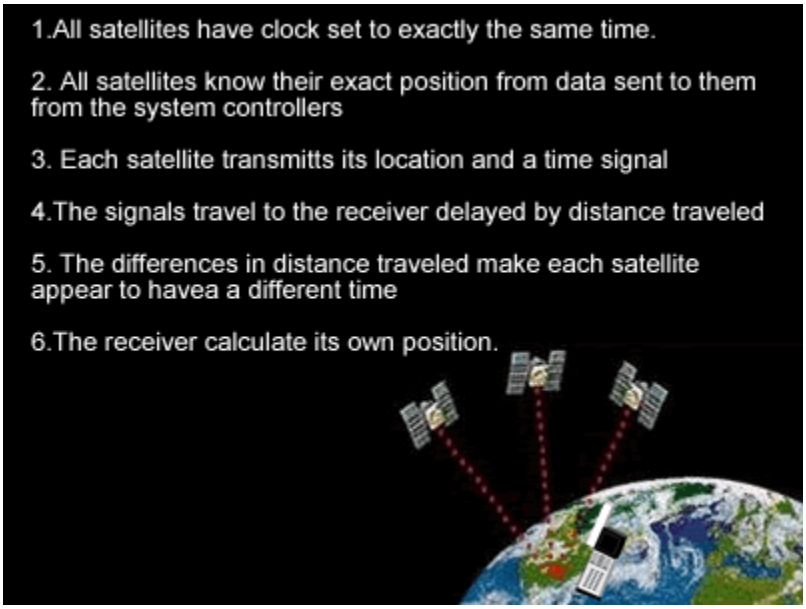

Figure 2-4 How GPS Works (Adapted from The Aerospace Corporation, www.aero.org)

When the satellite data is received by the GPS receiver, the GPS application processes the raw satellite data and finally presents an accurate location to the end users. The location data includes latitude, longitude and altitude (or some similar measurement) of its current position. The processed satellite data, integrated with other applications or services, then provides services of location, navigation, tracking, mapping and timing (GPS Resource Center, Palowireless, accessed June 2008).

2.2.3 Wi-Fi Networking Technology and IEE 802.11 Standard

Wi-Fi stands for *Wireless Fidelity* and is used to describe the underlying technology of wireless local area networks (WLAN) based on the IEEE 802.11 specifications. It has become the *de facto* standard for broadband connectivity and mobile computing devices, such as laptops and in wireless LANs, but is increasingly being used

for more services, including Internet and VoIP (Voice over IP) phone access, PDAs (Personal Data Assistants), mobile phones, and basic connectivity of consumer electronics such as televisions, DVD (Digital Versatile Disc) players and digital cameras.

IEEE 802.11 is a set of standards for wireless local area network (WLAN) computer communication, developed by the IEEE (Institute of Electrical and Electronics Engineers) LAN/MAN (Local Area Network/ Metropolitan Area Network) Standards Committee (IEEE 802) in the 2.4 GHz and 5 GHz public spectrum bands. These public spectrum bands are unlicensed, and thus the unlicensed links can be deployed at owners' discretion, offering greater flexibility to serve mobile and related services. However, because the bands are actually shared, the spectrum does not promise exclusive use of the bands, and it has to deal with interference from noise source and other networks. The Standards Committee was formed and held first meeting in February 1980 and already created over 50 LAN/MAN related standards. The first IEEE 802.11 Wireless LAN (WLAN) standard was created in 1997. Currently, there are a number of variants of IEEE 802.11 standards in terms of operation frequencies, data rate, and covered range, including IEEE 802.11a/b/g and IEEE 802.11n (Mitchell, Bradley wireless Standards, accessed June 2008). A comparative summary of the features of the different standards is presented in Table 2.1:

Standard	Operation Frequency (GHz)	Typical Data Rate (Mbps)	Max Data Rate (Mbps)	Covered Range	Advantages	Disadvantages	Common Usages & Applications
802.11a (Final approval in July 1999)	5	23	54	~35m	Fast max data rate, No interference	Highest cost, shorter range and more easily obstructed	Both indoor and outdoor home and corporate WLANs
802.11b (Final approval in July 1999)	2.4	4.5	11	~38m	Lowest cost, signal is good, and not easily obstructed	Slowest max data throughput, possible interference	Small indoor WLANs deployed in "hot spots" in home, airports, hotels, etc.
802.11g (Final approval in June 2003)	2.4	23	54	~38m	Fast max data rate, signal ranges is good, not easily obstructed	Higher cost than 802.11b, possible interference with unregulated signal frequencies	Current dominant Wi-Fi technology (replacing 802.11b) for all indoor and outdoor WLANs
802.11n (came in early 2006 and to be ratified in June 2009)	5 and/or 2.4	74	300	~70m	Fastest max data rate, best signal range, more resistance to signal interference from outside sources	Standards not finalized yet, higher costs, issues of interpretability with 802.11b/g	Large outdoor enterprise WLAN, Metropolitan Area Networks

Table 2-1 Major IEEE 802.11 Standards

A typical enterprise application of a Wi-Fi network involves attaching multiple wireless access points (WAPs), or base stations, to a wired network and then providing wireless access for mobile devices to access the enterprise LAN (Figure 2.5). This is referred to as WirelessLAN (WLAN). WLAN utilizes spread-spectrum or Orthogonal

Frequency-Division Multiplexing (OFDM**)** modulation technology based on radio waves to enable communication between devices in a limited area, also known as the basic service set. This gives users the ability to move around within a broad coverage area and still be connected to the network.

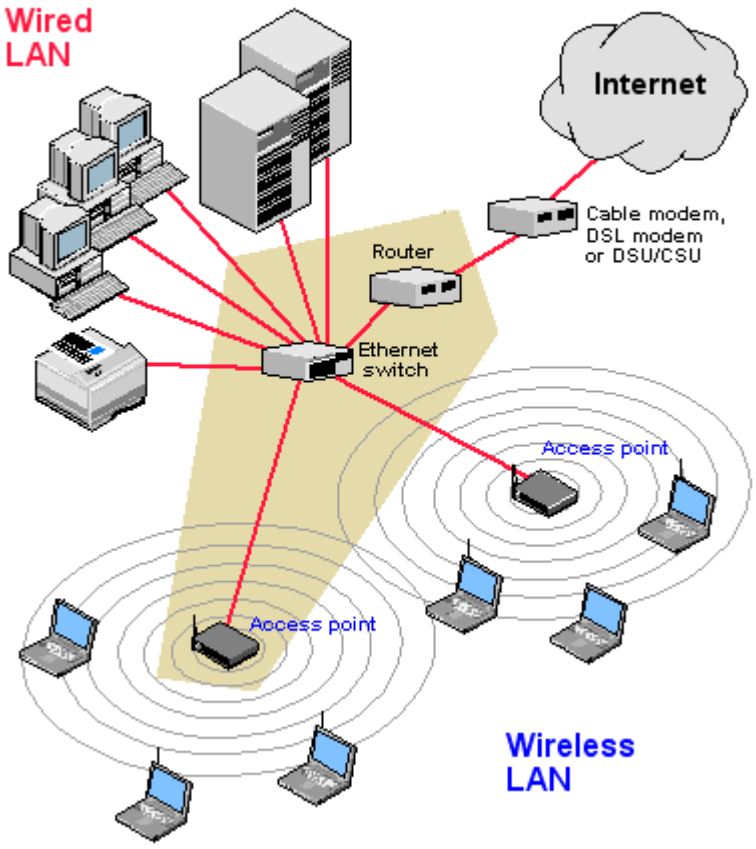

Figure 2-5 Wireless LAN (Adapted from ZDNet)

As WAP is the central device that manages the transmission of wireless signals, high quality and capable WAPs, as well as their deployment and positioning in outdoor wireless network infrastructure, are critical to provide good signal quality in data

communications. Because the antenna system on WAPs is the single important channel the data flows through, WAPs with better designed antenna systems will not only ensure extended areas and range of open space covered, but also improved signal quality, especially in structures or environments with walls, buildings and other objects that obstruct the signal transmissions.

2.3 Access Point with Smart Antennas and Wi-Fi Network

A Smart Antenna System combines multiple antenna elements with a digital signal-processing capacity to optimize its transmission and/or reception pattern automatically in response to the signal environment. Unlike conventional cellular antennas, which broadcast energy over the entire cell, smart antennas are adaptive. The antenna arrays actually confine the broadcast energy to a narrow beam. This method significantly improves the performance by increased signal gain, greater range of the signal path, reduced multi-path reflection, enhanced spectral efficiency, and increased network capacity (TEC Newsletter, 2001).

There are many players in the wireless access point device and equipment market. Most design and manufacture WAPs based on IEEE 802.11b/g standards for consumer use in home environments and small and medium sized businesses, primarily for in-door use. The well-known brands include D-Link and Linksys (acquired by Cisco Systems in April 2005). For enterprise level or business class wireless networks, especially for outdoor implementations, more powerful access point devices, or base stations, with better designed antenna systems have been developed. Furthermore, IEEE 802.11n based

access point devices are available from a few vendors, such as Netgear (MSN News, April 28, 2008) and Broadcom (Krazit, Tom April 22, 2008).

2.4 Technological Features of Operations

The Port of Vancouver is currently using a Wi-Fi wireless network infrastructure, combining GPS technologies and enterprise management software to implement solutions to container tracking and port operations. As RFID technology is not yet fully integrated with the entire system, in the port's container operations, optical scanning technology is still being used to scan bar codes. Bar code method restricts the available information to only container types and sources of containers, not being able to identify individual containers with more detailed data, such as the contents, shipping history and other supply chain related information. Therefore, the optical scanning technology compromises the effectiveness and efficiency of the container tracking system. In addition, the Total Cost of Ownership (TCO) is higher because of the increasing number of one-time-use-only bar code labels and labor involved.

The data communication software and applications for container tracking and positioning are provided by Satellite Telemetry Pty Ltd. in Australia (Sattel Systems, accessed June 2008). The software application for planning, management and control of port and terminal operations is provided by Navis, a division of Zebra Technologies (Navis, accessed June 2008). The Port of Vancouver's wireless network uses two frequencies: an older 900MHz system and a 2.4GHz system. The network infrastructure, including hardware, software and services, is provided by a local company, CIMS

Industries in Langley, BC. (CIMS Industries, accessed June 2008). They have an on-site representative to assist with the operations and provide support.

All of the equipment in the port is equipped with a wireless link. This includes pick-up trucks, rubber tired gantries (RTGs) and Top Picks (forklifts). RTGS are heavy duty machines used to move containers. Ruggedized laptops run software that integrates and coordinates all of the activities involving container operations in the port. Additionally, each of these vehicles is equipped with a GPS system attached to a laptop, and the integrated software is used to keep track of all of the equipment in real-time as well as accurate positioning of pick up vehicles and containers within the port area.

3: INDUSTRY AND MARKET

3.1 An Overview of the Container Shipping and Handling Industry

The modern economy is global in nature. Today, international trade is driving the economy of all countries, especially those bounded by oceans, in ways previously unimaginable. Before the container shipping system was introduced about half a century ago, the world was full of small local manufacturers selling locally. By the end of the 20th century, with the emerging Internet and World Wide Web facilitating e-commerce, purely local markets for any sort of goods were disappearing. With more efficient and affordable transportation systems, this trend will continue.

International container shipping has been one of the most dynamic economic sectors in the last few years. Between 1990 and 2005, global container trade expanded by an average of 10% annually. It has been estimated that the growth in international container shipping will continue for the next ten years at an annual rate of about 9% up to 2015 (Deutsche Bank Research, 2006).

Another source also indicated that, during 2001 and 2005, the global containerized trade has grown at a compound rate of 12%. As forecast, the growth rate for the 2005 to 2011 will be 6.5%, reaching 134 million Twenty-foot Equivalent Units (TEUs). This is 2.3 times greater than the 58 million TEU transported in 2001(Levinson, 2006).

Nowadays, thousand of containers arrive and depart every major port around the world every day. Container handling is growing even faster than container trade. Since 1990, the growth of this sector has averaged 10.6% annually. Similar to the hub strategy in international air transport, an increasing proportion of containers are being shipped to large container trans-shipment ports (hubs) by feeder services. The ships' cargos are then assembled and transported to other hubs or to the actual destination port. This configuration is known as the hub & spoke model. This type of trans-shipment traffic has been considerably larger than container transport traffic (2005: 400 million TEU vs. 114 million TEU), and it has grown significantly. It represented 11% of the traffic in 1980 and 27% in 2005 (Deutsche Bank Research, 2006).

The major reasons behind the phenomenal growth of container shipping are increased productivity, structural changes in the transportation industry, increasing trade volumes favouring economies of scale and vice versa, and continuously decreasing shipping costs (Volk, 2002). However, continuous oil price increase since 2003 led to high costs of fuel and imposed a negative impact on transportation and shipping industry. Nevertheless, to compare with air shipping and break cargo sea shipping, the cost of containerized sea shipping is still competitive as ports are improving container handling efficiency, achieving economies of scale by increased fleet capacity, and upgrading port infrastructures to maximizing handling volumes and minimizing vessel dwell time at ports. On the demand side, other factors include the increasing international division of labor, the rise in importance of goods eminently suited to transport by containers. On the supply side, the relevant factors are considerable expansion of the container ship fleets

and faster loading and unloading procedures resulting in shorter turnaround times in port (Deutsche Bank Research, 2006).

3.2 Container Port Operational Efficiency and Security

Two market drivers propel the need for a secure and efficient container tracking system. They are port operational efficiency to streamline the supply chain and container security to protect the container from theft and attack. Every day at every major seaport around the world, thousands of containers arrive and depart by ships, trucks and trains. The activities involved include loading, uploading and delivering, information scanning and processing, real time tracking, etc. Efficient shipping of freight from beginning to end over the entire supply chain requires seamless coordination and integration.

Due to the fact that multiple players are involved and responsible for different segments of the container transportation process, a container tracking system is needed to track and monitor every phase and process. The real time information provided by a tracking system is likely to increase supply chain visibility, which can, in turn, improve efficiency, lower costs, and increase profits. A container tracking system allows end users and shippers to monitor the container during all segments of its journey. Continual monitoring systems ensure that the container remains secure, thus preventing losses due to theft or misrouting and/or terrorism as well as maintaining required productivity.

Container tracking systems must also address security issues to prevent container loss and reduce terrorism. With increasing security concerns in international trade, the US Government has passed a plethora of port and container specific legislation and put many non-statutory regulatory initiatives in place (Frost & Sullivan, 2007). Other US

Government policies and laws were also established to protect America's maritime community against the threat of terrorism. These include the Maritime Transportation Security Act (MTSA) of 2002, Public Law 107-295, and Presidential Directive 13 (PD 13), which was passed in 2004. Similarly, a number of international policies were established and passed. These include the International Convention for the Safety of Life at Sea (SOLAS) and amendments to the International Ship and Port Facility Security (ISPS) developed by the International Maritime Organization in 2002 (Balog, Adelina et al. 2005).

To increase operational efficiency and supply chain security, a high level of collaboration between all players in all sectors of the transportation and logistic industry is required. With increasing size and speed of container ships, the turnaround time for ships has become a crucial factor for shipping lines when they evaluate the attractiveness of a container port. In order to gain a competitive advantage, ports have to employ a sophisticated management system as well as to invest heavily in expensive, state-of-the-art equipment and collaborative human resources. The container tracking system assists all the stakeholders in reducing costs and security risks while improving customer service.

3.3 Current Market Status and Future Trends

3.3.1 Container Tracking Systems

A number of software and hardware vendors, such as WhereNet and Navis, are active in the emerging market of container tracking systems. Other vendors directly involved in trials or product tests provide various types of tracking solutions. These include commercial telematics vendors, such as Savi Networks, Unisys and IBM (ABI

Research, 2002). In 2007, Global Tracking Technologies LLC, a privately held GPS tracking solutions provider, launched a container tracking system that aims to "…become the de-facto solution for governments and shipping lines across the Globe for the management, control and tracking of container shipments" (GTT News, 2007). In 2002, the Alameda Corridor Transportation Authority (ACTA), working with TransCore Inc. of San Diego, the Burlington Northern and Santa Fe Railway (BNSF) and the Union Pacific Railroad (UP), tested a cargo container tracking system for the United States Department of Homeland Security in order to electronically track the movement of cargo containers from the moment they arrive at a US port (ABI Research, 2002). The newly released WhereTrack controller by WhereNet transfers GPS, Real Time Location Service (RTLS) and telemetry data over a Wi-Fi link that is part of the WhereLAN network of locating access points (WhereNet Press Release, 2007). SAA Marine, one of the largest privately held container terminal operators and cargo handling companies in the world, worked with WhereNet and intended to deploy wireless infrastructure and a marine terminal solution that combined RFID based wireless tracking system at four west coast ports in 2005 (Wi-Fi Technology Forum, 2005).

On the demand side, in contrast to the heavy human involvement in previous container tracking systems, the processes employed currently at ports are becoming more automated. Although the market still is a long way from seeing fully automated container tracking, ports and container terminals have been quick to implement their own internal container tracking schemes to identify where specific containers are located in yards and to streamline their operations. More specifically, the ports on the west coast of North America have been very actively involved in the process of developing, testing and

deploying tracking solutions to deal with growing container volumes and rising labor costs (ABI Research, 2007). For example, the Port of Oakland, jointly with Bay Area World Trade Center and several private vendors, deployed Advanced Transportation Communication systems (ATC) to provide "first and last mile" visibility of cargo containers as they are nearing the Port of Oakland and as they are delivered to retailers and distribution centers around Northern California (Buxbaum, Peter A., 2007).

The container tracking system market is still immature from many perspectives. The immaturity is evident in three factors: 1) many systems are in a very early testing stage, or are small scale pilot projects; 2) the reliability of the systems for full scale deployments are still questionable, and 3) there is an absence of accepted standards, government legislation or regulations (ABI Research, 2007). However, with the technological advances and increased participation of governments concerned about security, much of pilot testing and deployment has been done by governments and commercial companies in this sector in recent years. How the future market shifts will be determined by many variables, such as government legislation and regulations, establishment of standards, security and visibility of containers and their contents, demand for high level operational efficiency and customer service, and cost-benefit considerations. The market is promising in the medium and long term, with 8-9 millions containers arriving in US ports each day, but it greatly depends on how the above factors and issues will be addressed (Orbcomm, 2006).

3.3.2 Wi-Fi Network Infrastructure Equipment

The data transfer component in a container tracking system relies on a well structured and widely deployed Wi-Fi wireless network infrastructure, including the

Access Point device and its signal transmitting/receiving mechanism. Wireless technologies differentiate by standards, bandwidth (data transfer speed), range and scope of coverage, and methods of signal processing and information encoding. The strategic positioning of various wireless technologies and their applications is shown in Figure 3.1.

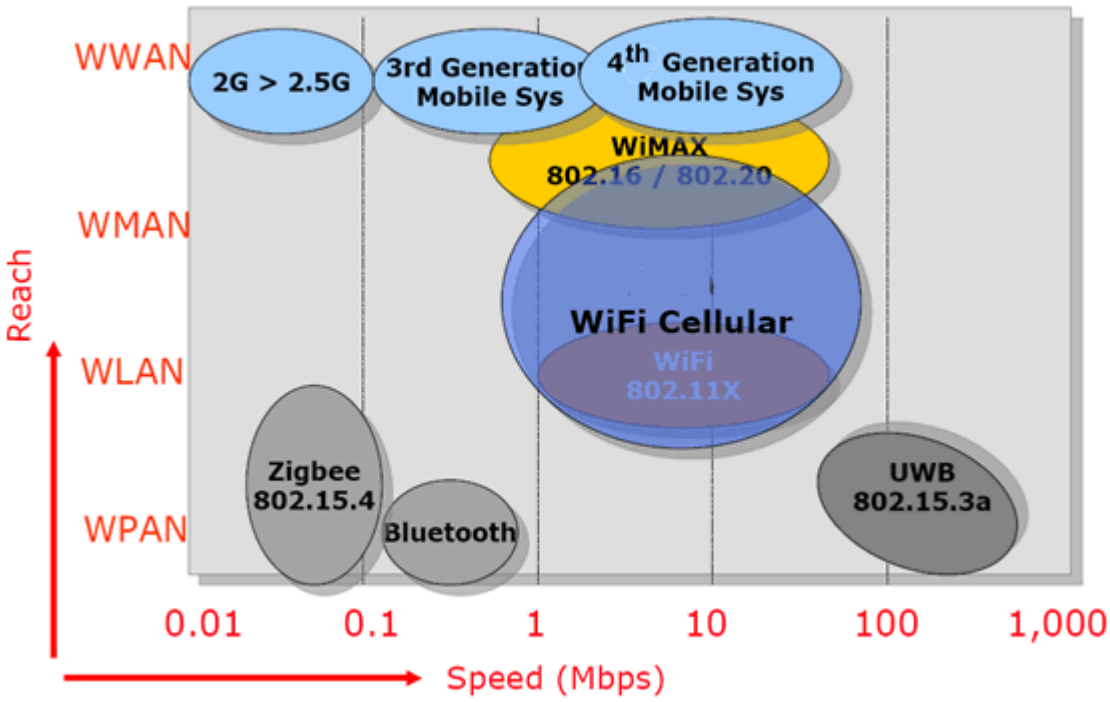

Figure 3-1 Positioning of Wireless Technologies (Adapted from Altai Technologies)

The Wi-Fi market is very active and dynamic. According to Infonetics research reports published in September 2006, worldwide RAN (Remote Access Network) equipment sales jumped 20% to $8.9 billion between the first and second quarters of 2006. WiMAX equipment sales shot up 107% to $141 million and, while wireless LAN equipment sales dropped slightly by 7% to $654 million; growth is expected to be steady

through 2009, fueled by strong WLAN switch and controller sales (Infonetics, 2006). The sales growth in the outdoor Wi-Fi equipment market is depicted in Table 3.2.

Region	Asian Pacific (A/P)	North Americas (NAR)	Central Americas and Latin-Americas (CALA)	Europe, Middle East and Africa (EMEA)
Market Share	18%	55%	4%	23%

Figure 3-2 Market Share by Regions (Source: Altai Technologies Year: 2006)

3.3.3 The Smart Antenna Market

Smart antennas are established as one of the key technologies helping to change and transform the existing wireless market. This technology increases the performance and economics of wireless networks, typically through the combination of multiple antennas (antenna array) and advanced signal processing software, especially in outdoor and more complex environments. Many base station manufacturers are now looking to incorporate this technology into their product lines, following years of the product being pushed by a number of technology innovators and start-up ventures (Unstrung News Feed, 2003). According to a new Visant Strategies study, 'Smart Antennas: Wading into the Mainstream 2003', Smart Antenna technology is now deployed in one out of every ten base stations in the world. The research group predicted that the smart antenna systems market would reach 1.6 billions in sales globally by 2008. This is a significant

development for wireless operators seeking a proven technology to expand the capacity and performance of digital wireless network (Highbeam Research, 2003).

One of the strongest drivers for smart antenna technology is their performance-enhancing benefits in terms of capacity, coverage and range, as indicated by Frost & Sullivan Growth Partnership Services (Frost & Sullivan, 2006). The growing necessity for higher data rates in emerging communication systems has been acknowledged in many applications. Pioneering applications based on the benefits of these technologies, such as those providing location and tracking information, are also emerging in the market.

The Frost & Sullivan study also indicted that in the future, smart antenna are expected to become a common feature in many application areas. In fact, research on smart antenna technologies has increased tremendously to keep pace with the constantly expanding needs of the wireless communications industry. Emerging application areas such as Ultra Wideband (UWB), Radio Frequency Identification (RFID), and Mobile Direct Broadcast Satellite (DBS) are expected to see extensive adoption of these technologies in the next few years. In particular, the study noted that with the confirmation of 802.11n standards, the number of smart antenna products entering the market was likely to increase considerably.

The Wi-Fi market has paid a significant amount of attention to the development of the IEEE 802.11n standard over the past several years, since the first MIMO-based products came to market. This strong interest continues as the draft standard of 802.11n is being developed during the first half of 2008 (IEEE 802.11, 2008), as 802.11n is

expected to become the de-facto standard for all future smart antenna technologies. In the mean time, the development of smart antenna technologies, including switched beam and adaptive array, and multiple antennas, is a parallel effort for Wi-Fi based WLANs. This is because there have been proprietary MIMO chipsets in the market before IEEE 802.11n reached current draft 2 status, and they attempted to apply the principle of MIMO to enhance the existing 802.11a/b/g networks in the most cost effective way. According to ABI Insight, which examined the technologies, vendors, challenges, and future prospects for the smart antenna market, there are specific market opportunities available for various smart antenna sub-set technologies (ABI Research, 2006).

3.3.4 Summary of the Market

International container shipping has been one of the most dynamic and rapidly growing economic sectors in the last few years. This is mainly due to increasing volume of international trade, especially between Asian Pacific countries and North America and Europe. Other significant factors contributing to the sectors' growth and change have been decreased shipping costs and the increased handling capacity of the major seaports around the world. Recent oil price rise will significantly affect the overall costs of shipping industry and may even slow down global trade and drive up inflation levels. However, with other efforts in terms of operational efficiency and fleet capacity and speed, the containerized shipping is still attractive.

A container tracking system is essential for operational efficiency and container security against theft and terrorism as it can provide real time monitoring and tracking of the positions and status of the containers as they arrive at and leave the port. Container tracking systems provide essential information for both end users and management.

Although the container tracking market is still immature due to lack of standards, regulations and some technology barriers, various container tracking systems have been deployed in many ports around the world.

One of the enabling technologies in a container tracking system is a wireless network system that collects and transfers real time data. The key component in a wireless network infrastructure is the access point, or base station, that transmits and receives radio frequency signals. 802.11x based Wi-Fi network markets around the globe are active, with increasing sales volumes of the equipment and installed bases. Smart antenna enabled access point devices have increased capacity and improved performance and are in great demand by enterprise customers. The new IEEE 802.11n is on the way to being finalized and many vendors have already flooded the market with various smart antennas integrated access points to meet the requirements of enterprise customers. The technology and market demands pose a huge opportunity in this area. It is a promising market, in spite of some uncertainties and technical issues.

4: MAJOR PLAYERS

4.1 The Strategic Supply Chain

Cargo and supply chain operational efficiency and security have been widely recognized as being a collaborative effort between all players in all related sectors of the transportation and logistics industry. The major stakeholders are shippers (manufacturers/retailers), freight forwarders/logistics services providers, carriers (ocean, air and ground), warehousing/distribution facilities, port authorities and operations, technology and business consultants, as well as governmental and legislative agencies. The high-level supply chain for cargo transportation and logistics is depicted in Figure 4.1. Different stakeholders in the supply chain have particular areas of responsibility and interests (Table 4.1).

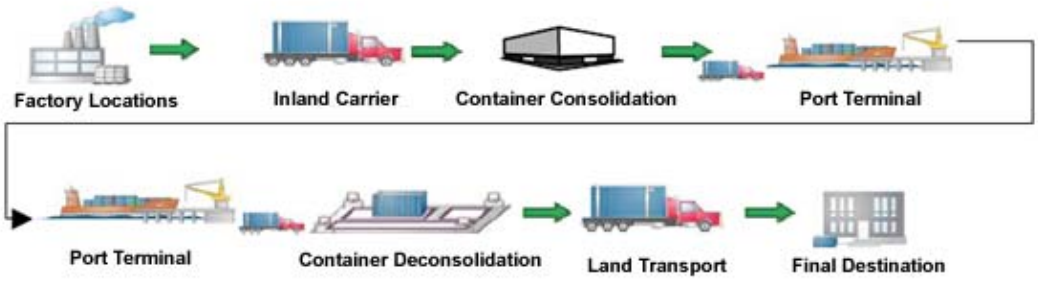

Figure 4-1 The Supply Chain (Adapted from Balog et al.*)*

Stakeholder	Area of Responsibility & Business Interests
Shippers	Business continuity and reliability of supply
Freight Forwarders & Logistics Serviced Providers	Efficiency, industry standards, and best practices
Carriers	Efficient, reliable and secure transportation.
Warehouse & Distributions	Efficient and secure storage and work flow
Technology & Business Consultants	Involved in the establishment of technology standards, and technology innovation.
Government	Legislation, Regulations, and Policies.

Table 4-1 Stakeholders and Areas of Responsibility, Business Interests

A comprehensive electronic container tracking system can be implemented from the point of origin to the destination, with the integration of existing technology. In a narrower point of view, a container tracking system implemented in a port environment will effectively monitor and track the flow of containers and their contents to ensure the operational efficiency and security. In the container tracking solutions' market, the major

players are hardware and software providers, customers and system integrators. These are summarized in Table 4.2.

Stakeholder	Area of Responsibility and Business Interests
Hardware & Software Providers	Basic hardware and software component design, development and manufacturing.
Customers (port authorities, shippers, carriers, etc.)	Port operational efficiency and container security, real time container tracking, etc.
Systems Integrators	Technology infrastructure deployment and on-going support

Table 4-2 Stakeholders in Container Tracking Industry

A comprehensive container tracking could begin when containers arrive at a port, or potentially earlier at the point of product inception. Tracking from the point of product inception is especially significant for security reasons. With improvement and enhancement of supply chain management, integrated with advanced technology, and with government and international initiatives, the goals and objectives of both operational efficiency and security can be achieved.

4.2 The Customers

The customers for container tracking systems are primarily seaports that handle containers. The SFU technology research team has been working with the Port of Vancouver to review the current Wi-Fi network infrastructure, with emphasis on the performance and capacity of wireless access point device, and are looking for ways to

improve and enhance the performance of the network by developing a more advanced design integrated with smart multiple antennas (antenna array). There are around 100 seaports registered with the America Association of Port Authority (2008 AAPA Directory). In Canada, major sea ports include the Port of Montreal, the Port of Nova Scotia, and the Port of Halifax in Eastern Coast, and the Port of Vancouver in West Coast. Appendix A provides an overview of the World's Busiest Sea Ports.

4.2.1 The Port of Vancouver

Located on the west coast of North America, the Port of Vancouver is Canada's flagship seaport and the largest port in Pacific Northwest. It is the major gateway linking Asia Pacific Rim markets to North America. In 2006, containerized tonnage increased to a new record of 2.2 million TEUs, up 25% over the previous year. After experiencing record container growth for 13 consecutive years, the forecasts indicate that container volumes through the Lower Mainland of British Columbia could reach 5.3 million TEUs, with volume through the Port of Vancouver reaching more than 4.8 TEUs by 2020 (2006 Annual Report: the Port of Vancouver). To further streamline the supply chain management process, the Vancouver Port Authority approved a $31 million transportation logistics program to develop and implement initiatives to improve and enhance their supply chain in terms of reliability, performance and competitiveness and to support planned increase in terminal throughput capacity in the Gateway. Working with the stakeholders and partners, the Vancouver Port Authority also integrated its security and marine operations to provide enhanced services to the port community with a five-year Federal government security investment program.

Dubai Ports World (DP World), one of the world's largest port operators based in Dubai, United Arab Emirates, and operating 44 terminals across 24 countries, acquired the Centerm Container Terminal at the Port of Vancouver in 2006 and invested $140 million USD on a capacity expansion project. This project would increase the capacity of the Port of Vancouver by 40% (DP World, 2006). The first phase of the project began in the third quarter of 2004 (AME Info, 2006).

The Port of Vancouver could be a good entry point for a new container tracking system product to enter the market. If the new access point was successfully deployed in the port and resolved the present problems, it would be easier to penetrate other DP World owned ports or terminals. In fact, information from the technology team indicates that the Port of Vancouver would like to enter an exclusive agreement to ensure that the newly developed access point device with integrated smart antenna (antenna array) would not be sold to competitors of the Port, especially the seaports in West Coast of North America. The exception is the other ports owned and operated by DP World.

4.2.2 DP World Owned and Operated Ports

Currently, DP World owns and operates five port terminals (one under development) in the region of America, which covers Canada and Latin America (DP World Official Site, accessed June 2008). They include the Port of Vancouver in Canada, the Port of Caucedo in Dominican Republic, the Puerto Nuevo, Buenos Aires in Argentina, the Puerto Cabello in Venezuela, and The Puerto Callao in Peru, which is currently under development. DP World currently owns no US ports.

Although, DP World recently owned and operated 22 US ports (CNN Report Transcripts, 2006), DP World sold all of their US port operations in New York, New Jersey, Philadelphia, Baltimore, New Orleans, and Miami to AIG Global Investment Group in December 2006 (AIG, 2006). These ports had been operated by a British company, Peninsula & Oriental Steam Navigation Co., which was acquired by DP World in March 2006. DP World divested themselves of these US port operations because of the "Dubai Ports World Controversy" which began in February 2006 and rose to prominence as a national security concern in US Congress (Wikipedia, 2006). Currently, most of DP World's port operations are in Asia where they operate 28 terminals. As well, they have 8 terminals in Europe and 5 in Oceania/Australia.

Given this situation, the Port of Vancouver is the only port in North America owned and operated by DP World. If this new wireless access point device with smart antenna is successfully adopted and accepted by the Port of Vancouver, with an exclusivity agreement with DP World, the potential North American market would be very limited. However, there is a huge potential market in Asian ports, primarily in

China, India, and United Arab Emirates. According to 2004 statistics, of the 25 largest ports in the world, measured by volume (TEUs), 16 are in Asia. Only three US ports, Los Angeles at 8th, Long Beach at 12th and New York at 15th are on the list. Thus, Asian ports represent a sizeable growth opportunity.

4.2.3 Other Ports in North America and Around the World

There are many other ports around the world which represent opportunities for multiple antenna systems. Other large and busy seaports in North America are located on the Pacific West Coast and the Atlantic and Gulf Coasts. West coast ports handled 46% of all imports shipped to U.S., followed by South Atlantic ports (from Norfork to Miami) at 24% and North Atlantic ports at 22% of total containerized imports (Martin Associates, 2008). The Ports of Los Angeles and Long Beach, the busiest harbor complex in the US and one of the premier US gateways for international trade and commerce, handled more than 14 million containers in 2005 alone, 8% more than the previous year.

A report published in 2006 focused on container shipping and the anticipated volume of trade with Asian Pacific countries. This study polled officials from 24 ports that handle 84% of North American container traffic and the results indicated that port capacity would be insufficient, creating transportation bottlenecks. As well, the current plans for expansion of port facilities and technology infrastructure for the next 15 years significantly underestimated demand (White, Donald D., 2006). Furthermore, statistics show that until 2002, the Ports of Los Angeles handled about 35% of imported Asian containerized cargos. After 2002, influenced by events such as 9/11 in 2001, some west coast ports were shutdown by labor disputes and continuous congestion in active ports occurred. The result was an increased focus on containerized cargos going through other

U.S. ports in the north and south Atlantic region and in the Gulf area. The Atlantic ports in US and Canada will benefit from increased all-water routings through the Suez and Panama Canals as shifts in manufacturing in Asia move toward Viet Nam and India (Martin Associates, 2008). Increased volumes of containerized cargos and level of activities provide more business opportunities for technology vendors to develop, deploy and support more sophisticated tracking solutions and wireless data network infrastructures.

4.2.4 Current Implementations in Ports

Working with business and technology providers, many sea ports are currently implementing a variety of container tracking systems in order to increase the operational efficiency, meet end users' shipping requirements, and comply with security legislations established by domestic and international law makers. Wireless network infrastructure, as a core technology of container tracking system, has been in place in these ports so that the real-time tracking data captured and filtered by RFID sensors and GPS can be transferred to a data center for further processing. An efficient and robust wireless network guarantees the accurate and timely data transfer and acts as a focal point that connects all the core components of a functional and performing container tracking system.

In North America, for example, P&O Ports North America Inc., a New Orleans-based terminal operator, has hired TransCore, a Dallas-based transportation services company, to install a wireless access and tracking system for its operations at the new Napoleon Avenue Container Terminal at the Port of New Orleans. The radio frequency identification technology will help handle container transactions at P&O's new terminal

by electronically identifying approaching trucks and, if validated, granting access. It will also track truck location and activity until departure (New Orleans CityBusiness, 2003). In 2006, WhereNet, working with terminal operators, deployed the WhereNet MTS solution, utilizing Wi-Fi links to transfer GPS, RFID, Real Time Location Services (RTLS) and telemetry data, in the Port of Los Angeles-Long Beach terminal. In 2007, the same technology was implemented in the Port of Oakland and the Port of Seattle (WhereNet Press Release, June 29, 2007, and March 13, 2007). Similarly, the Port of Halifax in Canada, contracting Nicom and other network and communications providers, implemented CTS (Container Tracking System) as well as Vessel Tracking Management System in 2007 (Nicom, 2007).

In the Far East and Europe, the Port of Busan, the largest and busiest port in Korea which is ranked as fifth in the world as a high volume shipping hub in Asian-Pacific region, started pilot testing on a RFID based container tracking system in early 2005 to investigate how the technology will help with productivity and security (RFID Journal, 2005). It rolled out the system in 2006 in a joint venture between Savi Technology and the terminal operator, Hutchison Port Holdings, in both the Port of Busan and the Port of Rotterdam, Netherlands (RFID Journal, February 2, 2007). The Port of Hong Kong also deployed a new screening and tracking system in 2005 to improve the level of security and container movement (SCDigest editorial, August 4, 2005). The Port of Shanghai, the second largest port in the world, with the help from The Port of Savannah, Georgia, USA, tested tagging technology to track all cargos shipped between them, especially for security purposes (Bynum, Russ, June 6, 2008). Other large

Asian ports in Singapore, China, Malaysia, Thailand, Taiwan and Korea, as well as European ports are also potential customers.

Major terminal operators at three of the world's largest mega ports--in Rotterdam, Antwerp and Felixstowe, which together account for nearly half of all container shipments from Europe to the United States, --have installed automated security network infrastructure as partners in the rapidly growing Smart and Secure Tradelanes (SST) consortium to improve the end-to-end security and management of cargo shipments (AllBusiness, 2003). The security network linked these three European mega-ports to the SST global security and information network already deployed in Asia and North America. This industry-led initiative has brought together more than 60 leading port operators, shippers and service and solution providers to define and implement solutions that provide both security and economic value to the global supply chain.

As sea ports around are highly concentrated in the Asian and European regions, they must be seriously considered as potential customers for container tracking systems and required wireless network infrastructure equipment, more specifically, smart antenna integrated access points. However, there are more advantageous and less difficult to enter and access markets in North America due to the common cultural background and similar business environments and government regulations. The current implementations of container tracking systems give an indication that the process needs highly collaborative efforts from many participants as the system contains many different technology components and interactive process between multiple stakeholders. Government and legislation bodies also have in-depth involvement in the implementation process and lifecycle.

4.2.5 Summary of Customers

In the container tracking system market, the customers are seaports in North America and around the world. A wireless data network is an essential part of the tracking system, and many ports and port authorities are in the process of deploying and implementing tracking systems to increase operational efficiency and enhance container security. Wireless Access Points with smart antennas will increase the capacity of the Wi-Fi network, improve the performance in terms of higher data transfer rates and lower dropped data rates, and extend coverage scope and range to ensure real time data availability. With the establishment of government legislation and industry regulations, particularly focused on security, container tracking systems will become mandatory for port operations. Furthermore, a wireless network system is the enabling technology for workflow and activity automation and management in many types of outdoor enterprises. All of these offer a potential business opportunity for wireless communication vendors, including hardware, software and other complementary products and services.

4.3 Competitors

4.3.1 Overview

The WLAN (wireless LAN) market symbolizes the continuing emergence of higher-performing, more specialized products pushing the evolution of the market. The development of WLAN antennas received the most attention in a 2004 WLAN market overview (Thuresson, Michael, 2004). In the marketplace, smart antenna vendors are involved in research and development to improve the design and effectiveness of antennas. Base station manufacturers then integrate the improved antennas with their own product lines. The smart antenna vendors focus on specific access techniques and have

short development lifecycles, and usually enter partnerships or license their technology to base station manufacturers. On the other hand, the base station manufactures use the technology to develop and build their products, as a partner or an OEM (Original Equipment Manufacturer). Partnerships between smart antenna developers and Wi-Fi equipment manufacturers provide a path to the complete solution, which may well include smart antenna integrated base stations, controllers and switches. This business model will optimize the contributions from both parties as smart antenna technologists bring the expertise in the technology and the manufacturers bring the productization, volume manufacturing capacity and distribution channels.

4.3.2 Major Smart Antenna Vendor Competitors

As one IEEE 802 standard, the 802.11n standard is based on a smart antenna technology with multiple-input and multiple-output (MIMO) capacity which differentiates it from legacy 802.11 wireless standards. A commercial product, an 802.11n access point device usually contains multiple RF antennas that are used to split data streams for faster, more efficient transmission and reception. The market competition is fierce, as many vendors offer different products with different architectures and chipset designs to meet the growing demand of enterprise wireless computing. Two categories of smart antenna vendors are chipset makers and equipment manufacturers. The remainder of this section surveys a few major North American smart antenna vendors. The competitors that are studied in this section are summarized in Table 4.3 at the end of the section.

Major chipset makers involved in development of smart antennas, as surveyed in the following sections, include Motia, Airgo, Broadcom, Marvell, Atheros and the recent

partnership of Applied Micro Circuit Corp and TeamF1 Inc. They focus on technology R&D and either produce the chipsets or provide reference design specifications for their OEMs. ArrayComm provides software for signal processing embedded in smart antenna integrated chipsets. Motia (www.motia.com), a fabless semi-conductor company, based in Burlingame, California, USA, focuses on development of smart antennas for wireless providers, and officially launched its first smart antenna product, Javelin, on December 2003 (Business Wire, Dec. 2, 2003). Motia's Javelin is a standards-compliant application that incorporates smart antennas into 802.11 systems without major modifications to the existing product. The design architecture allows Javelin to work with the installed base of Wi-Fi devices. In 2004, Motia announced that it had closed its third round of funding, with $12 million from Prism Ventures Partners, Intel Communications Funds and Prior Investors. Motia intends to retain its leadership and remain focused on applying effective smart antenna technology to wireless systems (Wi-Fi Technology Forum, 2004).

Another MIMO pioneer is Airgo Networks (http://www.qctconnect.com). The Palo Alto, California based company announced its 4th generation MIMO chip with draft 2 of 802.11n compatibility in early 2007 (Lycos Retriever, 2007). Airgo is the first-to-market with an 802.11a/b/g-compliant MIMO enhanced chipset, software and reference design solutions. Its first MIMO chipset, AGN 100 demonstrated range that was 2-6 times greater than that of competing WLAN chipsets. This increased range results in a significant expansion of the area covered by each access point. The development was announced in August, 2003. Airgo was acquired by Qualcomm (http://www.qualcomm.com), a CDMA and 3G Network technology provider based in San Diego, California, at the end of 2006. Qualcomm primary business had been to

enable OEM delivered products based on intellectual property (IP) and associated technologies. Levering the acquisition of Airgo, by the end of 2004, Qualcomm had sold over a million of MIMO chipsets and had a list of customers that included Belkin, Buffalo, Linksys, Netgear, Planex Communications, Smartvue, and SOHOware (Broadband Wireless Exchange Magazine, 2005).

Atheros Communications, Inc. (NASDAQ:ATHR, http://www.atheros.com), has introduced the new AR5005VL wireless solution that employs multiple-radio, smart-antenna technologies to deliver MIMO (multiple-input, multiple-output) performance and throughput to standard 802.11 WLAN products (Gloliath, 2005). This chipset supports up to four antennas to extend range and improve network performance, and is fully compatible with existing WLAN radios. The chipset also uses advanced signal processing techniques to combine multiple 802.11a/g radio inputs so as to improve overall signal strength and quality. This approach increases performance and maximizes compatibility with both MIMO and non-MIMO devices.

Recent industry communiqués indicate that Applied Micro Circuits, Corp (AMCC), in partnership with TeamF1 Inc. (http://www.teamf1.com), an industry leader in embedded security and wireless software, headquartered in Fremont, California and Senao Networks Inc., a Taiwan based ODM with extensive experience in enterprise WLAN products (http://www.senao.com/English), has developed a comprehensive hardware/software reference design kit for customers' enterprise 802.11n Wireless Access Points (Wireless Design and Development Asia, 2008). The reference design includes the Managed Access Point Software (MAPS) from TeamF1, and the Makalu network appliance hardware design platform developed by Senao Networks.

Three other relevant vendors are Broadcom, Marvell,® and ArrayComm. Broadcom, a wireless chipset vendor with 35% market share of consumer Wi-Fi chipsets, entered the high-speed enterprise wireless LAN network arena with a new chipset and software offerings early in 2008 (ITPro, April 23, 2008). The company is offering both a single chip access point solution and an enterprise access point reference design for its OEM customers. At the International CES 2008 trade show, Marvell® (www.marvell.com), a Santa Clara, California based chipset maker, announced the development of the Marvell® TopDog® 11n-450, an 802.11n 3x3 WLAN solution with three spatial streams, the industry's first 802.11n chip operating at 450 Mbps anticipated to be available for mass shipment to device manufacturers in Q2 2008 (Daily Tech, 2008). Lastly, ArrayComm (http://www.arraycomm.com), a San José, California based wireless technology company, is involved in commercializing Multi-Antenna Signal process software for global wireless access point device manufacturers.

Equipment manufacturers represent another category of vendors in the smart antenna market which is full of a number of well established brand names, such as Cisco, and many smaller start-ups. Some of them are integrated to some extent with technology development, product design, manufacturing and distribution, and some of them are OEMs licensed by technology providers. Vivato Networks (www.vivato.com) is a wireless equipment manufacturer which is fully integrated with technology development, manufacturing and distribution. It has extended the range of coverage of WLAN with its phased-array smart antenna and switching technologies. Vivato's devices can send and receive multiple transmissions simultaneously and operate at distances of up to 4 km outdoors and 300m indoors. Vivato's VP2210, an outdoor base station (access point)

which is currently being used in the container tracking system in the Port of Vancouver as the core component in the wireless data network, is actually an 802.11g device. But, as claimed by Vivato, it is a smart antenna base station that combines *PacketSteering*™ technology and a phased array antenna to provide up to 12 times the coverage area of industrial-grade Wi-Fi products (Vivato product data sheet). Actually, VP2210 is only able to provide a 54 Mbps data rate. Vivato is the current technology provider of wireless access points in the Port of Vancouver. Therefore, it is the main competitor of the technology research team of SFU as the team is exploring the opportunity to enter the market. Cather Inc., a Virginia based portable handheld computing platform developer, acquired Vivato at the end of 2007 (CBR Online, 2007).

Due to growing market demand for higher-performance WLANs, especially for enterprise environments, and the ready-to-ratify status of the IEEE 802.11n standard, more and more vendors are flooding the market with many new wireless devices that comply with the draft 2 standard. At Interop Las Vegas, an IT conference and exposition, (CRN Online, 2007), a few vendors showcased their new 802.11n based WLAN enterprise access point devices (Netstumbler.com, 2007). The Multi-service Access Point (MAP-625) from Colubris (http://www.colubris.com/) has two radios. One radio supports 802.11a, b, and g while the other is compatible with the Draft 2 of 802.11n standard. The MAP-625 11n radio promises a minimum useable throughput of 100Mbps, which could go up by another 24Mbps via the 11a/b/g radio. Ruckus (www.ruckuswireless.com), a Sunnyvale, California based company, introduced a new *ZoneFlex* WLAN product line, including *ZoneFlex* 7942 11n based access point that features 2.4 GHz and support for both 11g and 11n. Ruckus patented BeamFlex™ smart antenna technology supports up to

six vertically-polarized and six horizontally-polarized antenna elements. A companion product, the *ZoneFlex* 1000 Controller can host up to 25 access point devices for enterprise wireless networks. Trepeze Networks (http://www.trapezenetworks.com) announced its mobile access point, Mobility Point (MP-432), that features a 3x3 antenna array configuration, MIMO, frame aggregation and 40 MHz channels, based on Atheros' (http://www.atheros.com/) dual-band MIMO chipset. It claimed that MP-432 is able to operate simultaneously in both 2.4 GHz and 5 GHz bands at 300 Mbps per band for a total of 600 Mbps. It also features Smart Mobile architecture that enables wireless traffic to be forwarded at the access point layer. It features an internal antenna design that can operate with existing 802.3af PoE (Power on Ethernet), a smoke detector form-factor, and 2 Gigabit Ethernet uplink ports (Thomas Net, 2007).

On May 9, 2008, Aruba Networks, Inc. announced that its shipment of 802.11n enabled access points have passed the 10,000 units milestone. Its dual-radio AP-124 and AP-125 802.11n Access Point family of products were released in November 2007 and volume shipments commenced in February 2008 (Unstrung News Feeds, 2008). Based on 2nd generation RF chips and a high-performance MIPS CPU with hardware accelerated cryptographic processing, the access points integrate the security features of intrusion detection monitoring and traffic analysis across the 2.4-2.5 GHz and 5 GHz RF spectrums. The access points can be powered from a single 802.3sf PoE source and feature 3x3 MIMO operation and ultra-compact packaging (www.arubanetworks.com).

Cisco Systems (www.cisco.com), a brand name with the largest market share of WLAN products, also jumped into the emerging enterprise 802.11n WLAN market with its Aironet 1250 Series, an enterprise-class access point that supports the 802.11n draft

2.0 standard and has a modular design to incorporate emerging higher-speed WLAN technologies, including the final ratified 802.11n standard. Although currently, it only supports the 802.11n Draft 2.0 standard, as the technology evolves, the existing radios can be replaced with more sophisticated devices that offer end users more consistent throughput and improved reliability (Cisco White Paper). The Aironet 1250 access point has two 802.11n based radios, with chipsets that can also run as 802.11a/b/g to provide backward compatibility supporting existing WLAN clients. One radio operates in the 2.4GHz band and the second in the 5 GHz band. While Cisco is also working towards addressing the issue of extra power consumption, which is common for a 802.11n access point operating on PoE (Network World, 2007), in January 2008, Siemens announced its plan to release HiPath 802. This is an access point product family that has the capacity to work with the same 802.3sf PoE systems that many firms already use to power legacy 802.11a/b/g access points, while still delivering full 802.11n functionality (IT Week, 2008). The ability to work with 802.3sf PoE systems makes it possible for Siemens' HiPath technology to use around 12W and support 802.3af without compromising coverage, throughput or the distance between the AP and WLAN controller. Another established vendor, Netgear (http://www.netgear.com), announced the launch of the ProSafe 802.11n Dual Band Wireless Access Point, WNDA330, a feature-rich dual-band wireless solution with the enhanced speed and coverage benefits of 5 GHz 802.11n wireless technology, while maintaining backward compatibility with legacy 802.11a/b/g devices (Netgear, 2008).

Meru Networks (www.merunetworks.com), has introduced the first wireless access point that conforms to legacy IEEE 802.11a/b/g standards and be upgraded, through a software patch, to the high-performance 802.11n draft 2.0 standard. This provides enterprises an easy and cost-effective migration path to advanced wireless LAN technology (Reuters, 2008). The company further introduced a four-radio 802.11n wireless access point, AP440, which supports access up to a total of 1.2 Gbps capacity. This feature is facilitated by Meru's patented antenna design that allows multiple radios to operate simultaneously on different channels (Converge!, 2008).

Chipset Makers	
Company Name	**Major Products**
Motia (www.motia.com)	Standards-compliant smart antenna chipset, Javeline. Patented Real-time Beamsteering technology, capable of being applied to existing and emerging radio systems.
Airgo (http://www.qctconnect.com)	IEEE 802.11n Draft 2 compliant MIMO chipsets, with backward compatibility with 802.11a/b/g, acquired by Qualcomm in 2006.
Broadcom (www.broadcom.com)	BCM series processor with 802.11n Draft compliant MIMO configuration, two or three antenna array.
Marvell® (www.marvell.com)	Marvell® TopDog® 11n-450, an 802.11n 3x3 (three spatial streams) with highest throughput of 450Mbps.
Atheros Communications (www.atheros.com)	AR5005VL chipset with up to four antenna support, 802.11n compliant, and backward compatibility with 802.11a/b/g WLANs.
Applied Micro Circuits Corp (www.amcc.com), TamF1 Inc. (http://www.teamf1.com) and Senao	Managed Access Point Software (MAPS) and IEEE 802.11n compliant hardware design reference (Makalu)
Equipment Manufacturers	

Company Name	Major Products
Vivato (www.vivato.com)	VP2210 outdoor base station (access point) with *PacketSteering*^{TM} technology and a phased array antenna, up to 4 km in range and 54 Mbps data rate.
Colubris (http://www.colubris.com)	Multi-service Access Point (MAP-625) with two antennas, one supporting 802.11a/b/g (throughput of 24 Mbps), and the other one supporting 802.1n with minimum useable throughput of 100Mbps.
Ruckus (www.ruckuswireless.com)	*ZoneFlex* 7942 11n based access point that features 2.4 GHz and support for both 11g and 11n, with Ruckus patented BeamFlex™ smart antenna technology, supporting up to six vertically- and six horizontally-polarized antennas.
Trepeze Networks (http://www.trapezenetworks.com)	Mobility Point (MP-432) that features a 3x3 antenna array configuration, based on Atheros' dual-band MIMO chipset, operating simultaneously in both 2.4 GHz and 5 GHz bands at 300 Mbps per band for a total of 600 Mbps with existing 802.3af PoE (Power on Ethernet),.
Aruba Networks (www.arubanetworks.com)	Dual-radio AP-124 and AP-125 802.11n Access Point family of products, integrated security features, 3x3 MIMO operation and ultra-compact packaging.
Cisco Systems (www.cisco.com)	Aironet 1250 series enterprise-class access point that supports the 802.11n draft 2.0 standard and has a modular design, backward compatibility supporting existing 802.11a/b/g WLAN clients. Two radios, one operates in the 2.4GHz band and the second in the 5 GHz band.
Meru Networks (www.merunetworks.com)	AP440, supporting access up to a total of 1.2 Gbps capacity by Meru's patented antenna design that allows multiple radios to operate simultaneously on different channels, upgrading legacy equipment to 802.11n standard by software upgrade.

Table 4-3 Competitors and Products

The high-throughput update to the IEEE 802.11n standard is scheduled for formal ratification in June, 2009, further increasing the potential for boosting wireless network performance and capacity, especially for enterprises. Consequently, leading wireless communication vendors have released 802.11n access point based on the Draft 2 standard. It has been estimated that by 2010, 80% of Wi-Fi network in the world will be 801.11n based. Another study has shown that by the spring 2008, the installation base of enterprise 802.11n access point was more than 15,000 units, and that approximately 230,000 units will be shipped by the end of 2008. If consumer access point and client devices are included, the total shipment of 802.11n products will reach over 17 million by the end of 2008 (Dell'Oro, 2007). The wireless communication market is continually developing and growing, but the future still holds many different possibilities and faces many unknown issues and challenges, especially the establishment and recognition of standards, specifically IEEE 802.11n, in this case. According to a recently published report from Dell'Oro group, Wireless LAN market sales will almost double during next five years, surpassing $8 billion in 2012 (bNET, 2008).

4.3.3 Summary of Competitors

Many different players are competing in the WLAN battlefield. Chipset makers use the technology developed by their own R&D teams or under licenses issued by technology developers to produce chipsets. These chipsets are, in turn, sold to equipment manufacturers (OEMs) who integrate the chipsets into the WLAN equipment, such as access points or base stations. The functionality and features vary depending on the chipset used in the equipment. The smart antenna technology (MIMO) is currently based on IEEE 802.11n Standard Draft 2, and all the current installed access points are

compliant with this draft standard. The technology providers are usually small start-ups and they usually license chipset makers or outsource the manufacturing of the chipsets, although some of them may form partnerships with chipset makers and equipment manufacturers. Equipment manufacturers usually are large hardware vendors, such as Cisco, Nortel, and 3Com who buy chipsets to build equipment under their own brands. In the enterprise marketplace, product differentiation and post-sales services and support are the points on which the competition focuses.

5: STRATEGIC ANALYSIS AND MARKET RESEARCH

Strategy describes how an organization matches or aligns its own capability with the opportunities in the marketplace to achieve its overall objectives and goals. The toolkit for strategic analysis includes Porter's Five Force Model (Porter, 1980), SWOT analysis, Value Chain analysis (Porter, 1985) and the Balanced Scorecard Method (Kaplan, et al, 1992). Industry analysis with Porter's Five Force Model gives a framework that describes the firm's strategic positions in the target market and an evaluation of the industry context. SWOT analysis, which is credited to Albert Humphrey, who led a research project at Stanford University in 1960s and 1970s, provides an evaluation of the internal and external environment factors that assist in matching the firm's resources and capabilities to the competitive environment in which it operates. As a strategic planning and performance measuring framework, introduced by Kaplan and Norton, the Balanced Scorecard Method originally intended to supplement the traditional financial analysis with criteria that measured performance with three additional perspectives: customers, internal business processes, and learning and growth. By 1996, many companies had further developed it as a strategic management system, linking long term strategy to short-term targets (Stewart, Alice C., et al, 2000). This information and analysis of the internal and external environment assists in the creation of competitive strategies.

5.1 Five Forces Analysis of the Global WLAN Equipment Industry

Michael Porter (Porter, 1980) argued that five forces determined the profitability of an industry. These five forces are illustrated in Figure 5.1. Porter's Five Force model consists of those forces surrounding an average company in the industry that affect its ability to serve its customers and make a profit. Ideally, a change in any of the forces requires a company to re-assess the marketplace. In order to achieve a profit above the industry average, a firm needs to strategically apply their resources, business model and/or network, based on a thorough analysis of the competitive environment.

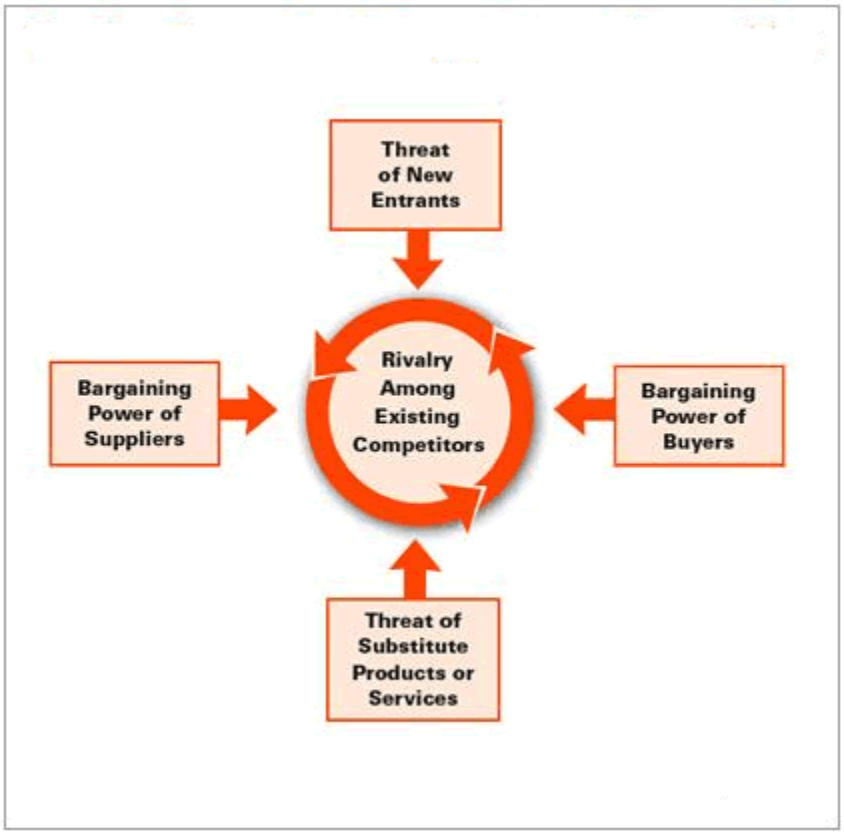

Figure 5-1 Porter's Five Forces (Adapted from Porter, 1980)

5.1.1 Rivalry

Among the main industry characteristics that influence rivalry intensity in the market, four of them have major impacts on the WLAN equipment market:

1. **The large number of firms.** As indicated in the previous chapter, there are many players in this rapidly changing battle field, including OEM developers of products that utilize antennas and antenna systems, antenna integrators and manufacturers, and materials and component suppliers.

2. **Slow market growth.** Although the new IEEE 802.11n poses a new market opportunity, it is still in Draft 2.0 phase, and there are still future uncertainties, especially with regard to the details of the standard. While the profit margin of vanilla plain Wi-Fi chips is very low and newer 802.11a/g chipsets are widely used and products featuring the 802.11n are mushrooming, a critical question remains. There is uncertainty regarding how effective the promised backward compatibility for the widely deployed legacy 802.11a/b/g access points will be. Development continues and the number of deployments of 802.11n based access points is steadily growing, but many products are still in pilot or testing stages.

3. **Low level of differentiation.** Product differentiation could be low due to the characteristics of the technology and accepted industry practices. Usually there are number of technology providers who design and develop the specifications and license technology to equipment manufacturers to build products based on their specifications. There are also chipset makers who actually fabricate the chipsets and sell them to equipment vendors. Although the smart antennas can be

differentiated by the number of antennas (antenna array) and embedded signal processing software, the room for differentiation is limited. In this case, brand names play an important role in product selection by customers.

4. **Low switching costs.** There are no significant switching costs when customers choose different vendors for this type of equipment because the WLAN access point is standard compliant (IEEE 802.11x) and acts as a black box that bridges the gap between centralized network servers and distributed client devices. Consequently all equipment fits that role can be simply plugged in. The most significant switching cost lies in the level, quality, availability and reliability of technical support from the vendors. Customers usually tend to choose hardware and software from a single or a few vendors to reduce the multiple contacts to lower the costs involved in support from multiple vendors.

Overall, the level of intensity of rivalry is considered high, which contributes to low to medium attractiveness of the global WLAN equipment industry. However, due to the emerging of a new technology standard and related increase of market demands, the opportunities are present and can also be influenced by internal factors, such as resources, competence and competitive strategies.

5.1.2 Bargaining Power of Buyers

Although a multiple antenna system can be used in many enterprises environments, especially outdoor enterprise campuses, the primary market for container tracking systems are seaports. The technology team has chosen the Port of Vancouver as the entry point and will explore the potential market in other ports in North America and around the world. Large seaports are usually managed by international port operators.

The port customers are concentrated to some extent. The top 50 ports handled about 80% of the total containerized cargos in the world (Deutsche Bank Research, 2006, and American Association of Port Authority, 2006). The statistics also showed that in 2006 the top four container ports, in Singapore, Hong Kong, and Shanghai and Shenzhen in China, account for 20% of total containerized cargos of world port throughputs (UNCTAD Transport Newsletter, 2007).

Based on the fact that there are probably have only a handful of large potential customers, as well as the fact that seaports are usually in large scale and have relatively large budget for technology investment, easy access to market information, and that there is relatively low product differentiation and many competitors, it is safe to conclude that customers have significant leverage to negotiate lower prices and more favorable terms. Thus, customers bargaining power is high, which negatively impacts the attractiveness of the WLAN equipment industry.

As previously mentioned, based on information from the technology research team, the Port of Vancouver proposed to enter an exclusive agreement that the multiple antenna based access points cannot be sold to any ports that are not operated by DP World. However, the United Arab Emirates based and world's 4th largest port operator as ranked in 2006 only had a market share of 9.49%. That means if the product successfully entered the Port of Vancouver and other DP World's ports, the larger part of the market would not be accessible. Other significant port operator are Hutchison, base in Hong Kong with 13.4% market share, PSA Corp, based in Singapore with 11.59% market share, and APM Terminals of Denmark with 9.72% market share.

5.1.3 Threat of New Entrants

Assessing the threat of new entrants involves examining the barriers to entry. In this WLAN technology and equipment market, the barriers to entry are low to medium due to three significant reasons. First, there are no requirements for large initial capital. Second, there are no legal or any other regulatory requirements, such as licensing, to enter this market. Third, economy of scales could be minimal if a company only acts as technology developers involving chipset design and development and then licenses it to equipment manufacturers. In addition, the low uniqueness of the product and relatively low switching costs contribute to low barriers to entry. However, entry into this market does require an expert research force, extensive experience in wireless equipment manufacturing and assembly as well as experience with patents or other type of IPs. This force contributes to low to medium attractiveness of the global WLAN equipment industry.

5.1.4 Bargaining Power of Suppliers

The bargaining power of suppliers is weak to medium. In the supply chain of technology developers, chipset designers and developers for equipment manufacturers as well as a variety of chipsets IC boards are widely available, and there are only a few electronic equipment manufacturers available to take contracts or to enter partnership or strategic alliance. This force contributes to medium to high attractiveness of the global WLAN equipment industry.

5.1.5 Substitutes

There are probably no or few substitutes in WLAN equipment industry for an access point device, because it is mandatory core equipment in any wireless network infrastructure, and without it, wireless communication is not possible in enterprise level. It should be noted that *ad hoc* deployment of wireless equipment without an access point only works for a very small scale, like small office or home office (SOHO) cases. Thus, this force contributes to high attractiveness of the global WLAN equipment industry.

5.1.6 Summary

The Five Force analysis for the WLAN equipment industry is summarized in Figure 5.2 below. Given strong buyer power, a strong threat of new entrants, and a strong rivalry, along with weak to medium supplier power and a weak threat of substitutes, the global WAP industry is of low-medium attractiveness. However, due to the assumption of relatively static market structures, Porter's model can be extended by introducing the sixth force, which is defined as the relative power of other stakeholders. These "other stakeholders" could be a number of other groups or entities, depending on the factor that has the greatest influence and might include complementors, governments, the public, shareholders and employees. In this instance, complementors could be considered as the sixth force. In this case, complementors are technology providers of container tracking systems that requires an efficient Wi-Fi network for real time data collection and transfer. As has already been established, more and more ports around the world are planning and implementing tracking system for either operational efficiency or security, or both. These will lead to increasing demand for Wi-Fi equipment and thus increase the attractiveness of the industry.

The government could also be a sixth force by passing mandatory legislation or administrative regulations addressing the security concerns of container transportation. Actually, we have already seen the establishment of many related legislative and regulatory initiatives. Finally, employees can impose an extraordinary impact on the performance of the firm. A winning team of employees will be the intermediary adhesive between corporate strategic plans and actions, and collectively can make a great contribution to the success of the firm.

Figure 5-2 Five Forces Analysis in Wireless Access Point Industry

5.2 SWOT Analysis

5.2.1 The Methodology

A **SWOT** Analysis looks at a firm's strengths, weaknesses, opportunities and threats, and aims to reveal the competitive advantages of the company as well as analyze its prospects for sales and profitability. Strengths and weaknesses are the internal value creating factors that a company has at its disposal, such as assets, resources and skills, etc. Opportunities and threats are external value creating factors, including economic or social trends, changes of behaviors of other competitors, over which the company has no control. A SWOT analysis is usually based on an assessment of facts and assumptions about the company and on market research findings.

SWOT analysis methodology involves collecting the information from the environmental analysis and filtering it into internal issues (in the form of strengths and weaknesses) and external issues (in the form of opportunities and threats). Once the information is collected and filtered, SWOT analysis determines what the information means strategically and how that will assist the firm in accomplishing its objectives (a strength or opportunity), or if it indicates an obstacle that must be overcome or minimized to achieve desired results (weakness or threat). A company that wishes to enter the market of an 802.11n smart antenna access point device as a startup business entity, in addition to the knowledge of market structure and trends, must have a clear understanding and unbiased assessment of these internal and external environments and factors in order to create an effective strategy that maximizes strengths and opportunities and minimizes weakness and threats.

5.2.2 SWOT Matrix

The SFU technology research team has strong R&D research capability and technical expertise in the area of broadband communication and antenna technologies. The team is led by Dr. Rodney Vaughan, who has a strong background in mobile communications, signal processing, antenna theory and design, especially in MIMO design and implementation. Other team members include a group of graduate students (PhDs and Masters) specialized in the area. The team also has access to the latest research results and is positioned in the frontier of research in this area. These factors result in cost-effective human and technical resources. Having industry connections is another strong positive point. The team has contacts in the Port of Vancouver, especially with the IT department, from which the SFU team gained information about the particular issues that affect the Port of Vancouver. With the information provided by the Port of Vancouver, the team will be able to seize the opportunity to commercialize their research and innovations.

However, the team consists primarily of researchers and graduate students in an academic environment, and has no or little experience dealing with customers, suppliers and partners. In addition, there is currently no management team with business experience. This could be an issue if the team seeks to establish its own startup business entity during the commercialization process. Although SFU's UILO will be a valuable resource, the team's lack of business experience and well-structured and seasoned management personnel may also mean that they will encounter difficulties when seeking financing from potential investors.

WLANs are not only becoming significantly cheaper and faster but also are particularly driven by the market's strong desire for mobile access in corporate and enterprise environments. With this booming market, a study has indicated that revenues in the enterprise mobility market in Europe are expected to reach $33.28 billion in 2012. In North America will remain the largest market with regard to WLAN spending, with enterprises in the region investing over $500 million in related equipment in 2008. Global enterprise WLAN infrastructure revenues are expected to around $1.4 billion by the end of 2008, from $1.07 in 2006 (PR-inside.com, July 2008). IDC also found the worldwide market for WLAN ICs will reach $3.2 billion in 2010, having experienced a 17 percent compound annual growth rate (EETimes Asia, 2006).

The WLAN market is full of players who provide various technologies and products. The current emphasis on smart antenna technology even is stronger as the IEEE 802.11n Draft 2.0 progresses and is expected to become an official standard by June 2009 as official ratification. The market condition creates many opportunities, especially in enterprise Wi-Fi deployment and support. Although Porter’s five force analysis showed a market of low-medium attractiveness, the smart antenna technology provides a new area in WLAN equipment industry. With new and advanced technologies, strong market needs right products, there are still opportunities of success. Also, as mentioned above, the Port of Vancouver is currently experiencing technical issues with the current equipment in their wireless network infrastructure, and the team has already had a chance to explore the possibility of providing solutions with their innovative technology.

While access points based on 802.11n standards are widely expected to dominate the market, it is still arguable whether the standard is really ready for enterprise

computing. A few issues, such as extra power consumption, are still open. Such unresolved issues may lead to extensive requirements to upgrade the existing network or Power over Ethernet (PoE) infrastructure. As well, potentially increased network traffic may require re-structuring of the existing network topology and architecture (Siemens Enterprise Communications White Paper, February 2008). An additional issue involves reliability and performance in the already crowded airspace (unlicensed bands, e.g. 2.4 -5 GHz). Finally, there are backward compatibility and interpretability concerns as many enterprises have large installed bases of legacy 802.11 a/b/g based wireless networks. Uncertainty around the specifics of the final 802.11n standard will also pose concerns about the current R&D for some vendors. The complex and tumultuous IEEE standards process is still months, and maybe years, from completion and the current market is only for early adopters.

In order to develop strategies based on the SWOT profile, a matrix of these internal and external factors has been developed, and it is shown in Figure 5.4. The purpose of constructing a SWOT profile is to assist the firm to create competitive strategies. From the SWOT matrix below, we can conclude that the technology team could pursue the opportunities in the growing smart antenna market with the company's strengths in technology expertise, take the advantages of broad access to cost-effective resources and the industry connection with the Port of Vancouver to capitalize its intelligence assets. In the meantime, the team should seek help to design the internal business process to overcome the weakness so that it can identify and mitigate the external threats by establishing a defensive plan to prevent the firm's weaknesses from making it susceptible to external threats.

STRENGTHS	WEAKNESSES
1) Strong R&D capabilities and technology expertise 2) Broad access to academic and technical resources in a cost-effective way (in University environment) 3) Industry connection with the Port of Vancouver	1) Lack of business experience and a well-built management team 2) More theory focused than product real world commercialization process
OPPORTUNITIES	**THREATS**
1) The booming WLAN market with IEEE 802.11n standard on the way to official ratification 2) The needs to resolve the specific issue at the Port of Vancouver	1) Uncertainty of the future of 802.11n standard 2) Immature smart antenna technology and the application in enterprise environment.

Figure 5-3 SWOT Matrix for Smart Antenna Technology

5.3 Balanced Scorecard and Application in Strategic Analysis

5.3.1 The Balanced Scorecard Method

Professors Robert Kaplan and David Norton developed the Balanced Scorecard (BSC) in the early 1990s. According to Kaplan and Norton (Kaplan, et al., 1996), "the Balanced Scorecard translates an organization's mission and strategy into a comprehensive set of performance measures and provides the framework for strategic measurement and management". Traditionally, most organizations look at their corporate

performance by reviewing the financial aspects. However, financial measures alone are not a balanced view of the critical success factors of any organization, mainly because financial measurements tend to measure the past. The four "new" perspectives from which the firm's performance is measured and the strategic plan is prepared are financial, customer, business process, and learning and growth. The Balanced Scorecard Method is shown in the Figure 5.4.

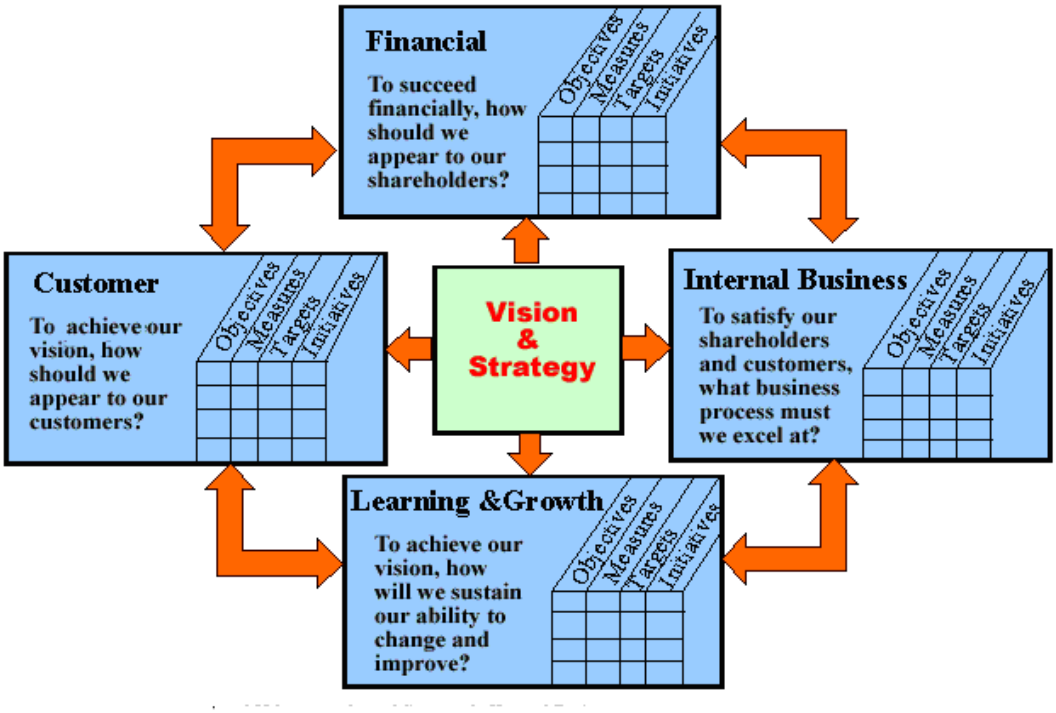

Figure 5-4 Balanced Scorecard Method (Adapted from Kaplan et al, The Balanced Scorecard, 1996*)*

Although the Balanced Scorecard method was originally introduced as a more comprehensive performance measuring tool, Professor Kaplan and Norton did indicate that the first step of the actual implementation of the Balance Scorecard is to clarify the firm's vision and strategy (Kaplan and Norton, 1996). As the Balanced Scorecard Method is becoming a full strategic planning and management tool, it translates the organization's vision into implementation by linking an organization's strategic plan to the low level action and execution plan for the organization on a daily basis. Adoption of a SWOT analysis will develop a set of strategies that makes sense and serve as a stepping-stone towards the actual implementation of the Balanced Scorecard (Lee, S.F, et al, 2000).

5.3.2 SFU Technology Team Balanced Scorecard for Strategic Planning

The Balanced Scorecard is a proven tool for established companies to align their decisions with their priorities to achieve strategic goals. It can also be adapted for early-stage hi-tech ventures to leverage the value of the strengths through their various stages of growth. In order to develop a balanced scorecard for the SFU technology team or any intended start-ups to select an entry strategy to the WLAN equipment market, all four perspectives are analyzed in a framework of strategic management that drives improvement and that allows to prepare for the future. In addition, the method uses a three-layered structure: strategic goal, critical success factors and key performance indicators. As the SFU team was not able to indicate their specific preferences, a balanced scorecard was created by the author to represent the decision making priorities of a typical technology start-up venture.

5.3.2.1 Financial Perspective

The ultimate goal of an organization is to satisfy the Board of Directors and consequently the shareholders. For an early-stage venture, there might be various capital suppliers, including investors and other source of funding, who seek financial returns on their investments. For the venture, meeting the expectations of its capital suppliers is vita to ensuring continuous access to capital.

5.3.2.2 Customers Perspective

The customer perspective evaluates the performance of the organization from the viewpoint of the business customers. These measures describe the company's success in acquiring and retaining customers and sales. For a new venture, customers not only provide revenues, but also aid the venture with early references.

5.3.2.3 Internal Process Perspective

The internal process, or operational perspective, focuses on the internal business conditions for satisfying customer expectations. It measures the efficiency and effectiveness of the technology development process, product and service management. In terms of organizational management, early-staged ventures have a variety of advantages over established organizations. These include the manageable scale that makes it easier to focus on efficient use of resources and flatter organizational structure that has fast decision making, response to the changes, and closer contact with customers.

5.3.2.4 Future Growth and Learning Perspective

The Future Growth and Learning perspective examines the company's ability to effectively make use of existing resources and skills as well as to improve the

performance nowadays and in the future. This is an employee-centred measure that depends on the knowledge and expertise of the employees, availability of education and training in new technologies. A new venture usually has a flexible and casual working environment that attracts adaptable and skilful employees who can take multiple roles as needed.

5.3.3 Overall Balanced Scorecard

The four perspectives being considered in the balanced scorecard method are connected and have cause and effect relationships (Sinha, A., 2006). When the learning and growth are taken care of seriously in an organization, better internal business processes are expected. This in turn would be followed by increased customer value by producing better products and services which ultimately lead to improved financial performance. Based on the above perspective analysis, the final balanced scorecard has been developed and summarized in Table 5.1. A more detailed balanced scorecard with three layered presentation can be found in Appendix B. This balanced scorecard is utilized in section 6.4 to evaluate the strategic options available to the SFU team.

Customer Perspective **How do the customer view the company?**	**Business Process Perspective** **How do we do the business?**
▪ High quality and reliable products ▪ Comprehensive product portfolio ▪ Superior customer services and support ▪ Compelling solutions to add values	▪ Well defined and properly managed internal value chain activities ▪ Efficient and effective business and technological infrastructure ▪ Fast decision making and response to changes in the market
Financial Perspective **How do the shareholders view the company?**	**Future Growth and Learning Perspective Can the company sustain and improve in the future?**
▪ Short term revenue ▪ Long term return on Investment ▪ Mid to long term profitability ▪ Cost competitiveness	▪ Wining team with high productivity ▪ Investment in emerging technologies ▪ Consistent technology and business innovations

Table 5-1 Overall Balanced Scorecard

In addition to the four critical processes provided by the balanced scorecard as a strategic management tool, combined with the SWOT profile of the firm, the balanced scorecard can become a useful tool to help identify pressures, resolve conflicts, prioritize objectives and mitigate risks and threats. Ultimately, the combination can facilitate translating the firm's vision and strategy into action, linking and communicating the objectives to all staff, and planning and aligning the strategic initiatives in order to

achieve the long-term goals. It also makes getting feedback for further learning and growth easier and more effective.

5.3.4 Summary

Strategic analysis and planning using Porter's Five Forces, a SWOT analysis and the Balanced Scorecard framework gives a snapshot of the firm's competencies and surrounding competitive environment. When used properly, these three frameworks will equip the entity with useful tools to create strategies that are adaptive and dynamic to meet the intensive competition in the current dynamic marketplace. However, it is important to understand that each of these three strategic analysis models have their own particular emphasis that is applied in different aspects and from different perspectives within the organization. Porter's Five Force framework focuses on the external environment with three "horizontal forces", rivalry, substitutes and threat of new entrants, and two "vertical forcers", bargaining power of the customers and suppliers. While a SWOT analysis highlights the resources and the capabilities of the firm from internal and external perspectives. The Balanced Scorecard measures a firm's overall performance and also provides a tool to manage the strategy implementation. The other tool, value chain analysis, which is very useful to analyze the competitive positioning and formulate business models, will be discussed in the following chapter about market entry strategy.

6: MARKET ENTRY STRATEGY FOR WLAN ACCESS POINT STARTUP

The Wi-Fi based wireless LAN market has been expanding for years along with the rapid evolution of IEEE 802.11 compliant broadband infrastructure. Recent advances in smart antenna technology with integrated IEEE 802.11n standard compliance have made potential commercial deployments of wireless networks possible, opening up a potentially huge business opportunity. Although relatively new, the 802.11n market has experienced tremendous growth as enterprises demanding more bandwidth and capacity shift to smart antenna technology. The overall WLAN market was projected to grow at an annual rate of 30% per year to nearly $5 billion by 2006. WLAN equipment sales have jumped 60% from this time last year to the present. In a research published in 2005 by RNCOS, WLANs for the home and small offices were projected to grow 103% and WLAN sales to the enterprise sector were forecast to grow at an annual rate of 32% (Research and Markets, 2008).

The fact that many 802.11n based WLAN access points are being developed and that a number of them have been deployed in many enterprises' networks with smart antenna technology, poses a considerable competitive threat to the new WLAN access point manufacturers and technology providers. The new startups may observe the fierce competition from incumbent WLAN equipment vendors who added 802.11n support to their existing product lines and differentiating products against competitors' offerings will be a challenge in a crowded market. It is evident that startups will be fighting for

market shares in a new and not yet fully developed market. With the demand for broadband wireless networks that increase data rate and capacity for enterprises, this market is still promising. The focal point must be how to develop competitive advantages to determine appropriate and winning Go-To-Market strategy to achieve the goals. The next section investigates Go-To-Market strategies and options based on a value chain analysis and the business model reviews, and the balanced scorecard from Chapter 5.

6.1 Strategic Options

6.1.1 Value Chain Analysis

A value chain is identified as a set of interrelated generic activities common to a wide range of firms and it describes the activities the organization performs and links them to the organization's competitive position. This concept is based on the idea that an organization is more than a random compilation of resources, such as machinery, equipment, people, and money, and only if these things are arranged into systems and systematic activates will it become possible to produce something for which customers are willing to pay. The firm's value chain links to the value chains of upstream suppliers and downstream buyers. These streams of activities result in the value chain system. The development of competitive advantage depends not only on the firm-specific value chain, but also on the value chain system of which the firm is a part.

From the information collected on market structure, profiles of customers and competitors, the constructed value chain system in the smart antenna industry consists of technology R&D providers, chipset makers, equipment manufacturers and end users. Technology R&D providers are focusing on Research and Development of new

technologies. In our case, it is smart antenna technology in compliance with de factor standards. The results are generally intellectual property, such as patents. Chipset makers fabricate chipsets based on the technology developed by their own R&D team or licensed by technology providers. Equipment manufacturers are hardware vendors who manufacture equipment with purchased chipsets and related technology that are integrated with the final products. In our case, the products are wireless access point devices with smart antenna integration. Finally, the end users are enterprises that need access point devices to build their Wi-Fi network infrastructures. In our research project, they are seaports that implement container tracking systems and need a Wi-Fi network for data transfer and real time monitoring of the workflow and activities. The value chain system in the smart antenna industry is shown in Figure 6.1.

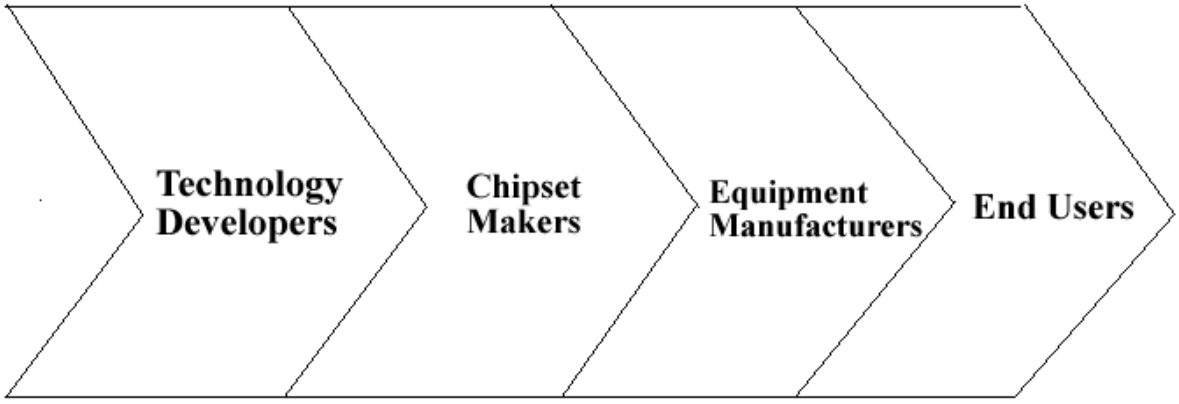

Figure 6-1 WLAN Access Point Industry Value Chain System

6.1.2 Business Model Analysis

A business model specifies the relationship between different participants in a commercial venture, the benefits and costs to each and the revenue flows (Papazoglou, et

al, 2006). An alternative definition also states that a business model describes how the enterprise produces, delivers and sells products and services, thus showing how it delivers value to the customers and how it creates wealth (Magretta, 2002). Based on the definition, a business model answers certain questions: Who is the customer? How do we make money? What underlying economic logic explains how we can deliver value to customers at an appropriate cost? In another word, a business model converts innovation to economic value for the business.

A business model could consist of six functional components: Value Proposition, Market Segments, Value Chain Structure, Generation of Revenue and Profitability, Position within the Value Network, and Competitive Strategies (Chesbrough, et al, 2002). This is actually a framework proposed by the authors that servers business functions and justifies the financial capital needed to realize the model and define the path to scale up the business. The prospective business models for the SFU technology team or other startups are constructed based on this framework and summarized in the Table 6.1.

Business Model	**Model 1**	**Model 2**	**Model 3**
Descriptions	Technology Provider: focusing on technology R&D only	IC Circuit Chipset Maker: integrating technology into chipsets	Equipment Manufacturer: manufacturing equipment based on own developed or purchase chipsets
Value Proposition	Offering innovative technology on smart antennas and license buyers of chipset makers	Offering finished IC chipset circuit boards to equipment manufacturers integrate into products under their own brands	Offering completed smart antenna integrated access point devices to enterprises that need high performance WLANs.

Market Segment	IC circuit chipset makers without internal R&D resources under licensing agreements	WLAN equipment manufacturers who purchase chipsets for their equipment	Enterprises that need smart antennas to build high performance WLANs.
Internal Value Chain Structure	R&D and customer services	R&D, product design and production, sales & marketing and distribution	R&D, product design and production, sales & marketing and distribution
Generation of Revenue and Profitability	Licensing	Selling finished products (smart antenna chipsets)	Selling finished products (smart antenna integrated access point devices) and providing solutions (technology consulting services: pre- and post sales)
Value Network Positioning (Vertical Value Chain System)	Suppliers: research forces, Competitors: other technology providers, Customers: chipset makers,	Suppliers: technology providers, Competitors: other chipset makers, Customers: equipment manufacturers,	Suppliers: chipset makers, Competitors: other equipment makers, Customers: enterprises and corporations, Complementors: other vendors of business software that needs WLANs, e.g. container tracking systems.
Competitive Strategy	Proprietary technology and IP protections	Cost advantages and/or superior products (differentiation)	Cost advantages and/or superior products and value adding activities (support and consulting)

Table 6-1 Summary of Business Model Analysis

These business models can be standalone or combined. Model 1, technology provider, can vertically integrate with downstream customers so that the combined model can do both R&D on the technology of smart antennas and produce finished IC chipsets

based on the R&D outcomes. Also, a chipset maker, with Model 2, can vertically integrate both upstream supplier and downstream customer to establish a fully integrated business entity. This case is also true for Model 3. Strategically, these business models can be used more creatively with joint ventures, partnership or strategic alliances, and outsourcing. Market entry strategies will be discussed in next section.

6.2 Strategic Options of Go-To-Market

In order to survive, to guide a firm's decision making process with regard to product and/or services as well as the market and organizational structure, a market entry strategy must be created before the actual product and/or service launch. Based on the business model and value chain analysis, there are three options to enter the market. The following sections present the options and analysis.

6.2.1 Option 1: Enter the Market as a Technology Provider or a Chipset maker (Licensing and OEM Agreement)

Based on the SWOT analysis, the technology research team's strengths are technology expertise and a strong R&D team with cost effective technology research and human resources. To capitalize on their strengths, the team can become a technology developer specializing in R&D on smart antenna technology, and license the technology to chipset makers to build IC chips that can be integrated into WLAN access points or base stations. Alternatively, the team can integrate the technology R&D and chipset manufacturing practice by outsourcing the actual manufacturing process. The final product is packaged with its own brand and is sold to equipment manufacturers.

Choosing this option, which involves being either a pure technology developer or an integrated chipset maker (with outsourced manufacturing), means to compete with other antenna vendors who develop and license the technology to other chipset makers. The merits of this option are that it takes advantage of the R&D strengths, focusing on technology innovation, and eliminating the complex manufacturing process and post sales support to end users. It also helps to jump start the business as this option presents the shortest delay to revenue. Seeking IP protection is another way to protect intangible assets and protect competitive advantages. The disadvantages of this option are that the profit margin could be limited due to its position in the value chain, because the profit margin varies at the different position, and in this case it only covers the R&D activities and looses the profits in other activities. Low product differentiation is another factor that leads to lower profit margin. It is also crucial to draft a good licensing agreement.

6.2.2 Option 2: Enter the Market to Form A Strategic Alliance or Partner (Strategic Alliances or Partnership)

This option involves forming a strategic alliance or partnership with one or more incumbent WLAN equipment manufacturers. The team can solely provide technology expertise and focus on R&D for antenna technology. The equipment manufacturing partner will provide end productization, mass manufacturing processes and distribution channels. The positive side of this option is obvious. The R&D group can still capitalize on its technology strengths and leave the manufacturing process and marketing/sales and management to the manufacturing partner, and share the higher profit margin. The negative side would be assuring that the complex partnership agreement or legal contract protects the entities interests and IP, and developing a mechanism for resolving future

disputes. These may be treated as transaction costs, similar to the outsourcing option. The other benefit of entering strategic alliances or partnerships is to create a superior technology product portfolio by combining the best aspects of both partners.

6.2.3 Option 3: Enter the Market as a Full WLAN Access Point Manufacturer with Outsourced Manufacturing Process (Fully Integrated with Outsourcing)

The final option is to integrate technology R&D, chipset fabrication, equipment manufacturing management (with outsourced manufacturing process) and marketing/distribution channel management in a single technology firm. It can be R&D focused, and outsource the actual manufacturing process, with or without assembly lines, instead of full vertical integration. With this option, the advantages are the ownership of the IP and branded product. What is different from option 2 is, with this option, the firm founders have full control of all aspects of the organization, from R&D, product management to manufacturing and distribution (marketing and sales), and receive all the profits. However, although outsourcing is a trend in Hi-Tech industries, management is a highly complex and challenging process. Consequently, there would be high transaction costs, in addition to the negative side of the outsourcing strategy, such as lack of full control, interest conflicts and possible performance related issues.

Manufacturing of equipment parts and components can be outsourced, and the assembly line can be vertically integrated or outsourced as well. In order to manage the distribution channel, Value Added Resellers (VARs), which are very common in Hi-Tech industries, can be used. VARs' value proposition to vendors is to offer access to local customers with whom the VARs have pre-existing relationships, plus local pre- and post-sales support, in exchange for a sales commission paid by vendors. To end-user business

customers, VARs are local services and support, including warranty and repair, from a known supplier with whom the customer may already have an established business relationship. However, managing this distribution channel is another challenge.

6.2.4 Summary of Strategic Options

The three options are summarized in Table 6.2.

OPTIONS	Advantages	Disadvantages
Option 1	▪ Focusing on R&D and technology innovation; ▪ Going to market quickly with low initial capital requirements; ▪ Eliminating manufacturing, marketing/sales headaches.	▪ Limited profit margin; ▪ Time and efforts of drafting licensing and OEM agreement; ▪ Limited expansion opportunities. ▪ More competition on low differentiated products
Option 2	▪ Focusing on R&D and technology innovation; ▪ Eliminating manufacturing, marketing/sales headaches. ▪ Having stronger support financially and from other resources; ▪ Receiving higher profits; ▪ Having more opportunity of future expansion	▪ More complex partnership or alliance agreement; ▪ More resources allocated to business related issues. ▪ Less control on technical and business decision making processes

Option 3	▪ Having full control of all technology and business processes ▪ Having opportunities to build own brands; ▪ Capturing all profits; ▪ Having stronger support financially and	▪ Higher initial investment capital, may need external financing; ▪ More complex business and technology process management, more resources allocated to internal business process, marketing, sales, etc. ▪ High costs to manage outsourced manufacturing process, and distribution channel, ▪ Longer time to go-to-market and get return of investment

Table 6-2 Summary of Strategic Options

6.3 Other Considerations

There are a few other factors to consider when formulating a market entry strategy, of these the current market structure changes and technology standard compliance are worth additional attention. First of all, the current market has shown a trend toward consolidation. Numerous mergers and acquisitions are occurring. The consolidation process will result in fewer, larger firms and may result in an environment in which it is more difficult for smaller startup to survive.

Very recently, it has been announced that Belden Inc., a St Louis based supplier of copper and fiber optic cabling and access technology company, will acquire Trapeze Networks, one of the largest privately owned wireless LAN providers (IT Channel News,

June 2008). This announcement provides another example of the observed phenomenon of continuing consolidation in the WLAN market. It raises the question whether it is still possible for small, independent players to stay afloat. Another trend is partnership. An independent WLAN player, Ruckus Wireless, is interested in partnering with Trapeze's value added resellers (VARs) to create an incentive-based channel program designed specifically for the resellers who are now in a position to look for a new deal. The goal of incentive program is to attract the over 200 resellers that felt burned by Belden's acquisition of Trapeze Networks (Hickey, Andrew R., 2008). This trend may have impacts on the entry strategy to this market.

One of the other issues associated with the current market is technology standards compliance. There have been some proprietary implementations of MIMO chipset technology available in the market. However, before the official standard is finalized, the implementation details, such as diversity methods, number of antennas, and types of multiplexing algorithms, have profound interoperability and cost implications. These proprietary products, some even hold patents or have pending patents, will likely become obsolete by the time the official 802.11n standard arrives. Therefore, it is very important that the new smart antenna technology being developed is compatible with any standard based 802.11 chipset, now and future.

Another factor influencing the market entry strategy is the fact that the Port of Vancouver would like to enter an exclusive agreement with the technology team that will prevent the products from being offered to potential customers other than DP World owned and operated container ports. As the research has established, the ports owned and operated by DP World have less than 10% market share globally. That may mean the new

products find it difficult, if not impossible, to access the larger potential market. Most of the DP World owned and operated ports are located in Asia and Europe. The differences in the business practice, investment environments, social surroundings, and legal systems in those regions, especially the emerging markets in developing countries in Asia, pose a lot of potential problems and uncertainties. Because of the complexity and the many different aspects it would affect, the matter of entering exclusive agreement has to be carefully considered and expert legal advice sought.

6.4 Evaluation of Strategic Options

The evaluation of these three strategic options is based on the balanced scorecard constructed in section 5.4, combining with other strategic analysis approaches, including industry analysis, SWOT profiling, value chain analysis, and business model review. As the framework under which the strategic options are evaluated, the balanced scorecard has been built with objectives or goals, critical success factors and key performance indicators for each of four perspectives. Due to the lack of inputs from the SFU technology team regarding their business vision, mission and strategic directions, the four perspectives of this balanced scorecard are weighted equally and are used to evaluate the strategic options. Then a score system applies to these perspectives for each option. The total score serves as a basis on which the market entry strategic decision or recommendation is made. The evaluation results are summarized in Table 6.3.

BSC Perspectives /Strategic Options	Option 1	Option 2	Option 3
Financial	LOW (1)	MEDIUM to HIGH (4)	HIGH (5)
Customer	LOW to MEDIUM (2)	MEDIUM to HIGH (4)	MEDIUM to HIGH (4)
Internal	MEDIUM to HIGH (4)	HIGH (5)	LOW (1)
Learning & Future Growth	MEDIUM to HIGH (4)	HIGH (5)	MEDIUM to HIGH (4)
Summary Score	**11**	**18**	**14**

Legends:

HIGH (5)
MEDIUM to HIGH (4)
MEDIUM (3)
LOW to MEDIUM (2)
LOW (1)

Table 6-3 Evaluation of Strategic Options based on the Balanced Scorecard

As shown above, Option 1 presents an opportunity to be a technology provider focusing on R&D and licensing OEMs to produce chipsets or final access point devices for end users. It scores the lowest due to low expected profit margins, and limited future growth and product portfolio to meet customers' expectations. The positive side includes the elimination of complex business processes, and both fast decision making and response to market and technology changes in the perspective of internal business process.

Option 3 scores higher than Option 1 in the perspectives of financial and customers based on the fact that full integration is expected to achieve higher profit

margins and that it is strong on diversity of product portfolios. However, it is scored low on internal business process due to the complexity and challenges in business processes, especially for new technology startups. Fully integrated enterprises are usually suffering slow early stage establishment, high initial capital requirements, delayed decision making and longer response time to changes.

Option 2 combines the best parts of option 1 and option 3. It scores the highest from the perspectives of internal business process and future growth, plus moderate to high from those of financial and customers. That is, option 2 takes full advantage of technology expertise in R&D, technology innovation for future growth, more chances of developing more comprehensive product portfolios to meet customers' needs, and shortens the prolonged time to setup the business infrastructure. It also benefits from anticipated higher profit margins, does not require manufacturing, marketing, or distribution capabilities and resources, and retains more authority over the critical technology oriented business decision-making process.

It is worth noting that although the four perspectives are weighted equally in this analysis, for a technology start-up, customer and internal perspectives may be more important than other two and, if so, should be given more weight during the evaluation process. That is because a strong customer base from the very beginning and efficient and effective internal business processes will likely lead to long-term profitability and sustainability. On the basis of this consideration, by eliminating the financial and future learning and growth perspectives, option 1, 2 and 3 will be scored 6, 9, and 5, respectively. Note that, with this way, the score of option 3 is lower than that of option 1: this implies that, for a hi-tech start-up, full integration is not the preferred choice. In

either type of weighting assumption, Option 2 still scores the highest, and, thus, it is recommended. .

In practice, Option 1 is taken by many startups because of low capital and business infrastructure requirements. As well, the enterprise can go to the market very quickly. In the beginning, a start-up will enter the market with very attractive penetration pricing to increase the installed base and market share. However, as the business grows, the start-up often seeks some type of partnership to further expand the business. Option 3 requires a large amount of investment capital and takes time to build the entire business infrastructure. Management of outsourced business processes and distribution channel requires more resources, time and effort. It is generally not recommended for a new technology startup.

As pointed out by Christensen, Musso, and Anthony (2004), two types of mistakes made by many technology developers were to 1) fail to integrate far enough forward to encompass within a single organization all of the unpredictable interdependencies in design and manufacturing that are entailed when building products that use the new technology, and 2) fail to decouple an integrated value chain and begin selling components into the open marketplace after improved technological understanding resolves the unpredictable interdependencies that earlier had been the mandate for integration (Christensen et al, 2004). The key point here is that technology companies should endeavor to find the appropriate decoupling point for different technology and different times, instead of employing a one-size-fits-all-forever strategy for capturing value across the life cycles of their technologies. Based on the principle proposed by Christensen et al (2004) that the companies should consider more integration

if they need to control all of the activities with which that technology interacts when commercializing a new technology, the appropriate integration for the SFU technology team to go to market would be integrating R&D technology with chipset making and partnership with incumbent equipment manufacturers.

7: CONCLUSIONS AND RECOMMENDATIONS

As the enabling technology of container tracking systems, the Wi-Fi network plays an important role in the technology infrastructure of a port's operational environment. In a Wireless LAN, a wireless access point allows wireless communication devices to connect to the wireless network and acts as a central transmitter and receiver of radio signals. Smart antenna technology makes use of multiple antennas on access point devices in multiple channels to overcome the shortcomings of traditional antennas in Wi-Fi networks or Wireless LANs (WLAN), and achieves increased performance and capacity.

A technology research team from the School of Engineering at Simon Fraser University is conducting a research project on the development of smart antenna integrated Wi-Fi access point to overcome the shortcomings of current implementations and enhance the capacity and performance of wireless LAN systems. The team is currently working with the IT team from the Port of Vancouver on a technology R&D project that will assist the port to address the issue of Wi-Fi network lost connectivity and provide solutions to improve the current radio frequency quality signals, coverage and capacity. The research team is also very interested in exploring an opportunity to commercialize the technology and IP and enter the market with its own startup business entity.

Based on the market research of the current market structure, customers and competitors, and the competitive environment, combined with strategic analysis from Porter's Five Force framework, SWOT analysis, Value Chain analysis and the Balanced Scorecard Method, we have investigated and explored various business models and market entry strategies and came up with three options that could be selected to develop a strategy for entering the current WLAN equipment market. The three options covered a range from forming a technology provider focusing on R&D and licensing to OEMs, to entering strategic partnership or alliances with one or more incumbent equipment manufacturers to establishing a new fully integrated equipment vendor with options of outsourcing manufacturing process.

Further assessment of the three options elicited the conclusion that option 2, entering a strategic partnership or alliance with incumbent equipment manufacturers to enter the market, is the best option to take. This conclusion is based on a careful assessment of the strengths and weaknesses of the team, internal and external factors and the competitive market environment. As well, it considered the principle of making use of strengths to take advantages of opportunities, overcoming weaknesses and reducing the likelihood and impact of the threats. This option also allows the team or the firm to rapidly explore the market and capture the opportunities as they become available. This is very important in the battle for the WLAN equipment marketplace because of the fast-paced dynamics of WLAN industry as a whole.

In summary, this is a growing market with opportunities for the right technology at the right time and with the right strategy. However, it is also a crowded and competitive market. The team should approach the market by choosing entry strategies

based on the viability of being able to leverage its core competencies to create values and competitive advantages while simultaneously being able to continue innovation in both technology and customer values. The level of success and sustainability that can be attained depends on the team's efforts to anticipate the market changes by continuous innovation, renewal of core competencies, adaptation to environmental changes, and successful partnership practices, after choosing the most appropriate initial strategic option.

Given the time frame and available resources, this market research project has just opened a door to further detailed market research. A more elaborate feasibility study and more detailed market research should be conducted, jointly with technology, business and marketing experts, before the final decision on market entry is made. That would require more effort in terms of time and other resources.

APPENDICES

Appendix A The World's Busiest Container Seaports

This is a list of the world's busiest container seaports, total mass of actual TEU transported through the port. This list contains all ports with more than 3,000 thousands of TEU.

Rank	Port	Country	2007	2006	2005
1	Singapore	Singapore	27,932	24,792	23,192
2	Shanghai	People's Republic of China	26,150	21,710	18,084
3	Hong Kong	People's Republic of China	23,881	23,539	22,427
4	Shenzhen	People's Republic of China	21,099	18,469	16,197
5	Busan	South Korea	13,270	12,039	11,843
6	Rotterdam	Netherlands	10,791	9,655	9,287
7	Dubai	United Arab Emirates	10,653	8,923	7,619
8	Kaohsiung	Taiwan (Republic of China)	10,257	9,775	9,471
9	Hamburg	Germany	9,890	8,862	8,088
10	Qingdao	People's Republic of China	9,462	7,702	6,307
11	Ningbo	People's Republic of China	9,349	7,068	5,208
12	Guangzhou	People's Republic of China	9,200	6,600	4,685
13	Los Angeles	United States of America	8,355	8,470	7,485
14	Antwerp	Belgium	8,176	7,019	6,482
15	Long Beach	United States of America	7,316	7,289	6,710
16	Klang	Malaysia	7,120	6,326	5,544
17	Tianjin	People's Republic of China	7,103	5,950	4,801
18	Tanjung Pelepas	Malaysia	5,500	4,770	4,177
19	New York/New Jersey	United States of America	5,299	5,093	4,785
20	Bremen/Bremerhaven	Germany	4,912	4,450	3,736
21	Dalian	People's Republic of China	4,574	3,212	2,665
22	Laem Chabang	Thailand	4,642	4,123	3,834
23	Xiamen	People's Republic of China	4,627	4,019	3,342
24	Tokyo	Japan	3,818	3,969	3,593
25	Gioia Tauro	Italy	3,445	2,900	3,161
26	Yokohama	Japan	3,400	3,200	2,873
27	Colombo	Sri Lanka	3,380	3,079	2,455
28	Felixstowe	United Kingdom	3,300	3,000	2,700

29	Jawaharlal Nehru	India	n/a	3,298	2,667
30	Tanjung Priok	Indonesia	n/a	3,280	3,282

Source: adapted from Wikipedia,
http://en.wikipedia.org/wiki/List_of_busiest_container_ports

Appendix B Final Balanced Scorecard

The final balanced scorecard with three layered presentation is shown as below:

Customer Perspective **How do the customer view the company?**	**Business Process Perspective** **How do we do the business?**
Goal: High level of customer satisfaction. *Critical Success Factor:* ▪ High quality and reliable products and related services ▪ Prompt response to customer requests and customer requirement changes ▪ Integration of Voice of Customers in product management ▪ Increased value to customers businesses with compelling solutions, instead of product-centric strategy. *Key Performance Indicator:* ▪ Technical support call volumes ▪ Average lifetime of open tickets ▪ Product/service cycle time ▪ Product portfolios ▪ Customer satisfaction survey results ▪ Service availability ▪ Number of new customers and growth rate	*Goal:* Efficiency, effectiveness and adaptiveness. *Critical Success Factor:* ▪ Well defined and managed internal value chain activities ▪ Efficient internal technical and business infrastructure to support product, services and solution development and delivery ▪ Fast decision making and response to changes ▪ Appropriate strategic partnership and alliances *Key Performance Indicator:* ▪ Number of products or solution projects successfully delivered ▪ Product development lifecycle and delivery cycle time ▪ Time ratio of technical activities to non-technical activities ▪ Quantity and quality of partnerships

Financial Perspective **How do the shareholders view the company?**	**Future Growth and Learning Perspective** **Can the company sustain and improve in the future?**
Goal: High profitability and stock value. *Critical Success Factor:* ▪ Project cost-benefits analysis ▪ Project ROI analysis ▪ Cost-effectiveness achieved from suppliers and operational efficiency ▪ *Key Performance Indicator:* ▪ Short term revenue ▪ Long term profitability of projects and organization and other financial ratios ▪ Long term ROI on projects and organization ▪ Operational cost reduction ▪ Actual vs. budgeted expenses	*Goal*: To develop opportunities to answer the future challenges. *Critical Success Factor:* ▪ Performing and winning team building ▪ Efficient and effective HR and hiring procedures ▪ Investment on R&D for emerging technologies ▪ Product/service portfolio and lifecycle management ▪ Encouragement of innovation *Key Performance Indicator:* ▪ Number of new products and new technologies ▪ Number of innovations and IPs ▪ Number of training/education programs and conferences attended and participated

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