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Working Paper #06-06

September 2006

Flexible Investment Decisions in the Telecommunications Industry: Case Applications using Real Options

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Flexible Investment Decisions in the Telecommunications Industry: Case Applications using Real Options[1]

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[1] This work is partially funded by the NET Institute www.NETinst.org. We gratefully acknowledge their financial support.

ABSTRACT

The telecommunications sector is one of the most innovative, high-growth, capital-intensive yet volatile sector of the economy. This research addresses critical concerns of how, when, and why an enterprise or a service provider should undertake new investments. The study investigates the power of flexibility in investment decision making process, by applying the real options methodology. Five case applications are studied: a) investment decisions in next generation wireless networks; b) investing in integrated wireless networks; c) migration to wireless broadband internet services; d) valuing deployment of Wi-Fi networks in enterprise markets; and e) valuing Hosted VOIP services for enterprise markets. The case studies are analyzed both qualitatively and quantitatively.

1. Introduction

The technology selection and deployment cycle is a multifaceted process. Defining requirements for the evolution of technology is straightforward; however, speculation on its use is challenging. Scheming for all contingencies is not always feasible, while quantifying all the possible future outcomes and requirements is often a daunting task.

Investments in the telecommunications industry inherently involve high uncertainty, significant costs and irreversibility. Real options methodologies are thus most suitable to study investment decisions in this industry. The telecommunications market is evolving rapidly due to new innovations and new emerging technologies. Market competition is fierce in this heavily regulated industry.

This research study addresses the question of how an enterprise or a service provider in the telecom sector can realize optimal future growth. The study investigates the power of flexibility, e.g., to reconfigure the system, network, or future network deployments. Today's economic conditions demand tools which can incorporate internal and external eventualities, provide flexibility in asset management, assess the timing of deployment to reduce downside risk, and increase/maintain growth. Success depends on the consistency of the business cases carried out for this purpose.

This research builds upon the knowledge gathered from past studies and applies real options concepts and tools in analyzing major issues related to wireless service providers and enterprise clients in selecting the optimal technology and making the right investments. The understanding of next generation wireless networks and a knowledge of real options methodologies allow us to provide realistic solutions supported by quantitative as well as intuitive qualitative analysis.

Real options is a methodological approach with which an investment can be analyzed while factoring for flexibility and uncertainty. Real options analysis helps top management ascertain the conditions in optimally selecting the most effective strategy under changing conditions. Good management has a sense of capacity planning, growth of the firm, demand, scale of deployment, technical uncertainty, knowledge of new products, market potential, and the alternative choices available. Management can garner the advantage of real options to incorporate dynamic thinking capability enabling the firm to adapt to changing conditions in the market.

The dynamic capabilities of real options have been successfully applied in industries like pharmaceuticals, energy, mining, the environment, forestry, and information technology (Trigeorgis, 1996; Schwartz and Trigeorgis, 2001; Benninga and Tolkowsky, 2002; Edelmann *et. al.,* 2002, Olafsson, 2003).

The telecommunications sector is characterized by high-cost technological investments and increased volatility, due to increased competition, deregulation, etc. Valuing a project that requires a significant irreversible investment up-front to develop networking equipment or a telecom service is a risky decision due to inherent uncertainty. Traditional Net Present Value (NPV) analysis is limited in handling uncertainly or changing course of action when new information becomes available. The real options framework is more suitable for such valuations, assuming that the models are calibrated to realistic (e.g., market) conditions.

Technology selection can be viewed as a compound option (Trigeorgis, 1996; Trigeorgis, 1993). Technology roadmap selection involves interdependency among equipment manufacturers (network and mobile phones), integrators, content providers, end users, and the threat of alternative technologies. For example, third generation technologies (3G) strive to improve in the key areas of voice and data services, mobility, and capacity. The success of each is evident from the increasing number of commercial networks around the world (GSM World, CDMA Development Group). A sufficient number of manufacturers of network equipment and devices exists to support both CDMA and GSM technologies. Threat from alternative technologies and devices, such as Wireless LANs has to be factored into the decision-making process. An important piece in the thread of interdependency is the end user. With technology advancements and availability of choices, the end user might look for alternatives which gives her greater power of selection. It is hard to resolve this issue of interdependency. Operators should carefully study (*option to discover*) the market needs before going commercial.

Based on the results in the discovery phase, new investment may allow the operator an option to expand in new markets. Alternatively, operators can decide to defer (*option to defer*) further investment at different stages, if market conditions are not suitable or if there is no serious competitive threat and time allows further information gathering. If a pilot project turns out to be successful, the operator has an option to scale its network into new areas. Finally, the project can be abandoned when no other options are viable.

Operators are dependent on equipment vendors, handset vendors, integrators, and third-party groups who sell services (*franchise*). The operator may have an option to contract its deployment and maintenance of its network to a company that specializes in this area, e.g., equipment vendors. It can also outsource its customer service division (e.g., business process management vendors) and may contract with third parties to sell their products to customers. Operators may lease out the spectrum to potential corporate clients, e.g., Virgin Mobile USA used Sprint PCS network in USA. By leasing the spectrum, the operator is exercising the option to let a third party use its network in offering services. Such strategy has its own advantages and disadvantages. The choice allows the operator to enter a segment of the market where he does not have the service expertise or experience. The downside of this strategy is the possibility of making a destructive investment by losing potential market in exchange for short-term monetary gains.

In formulating the investment decision and valuing projects using real options in the wireless industry, the service provider and enterprises adopting wireless technologies can take advantage of the inherent strategic flexibilities. A common objective of operators and customers is to enhance the current value of the project while maintaining flexibility to change the course of action in the future. Operators have to invest upfront to build the wireless network. If investment is irreversible and much uncertainty evolves around the success of deployment of new technology, one can choose a wait-and-see-strategy or delay the investment until new information is gathered (Amram & Kulatilaka, 1999;

Pindyck, 1988). Uncertainty is a key factor in real options analysis. The wait-and-see-strategy has its own intrinsic benefits and disadvantages. Real options can account for the impact of future uncertainty in a systematic manner.

Five current important case applications in telecommunications are analyzed below, namely:

A. Investment Decisions in Next-Generation Wireless Networks

B. Investing in Integrated Wireless Networks (WLANs and GPRS)

C. Migration to Wireless Broadband Internet Services

D. Deployment of Wi-Fi Networks in Enterprise Markets

E. Replacing Traditional PBX Systems with Hosted VoIP Services

2. Investment Decisions in Next-Generation Wireless Networks

The cellular industry has experienced unprecedented growth in the last twenty-five years. In the United States, service providers migrated from AMPS (Advance Mobile Phone System) to TDMA (Time Division Multiple Access) and CDMA (Code Division Multiple Access), which became the two most popular choices. Meanwhile, GSM (Global System for Mobile Communications), the European flavor of second generation (2G) systems, became the most widely adopted mobile system in the world. 2G networks opened the door for offering new data products and services (e.g., browsing, email, and interconnection to private networks) and high-quality voice services. With gradual improvements to 2G systems, two competing third generation technologies (3G) emerged: the UMTS (Universal Mobile Telephone System) and the CDMA2000 (Code

Division Multiple Access 2000). As 3G mobile systems, they promised to offer improved voice and broadband access to users. The challenge of providing broadband internet services, extending coverage areas while improving quality of service, remains a key issue for operators to this day. Increasing demand for high-speed wireless data services, subscribers' demand for integrated solutions (voice and data), higher mobility coupled with the operators' need to improve average revenue per user (ARPU) and provide high quality wireless services, induced operators to migrate to 3G systems. These systems require additional spectra, resulting in severe competition among service providers. Various policy applications attempting to maximize economic rents from bidders (network operators) and governments across Europe resulted in higher revenues (ranging from 20 Euros to 650 Euros per capita in Switzerland and the United Kingdom, respectively) (Kemplerer, 2002a, Kemplerer, 2002b). This prohibited many operators from rolling out networks as scheduled. Despite the hype surrounding 3G, operators have not been able to develop a business model to attract subscribers and garner higher revenues. At the end of the third quarter of 2005, there were only 37.9 million UMTS subscribers in the world (GMS World, UMTS World).

Operators still face challenges regarding the cost of deploying new infrastructure. How and when new applications, to enhance the market, should be released? In the wireless industry, a high percentage of invested capital is needed to deploy network infrastructure. Operators must evolve their infrastructure in a cost-effective manner, while meeting forecasted demand due to subscriber growth. In order for operators to expand their market, they need to exercise flexibility in investment decision making while taking into consideration the uncertainties inherent in these high-tech industries.

The option to defer (delay) allows delaying the investment decision for a certain period of time. In this section, we study the investment timing decision of a wireless company that has purchased the spectrum required to deploy 3G networks. The company has already acquired the required spectrum to deploy 3G wireless networks giving it exclusive rights to provide services.

Assumptions and Parameter Calculation

The maturity of the deferral option T is estimated to be five years (FCC[2] auction rules typically require companies to have their network partially developed and deployed after five years). The current value of the underlying project, V, is the present value of its expected future cash flows, the exercise price I is the present value of the investment cost, consisting of capital and operational expenditures. The annualized standard deviation, calculated from historical price movements of the company, is estimated at 38%. The risk free rate, r_f, estimated from the yield of US Treasury bond rates in 2004 corresponding to the life of the project, is 3.64%.

For the Discount Cash Flow (DCF) valuation, cash flows are discounted using the average WACC of similar companies in the wireless industry, of 10.8% (see Katz et. al., 2003).

The company covers a geographic area of 1,250 square miles, 40% of which are urban (and the rest suburban). A typical urban cell site covers approximately 3.14 square kilometers, whereas a suburban cell site covers an area of 19.5 square kilometers. Based on these estimates, a total of 512 cell sites covering the entire geographic area was estimated.

[2] Federal Communications Commission (FCC) Home Page – http://www.fcc.gov/

Capacity was estimated based on the following assumptions: All users are equidistant from the cell sites, transmit the same amount of power, and transmit at the same bit rate. The Number of subscribers that the system can serve at a time is 98,310. An over-booking factor of two, i.e., an over-subscription of 196,620, is assumed. This factor is important to wireless packet data services from a networking aspect since it allows the network operator to sell the same amount of bandwidth many times, e.g., 10X to 20X times multiple. The higher the over-booking factor the better. The over-booking factor plays an important role in the project. The major source of uncertainty is the number of subscribers for the new services. The subscriber base and the number of cell sites are expected to grow at a constant rate of six percent (6%) per year.

Cash Flow Breakdown and Option Valuation

Table 1 shows the investment cost breakdown for capital expenditures (CapEx) and operational expenditures (OpEx), and the cell sites used to calculate the present value of the investment cost I. Capital expenditures are comprised of the cell site construction, base station equipment, antenna, and integration cost. Operational expenditures are the expenses incurred in operating the network and keeping it functional. They are comprised of the costs of the cell site lease, power supply to the site, T1 lines, and cell site software.

Table 1: Option to Defer: Investment Cost Projections

Year	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Cell Sites	512	31	33	35	37	39
CapEx	$181.76m	$10.90m	$11.55m	$12.25m	$12.98m	$13.76m
OpEx	$14.33m	$15.19m	$16.10m	$17.07m	$18.08m	$19.18m

The amount of capital required to build the 3G network for the life of the project is based on the number of cell sites the company has in the coverage area each year. The cost of building a single cell site is approximately $355,000[3] (assumed constant during the life of the project). The company expects to construct 512 cell sites in the first year, adding new cell sites in subsequent years based on subscriber growth. Given the yearly cash flows from Table 1, the present value of the investment cost, I, is $274.5 million, based on a discount factor of 10.8%.

Table 2 shows the revenue projections for subscribers of the 3G network. The revenue stream consists both of voice and data subscribers. The base number of subscribers starts at 196,620 in Year 1, and grows at six percent (6%) per year. The revenue figures are calculated by charging a price of $80[4] per user in the first year. This charge, the Average Revenue Per User (ARPU), decreases by 5% each year for the next five years.

Table 2: Company with Option to Defer: Revenue Projection for 3G

Year	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Subscribers	0	196,620	208,417	220,923	234,178	248,229
Revenues	$0	$15.72m	$15.83m	$15.95m	$16.06m	$16.17m

Discounting future cash flows at a WACC of 10.8% results in a present value of future cash flows, V, of $53.4 million. The static NPV (no options) of the project is:

$$Static \quad NPV(No \;\; option) = V - I = -\$221.1m$$

Since the project has a negative net present value it would not be undertaken.

[3] Based on private discussion with faculty member of Stevens Institute of Technology who is also a senior consultant to a leading wireless service provider in United States.
[4] Based on Vodafone UK's 3G roll out press release on offering two different bundled packages to British subscribers in November 10th, 2004.

The company must make a decision whether or not to invest within five years. The goal is to determine the value of the option to delay the investment (provided by the license). Knowing the option's parameters—the present value of expected cash flows of $53.4 million (the current price of the underlying), the present value of investment costs of $274.5 million (exercise price), the volatility of 38%, the risk-free rate of 3.64%, and the expiration time of 5 years—the value of the option to delay developing the 3G network is estimated to be $0.027 million based on the Black-Scholes formula. Such a low value was to be expected, because the call option is deeply out of money. The (positive) value of the option to delay enhances the static (no option) NPV value:

$$NPV(With\ \ Option) = Static\ \ NPV + \ Value\ \ of\ \ \ the\ \ Option\ \ to\ \ Delay = -\$221.07m$$

Even with the value of the option to delay, the project has a negative present value of -$221.07 million. The option to delay is not of sufficient enough value, to justify the investment commitment for this company.

The impact of key parameters that can increase the value of the option to defer and make this project attractive is worth investigating. The real options toolkit can help management identify different scenarios and answer “what it takes” for the investment to be attractive. The effect of key parameters such as investment cost, volatility, and number of subscribers are investigated.

3. Investing in Integrated Wireless Networks (WLANs and GPRS)

Third generation (3G) technology promised to provide data rates up to 384 Kbps with a maximum speed of 120Km/hr. Yet, there has been a delay in the rollout of 3G networks. 3G spectrum auctions have not even taken place in the United States (as of Oct 2005), even though researchers have long encouraged operators to integrate their 2.5G networks with WLANs to provide 3G-like services to their subscriber base (Salkintzis et. al., 2002). WLAN technology is simpler, cheaper and easier to deploy. WLANs offer data rates between 11Mbps to 54Mbps, compared to the 171Kbps offered by GPRS networks (Salkintzis et. al., 2002). Integration can be a valuable option for network operators who are currently at 2.5G, since they already have a data subscriber base. By offering the new integrated service, operators could provide enhanced services and hold onto their subscriber base. They could also generate additional revenue by attracting customers to their WLAN network.

Users will gain a clear advantage as they will have the option of transmitting their data over two alternative networks. With a 2.5G network, they can get wider transmission coverage with lower data rates, whereas with WLANs subscribers achieve higher data rates but a smaller coverage area. Deploying WLANs in strategic locations, such as coffee shops, shopping outlets, and financial centers in major cities and airports, allows operators to cover vital areas with high speed data services. Deployment of WLANs can be a viable complement to 2.5G networks. Instead of waiting, operators can integrate WLANs with their existing 2.5G networks and provide 3G-like services.

The model we use calculates the additional revenue generated due to integration. First, the NPV of the integration project, i.e., integration of WLANs with 2.5G network, is determined. Then, real options is used to value the option, in this case an option to expand.

Assumptions and Parameter Calculation

The project involves an area of 23 square miles in downtown Manhattan. There are two scenarios regarding the revenue stream in the integrated services setting: In Alternative *A*, the company collects revenues from its existing customer base (i.e., a percentage of existing data subscribers). In Alternative *B,* the company generates revenues from both integrated network subscribers and Wi-Fi (new) subscribers.

The life of the option to expand is three years, based on a common belief about the timing of 3G spectrum auctions in the United States. Annual volatility, calculated using historical price movements of the US Telecom Index for the past three years, is estimated at 31%[5]. The risk-free rate is estimated at 2.62% based on the 2004 US Treasury bonds yields corresponding to the life of the option (US Department of Treasury).

Table 3 provides a break down of the investment cost into capital expenditures (CapEx) and operational expenditures (OpEx).

Table 3: Company with Option to Expand: Investment Cost Projections

Year	**Year 0**	**Year 1**	**Year 2**	**Year 3**
Wi-Fi APs	375	25	25	25
CapEx	$187,500	$12,500	$12,500	$12,500
OpEx	$562,500	$600,000	$637,500	$675,500

The CapEx figures are due to Wi-Fi Access Point (AP) infrastructure. The cost of installing a single Wi-Fi AP is $500 (Boingo Wireless). One Wi-Fi AP can cover 0.0102 square miles. In the first year, the operator, selecting strategic locations in downtown Manhattan, is estimated to install Wireless LANs in one-sixth of the total coverage area. At the end of the life of the project, the company would cover one-fifth of Manhattan.

[5] The proposed integration model can be deployed by any operator irrespective of current cellular technology in use. Telecom index is used as a measure of volatility for the proposed integration model. The IYZ index has, as major component (70%), public companies that offer cellular telephony services.

The firm starts with 375 APs in Year 0, with a plan to increase this number to 450 by the end of Year 3. It is assumed that the network expands by adding 25 APs per year.

The cost of a single business DSL line is approximately $75 per month, while the maintenance cost is $50 per month (Boingo Wireless). The OpEx numbers shown in Table 3 are based on the total number of Wi-Fi Access Points at the end of each year.

The present value of the investment cost, I, is estimated to be $2.1 million. Based on telecommunications traffic information, the subscriber base in downtown Manhattan is estimated to be 120,000 people. It is assumed that this base will grow at six percent (6%) per year. The percentage of data users starts at 7.5% and increases to 15% towards the end of the project. Among the data subscribers, 70% use the integrated network, while the remaining 30% use the GPRS network only.

Alternative A: Revenue from Integrated Network Only

In this scenario, revenues come from subscribers to the integrated network only. For the services of the integrated network, customers are charged according to the model proposed by Yaipairoj *et. al.,* (Yaipairoj et. al., 2006). This model calculates the additional revenue that can be made due to integration. The cost of transmitting one megabyte over a GPRS network is high compared to Wi-Fi. The proposed scheme uses a demand function to calculate the percentage of users who accept the pricing of the integrated network. The total revenue made by the operator is the sum of the revenue made from the percentage of customers using the GPRS network and the percentage of customers using the Wi-Fi network. The additional revenue made per connection is calculated[6].

[6] A logged session for a duration of 24hrs

Figures in Table 4 are calculated assuming each subscriber makes 30 connections per year. Each connection contributes $1.3 according to the pricing model.

Table 4: Option to Expand: Revenue Projection for Scenario A

Year	**Year 0**	**Year 1**	**Year 2**	**Year 3**
Existing Subscribers	6,300	8,904	11,798	15,007
Revenues	$245,700	$347,256	$460,114	$585,265

The NPV of the cash flows for Alternative A, V_{01}, are estimated to be $1.23 million (discounting at a WACC of 10.8%). The (static) net present value NPV_1 is $(1.23 - 2.1) = -$0.87 million.

The company has the option to expand to an integrated network (GPRS and WLAN) in downtown Manhattan any time within the next three years. Based on the Black-Scholes model, the option to expand by integrating GPRS and Wi-Fi is calculated to be $0.09 million. This option value is insufficient to make the project attractive. The net present value with the option, NPV_2, is still negative (-$0.78 million).

Both DCF and real options valuation confirm that it is not profitable to integrate the network when the current type of subscriber is the only revenue stream generator. If the company can only retain existing customers and not attract new customers, the investment is not justifiable.

Alternative B: Revenue from Integrated and Wi-Fi Network

For Alternative B, revenue projections consist of revenues from both Alternative A and the Wi-Fi subscriber base. Revenue figures in Table 5 are based on a connection fee of $5 to the Wi-Fi subscribers, assuming 10 connections per year by each subscriber (AT&T Wireless). To calculate revenue, a Wi-Fi subscriber base of 8,000 is assumed (remaining constant during the project).

Table 5: Company with Option to Expand: Revenue Projection for Alternative B

Year	Year 0	Year 1	Year 3	Year 4
Existing Subscribers	6,300	8,904	11,798	15,007
New Wi-Fi Subscribers	8,000	8,000	8,000	8,000
Revenue	$645,700	$747,256	$860,114	$985,265

The present value of future cash flows V_{02}, is estimated at $2.47 million, more than double that of Alternative A. The higher projected revenues are sufficient to make the (static) net present value of the project positive: $(2.47 - 2.1) = $0.37 million.

Taking into consideration the option to expand, estimated at $0.77 million, the project becomes even more valuable, with: NPV_2 : $(0.37 + 0.77) = $1.14 million.

The analysis demonstrates that when the operator considers revenue coming from an additional Wi-Fi subscriber base, the expansion which results from integrating the 2.5G network with a Wi-Fi network, becomes viable.

4. Migration to Broadband Wireless Internet Services (WIS)

The evolution of internet has led to the convergence of telecommunications networks and computers. Benefits associated with the World Wide Web (WWW) have acquired greater importance: people are able to communicate via e-mail, perform data transfers, online shopping, online auctions, etc. Main existing technologies are localized, difficult to deploy in accessible areas, time consuming and expensive. The increasing demand for wireless packet data services has opened a new market segment in the wireless industry, Wireless Internet Services (WIS). The WIS market provides excellent opportunities to telecom operators and entrepreneurs to become Wireless Internet Service Providers (WISP). WISs provide high-speed services in remote areas and offer cost effective solutions, overcoming the limitations of wired and short-range wireless services. The need for higher data rates and new applications has led the industry to re-think future network configurations. Since wireless companies already have stable voice subscriber bases, provision of internet services opens up a new segment for business and additional revenues. This presents a challenge to operators to re-design their business strategy to enhance their capability. This section deals with third generation wireless technologies (3G), such as the Global System for Mobile Communications (GSM) family (GPRS, EDGE and UMTS), Code Division Multiple Access (CDMA) and alternative technologies, specifically Wi-Fi.

The issues involved are of interest to operators not only in developed countries but in emerging markets as well. We approach the problem as follows. First, we compare and differentiate the next-generation wireless technologies focusing on broadband internet services capabilities. We then identify technological, economic and behavioral factors that affect the selection of wireless technologies for migration paths. Finally, we examine an application involving the national incumbent operator in India, the options this operator has in migrating to 3G systems, and we value the most suitable migration path towards 3G for this operator.

There are several technological, economic and behavioral factors that should be considered in the processes of deciding the best migration path to follow.

Technological Factors

Technological factors involve the availability of economical systems, provision of high speed access, user friendly devices, multimedia applications etc. Technology factors are the driving force of the next generation mobile systems and internet services. Here we compare different wireless technologies based on maturity, cost, embedded applications, business models, and the spectrum required to deploy such technologies.

Technology Maturity vs. Cost

Figure 1 shows a classification of wireless technologies based on maturity and cost. The most mature technology is WLANs (802.11b and HyperLAN2). Wi-Fi has been in the industry for more than a decade and the organizations involved in standardization and development are making continuous progress. Compared to other wireless products, Wi-Fi is cheap, easily available and easy to install. On the other extreme, 3G systems are by far the least mature and most costly solution. 2.5G systems are somewhere in the middle, less mature and cheaper in comparison with 3G systems.

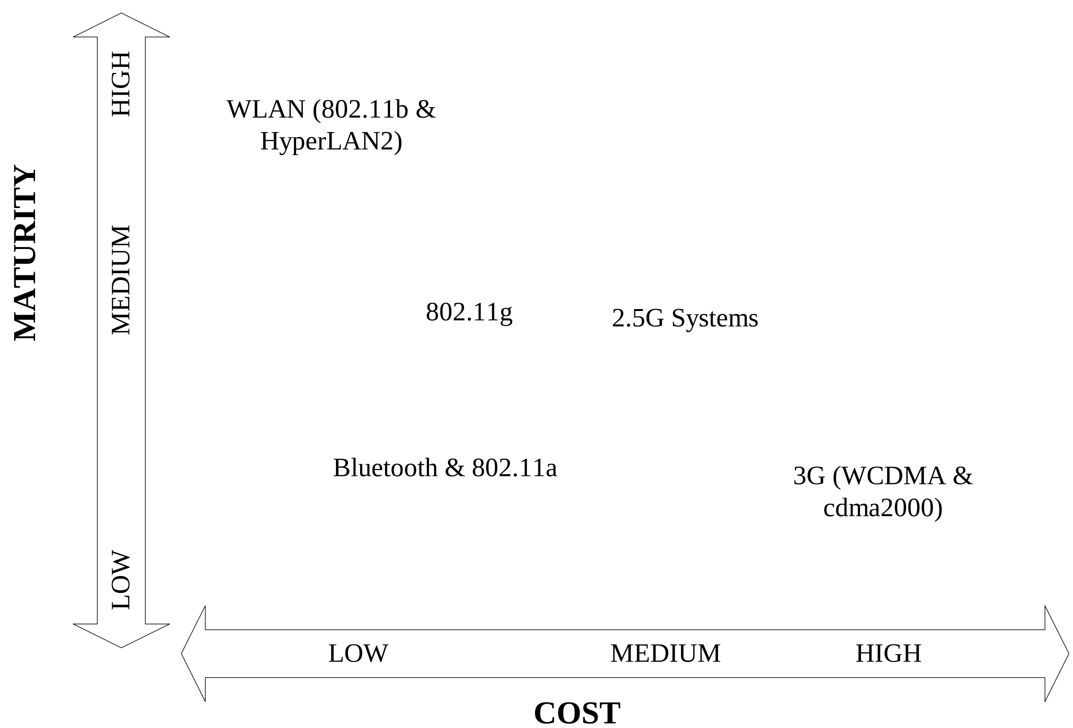

Figure 1: Wireless Technology: Maturity vs. Cost

Embedded Applications, Data Rates and Range

Figure 2 compares the evolution of wireless technologies with regard to range, applications and data rates. In short-range technologies, WLANs are the best performers. They offer data rates in the range of 11Mbps to 54Mbps, suitable for deployment at home, offices, public spaces and private networks. 2G, 2.5G and 3G technologies offer theoretical data rates in the range of 9.6kbps to 384Kbps, in some cases nearly 1Mbps. 2G systems have been deployed country wide as their main purpose is to provide voice services. 2.5G and 3G systems are deployed in big metropolitan areas to enhance voice and data services. Comparing short-range and long-range technologies in terms of embedded applications, short-range technologies offer an alternative solution to wired technologies. In terms of applications, they are good in offering video applications, web surfing, and video streaming.

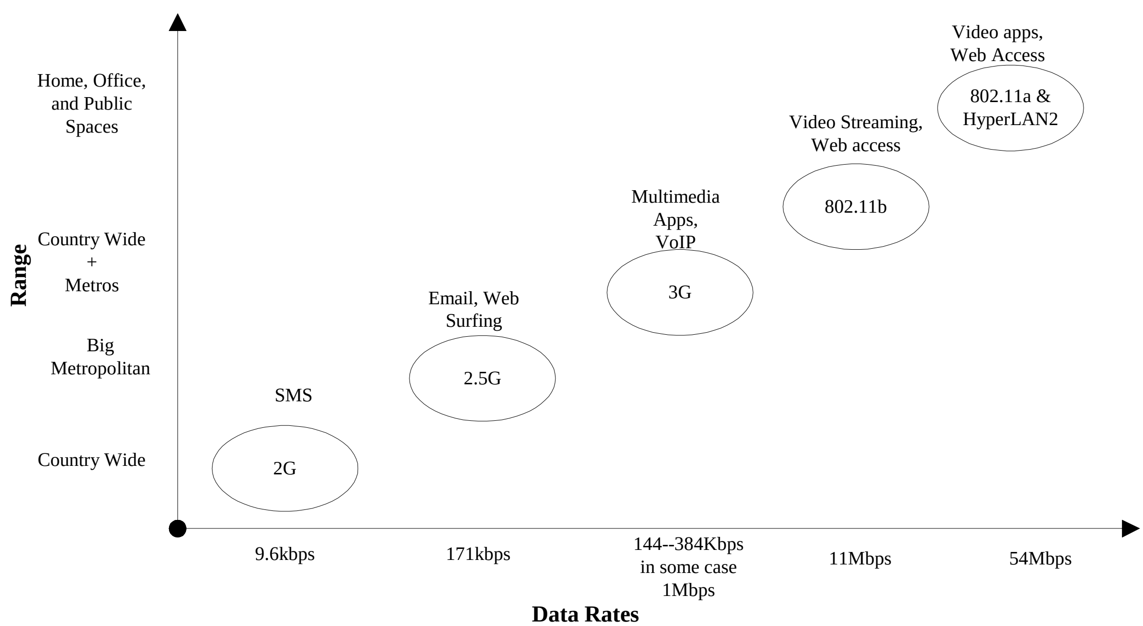

Figure 2: Comparison of Wireless Technologies Based on Application Range and Data Rates

Figure 1 pictures the cost versus maturity comparison of various technologies. Being less mature and more costly, 3G technology cannot single handedly be used to realize the aim of being a 3G internet service provider. 3G involves high cost and high uncertainty. Figure 2 shows that bandwidth-intensive applications may not be well supported by 3G systems because of limited bandwidth in a big geographical coverage. A combination of low cost and more mature technologies would provide 3G internet services at a reasonable cost and efficient data rates (Salkintzis, Fors & Pazhyannu, 2002).

Spectrum Management

It is commonly believed that 3G systems are the answer to providing high-quality voice and data services. To provide such services, 3G networks require additional spectrum to be released. European operators adopted UMTS as the 3G standard. During the auction era in Europe, owning spectrum was considered prestigious among the carriers. Europeans paid exorbitant amounts of money to acquire these licenses. The price varied from 20 to 650 Euros per capita (Klemperer, 2002a).

In the United States, the National Telecommunications and Information Administration (NTIA) has been working with FCC in 3G spectrum allocation. They focus on the 1710-1770 MHz band and 2110-2170 MHz band (FCC). While in Europe all bids are for national licenses, in the US operators bid for specific markets (Yazbeck, 2003).

Table 6: Spectrum Allocation for 3G and WLAN Technologies

<table>
<tr><th colspan="3">Third Generation Spectrum (3G) – Licensed Spectrum</th></tr>
<tr><th colspan="3">Region and Standard – UMTS</th></tr>
<tr><td></td><td>FDD Approach</td><td>TDD Approach</td></tr>
<tr><td rowspan="2">Europe</td><td>Uplink: 1920 to 1980 MHz</td><td>Uplink: 1900 to 1920 MHz</td></tr>
<tr><td>Downlink: 2110 to 2170 MHz</td><td>Downlink: 2010 to 2025 MHz</td></tr>
<tr><td>Japan</td><td>Same as Europe</td><td>No Specific spectrum allocated</td></tr>
<tr><td colspan="3">U.S.A no specific spectrum allocated</td></tr>
<tr><th colspan="3">Region and Standard – cdma2000</th></tr>
<tr><td>Europe</td><td>450MHz</td><td>Romania – Telemobil</td></tr>
<tr><td>South Korea</td><td>800MHz, 1700MHz</td><td>KT Freetel, SK Telecom</td></tr>
<tr><td>U.S.A</td><td>850MHz, 1900MHz</td><td>Verizon, Sprint PCS</td></tr>
<tr><th colspan="3">WLAN Technologies – Unlicensed Spectrum</th></tr>
<tr><th colspan="3">Region and Standard – IEEE 802.11(a, b, g) Technologies</th></tr>
<tr><td>U.S.A</td><td>2.4GHz and 5GHz</td><td></td></tr>
<tr><th colspan="3">Region and Standard – HIperLAN1 and HiperLAN2</th></tr>
<tr><td>Europe</td><td>5GHz</td><td></td></tr>
</table>

In the Asia-Pacific region, the Japanese government has awarded licenses to major operators in Japan without relying on auctions (UMTS World). This was a major step taken by the Japanese government and it helped operators to utilize their resources in the deployment of 3G networks. Table 6 gives a summary of spectrum band allocation in Europe, the US and the Asia-Pacific region. It is evident that next generation wireless networks need new additional spectrum. WLANs operate in unlicensed spectrum band, whereas 3G networks operate in licensed spectrum bands.

Behavioral Factors: User Requirements

The migration plan should include the users' expectation from the new technology. We classify users in three broad categories: students, home users, and enterprise users. Across all categories, common expectations include improvement in voice quality, coverage, capacity, enhanced mobility, availability of services “anywhere anytime”, friendly pricing plans, better customer services, availability of choices in selecting pricing plans according to customer needs, and simplified service contracts. In a quest to capture a varied market segment, operators develop solutions to attract customers with a friendly pricing scheme. Virgin Mobile offers flexible pricing plans to its customers in Australia, Canada, United Kingdom and the United States. In the United States, Virgin Mobile offers "Pay As You Go" services and targets customers in the age group of thirteen to twenty four years (Virgin Mobile). Boost Wireless USA is the fastest growing wireless provider in the U.S. in terms of the number of subscribers (Boost Mobile). Boost's success comes largely from its understanding of American youths' lifestyle market and from creating a brand differentiation (Boost Mobile). Services can be classified based on user category as shown in Table 7.

Table 7: User Categories: 3G Service Classification

Features & Categories	**Home**	**Student**	**Enterprise**
Service & Applications	web access, e-mail, online shopping, video applications	web access, e-mail, file transfer, gaming, navigation systems, video applications	B2B applications e-commerce, location based services, fleet mgmt, MMS

Economic Factors

Demand for wireless services has been growing substantially over the years. This was made possible because of technological advancements, price, and the plethora of choices given to subscribers. Voice has been the major source of revenue for operators around the world. So far operators have been surviving on revenue generated from voice services even after the introduction of 2.5G services that promised data capabilities. Today, operators are migrating from existing systems to 3G systems. The aim of migrating to 3G is to provide enhanced mobility and improved data services. Service providers are faced with the challenge of generating additional revenue and reducing cost while migrating from existing technology platforms to next generation wireless technologies.

Evolution in mobile industry is marked by infrastructure changes, software changes, introduction of new access devices, easily useable interfaces, and meeting user expectations. No matter which migration path an operator chooses, these economic issues are common for an incumbent and a Greenfield operator, operating in both developed and developing countries.

Operators should be able to avoid dramatic changes in existing infrastructure and balance the financials of the company, while they try to benefit from new technology while meeting clients' expectations. Those in migration should make optimum use of their legacy systems. Economic factors, such as capital expenditure, cost reduction, and additional revenue generation, are important issues facing operators today (see figure 9).

Cost Reduction

Reduction in cost and maximum use of available resources is a prime objective of a service provider. Figure 3 shows how an operator can reduce cost in the deployment of next-generation wireless technology, both by internal and external factors. *Internally:* there are three general directions in migrating from an existing to a future technology: upgrade overlay, and forklift. Careful consideration must be given to the selection process of infrastructure vendors, as equipment should be scalable. Reductions of recurring expenses on facilities, personnel and maintenance should be anticipated. Growing staff in not a healthy sign, as staff should be hired when and where required.

Externally: Operators typically find it economical to outsource departments such as billing, customer services and technical support.

Additional Revenue Generation

The next major challenge that service providers are faced with is how to generate additional revenue. Service providers must develop new innovative products for both general and corporate users. Figure 3 illustrates how operators can achieve this goal in two ways: *internally* and *externally*.

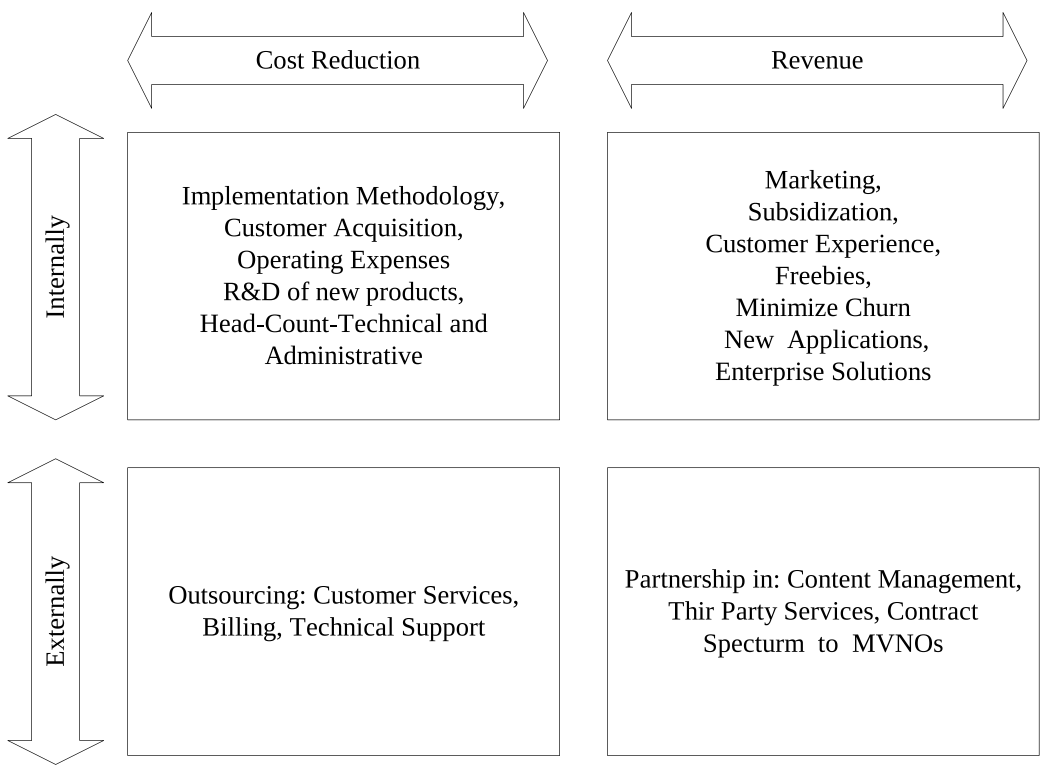

Figure 3: Economic Issues for Operator

Internally, phone subsidization can act as an incentive for existing customers to adopt new systems and attract new customers to adopt new technology at affordable prices. Customer experience in usage of previous technologies should be emphasized. New applications and solutions tend to attract new customers. Minimization of the churn rate can be achieved by service quality improvement, offering of better coverage capacity, voice quality, and new services. Numerous internet equipment companies provide software and technical know-how to wireless companies in managing their bandwidth efficiently and offer new services to customers. Companies such as IPWireless, Bridgewater Systems and Convergys Corporation provide software, tools, billing and customer care management services to help companies connect with their customers. Woosh in New Zealand in collaboration with IPWireless is offering a broadband solution. About 40% of all the new broadband subscribers in coverage areas choose Woosh's over Telecom New Zealand's DSL offering (IP Wireless, Woosh). Marketing or sales should also be coordinated with technical services, conveying the right information to customers.

Externally, the operator could tie up content management providers and third-party providers who specialize in specific services such as sports, stock market quotes and weather reports. The recent collaboration between Cingular Wireless and the mobile content and media provider Motricity helped Cingular to increase its mobile games services by 25% (Motricity). Operators can increase revenue and their subscriber base linking with mobile content hosts and service providers (9squared, UPOC Networks, (M) FORMA). They can also lease spectrum to MVNOs (Mobile Virtual Network Operators) in areas where it is not heavily used and earn additional revenue. For example, Virgin Mobile USA leases spectrum and infrastructure from Sprint PCS USA. Thus, service providers can diversify into new areas and offer attractive services to their customers.

Finally, operators should be able to use the legacy systems to realize gains in investment cost, scalability, faster time to market, availability of terminals, flexibility in future migration, services offering, and meeting user expectations.

Case Study: BSNL Indian Telecom Operator

Bharat Sanchar Nigam Limited (BSNL) is India's only national telecommunications service provider. BSNL offers a full range of world class telecommunications services, across India. Its services include basic telephone services, internet, ISDN, intelligent network solutions, a X.25 based packet switched public data network, leased lines and datacom, and cellular mobile services. As a national telecommunications service provider, BSNL also covers the remotest areas of India.

Table 8: Company Wise Market Share of Indian Operators as of 20004 (TRAI, 2004, July-Sep '04)

Mobile Group	Subscribers	Market Share	Technology
Reliance Group	9,041,113	21.0	GSM & CDMA
Bharti Group	8,702, 255	20.2	GSM
BSNL	7,964,284	18.5	GSM & CDMA
Hutchison Group	6,371,335	14.8	GSM
IDEA Group	4,355,230	10.1	GSM

BSNL offers countrywide cellular services using GSM technology, and Wireless Local Loop (WLL) services using CDMA technology. It is the third largest mobile service provider in the country, with a market share of 18.5%. It has a subscriber base of more than 7.5 million people on its GSM network, and a subscriber base of 0.4 million on its CDMA network. As of 2005, BSNL offers traditional voice, voice mail, and SMS, both national and international, country wide through its GSM network. It offers data services, e.g., MMS, GPRS and WAP, through its GSM/GPRS networks deployed in specific markets in India. In addition, it offers country-wide WLL services, using CDMA technology. WLL services are currently being offered in areas where wireline services are difficult to deploy. Table 9 summarizes BSNL's network information and services.

Table 9: BSNL's Network Information and Services (CDG, GSM World)

2G/2.5G/3G	Band	Status	Coverage	Service
2G-IS-95A	WLL 800MHz	3G-cdma2001x-RTT	Country	Voice
2G-GSM	900MHz	Active	Country	Voice
2.5G-GSM/GPRS	900MHz	Active	Geo. Markets	WAP/MMS

Most wireless mobile service providers adopt a migration path based on their existing technological infrastructure, upgrading to either cdma2000 or UMTS. BSNL is one of the few operators around the world who have both the IS-95 (CDMA) and GSM based technology in their portfolio of cellular services, having the option to migrate either towards UMTS or cdma2000 (see figure 4). We analyze the migration path for BSNL's two main alternatives. We tackle the problem from the perspective of the service provider, the equipment provider and the users, considering the business opportunities for the company.

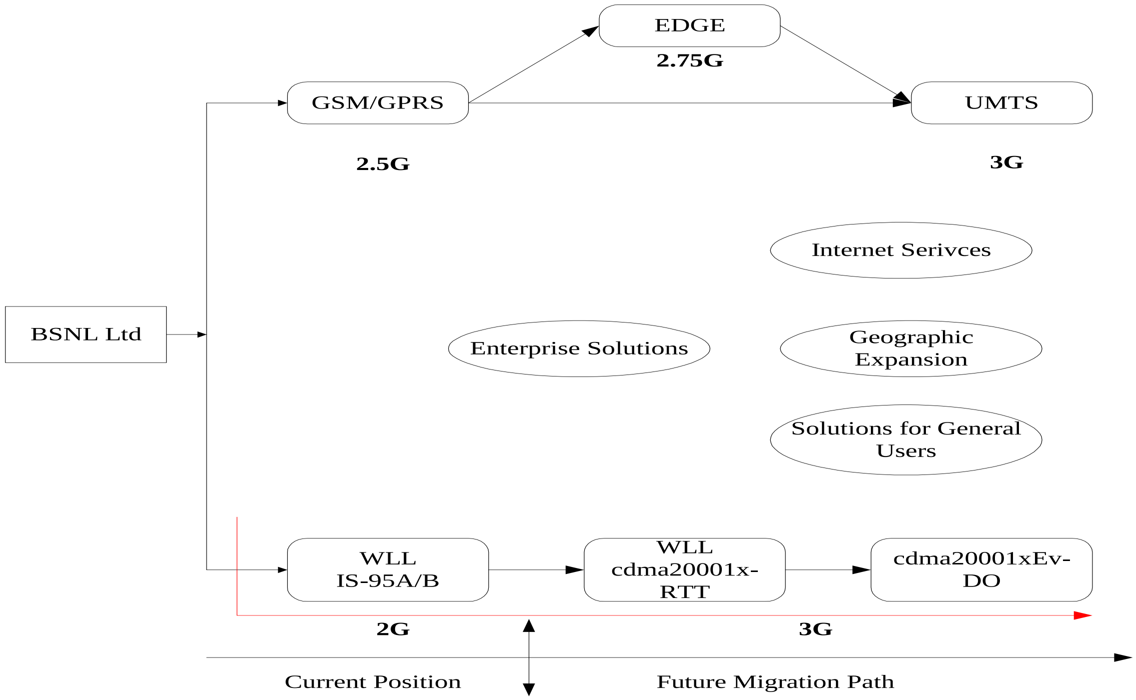

Figure 4: Possible Migration Paths for BSNL

Valuation

In developing nations the penetration rate of internet services is lower compared with developed nations. This can be attributed to a lack of social awareness and several socio- and techno-economic factors. According to a recent report of the Telecom Regulatory Authority of India (TRAI) India has 188 operational internet service providers across the country with a total subscriber base of 5 million (TRAI, 2004, July-Sep' 04'). The majority of subscribers are located in large urban areas, where telecom infrastructure is well developed. This is possible due to the existence of more than 10,000 internet cafes, an increase in the number of leased line connections and a 38.74% growth of high speed connectivity. These facts are attributed to personal computer penetration. However, in rural and remote areas where basic telephone service infrastructure is not well developed, wireless provision of internet services is a more viable solution. Operators can provide internet services using different pricing schemes, e.g., monthly flat fees for unlimited access, usage-based access, etc. BSNL as the incumbent provider enjoys the largest country-wide coverage in basic telephone services, is the leader in the ISP market with a market share of 28%. BSNL has country wide Wireless Local Loop (WLL) and GSM coverage, with clear advantages in evolving towards a Wireless Internet Service Provider (WISP).

Capital and Operational Expenditures

Upgrading from existing technology systems is a capital-intensive process. Investment costs of rolling out 3G vary, depending on the technological path that operators decide to follow. In the case of BSNL, the operator faces two choices: a) migrate from the existing GSM/GPRS (2.5G) system to EDGE or UMTS (3G); or b) upgrade the existing CDMA (WLL) network to CDMA2000 1x-RTT (3G) and then to CDMA2000 1xEV-DO. The cost of rolling out a nationwide coverage of 3G services for BSNL depends on: (1) the technology under consideration, (2) the spectrum band of operation, (3) equipment vendors, (4) terminal vendors, and (5) operational expenditure.

The technology selection process by BSNL is difficult, as the company has both GSM and CDMA based technologies in its portfolio. In the case of GSM evolution to UMTS (3G), the operator has to undertake major infrastructural changes. In the case of CDMA evolving to cdma2000 (3G), equipment upgrade (hardware and software) is required.

The spectrum requirements are also an issue of major concern in evolving the respective networks. New spectrum is required in the case of UMTS network deployments (which are cost intensive), whereas, cdma200 systems can be deployed in their existing 2G spectrum.

In order to cover the same geographic area with new 3G systems, the operator may have to build more cell sites, based on the different technological choices. The higher the frequency of operation, the smaller the coverage area, resulting in more cell sites to cover the same geographic area. The selection of the equipment and terminal vendor is also vital in terms of support.

Capital expenditures in the case of mobile services include the cost of base station equipment, cell site construction, rents, integration cost, switching cost etc. Table 10 shows the capital expenditure for several operators in different countries. Operational expenditures are also key issue for the network roll out. Expenses incurred in day-to-day maintenance, rents, customer acquisition costs, marketing; content cost and organizational cost must also be factored in.

Table 10: Capital Expenditure by Network Operators

Source: Morgan Stanley June 2002

Country	**Operator**	Total capital expenditure **(US $bn)**
Korea	SKT (CDMA2000 1x and CDMA2000 1xEv-DO)	2.4
	KTF (CDMA2000 1x and CDMA2000 1xEv-DO)	1.2
	LGT (CDMA2000 1x)	0.4
Japan	KDDI (CDMA2000 1x and 1xEv-DO)	2.5
	DoCoMo (WCDMA)	10.9
U.S.	Sprint PCS (CDMA2000 1x and 1xEv-DO)	2.4
	AT&T Wireless (GSM/GPRS/EDGE/WCDMA)	4.4

Revenues

Being an incumbent operator having a large coverage area and an established subscriber base gives an advantage in migrating to new technologies. To recoup the costs, the investing operator must increase the average revenue per user (ARPU). This can be achieved via a higher penetration rate, better services, user-friendly service plans, a reduction of subscriber volatility, bundling of voice and data services in the case of post and pre-paid services, etc. The average ARPU for mobile services for the quarter (Jan-Mar' 04') in India was Rs. 424 ($9.67) per month. BSNL's ARPU for cellular services during the quarter ending March 2004 was Rs. 453 ($10.34). As of September 2004, BSNL had a total subscriber base of about 8 billion of which 7.5 billion were GSM subscribers and 424.6 million were CDMA subscribers.

Valuation of CDMA Migration Path

In this section we value the CDMA migration path using traditional valuation and the real options approach. Wireless operators face several challenges in making key decisions in complex projects where huge investments are made. They also face tremendous uncertainty in market trends and fierce competition. Telecom projects in particular involve huge sunk costs. The decisions made have also a crucial impact on the future of the company and its business.

Consider BSNL's alternative to migrate from its current system to next generation technology via the evolutionary migration path of CDMA technology. The project has a life of five years with an initial upfront investment cost I of $2.4 billion (see table 10). This investment cost will generate revenues during the life of the project.

According to the Cellular Operators Association of India (COAI), the Indian mobile market subscriber base grown to about 37.38 million subscribers as of 31 December 2004. The Indian mobile market grew at a compound average annual growth rate of 87.8% since 1999 (COAI). This growth was due to regulatory changes, significant growth of the Indian economy, decrease of the unemployment rate, shift from a duopoly market to a competitive one, increase in investments in the private sector, reduced tariffs, and increased coverage area of the networks. India's penetration rate of 3.7% is considered low compared to other developing countries in Asia (DOT). With a population of approximately one billion, India offers a big market and great opportunities (Sinha, 2002; Srivastava, 2000; TRAI, 2004, 16/2004). Moving forward, the Indian cellular market is expected to experience the same or even higher growth rates, depending on the execution of strategic plans by cellular operators.

Table 11 shows projections regarding BSNL subscribers and revenue figures for next generation wireless networks. Starting from a subscriber base of 424,652 customers at the end of the first year, we assume that BSNL's base will grow at the recent market growth of 88% per year. The revenue figures are calculated considering an annualized industry ARPU of $10.34[7]. We assume that the ARPU will remain constant over the life of the project.

Table 11: BSNL: Predicted Subscriber Growth and Revenue Projections

	2004	**2005**	**2006**	**2007**	**2008**	**2009**
Subscribers	424,652	797,569	1,497,974	2,813,455	5,284,156	9,924,560
Revenue	$52.69m	$98.96m	$185.86m	$349.09m	$655.65m	$1,231.43m

Discounting the expected cash flows at a WACC of 15% (typical for Indian telecommunications companies), we estimate the present value of future cash flows, V, to be $1,443 million. Given an investment cost, I, of $2,400 million, the static NPV (no option) of the project is:

$$Static\ \ NPV\ = V - I\ = -\$957 million$$

The project has a negative net present value and therefore would not be undertaken. The operator is facing a challenge in selecting the right technology in order to migrate to

[7] Annualized ARPU of BSNL is Rs. 453 converted with a exchange rate of 1USD = Rs. 43.81, http://www.rbi.org.in

next generation wireless networks. In order to capture the growing cellular market, the operator has to make a decision between migrating to UMTS or cdma2000 (see figure 4). For BSNL, the migration of existing 2.5G system to UMTS can be delayed as there is uncertainty about spectrum auctions and the cost of deployment. However, BSNL can expand its CDMA network because of the inherent advantages mentioned earlier. This will allow the operator to use its resources in a cost effective manner.

The BSNL dilemma can be modeled as an American call option exercisable any time during the life cycle of the project. The option parameters are as follows: The life of the project T is five years. The present value of future cash flows, V, equals \$1,443 million. The investment cost I is \$2,400 million. The annualized standard deviation calculated from the historical price movement of the Bombay Stock Exchange Technology, Media and Telecom Index (BSE TECk[8]), σ, is 47%. The risk free rate, r_f, is 6.48%, estimated from yield of 5-year Government of India bonds. Based on the Black-Scholes model, the option value of migrating to cdma2000 (3G) is estimated to be \$499 million. The option value expands the NPV of the project:

$$NPV(With\ \ Option) = Static\ NPV + Value\ of\ \ Option = -\$457.61 million$$

Even with consideration of the option value, the project has a negative present value of -\$457.61 million. This is due to the high investment cost and moderate volatility (refer to Table 10 for investment cost figures in other countries as well).

[8] Bombay Stock Exchange (BSE), The Stock Exchange, Mumbai, http://bseindia.com

5. Deployment of Wi-Fi Networks in the Enterprise Market

Wireless data services have become a very important tool for companies looking for improvements in productivity, efficiency and communications. Mobile telephony operators, using different technologies, are currently offering wireless voice and data services to the general public and to business customers, who make up an important segment of the market. These are usually companies (e.g., financial institutions, insurance, etc.) that are adopting wireless services as a tool to increase productivity, support telephony, electronic mail, short message service (SMS), and synchronizing traditional office software applications (e-mail, calendar, to-do lists, contact lists, etc.) with a wireless handset. A perennial challenge for Wireless Service Providers (WSPs) is to extend their service coverage to difficult-to-reach areas, for instance, skyscrapers, where it is not easy to ensure basic Radio Link Quality standards. There are cases where the traditional cellular operators cannot guarantee coverage for their service in isolated spaces, such as basements, due to metallic structures, like elevators or buildings with thick walls blocking radio signals. These issues are common in skyscrapers, healthcare facilities, college campuses, government agencies, etc. In order to address these problems, cellular operators can deploy ad-hoc solutions, such as dedicated base stations, incurring additional expenses. The success of these alternatives depends on the consistency of the business cases carried out.

The challenge for cellular operators is to provide quality wireless services to business customers that can be reached in challenging coverage cases. Business customers that need these services have to evaluate the available choices in the marketplace and make decisions on the service to adopt, based on reliability, quality, customer service, technical support and cost. Both the current cellular network operators and the corporate market (companies with a significant mobile telecommunications infrastructure) need to better understand the challenges for their respective position in the wireless market. They desire to follow optimal strategies in order to maximize revenue and reduce risk (for operators), while keeping the mobile service performance at a desirable quality standard within a given budget (for business customers). This section evaluates the costs and risks for different alternatives regarding wireless data services for the corporate market, both from the service provider’s and the customer's perspectives.

Case Study

The company/client is located in downtown Manhattan and occupies five buildings with an average of 55 floors[9] each. It needs to implement wireless services for its staff, synchronizing the company’s office management software with personal wireless devices. Given the expectations for the number of subscribers, carried voice, data traffic, and implementation costs for different approaches, two possible solutions are considered:

- **Cellular Solution:** Wireless services provided by a cellular operator. This requires the installation of a dedicated base station system and required infrastructure involving cabling, antenna systems, fiber-based repeaters, and the acquisition of the wireless handsets. The cellular operator will be responsible for providing voice and data services to the employees of the organization.
- **Hybrid Solution:** Wireless services are provided by the company’s IT department covering the company’s facilities. The enterprise customer will install a WLAN system and implied infrastructure i.e., cabling, antenna systems, backhaul, etc., and the acquisition of the wireless handsets. VoWLAN and data

[9] Average from the most predominant high-rise buildings in the area.

services will be provided by the company's network within the company's facilities, and by a cellular operator outside the enterprise environment.

Based on observed traffic patterns, the following assumptions are made:

- For a 55-storied building, at least 1,000 wireless devices dedicated to voice and data services will be required; the 5 buildings involve the deployment of a wireless data service infrastructure for 5,000 mobile devices.
- The area to be covered for a 55-storied building is approximately 2,000 sq feet (around 36,400 sq feet per floor).
- The cost of each wireless device is about $366 (Ipsos, 2004).

The cellular solution involves an option to expand. It focuses on deployment of dedicated base stations to n customers, having the right to choose their own Wi-Fi infrastructure as the main resource for wireless services. In the case of the hybrid solution, an option to invest in deployment of WLAN infrastructure for provisioning of wireless services is evaluated. This is based on the risk associated with the availability of fully-integrated VoWLAN and cellular handsets.

The following option parameters are estimated:

- V , the present value of the future cash flows, from wireless services.
- The life of the project, T , is five years.
- The investment cost of the project, I , is the sum of capital and operation expenditures.
- The volatility of the underlying asset, σ , is calculated from the historical stock price movement of US Telecom Index (IYZ) for the *Cellular Solution*;

for the *Hybrid Solution*, the price movement of the device manufacturer for the life of the project is used.

- The risk-free interest rate r_f of 4.25% corresponds to the current US Treasury bonds yields, matching maturity of the option.

Analysis of Proposed Solutions and Alternatives

Downtown Manhattan is home to many important companies spanning the financial and insurance industries, accounting and consulting firms, etc. For cellular operators, this setting is quite challenging, given the fact that it is not always possible to provide quality wireless services. Potential radio link impairment, interference and fading are not uncommon in high-density metropolitan areas[10]. This limitation combined with the necessity of providing quality service to enterprise customers, makes In-Building dedicated solutions a preferable for coverage, capacity and quality concerns. The outcomes resulting from the two approaches are (see Table 12):

From the Cellular operator's standpoint:

- **Cellular and DAS,**: the wireless operator builds a base station within customer's premises, and implements a Distributed Antenna System (DAS).
- **Cellular and No DAS:** the wireless operator does not build any additional base station or DAS at all. This case is irrelevant from the corporate customer standpoint because it is not solving the problem but is taken as a reference for further comparison between itself and the Cellular Solution with DAS to see how revenues for the 2.5G carrier are affected.

[10] This limitation has a lower impact in rural and suburban areas. A high-density metropolitan area scenario is a challenging one for cellular service operators.

From the corporate customer's standpoint:

- **Hybrid Solution:** implement WLAN as on-premises solution for wireless services and a 2.5G carrier for out-of-premises service.
- **Cellular and DAS:** use a wireless carrier as a service provider with a dedicated antenna system solution on-location.

Table 12 Summary of Technical Solutions and Different Views

Technical Solution	**Standpoint**	
	Wireless Carrier:	**Corporate Carrier:**
2.5G with DAS	Implements base station and DAS (Case A)	Pays for devices and monthly fee for wireless service, in and out of premises (Case D)
2.5G with no DAS	Does not implement base station or DAS. It does not solve customer's problem (Case B)	Customer necessity is not addressed, not a valid case
2.5G + WLAN	Cellular services provided only out of premises (Case B)	Pays for devices, WLAN infrastructure for in-premises services and reduced monthly fee for cellular service out-of-premises (Case C)

The Cellular Solution with no DAS from the Cellular Operator standpoint and the Hybrid Solution from the corporate customer standpoint are actually complementary to each other: the same case viewed from two different perspectives: that of the cellular operator and the corporate customer.

Case A: Cellular Operator Installs Base Station and a Distributed Antenna System (DAS) within Customer Premises

In this case, the cellular operator installs a base station and a DAS to provide services in the five buildings. The following costs, expenses, and revenues are considered:

- Cellular base station includes equipment, construction, backhaul and installation related labour.
- Operation, Administration, and Maintenance (OA&M) cost for the base station(s).
- DAS includes equipment, antenna, fiber and/or coax cable deployment, and installation-related labour.
- Revenue generated by wireless service consumption due to voice traffic is usually very low. Traffic in In-Building solutions is normally associated with data services. On the other hand, corporate customers are ordering data-only enabled devices in an effort to reduce costs[11].
- Revenue generated by wireless service consumption due to data traffic[12].
- Rent: usually corporate customers allow cellular operators to be located on premises with no additional costs (for the cellular operator).

Table 13 summarizes capital expenditures (CapEx), operational expenditures (OpEx), and revenues. For the DCF valuation, expected cash flows are discounted using a WACC of 10.8% (Katz *et. al.*, 2003). The present value of expected cash flows, V , is estimated to be $10.97 million. The present value of investment cost I $9.19 million. The maturity of the option, T , is five years. Volatility, is determined from the historical price

[11] Observation based on experience
[12] For the cases involving a cellular solution from the operator's perspective, revenue per subscriber was taken from one of the wireless operator's website for an unlimited data plan, charging the subscriber $50/month for unlimited data services.

movements of the Dow Jones Telecom Index (IYZ)[13], is estimated at 28%[14] annually. The risk-free rate r_f is 4.25%.

Table 13 Case A: CapEx, OpEx and Revenue for the Cellular Operator Installing a Base Station and a DAS, with Option to Expand (Present Values in Millions)

Year	Year 0	Year 1	Year 2	Year 3	Year 4	Year 5
CapEx	$7.00	$0.00	$0.00	$0.00	$0.00	$0.00
OpEx	$0.00	$0.54	$0.48	$0.43	$0.39	$0.35
Revenue	$0.00	$2.69	$2.42	$2.17	$1.95	$1.75

From Black-Scholes equation, the value of the option to expand is estimated at $4.45 million. The combined value of the NPV of the project and the value of option to expand is $6.23 million.

Case B: Cellular Operator does not Install Base Station and No DAS system will be Built

- In this case, the cellular operator will provide services to the same number of subscribers (i.e., 5,000), but only out of the firm's premises. Assumptions regarding the number of subscribers and the geographical location are similar to the previous case. A main difference is the revenue generated by a different plan; now that the company has its own infrastructure for on-premises communications, it will switch to a plan with a lower monthly fee but will pay a higher price for additional kilobytes of data transmission. 80% percent of the data traffic will be carried out by the company's infrastructure so fees for additional kilobytes will be minimum.

[13] The IYZ index has as major constituents (70%) public companies that offer cellular telephony services.
[14] The proposed business model can be deployed by any operator irrespective of current cellular technology in use. Telecom index is used as a measure of volatility for the proposed business model.

Table 14 summarizes the investment breakdown and revenues for this case. The present value of future cash flows, V, is estimated to be \$4.39 million. The present value of investment costs, I, is \$2.19 million. In this case the cellular operator does not install any base station on the customer's premises. The annualized volatility σ is 28%. The maturity of the option T is five years, and the risk-free rate r_f is 4.25%. The value of the option to expand when the cellular operator does not install the base station and DAS systems is \$2.67 million. The expanded value of the project is \$4.87 million.

Table 14 Case B: CapEx, OpEx and Revenue for the Cellular Operator (No DAS or Base Station are installed) with Option to Expand (Present Values in Millions)

Year	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
CapEx	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00	\$0.00
OpEx	\$0.00	\$.54	\$0.48	\$0.43	\$0.39	\$0.35
Revenue	\$0.00	\$1.08	\$0.97	0.87	0.78	\$0.70

Case C: Corporate Customer: Company Uses its Own WLAN On-Premises Network to Provide Wireless Services

Here, the firm decides to provide on-premises wireless services using its own WLAN network. The following costs are considered:

- Cost of wireless access point and integration into the existing local area network (LAN). One access point per floor, including cabling and connections, connectors, and minor hardware related costs is assumed.
- Costs related to DAS, i.e., fiber, coax cable installation and antennae, labor costs, and costs associated with acquiring wireless devices.
- Deployment of security features to ensure integrity and confidentiality of data transported/transmitted over the wireless network. Security is crucial and

mandatory as the possibility of attacks and intrusions is very high in case of corporate networks (AirDefense, Young *et. al.*, 2006).

- Payments for wireless services provided to staff members when off-premises. Estimated proportion of geographical distribution of traffic is 80% on-premises, 20% off-premises. Plans with minimum monthly fee ($20/device[15]) that include 5MB for free can support 3.6MB per user.
- OA&M costs.

The value of the project is a function of estimated savings ranging from 1 million to 28 million. Based on a previous study (Ipsos, 2004) savings for a 5-building scenario are 27.9 million per year[16].

For a corporate customer adopting a hybrid solution, OpEx per subscriber is based on the wireless operator charging the subscriber $20/month for data services, and additional charges per minute if a limit of 5MB is exceeded. The assumption is that 5MB will be enough for back-office applications, but additional charges maybe incurred when the subscriber is off-premises. Most of the data traffic for corporate customers is located at the customer's offices and is carried during office hours. Table 15 shows the required capital expenditures, operational expenditures, and expected revenues.

Table 15 Case C: CapEx, OpEx and Revenue for the Corporate Customer Adopting a Hybrid Solution with Option to Invest (Present Values in Millions)

Year	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
CapEx	$5.11	$0.00	$0.00	$0.00	$0.00	$0.00
OpEx	$0.00	$4.06	$3.64	$3.27	$2.93	$2.63
Revenue	$0.00	$25.04	$22.48	$20.18	$18.11	$16.26

[15] AT&T Wireless, now www.cingular.com

[16] In order to calculate the revenues, we used the white paper written by Ipsos Reid that studies ROI for a corporate wireless back-office solution, and evaluated the savings per year for an estimated salary per employee of $60,000 per year. Those savings were estimated as $5,580 per employee per year.

The volatility involved in the option to invest will be affected by the potential risk of acquiring equipment that is not yet available in the marketplace. The volatility is derived from the historical stock price movement of a major wireless device manufacturer. This company is the one expected to build and sell the device that will work in both cellular and Wi-Fi worlds with total interoperability and handover functionality between different technologies. Its performance is representative of this new segment of the wireless industry for the upcoming five years due to economies of scale and experience in a field where competitors are just starting to participate.

The present value of the expected cash flows V is estimated to be $102 million. The present value of investment costs I is $21.65 million. The investment cost does not include the cost of installing base station on the customer's premises. The annualized volatility, σ estimated from the historical price movement of the leading device manufacturer, is 85.63%. Volatility is high due to outstanding growth in the previous years. Same assumptions hold for the maturity T of the option, risk free rate r_f, number of floors and number of devices.

The option to invest, when the company is willing to deploy its own Wi-Fi network to provide and serve its employees and pay cellular operator when out of premises, is estimated to be $90.5 million. The total value of the project is $170.92 million. This is a consequence of high volatility and high expected revenues associated with increases in productivity.

Case D: Corporate Customer: Company Using Cellular Operator as a Wireless Service Provider and Dedicated DAS System on the Premises

In this case, the cellular operator will act as wireless service provider with a dedicated antenna system on the location.

- Cost associated with wireless devices to be acquired; wireless devices in this case will have no WLAN roaming capability, just a 2G-2.5G solution.
- Software platform to integrate wireless devices with Office Management Software.
- OA&M costs associated with having cellular base station on premises.
- Payments for wireless services provided by the cellular operator.

Table 16 summarizes the required investment and expected revenue stream. Assumptions with regard to the maturity T of the option and risk free rate r_f are the same. The present value of the expected cash flows V is $102 million. The present value of the investment cost I is $26.78. The annualized volatility σ is estimated to be 28% (similar to the case of a cellular solution, from the cellular operator standpoint).

Table 16 Case D: CapEx, OpEx and Revenue for the Corporate Customer Adopting a Cellular Solution with Option to Invest (Present values in Millions)

Year	**Year 0**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
CapEx	$3.66	$0.00	$0.00	$0.00	$0.00	$0.00
OpEx	$0.00	$5.67	$5.09	$4.57	$4.10	$3.68
Revenue	$0.00	$25.04	$22.48	$20.18	$18.11	$16.26

The value of option to invest in wireless services for mobile subscribers (5,000) when they are located on campus, paying a monthly subscription fee for the services offered by the cellular operator who has installed one cell site and a DAS system in each of the five buildings is calculated to be $80.5 million. The combined value of NPV and the value of the option to invest is $155.8 million. The value of the option is high, basically due to the fact that the savings incorporated due to improvement in productivity are high.

With regards to the Hybrid Solution and the Cellular Solution with DAS, savings associated due to increased productivity, down-time reduction, and revenues are the same, regardless of the technology chosen for In-Building wireless access to corporate back office applications. Figure 5 shows the value of the option, NPV (no option) and Expanded NPV (with option) of the project for a company paying for wireless data services to a cellular operator that provides services in and out of the customer premises.

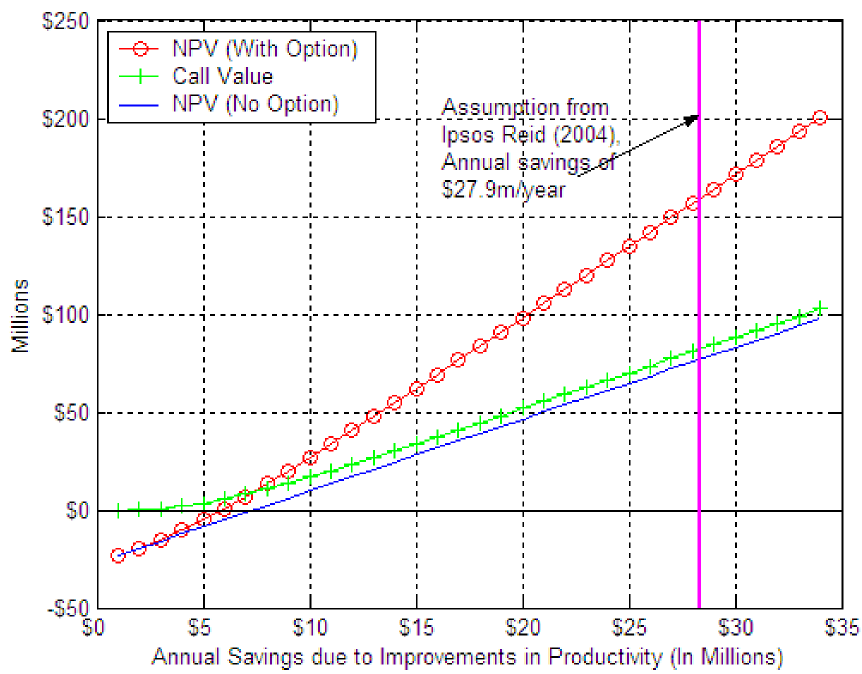

Figure 5: Change in NPV, Option and Investment Value (NPV + Option) for a Cellular Solution Adopted by a Corporate Customer Due to Change in Annual Savings

From the corporate client's perspective, Figure 6 confirms that the value of the option to invest in deploying a Wi-Fi network (hybrid solution) is always higher than the value of the option to invest in services provided by a cellular operator. Figure 7 confirms the NPV of implementing a Wi-Fi network for providing wireless services on premises is always higher than the NPV for paying a cellular operator for the same purpose. The difference is due to the reduction in the monthly fee from $50 to $20 per subscriber.

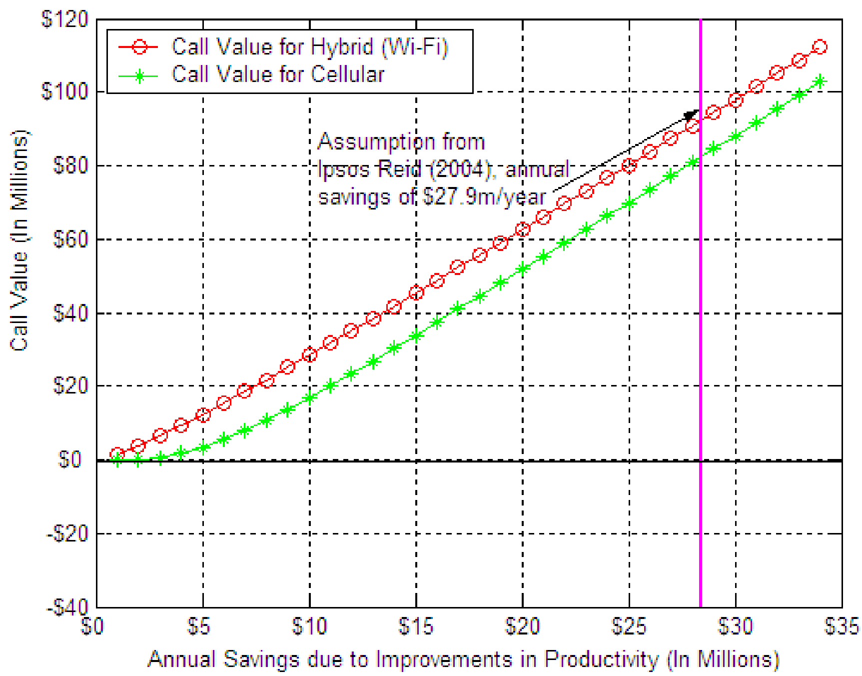

Figure 6: Corporate Customer Standpoint: Variation in Call Value for Cellular and Hybrid (Wi-Fi) Solutions Due to Change in Annual Savings

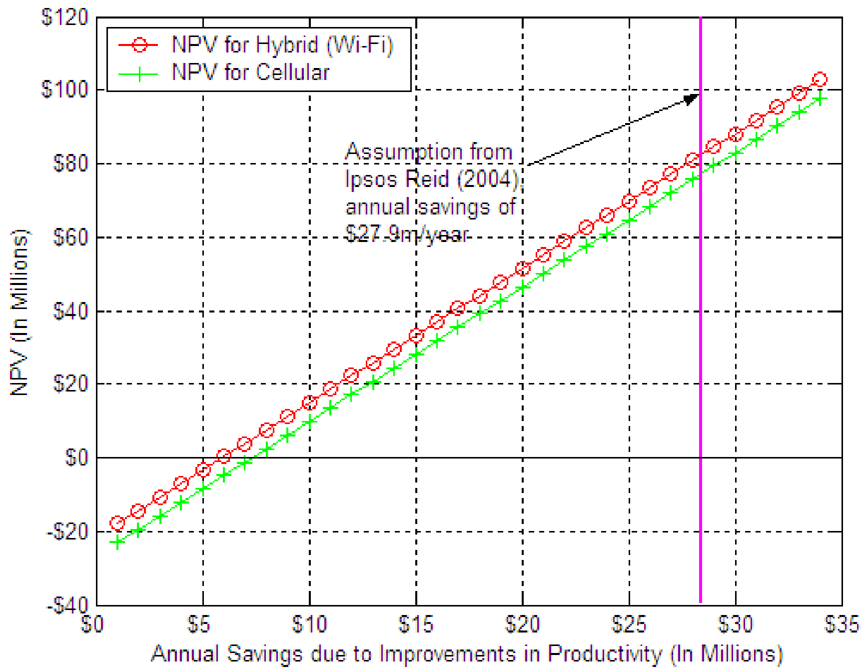

Figure 7: Corporate Customer Standpoint: Variation in NPV for Cellular and Hybrid (Wi-Fi) Solutions Due to Change in Annual Savings

Figure 8 summarizes the project values for the four cases from the cellular operator's and corporate customer's point of view. The total project value is the sum of the NPV and the option value (expand/invest) in the project. The maximum value of the expected cash inflows (annual savings) is similar to the one proposed by Ipsos Reid (2004). It can be seen that even for low values of expected savings due to increase in productivity, the value of a project from the corporate customer's point of view is higher than the solution involving implementation of network by the cellular operator (annual savings greater than $6 million/year). From the cellular operator's perspective, expected cash flows are the same, because the revenues are determined by the number of subscribers and monthly fees.

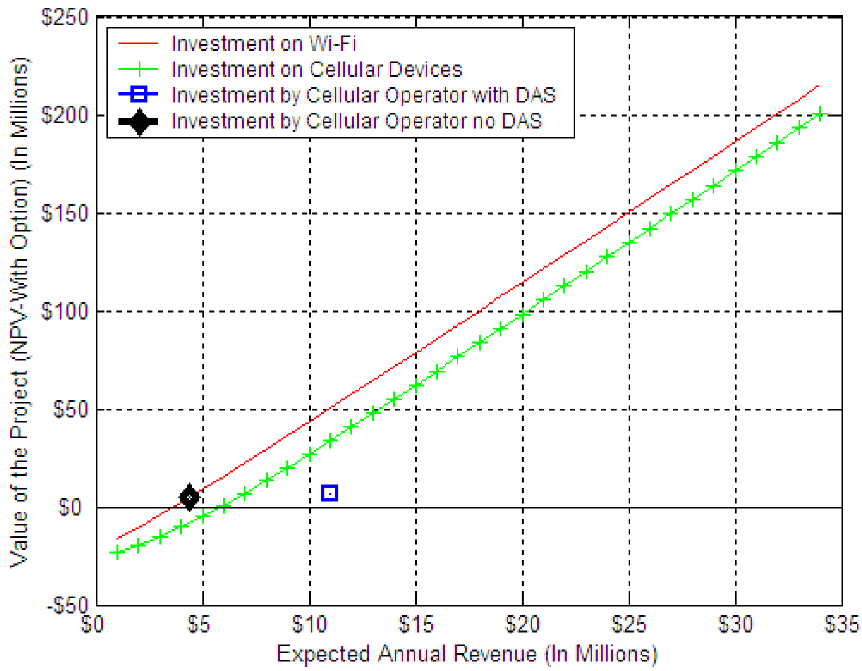

Figure 8[17] Variation in Value of Investment (NPV + Option) for both Cellular and Corporate Customer Perspectives Due to Change in Revenues

6. Replacing Traditional PBX Systems with Hosted VoIP Services

The deep-rooted old Public Switched Telephone Network (PSTN) has evolved from traditional circuit-switched systems to digital circuit-switched systems. Telephone service carried by the PSTN is referred to as Plain Old Telephone Service (POTS). PSTN networks, initially used for end-to-end voice communication, are now used as data networks. With the evolution of the Internet, the telecom industry has witnessed the convergence of voice and data applications thanks to the success of Internet Protocol (IP) and IP based networks.

[17] From the cellular operator perspective, there is no variation on revenues, because they are already given by the charges applied to the customer. From the corporate customer perspective, revenues can vary, because they depend of the estimated annual savings associated to improvement on productivity, measured by the corporate customer on its own.

IP is now used to transport voice packets within the IP datagrams through a variety of link layer systems. IP has been successful in making the network transparent to the upper layers involved in voice transmission through an IP based network. Even with the recent success and advancements it is not yet mature for voice communications. Private Branch Exchange (PBX) is a private telephone network within an enterprise that allows users to share a set of common telephone lines for making outside telephone calls or connecting to external PBX's. Many medium- and large-sized companies use a PBX because it is much less expensive than connecting an external telephone line to every telephone in the organization. Strong growth, about 100% year-over-year, is forecasted for IP Centrex/Hosted PBX through 2008. Nortel, Avaya, and Toshiba own most of this market. Much of this growth comes from Tier 1 providers entering the market. A network-hosted voice application, IP Hosted PBX Voice, provides business users with local dial tone, long distance, and voice features similar to those of an IP PBX. At present, this service is provided by Competitive Local Exchange Carriers (CLECs). New entrants to the market will likely include the Regional Bell Operating Companies (RBOCs), such as Verizon, SBC and Qwest, along with cable companies like Comcast, Cox and Cablevision. Revenues for the overall market are projected to grow from $281 million in 2003 to $6.7 billion by 2007. Much of this revenue will consist of account conversion from the traditional Centrex base, which may decline to $2.8 billion in 2007.

This section examines potential savings in hardware costs, provisioning, billing, maintenance and service with the new feature sets created as a result of converging voice on a data platform using the Internet Protocol (IP). An important factor is the drastic reduction in costs for providing VoIP services due to the new high-performance networks that scale efficiently and reduce costs from the legacy Class 4 and Class 5 switches. We compare the Centrix-based solution currently deployed by traditional voice carriers, e.g., the RBOC's and IXC's, using the hardware from Nortel Networks, Avaya and Siemens, with the one gradually being developed and deployed by the new VoIP providers, such as Vonage, 8 by 8, Deltathree, Net2Phone, and Skype in Europe.

Value Proposition: Hosted Service

The core value proposition for Hosted PBX business revolves around speed to market and providing a turn-key solution (Level 3):

- *Speed to Market:* Hosted PBX solution can be provided in 60-90 days from time of placing an order.
- *Turn-Key Solution:* The Hosted PBX solution provides a complete suite of interoperable services, including voicemail, conferencing, user and administrative portals, Local Number Portability (LNP), 911, and Class 5 services.
- *Reduced Capital Outlay:* Costs are only incurred as seats are sold, i.e., cost increases as business grows.
- *Ease of Use:* With the web-based Office Administrator (OA) interface, an administrative employee can perform all basic management functions needed to maintain the system. This leads to significant operational expense savings. The web user interface also provides easy access to the enhanced features of the product without complex telephone key-pad sequences.

Reduced Capital Costs

New capital investments for communications can eliminate the need for incremental PBX, IP-PBX, and voicemail system equipment. Operating budgets can be devised based on actual head count rather than by amortizing equipment over a fluctuating number of employees, thereby enabling the finance department to better manage their costs.

The high-tech market research firm, In-Stat/MDR[18], forecasts strong growth, about 100% year-over-year, for IP Centrex/Hosted PBX through 2008. It has also found that:

- At the end of 2003, service providers had approximately 40,200 IP Centrex/Hosted PBX seats in service in the United States. Covad (GoBeam) had the largest market share with 32%.
- The RBOCs' entrance into this market will greatly accelerate overall growth. Both SBC and Qwest launched their service offering in 2004. The other two U.S. RBOCs, Verizon and Bell South, are expected to enter the market as well.
- The current average monthly service for IP Centrex/Hosted PBX is $65, with $20 going toward Internet access and $45 for voice applications. The estimated average service installation fee is $175 per seat. These prices are expected to remain relatively constant during the forecasted period as a result of the overall competitive nature of the IP Centrex/Hosted PBX market.

[18] http://www.instat.com/

Reduced Operating Expenses (OpEx)

Many of the core operating expenses necessary to support a traditional IP PBX, TDM PBX or Centrex environment are eliminated with hosted services (Level 3). These include:

- *Telephony support staff costs*. The Office Administrator (OA) portal allows all service administration functions such as Moves, Adds, and Change (MACs) to be performed for any location from any location over the Internet. Basic functions such as MACs, establishing hunt groups and Bridged Line Appearances (BLAs), managing voice mail, and conferencing can be supported by an administrative specialist rather than requiring a telephony professional.
- *New capital cost*. As an enterprise grows or contracts, Hosted services sizes immediately to the appropriate scale since operating budgets can be devised based on actual head count.
- *Voice mail and conferencing costs and complexity*. Costs of supporting and maintaining multiple disparate voicemail and conferencing system can be eliminated. Employees can self-manage conferencing and voice mail features through the web-based Personal Communications Manager.
- Costs for Centrex system access and support are eliminated.
- Incremental costs for MACs and disconnections are eliminated.
- Reimbursements for communications costs to remote and mobile workers are eliminated.

Business Case Study: Financial Investment Firm

Hosted Voice over Internet Protocol (VoIP) Services

The case of a financial investment firm's investment decision is considered next. The company is headquartered in downtown New York City, with small offices in three other cities, Chicago, Atlanta and Los Angeles. Most of its fifty strong staff consists of account executives, project managers, designers, and copy specialists who are full time employees or contract workers.

Projections for the new Hosted services require purchasing new telephone sets for the offices. It is anticipated that 20% of the telephone sets will have advanced features, mostly used by administration and senior management. 50% will have medium set of features, and 30% will have basic features used in lobbies, copier rooms and general areas.

The backbone carrier is a VoIP service provider. A service provider has a robust network infrastructure with the ability to provide circuits on a VPN network solution using Quality of Service (Quest) and Priority Queuing of voice traffic within the network infrastructure. The cost of a voice Primary Rate Interface (PRI) line with 24 channels is $1,150 per month with a non-recurring one-time installation charge of $575 (Level 3). For individual Digital Signal One (DS1), a fixed nationwide price of $545 per month and a one time install charge of $350 are assumed (Level 3).

Assumptions in regard to local and long distance usage and charges are based on market research. Companies such as Vocaldata and Sylantro have done internal research with similar numbers. The number of calls per day per VoIP station is 13, of which 5 are local, 2 intrastate, and 7 interstate. The average length of these calls is 3 minutes. A 20-

day month is assumed resulting in minutes on a per seat per year basis: 3,600 local minutes, 1,440 intrastate and 5,040 interstate minutes. The average call breakdown is 50% interstate, 15% intrastate, and 35% local calls.

A Hosted VoIP solution requires upfront costs for the telephone system and installation or for leasing one of the three alternative solutions (Centrex, IP PBX, and TDM PBX). The Centrex solution is usually leased from a regional Bell company, e.g., Verizon. The IP PBX solution chosen to evaluate is from CISCO systems. The traditional TDM PBX market has been dominated by Nortel, Lucent and Ericcson. For comparative analysis, the Nortel solution is selected since it was the industry leader in the TDM-PBX market space (Nortel Networks). Again, similar to the IP-PBX, TDM-PBX has to be leased through a Nortel VAR member, e.g., Presidio Communications. The total capital required to migrate from a non-hosted environment to a hosted environment is broken down into three cost categories:

- Service costs associated with the lease of the hardware and software,
- Phone costs linked with the purchase or lease of the desktop phones, and
- Staffing costs related with the maintenance, MAC, upgrade costs, and labor costs associated with the maintenance.

In order to provide a framework for the analysis and to evaluate the costs of migrating to VoIP solution, two VoIP models currently available to the enterprises are selected: the Nucleus Research VoIP model as one comparison factor, and a model developed internally by Level 3 communications to help the channel partners evaluate the best VoIP solution for their enterprise customers.

The preferred solution is not a migration solution but rather an overhaul of the existing solution. Co-existence and any salvage value of the existing system are ignored. The solution provided assumes that the data infrastructure is already in place, for instance, there exists a private line, Frame Relay, or some type of IP-VPN solution. It is assumed that voice will ride over the same data network but with additional bandwidth. In calculating operational monthly charges, a transport cost associated with additional bandwidth riding over the same data network is included.

First-year costs include installation costs associated with setting up and configuring the solution. These include costs associated with setting up hardware, software, telephone installation, along with configuring the call manager and voice mail software. A 10% year-to-year growth in stations is assumed. The project starts off with 50 stations and ends with 83 stations at the end of the 5 year period.

As far as operational costs are concerned, the cost of transport is assumed to be a fixed charge for the life of the project. The value of the transport cost will differ in each of the alternative solutions since the amount of bandwidth required per voice line differs in order to maintain Quest and hardware constraints. In case of Centrex systems, there are no transportation costs involved as RBOC's include the cost of transport in the total lease price. Table 17 shows the capital expenditures (CapEx) and operational expenditures (OpEx) associated with each alternative solution for VoIP for a 5 year period.

Table 17: Investment Cost Break Down for Each Alternative

Year	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Hosted	$45,370.34	$42,391.38	$44,748.11	$46,899.52	$49,563.60
Centrex	$48,385.77	$47,421.04	$52,474.72	$57,558.55	$63,338.49
IP-PBX	$121,272.50	$110,401.80	$112,175,11	$113,480.94	$115,440.80
TDM-PBX	$139,547.26	$130,813.23	$132,737.34	$134,401.13	$136,562.92

The costs of an investment in present value terms for each of the alternatives are as follows: Hosted Services $172,708, Centrex Services $201,244.5, IP PBX solution $434,956.4, traditional TDM PBX solution $511,291.4.

Table 18 shows the cost savings of selecting a Hosted solution when compared to alternative solutions. Year 1 costs are higher due to the initial investment in operational costs to install, program desktop phones and associated switches, and train the user base. For the TDM and IP-PBX solutions, the costs tend to flatten out with gradual reduction in year 2 since the lease costs of equipment, software and phones will remain fixed for the duration of the lease. Discounting projected savings at a discount rate of 10%, the present value of the savings for the respective alternatives is as follows: Centrex $28,536.5, IP-PBX $262,248.4 and TDM-PBX system $338,583.4.

Table18: Capital Savings Projections per Solution

Year	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**
Hosted	$0	$0	$0	$0	$0
Centrex	$3,015.42	$5,029.66	$7,726.60	$10,659.03	$13,774.89
IP-PBX	$75,902.16	$68,010.43	$67,427.00	$66,581.42	$65,877.20
TDM-PBX	$94,176.92	$88,421.85	$87,989.23	$87,501.61	$86,999.32

The enterprise can replace the current costly solution with a Hosted solution (*option to switch*) as long as the benefits outweigh the costs. The firm can lease the services from service providers (*option to lease*). In this way the organization can eliminate in-house operational expenditures. In this scenario, the firm is simply paying the third party provider a monthly or an annual fee for the service and any additional fees for activating new features.

The Hosted VoIP market is faced with by multiple uncertainties: technical uncertainty, market uncertainty, heavy interdependence among the equipment players, etc. Provisioning of Hosted solution is like an option: the hosted solution provides the enterprise with the flexibility of subscribing features and services based on the need of the organization and scale of growth at will. Potential downside risk is associated with the heavy interdependence between the players and ever evolving substitutes in the market.

The opportunity to save in terms of initial investment costs, human resources, and billing and provisioning can be viewed as a portfolio of options. In the current scenario, management can gather information on available VoIP solutions and its potential to see if they fit into the organization's requirements, and then invest in deploying the Hosted solution. Moreover, the firm can expand using the Hosted services or switch between alternatives based on cost savings should the savings outweigh the costs. The service provider can expand into new market segments, offer new features and exploit advantages from provisioning the Hosted solution by being first in the market.

The firm desires to select the best solution based on comparative analysis of the Hosted solution with other systems currently available in the market. The problem is modeled as an American call option. The value of the underlying asset V is the present value of savings when a Hosted solution is deployed instead of an alternative solution (IP PBX, TDM PBX, and Centrex). The investment cost, I includes the costs associated with service, phone, and staffing of the alternative solution. The life of the project T is five years. Volatility, σ estimated from the historical stock price movement of hardware vendors (Lucent, Cisco, and Nortel) over the past five years, is 50%. The risk-free rate r_f is 8%. Table 19 gives the option value calculated with respect to the Hosted VoIP solution.

Table 19: Real Option Value

Solution	**Centrex**	**IP PBX**	**TDM PBX**
Real Option Value	$2,332.99	$103,183.49	$142,322.03

Table 19 summarizes the option value associated with each alternative in the telecom market compared to the Hosted solution. The real option value is high when the firm replaces the in-house switching services such as IP-PBX and TDM-PBX with Hosted managed solution. This is reflected in the cost savings projections (Table 19). Table 18 confirms that savings are higher when customers opt for Hosted solutions as compared to IP-PBX and TDM-PBX solution. In case of Centrex systems, the value of the option is small because of the small scale of deployment (the company is a 5-50 user business unit). The option value can make a big difference in case of large-scale deployment, e.g., by universities or government agencies.

7. Summary and Conclusions

Technology selection and deployment is a multifaceted process. The decision to deploy new networks involves not only acquiring the rights but is a consideration of capital expenditures, operational expenditures, number of subscribers, type of market, uncertainty around the market conditions, competition, and regulatory constraints. Real options theory presents an appropriate framework to analyze such investment decisions in the telecom industry.

We have analyzed five different case studies set in service as well as an enterprise market.

In the first case, a company that owns 3G spectrum considers deferring the deployment until favorable conditions develop. An immediate expansion of 2.5G network to 3G is not a profitable proposition, as both the capital expenditure and the uncertainty around the number of subscribers is high. The value of the option in this case was low given the prevailing market conditions and investment costs. Uncertainty around the number of subscribers is a key factor. The value of the project can become positive if there is a ten-fold increase in the number of subscribers.

In the second case, the company faces the option to look for alternative technologies to substitute in place of 3G networks. The company considers the option of integrating the 2.5G network with WLAN network to provide 3G like services. The investment is not a profitable solution when the operator is considering only the revenue from its existing subscribers of the integrated network. The option to expand is more profitable and viable when the operator is able to attract new subscribers to its existing Wi-Fi network. Expansion by integration provides a platform for offering new data-centric services, offers 3G-like services, and allows holding on to subscribers.

The third case centered on the challenges faced by an operator in becoming a successful WISP. The decision involves the evolutionary migration path from second to third generation systems. Technological, economic, and behavioral factors related to the decision-making process were considered. The case considers the possible migration paths that can be followed by BSNL, the national incumbent telecommunications services provider of India. Analysis discusses in detail the possible migration paths the company can follow. It considers the issue from the perspective of the operator, the equipment manufacturer, and the users. When flexibility and uncertainty are incorporated into the analysis, the project is more attractive. However, the NPV (with option) is still out of money. This is an example that real options consideration cannot always lead to positive NPVs.

The fourth case study deals with wireless services and their importance in the enterprise market. The benefits for the corporate customers and the cellular operators' point of view are substantially different. The savings due to the improvement in productivity are higher than revenues perceived by cellular operators from provision of wireless services. If integrated devices become a reality, corporate customers will have an important alternative to choose from, and cellular operators will have to adapt to reality. We saw that, it is more profitable for 2.5G operators to implement dedicated antenna systems for corporate customers than do nothing. For the corporate customers, an in-house, self-provided wireless service can represent a better opportunity for cost reduction.

The fifth case study dealt with the replacement of traditional PBX telephone systems with Hosted VoIP services. Adoption of VoIP has been slower than predicted. Early adopters of VoIP will likely be small companies with small number of employees. We saw that a managed solution is likely more effective for a company engaged in acquiring a new telecommunications solution. Our study involved a small company with a base of 50 employees. For companies with a large number of employees it might be cost prohibitive to migrate to a full-scale VoIP deployment. Firms with over 1,000 employees and those who have already invested in a traditional TDM-PBX system will find it less cost effective to move over to VoIP in a short period of time.

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2. 3rd Generation Partnership Project (3GPP), http://www.3gpp.org.
3. 3rd Generation Partnership Project 2 (3GPP2), http://www.3gpp2.org.
4. 9squared - Wireless Content Providers, http://www.9squared.com
5. AirDefense, http://www.airdefense.net
6. Alltura Solutions – http://www.alturacs.com /
7. AT&T Wireless, www.attwireless.com

8. Ayava — http://www.avaya.com/
9. Boingo Wireless, www.boingo.com
10. Boost Mobile, http://www.boostmobile.com.
11. Broadsoft hosted services provider — http://www.broadsoft.com/
12. CDG: CDMA Development Group, http://www.cdg.org.
13. CDMA Development Group (CDG), www.cdg.org
14. Cisco Systems – http://www.cisco.com/
15. DOT: Department of Telecommunications India (Licensor), http://www.dotindia.com.
16. Federal Communications Commission (FCC), http://www.fcc.gov.
17. GSM World, The Website of the GSM Association, http://www.gsmworld.com/index.shtml
18. Institute of Electrical and Electronics Engineers (IEEE), http://www.ieee.org.
19. Interlink Networks, http://www.interlinknetworks.com.
20. IP Wireless - Generation Ahead, http://www.ipwireless.com/index.html.
21. Level (3) Voice Services – http://www.level3.com/
22. Motricity, http://www.motricity.com
23. Nortel Networks – http://www.nortel.com/
24. Presidio Corporation TDM services Provider – http://www.presidio.com/
25. Qualcomm, www.qualcomm.com
26. SK Telecom, Most Valuable Company, http://www.sktelecom.com/eng/index.html/
27. Sonus softswitch services – http://www.sonus.com/
28. Sylantro Systems softswitch services – http://www.sylantro.com/
29. Tekcetera hosted services provider – http://www.tekcetera.com/voip.htm
30. T-Mobile USA, http://www.tmobile.com/
31. UMTS Forum, www.umts-forum.org
32. UMTS World, www.umtsworld.com
33. United States Department of Treasury, www.ustreas.gov
34. UPOC Networks, http://upocnetworks.com.
35. Veraz Networks softswitch services – http://www.veraznetworks.com/
36. Verizon Networks – http://www.verizon.com/
37. Vertical Networks, total solutions provider – http://www.vertical.com/
38. Virgin Mobile, http://www.virgin.com/gateways/mobile.
39. Vocaldata hosted services provider – http://www.vocaldata.com/
40. Vonage voice services – http://www.vonage.com/
41. Web Site Optimization, http://www.websiteoptimization.com.
42. Woosh in New Zealand, http://www.woosh.com
43. IEEE 802.11, The Working Group Setting the Standards for Wireless LANs, http://www.ieee802.org/11/