
Valuing wireless data services solutions for corporate clients using real options

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Abstract: The paper deals with wireless data services and their importance in the enterprise world. Provisioning in difficult-to-reach areas of tall buildings is challenging. To extend coverage, operators deploy ad-hoc solutions that are usually costly. Four alternative deployment cases from both the corporate customer's as well as service provider's point of view are proposed and quantified using real options. The objective is to maximise revenue and reduce risk for operators while improve customer satisfaction levels within the budget constraints of the customer. Analysis suggests that savings due to improvements in productivity are much higher than revenues perceived by the service provider.

Keywords: wireless; Global System for Mobile Communications (GSM); EDGE; UMTS; Wi-Fi; real options; investment analysis decisions; Net Present Value (NPV).

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1 Introduction

Wireless data services, an industry that is starting to generate important revenues for service providers and benefits for subscribers, has become a very important tool for companies that are looking for improvements in productivity, efficiency, and communications (Wickramasinghe and Goldberg, 2004).

Mobile telephony operators, using different technologies, are currently offering wireless voice and data services to the general public and also to business customers, who are an important segment of the market. These are usually companies (e.g., financial institutions, etc.) that are adopting wireless services as a tool to increase productivity, support telephony, Short Message Service (SMS), and most importantly, to have the possibility of synchronising traditional office software applications (e.g., 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 (Varshney et al., 2004). There are scenarios where the traditional cellular operators cannot guarantee coverage for their service in isolated spaces, for example, 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. (Lin and Vassar, 2004). In order to address these problems, cellular operators can deploy ad-hoc solutions, dedicated base stations for example, incurring additional expenses. The success of these alternatives depends on the consistency of the business cases carried out for that purpose.

The aforementioned challenge forms the foundation of our research and leads to a potential case: the necessity of cellular operators to provide quality wireless services to business customers that can be reached in challenging coverage areas. At the same time, business customers that need these services have to evaluate all the available choices in the marketplace and make decisions on the service to adopt based on reliability, quality, customer service, technical support and, last but not the least, cost (Varshney et al., 2004).

Both the current cellular network operators and the corporate market (companies with a significant mobile telecommunications infrastructure) have to understand the challenges for their respective position in the wireless market and follow optimal strategies in order to maximise revenue and reduce risk (for operators), as well as keep the mobile service performance at a desirable quality standard within a minimum budget (for business customers).

Cellular operators would like to consolidate themselves as the main mobile communications service providers for the corporate market. They are challenged by high investment cost to deploy high-speed wireless data networks with no certainty of success in the upcoming years. Secondly, the availability of disruptive technologies like Wi-Fi (currently available), and some still-under-development technologies promising to offer wireless broadband data services, e.g., WiMAX, could change the scenario for enterprise customers in highly dense metropolitan areas like New York City.

On the other hand, the enterprise market has more choices to choose amongst the wireless data technologies. Because of that, companies or government agencies need to follow an optimal strategy for their organisation, and at the same time, keep corporate mobile communications at desired performance levels and minimum cost (McMohan et al., 2005).

This paper aims to evaluate costs and risks for different alternatives regarding wireless data services for the corporate market, both from the service provider's and customer's perspectives. Real options analysis will be used to evaluate and determine viable choices for wireless mobile telecommunications in the corporate market.

The following section reviews the wireless data services, and provides an overview of financial as well as real options theory. In Section 3, detailed qualitative and quantitative analyses of proposed individual cases are presented. In Section 4, the proposed cases are compared. Finally, in Section 5, the study is summarised.

2 Background

2.1 Wireless data services overview

The evolution of wireless technologies has provided new tools and different ways to solve not just communication problems but also organisational and practical issues that affect everyone.

Second Generation (2G) cellular telephony platforms emerged in the marketplace during the 1990's with improved network capacity and new services. Advances in modulation and process of voice signals allowed the systems to allocate more phone calls along the available spectrum. More dramatic was the progress on additional services, given the fact that all of the information involved on call processing was not analog anymore. The possibility of integrating that information on different databases opened a new world of possibilities: SMS, Call Forwarding Features, advanced encryption, security enhancements, and interoperability with data networks. In the USA, Time Division Multiple Access (TDMA) and Code Division Multiple Access (CDMA) became the most popular choices, gradually improving the existing first generation Advanced Mobile Phone System (AMPS) networks. Another proprietary technology, Integrated Digital Enhanced Network (iDEN) became commercially available, offering wireless telephony and two-way radio services. At the same time, Global System for Mobile

communications (GSM), the European counterpart of 2G services, positioned itself as the most widely adopted standard all around the world (Europe and most Asian countries). Personal Digital Cellular (PDC) was the Japanese approach.

Initially, cellular networks were primarily designed to provide voice services. Progressively, alternatives to provide data services were implemented, supported by the existing networks. For the AMPS/TDMA world, Cellular Digital Packet Data (CDPD) was the proposed solution. GSM offered General Packet Radio Service (GPRS) and CDMA offered 1X Radio Transmission Technology (1XRTT); iDEN offered packet data. These technologies allowed subscribers to get connected to private (corporate) and public networks (internet). Although more advanced services are already available in the market place, GPRS, 1XRTT and packet data are still the most widely adopted wireless technologies representing the most significant source of revenue for offered wireless data services in highly dense metropolitan areas.

2G wireless data services created the platform for new applications and devices by offering integrated solutions. Data services (e.g., web browsing, wireless email) and interconnection to office management applications (e.g., calendar, to-do lists and contact information) on one single device were provided along with existing voice services. These integrated solutions have become helpful for the corporate world given the possibility of efficiency improvements and savings due to more efficient access to information technology tools virtually 'anytime, anywhere' (or at least where cellular service is available). It is true that wireless services provided by cellular operators have limited coverage; it is not easy to predict and propose a network infrastructure able to offer quality wireless services with 100% accuracy and guaranteed coverage everywhere (Varshney et al., 2004).

Nowadays, mobility has become a necessity, and permanent access to email and information technology tools provides benefits on immediacy (reaction to sensitive information within a short timeframe) (Wickramasinghe and Goldberg, 2004). E-mail is one of the fastest and most efficient ways to relay any kind of information. A single device that allows users to have access to an integrated information system becomes crucial for telecommuters, not to mention the possibility of having access to these resources out of premises.

Regarding the design of cellular networks, base stations' location is generally oriented to provide service to a given amount of subscribers in a given area with no common circumstances, activities, or behaviour patterns, thereby making the design assumptions more generic. The corporate market is a case where operators have to ensure quality service for specific circumstances and subscribers who follow very well-defined behaviour patterns. Bottom line is, a generic approach to a specific problem cannot guarantee customer satisfaction.

For these previously mentioned reasons, cellular operators can offer specific solutions. Distributed Antenna Systems (DAS) connected to a cell site station located on customer's premises can solve this problem, at least from the technical point of view. A solution designed to provide wireless services on an In-Building scenario can be implemented, installing antennas on suitable locations and connecting them to the on-premises cell site using DAS. The problem that comes with a tailored solution is not just technical, but financial, too. These ad-hoc solutions imply higher costs (material- and labour-related), making this approach technically possible but not always financially feasible.

On the other hand, the appearance of potential disruptive wireless technologies introduces more variables on the corporate market regarding wireless infrastructure. Wireless Local Area Networks (LANs), or, Wi-Fi, have reached a significant level of popularity in offering new choices for data services. WLAN, already standardised (<http://www.ieee802.org/11/>) and widely available, can offer higher throughput and easier implementation than cellular-based solutions, not to mention lower costs (IEEE 802.11 WG). Main drawback could be the lack of mobility, given the fact that WLAN coverage is usually limited to very small areas ('hot spots'). One of the most important advantages associated with WLANs is that they can operate in an unlicensed spectrum. WLAN technology is simple to deploy, is cheap, and offers high speed data connections. Furthermore, no fee – or, a reduced one – has to be paid to a cellular operator. Due to WLAN's limited coverage area, an individual can manage the coverage and interference limitations easily.

Emerging wireless technologies for fixed and mobile communications, like WiMAX, are expected to hit the marketplace in the upcoming years. The reason for choosing a hybrid scenario involving cellular and WLAN for this analysis lies in the fact that WiMAX for mobile communications has not been standardised at the time of writing this paper. Metropolitan WiMAX networks are not built yet; it will take several years for this technology to provide a competitive coverage comparable to the one already available (i.e., cellular) and achieve economy of scale. For example, in the USA, the spectrum band for WiMAX deployments is not yet available. So far, FCC has granted experimental trail licenses to potential providers in 3.5 GHz band.¹ On the other hand, WLAN has been extensively deployed all around the USA and other developed economies and its implementation and constraints are very well known, not to mention the commercial availability of network equipment and compatible mobile devices (e.g., offered by <http://www.sktelecom.com> and <http://www.t-mobile.com>).

The idea of a hybrid scenario, where cellular operators provide services to corporate customers when they are out of the company's premises and use WLAN as internal wireless service solution, becomes a possibility to take into account. Cellular operators offer different plans for data services, e.g., paying a low monthly fee, plus additional charge if a given amount of received kilobytes is exceeded, or just a higher monthly fee with no additional charge, as an unlimited service, regardless of the received kilobytes. Most of the traffic that is generated by integrated devices is located on premises during work hours, thereby making the hybrid scenario a choice that deserves attention. A study of costs and profitability would validate (or reject) the possibility of additional savings for corporate customers that employ wireless data services as an information technology tool.

At the time the research was conducted, a device capable of offering interoperability between cellular and WLAN network was not available in the market place. According to a press release by Nokia, Nokia 6136 phone capable of offering interoperability would be commercially available by June 2006.² This device would allow corporate customers to use Voice over Internet Protocol (VoIP) over WLAN (VoWLAN), which then could be integrated to an existing iPBX (a local dedicated telephony exchange that works over IP protocol), providing an extended feature set for total integration, resources optimisation and, at the end of the day, savings.

2.2 Traditional valuation

Typical Discount Cash Flow (DCF) analysis provides the cost of an investment in present value terms, assuming that future cash flows are known and discounted at a risk-adjusted factor, e.g., Weighted Average Cost of Capital (WACC) (Damodaran, 2002). The Net Present Value (NPV) is the difference between the present value of the asset and the initial investment cost K . The NPV today is given as follows:

$$\text{NPV} = \sum_{n=1}^N F_n (P/F, i\%, n) - K = V - K \quad (1)$$

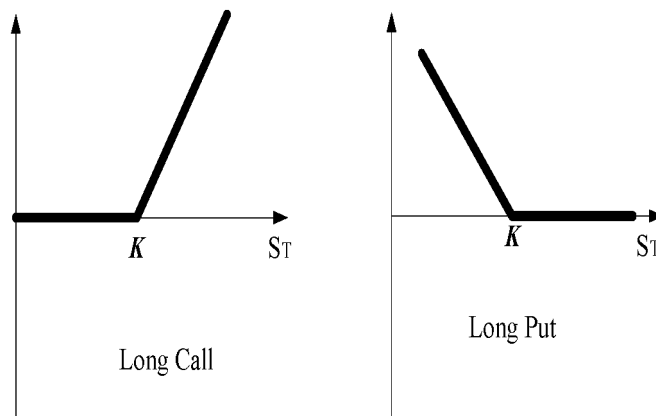
where F_n is the expected cash flow at the end of n th period, and i is the discount rate per period. In this study, it is assumed that the discount rate remains constant during the life of the project. Finally, the project should be undertaken if $V > K$, i.e., the project has a positive NPV and should be abandoned if $V < K$.

2.3 Financial options theory

An option is a contract that gives the buyer the right, but not the obligation, to buy or sell an underlying asset at a specific price on a certain future date (Hull, 2003). There are basically two types of options: call options and put options. A call (put) option permits the holder the right, not the obligation, to buy (sell) the underlying asset at a certain date for a certain price. The price in the contract is known as the exercise price or strike price; the date is known as the expiration date or maturity. US options can be exercised at any time up to the expiration date; whereas European options can be exercised only on the expiration date itself.

If K is the strike price and S_T is the final price of the underlying asset, the payoff from a long position in a European call option is: $\max(S_T - K, 0)$. The payoff to the holder of a long position in a European put option is $\max(K - S_T, 0)$. The payoffs of the different positions are shown in Figure 1. In order to price options, the Black Scholes-Merton Partial Differential Equation (PDE) is used. There are several ways to solve that PDE: numerically (lattices), in discrete-time via binomial/trinomial trees, or via the Black-Scholes formula, if it is a European option.

Figure 1 Payoff from options



2.4 Managing real options

Real options theory is a methodological approach within which a real life investment can be analysed while factoring in flexibility and uncertainty. Real options have been applied in many different sectors, such as Pharmaceutical, Energy, Mining, and Information Technology (Mun, 2002; Schwartz and Trigeorgis, 2001; Trigeorgis, 1996; Benaroch and Kaufmann, 1999). In the telecommunications industry, real options methods have been used in valuating products, companies, as well as forecasting capacity (Alleman and Noam, 1999; Alleman, 2002; Alleman and Rappoport, 2002, d'Halluin et al., 2002, 2003; Athwal et al., 2005; Harmantzis and Tanguturi, 2004a, 2004b; Tanguturi and Harmantzis, 2005).

Pricing techniques developed for financial options can generally be mapped to investment options, as shown in Table 1. Table 1 helps managers identify the parameters in financial options and map them to real options in order to model the investment problem.

Table 1 Mapping between investment opportunity and financial (stock) options

<i>Investment opportunity</i>	<i>Variable</i>	<i>Stock options</i>
Expenditure required to acquire the assets	K	Exercise price
Present value of the assets	S_0	Current stock price
Time to expiration	T	Time to expiration
Riskiness of underlying assets	σ^2	Variance of returns
Time value of money	r_f	Risk free rate

Valuing a project that requires a significant irreversible investment and up-front cost to develop a new product or services is a risky decision due to the inherent uncertainty in the field. Telecommunications industry is a suitable domain with high volatility and high-technology investments (Alleman, 2002; Bughin, 2001). The wireless arena is evolving at a fast pace with newly emerging technologies and applications. The wireless industry is much more complex with fierce competition to capture a niche market. Users have the choice to select from an array of existing technologies based on their needs. Technology choices are complex as the current telecommunications business is highly interdependent on different players, e.g., equipment providers, integrators, service providers, application service providers, and device manufacturers. Final decisions are dependent on multiple variables. Traditional NPV does not factor the project's risk except for an increase in the discount rate used in the calculations. DCF leaves no scope for changing the course of action when new information becomes available. Because the project is a set of different options, a model is needed to account for uncertainty and to permit flexibility.

Dynamic capabilities of real options have been applied in different industries and have been proposed in the wider area of telecommunications, e.g., telephony, broadband, internet, cable, wireless, etc. (Alleman and Noam, 1999; Alleman, 2002; Alleman and Rappoport, 2002; Bughin, 2001; Iatropoulos et al., 2004). Researchers have applied real options theory to issues related to strategic evaluation, estimation, cost modelling, quantifying regulation issues, and successfully demonstrating the impact of regulatory constraints on cash flows and the investment valuation process (Alleman and Noam,

1999; Alleman, 2002; Alleman and Rappoport, 2002; Economides, 1999). d'Halluin et al. study the risks faced in the bandwidth market using real options to determine optimal time for investments into increasing network capacity (d'Halluin et al., 2002, 2003). Herbst and Walz (2001) adopt real options to analyse the value of auctioned UMTS licenses in Germany, the largest European market. Their model is based on an *option to abandon* and *growth options*. Edelman et al. (2002) use real options to shed light on the complicated issues of strategic alternatives in the telecommunications industry. Kulatilaka (2001) explains the current situation in 3G deployment with the help of fundamental critical management questions such as what, why, when, and how the real options approach helps in the decision-making process in a comparative manner. Kulatilaka and Lin (2004) find the unique optimal licensing fee that results in a single standard. Paxson and Pinto (2004) examine the timing issue of a Portuguese telecom carrier in 3G investment using real competition option models. They showed that while traditional NPV calculations point to an immediate investment and entry of all the players in the market, in reality it does not happen. Their options models suggest delay of entry for the follower. Iatropoulos et al. (2004) apply real options to examine the economics and the risk associated with broadband network roll out in Greece for 'Egnatia Odos SA' (EO). Bughin (2001) outlines the broadcasting industry's major option types, illustrates the way to value them, and finally discusses the real options process which has been implemented by various broadcasters around the world.

2.5 *Valuation of embedded option: option to expand*

The option to expand provides the ability and the right to expand into different market segments. The value of the option to expand can be estimated using the Black-Scholes option pricing model (Damodaran, 2002). For example, Basili and Fontini (2003) apply the Black-Scholes Model to value the aggregate option value of the UK 3G telecom license. Furthermore, Bowman and Moskowitz (2001) as well as Benninga and Tolkowsky (2002) use Black-Scholes and the binomial tree method to show an application of real option evaluation to research and development valuation in the pharmaceutical industry. Amram and Kulatilaka (1999) use Black-Scholes model in one of the cases analysed in their book. Benaroch and Kaufmann (1999) suggest that Black-Scholes and Binomial models are appropriate for emerging technology investments, technology-as-product investments, and IT infrastructure investments.

The project can be formulated as an USA call option because the option can be exercised any time until the expiration date, which is an approximation contrary to the European call option. Pricing of the USA option is usually done numerically (finite difference method, trees, Monte Carlo simulations, etc.). The Black-Scholes closed form solution for European options can be used as an approximation. The value of the option to expand can be estimated by using a modified Black-Scholes formula (Damodaran, 2002):

$$c = S_0 N(d_1) - Ke^{r_f T} N(d_2) \quad (2)$$

$$d_1 = \frac{\ln(S_0 / K) + (r_f + \sigma^2 / 2)T}{\sigma\sqrt{T}} \quad (3)$$

$$d_2 = d_1 - \sigma\sqrt{T} \quad (4)$$

in which S_0 is the current price of the asset, K is the exercise price or the strike price, T is the time to expiration, r_f is the risk-free rate of return, σ is the annualised standard deviation, and $N(d)$ is the cumulative normal density function.

3 Case study framework

The company/client is located in downtown Manhattan, occupies five buildings with an average of 55 floors³ each. It needs to implement wireless services for its staff, synchronising 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 implies the installation of a dedicated base station system and required infrastructure i.e., cabling, antenna systems, fibre-based repeaters, etc., and the acquisition of the wireless handsets. Cellular operator will be responsible for providing voice and data services to the employees of the organisation.
- *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 services will be provided by the company's network within the company's facilities, and by a cellular operator outside the enterprise environment.

Furthermore, based on observed traffic patterns, the following realistic assumptions are made for the analysis:

- for a 55-storied building, at least 1,000 wireless devices dedicated to voice and data services will be found; the five 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 million sq feet (around 36,400 sq feet per floor)
- the cost of every single wireless device will be approximately \$366 (Ipsos, 2004).

The proposed methodology for the cellular solution is based on an option to expand. It focuses on deployment of dedicated base stations to n customers, given the risk that could represent the customers' 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 evaluation is based on the risk associated with the availability of fully-integrated VoWLAN and cellular handsets.

In regards to the option parameters, the following assumptions are made:

- S_0 , the current price, is the present value of the future cash flows, i.e., revenue from wireless services as the underlying asset
- the life of the project is five years which relates to the maturity of the option T
- the strike price K is the investment cost of the project that is the sum of capital expenditure and operation expenditure

- 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 considered
- the risk-free interest rate r_f of 4.25%, corresponds to the current US Treasury Bonds Rates, and corresponds to the maturity of the option (www.ustreas.gov).

3.1 Analysis of proposed solutions and resultant alternatives

Downtown Manhattan is home for very important companies spanning across the financial as well as 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.⁴ This limitation and the necessity of providing quality service to enterprise customers makes In-Building dedicated solutions an ideal solution for coverage, capacity and quality concerns.

Based on the two proposed solutions, i.e., 2.5G services without WLAN services and a hybrid solution (2.5G + WLAN), the outcomes resulting from the two approaches are analysed (Table 2):

- *Cellular and DAS, from the cellular operator's standpoint.* the wireless operator builds a base station within customer's premises, and implements a DAS.
- *Cellular and no DAS, from the cellular operator's standpoint.* 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.
- *Hybrid solution, from the corporate customer's standpoint.* Implement WLAN as on-premises solution for wireless services and a 2.5G carrier for out-of-premises service.
- *Cellular and DAS, from the corporate customer standpoint.* Use a wireless carrier as a service provider with a dedicated antenna system solution on-location.

Table 2 Summary of technical solutions and different views

<i>Technical solution</i>	<i>Standpoint</i>	
	<i>Wireless carrier</i>	<i>Corporate client</i>
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.

3.2 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, fibre 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.⁵
- Revenue generated by wireless service consumption due to data traffic.⁶
- *Rent.* Usually corporate customers allow cellular operators to be located on premises with no additional costs (for the cellular operator).

For this and the other three cases, assumptions for implementation cost, labour, and equipment have been taken from real life experience and available public information for hardware, handsets, network gear, and maintenance.

Table 3 summarises capital expenditure (CapEx), operational expenditure (OpEx), and revenues. For the DCF valuation, the cash flows are discounted using a WACC of 10.8% (Katz and Junqueira, 2003); implementing this stipulation, the present value of expected revenues S_0 is calculated to be \$10.97 million and the present value of investment cost K is calculated to be \$9.19 million. In regard to the maturity of the option, T is five years (Infinite life is not a realistic assumption because of the limited service life of the wireless devices caused by changes in technology or equipment upgrades). The volatility σ of the option to expand is affected by the potential risk of deploying equipment that will be obsolete due to the success of disruptive technologies capable of providing the same telecommunications solutions for a lower price. The wireless arena is characterised by tough competition, mergers and acquisitions, regulatory concerns, and uncertainty. The volatility used here is calculated from the historical price movements of the Dow Jones Telecom Index (IYZ)⁷ and is estimated at 28.15%⁸ annually. The risk free rate r_f of 4.25% is consistent with US Treasury Bond rates, corresponding to the life of the project (www.ustreas.gov).

Table 3 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)

<i>Year</i>	<i>Year 0 (\$)</i>	<i>Year 1 (\$)</i>	<i>Year 2 (\$)</i>	<i>Year 3 (\$)</i>	<i>Year 4 (\$)</i>	<i>Year 5 (\$)</i>
<i>CapEx</i>	7.00	0.00	0.00	0.00	0.00	0.00
<i>OpEx</i>	0.00	0.54	0.48	0.43	0.39	0.35
<i>Revenue</i>	0.00	2.69	2.42	2.17	1.95	1.75

From equation (2), the value of the option to expand is calculated as \$4.45 million. The combined value of the NPV of the project and the value of option to expand is \$6.23 million.

3.3 Case B: cellular operator does not install base station and no Distributed Antenna Systems (DAS) system will be built either

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. Furthermore, assumptions regarding the number of subscribers and the geographical location remain similar to the previous case.

- Operation, Administration and Maintenance (OA&M) cost for the system.⁹
- 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. The crucial point is that 80% of the data traffic will be carried out by the company's infrastructure so fees for additional kilobytes will be minimum or even null.

Table 4 summarises the investment breakdown and revenues for the case. The present value of the future cash flows S_0 is calculated to be \$4.39 million using a discount factor of 10.8%. The present value of investment cost K is \$2.19 million discounted at 10.8%. It is important to note that in this case the cellular operator does not install any base station on the customer's premises. The annualised volatility σ is calculated to be 28.15%, similar to the previous case. The maturity of the option T is five years. The risk free rate r_f of 4.25% is consistent with the USA Treasury Bond rates corresponding to life of the project. From equation (2), 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. It is worth emphasizing to the reader that, in this case, the 2.5G operator will provide guaranteed services to its 5,000 corporate customers outside of the company's premises, whereas the In-Building cellular coverage is not guaranteed. One can observe that this case is not addressing the main problem of providing quality In-Building coverage for the company.

Table 4 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)

<i>Year</i>	<i>Year 0 (\$)</i>	<i>Year 1 (\$)</i>	<i>Year 2 (\$)</i>	<i>Year 3 (\$)</i>	<i>Year 4 (\$)</i>	<i>Year 5 (\$)</i>
<i>CapEx</i>	0.00	0.00	0.00	0.00	0.00	0.00
<i>OpEx</i>	0.00	0.54	0.48	0.43	0.39	0.35
<i>Revenue</i>	0.00	1.08	0.97	0.87	0.78	0.70

3.4 Case C: corporate customer: company uses its own WLAN on-premises network to provide wireless services

For this specific case, the firm decides to provide on-premises wireless services using its own WLAN network. The following cost assumptions have been considered:

- Cost of wireless access point and integration into the existing LAN. For the simplicity of the analysis, one access point per floor, including cabling and connections, connectors, and minor hardware related costs are considered.
- Cost related to DAS, i.e., fibre, coax cable installation and antennae, labour cost, and cost 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 (<http://www.airdefense.net>; Young et al., 2006).
- Payments for wireless services provided to staff members when off-premises. Estimated proportion of geographical distribution of traffic will be 80% on-premises, 20% off-premises. Plans with minimum monthly fee (\$20/device)¹⁰ that also include 5 MB for free are enough to support 3.6 MB per user (approx.).
- Finally, the OA&M costs.

It is argued that expected revenues are important for this case. For this analysis we refer to a previous study on savings due to improvements in productivity (Ipsos, 2004). At the same time, this study also takes into account a wide range of possible values for that matter. The value of the project is a function of estimation of savings ranging from 1 million to 28 million. Based on a previous study (Ipsos, 2004) savings for a 5-building scenario is 27.9 million per year.¹¹

For a corporate customer adopting a hybrid solution, OpEx per subscriber with regards to wireless services is taken from one of the wireless operators' website for a limited data plan, which charges the subscriber \$20/month for data services, and additional charges per minute are incurred if a limit of 5 MB is exceeded. The assumption is that 5 MB will be enough for back-office applications, additional charges may be incurred when the subscriber is off-premises. Also, based on experience and observation of data traffic patterns on the field, most of the data traffic for corporate customers is located at the customer's offices and is carried during office hours. Table 5 shows the required capital expenditure, operational expenditure, and expected revenues.

Table 5 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

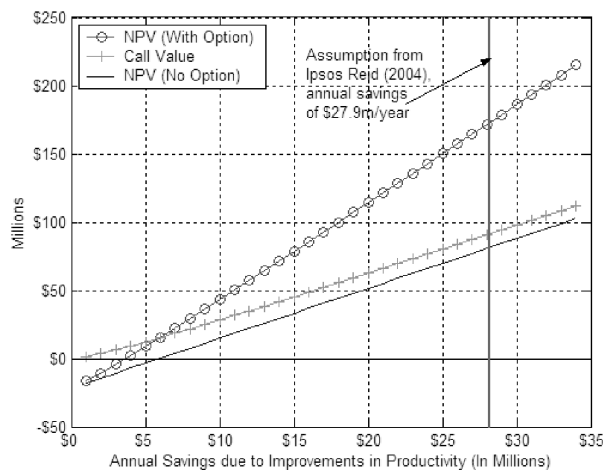
Before calculating the option parameters, it is worthwhile to discuss the volatility factor. The volatility involved in the option to invest will be affected by the potential risk of acquiring equipment that is not yet available in the marketplace. The volatility in this case is derived from the historical 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. Some competition is expected for this company in the future, but at this juncture, it is the leader in wireless handsets for back-office applications. Its performance will be representative of this new segment of the wireless industry at least for the five upcoming years due to economies of scale and experience in a field where competitors are just starting to participate.

From the traditional valuation approach, the present value of the expected revenues S_0 is calculated to be \$102.07 million. The present value of investment cost K is \$21.65 million. The investment cost does not include the cost of installing base station on the customer's premises. The annualised volatility σ is calculated from the historical price movement of the device manufacturer, and came out to be 85.63%. Calculated volatility is high as the manufacturer has experienced an outstanding growth in the previous years. Furthermore, manufacturer products and current market share in the industry hold relevance to the above discussion. Same assumptions hold for the maturity T of the option, risk free rate r_f , number of floors, and number of devices, as in the previous case.

From equation (2), the value of the option to invest, i.e., 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 calculated to be \$90.50 million. The total value of the project, i.e., sum of NPV and value of the option to invest in the project, is \$170.92 million. This is a consequence of both high volatility and high expected revenue associated with increase in productivity.

Figure 2 shows different values of the option and the whole project value associated with different values of savings. It can be seen that the project will have positive NPV for a wide range of possible values of savings, much lower than the already proposed value.

Figure 2 Change in NPV, option and investment value (NPV + option) for a hybrid solution



Source: Adopted by the corporate customer, due to change in annual savings

3.5 Case D: corporate customer: company using cellular operator as a Wireless Service Provider (WSP) and dedicated DAS system on the premises

In this case, it is hypothesized that cellular operator is going to act as WSP 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 2–2.5G 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 6 summarises the required investment and expected revenue stream. As far as the option parameters are concerned, assumptions with regard to the maturity T of the option and risk free rate r_f remain the same, as in previous cases. Via DCF calculations, the present value of the expected revenues S_0 is calculated to be \$102.07 million using a discount rate of 10.8%. The present value of the investment cost K is calculated to be \$26.78 million discounted at 10.8%. The annualised volatility σ is calculated to be 28.15%, similar to the case of a cellular solution, from the cellular operator standpoint.

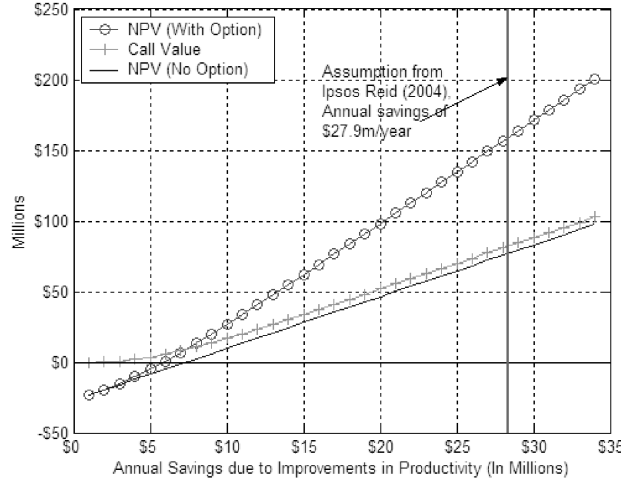
Table 6 Case D: CapEx, OpEx and revenue for the corporate customer adopting a cellular solution with option to invest (present values in millions)

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 \$80.48 million. The combined value of NPV and value of the option to invest is \$155.78 million. As expected, the value of the option is high; this can be attributed to the fact that the savings incorporated due to improvement in productivity are high.

It is important to note that in regard to the Hybrid Solution and the Cellular Solution with DAS, savings associated due to increased productivity, down-time reduction, and revenues are the same. This is regardless of the technology chosen for In-Building wireless access to corporate back office applications. Figure 3 shows the value of the option, NPV (no option) and 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 3 Change in NPV, option and investment value (NPV + option) for a cellular solution



Source: Adopted by a corporate customer due to change in annual savings

4 Comparative analysis of proposed cases

In this section, proposed cases are compared in order to recognise the best alternative in the provisioning of wireless services. From the corporate client’s perspective in Figure 4, 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. As Figure 5 shows, 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 4 Corporate customer standpoint: variation in call value for cellular and hybrid (Wi-Fi) solutions due to change in annual savings

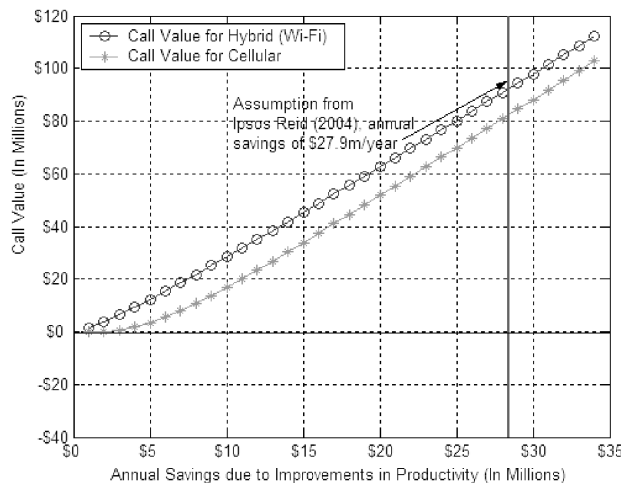
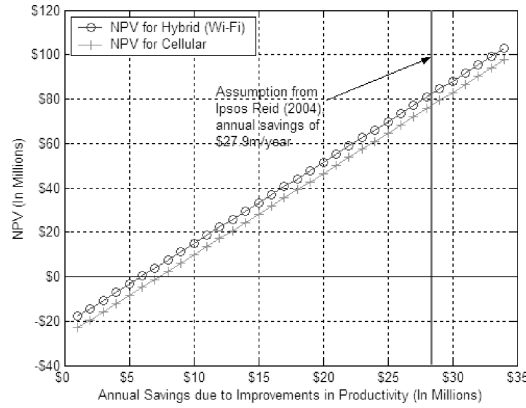
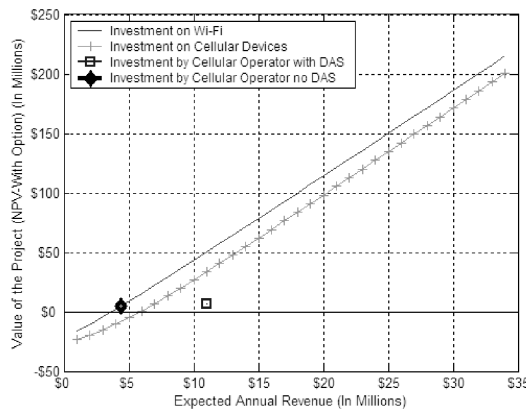


Figure 5 Corporate customer standpoint: variation in NPV for cellular and hybrid (Wi-Fi) solutions due to change in annual savings



In Figure 6, the project values for the four proposed cases from the cellular operator's and corporate customer's point of view are shown. The total project value is the sum of the NPV and the option value (expand/invest) in a project. The maximum value of the expected cash inflows (annual savings) is similar to the one proposed by Ipsos (2004) which is taken as a reference point in this analysis. It can be observed that even for lower values of expected savings due to increase in productivity, the value of any project from the corporate customer point of view is higher than the solution that involves implementation of network by the cellular operator (annual savings greater than \$6 million/year). Furthermore, from the cellular operator's perspective, expected cash flows are constant. This is because the revenues are fixed, determined simply by the number of subscribers and monthly fees.

Figure 6 Variation in value of investment (NPV + option) for both cellular and corporate customer perspectives due to change in revenues*



*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.

5 Summary and conclusion

Significant changes in wireless technologies and the way they are sold and employed (especially to big corporations located in high-density metropolitan areas) are expected in the upcoming years. Wi-Fi, nowadays (2006) one of the stronger players in the arena, could represent a big opportunity for the corporate market, given the fact that companies could deploy their own infrastructure for wireless services for employees located on premises. These deployments are not as expensive as cellular base stations, and open the possibility of reducing operative expenditures. Although a wireless device with total interoperability between Wi-Fi cellular networks is not available yet, it is expected soon; the proposed scenarios here illustrate what would happen if this technological solution is fully realised. The benefits from the corporate customer's and the cellular operator's point of view are substantially different. The savings due to the improvement in productivity are much higher than revenues perceived by cellular operators from provided wireless services. Therefore, if the much anticipated integrated devices become a reality, corporate customers will have an important alternative to consider, and cellular operators will have to adapt to that reality.

It is also remarkable that it is more profitable for 2.5G wireless carriers to implement dedicated antenna systems for important customers than do nothing, although, for the corporate customers, an in-house, self-provided wireless service can represent an opportunity for cost reduction. Therefore, the 2.5G carriers would have to come up with a solution that can fulfil customer's expectations, solving coverage challenges and, at the same time, be able to compete with potential disruptive technologies. This challenge, ultimately, will benefit the customer who will be able to choose the most convenient alternative for a given point in time and scenario.

References

- Alleman, J. (2002) 'A new view of telecommunications economics', *Telecommunication Policy*, Vol. 26, Nos. 1–2, pp.87–92.
- Alleman, J. and Noam, E. (1999) *Real Options: The New Investment Theory and its Implications for Telecommunications Economics*, Kluwer Academic Publishers, Norwell, Massachusetts.
- Alleman, J. and Rappoport, P. (2002) 'Modelling regulatory distortions with real options', *The Engineering Economist*, Vol. 47, No. 4, pp.390–417.
- Amram, M. and Kulatilaka, N. (1999) *Real Options: Managing Strategic Investment in an Uncertain World*, Harvard Business School Press, Boston, Massachusetts.
- Athwal, B., Harmantzis, F. and Tanguturi, V.P. (2005) 'Replacing centric voice services with hosted VoIP services – a real options approach', *Proceedings of the 16th International Telecommunications Society (ITS) European Regional Conference*, Porto, Portugal.
- Basili, M. and Fontini, F. (2003) 'The option value of the UK 3G telecom licenses: was too much paid?', *Info: the Journal of Policy, Regulation and Strategy for Telecommunications*, Vol. 5, No. 3, pp.48–52.
- Benaroch, M. and Kaufmann, R. (1999) 'A case for using real options pricing analysis to evaluate information technology project investments', *Information Systems Research*, Vol. 10, No. 1, pp.70–86.
- Benninga, S. and Tolkowsky, E. (2002) 'Real options – an introduction and an application to R&D valuation', *The Engineering Economist*, Vol. 47, No. 2, pp.151–168.
- Bowman, E.H. and Moskowitz, G.T. (2001) 'Real options analysis and strategic decision making', *Organization Science*, Vol. 12, No. 6, pp.772–777.

- Bughin, J. (2001) 'Managing real option in broadcasting', *Communications and Strategies*, Vol. 41, 1st Quarter, pp.63–78.
- d'Halluin, Y., Forsyth, A.P. and Vetzal, R.K. (2002) 'Managing capacity for telecommunications network under uncertainty', *IEEE/ACM Transactions on Networking*, Vol. 10, No. 4, pp.579–588.
- d'Halluin, Y., Forsyth, A.P. and Vetzal, R.K. (2003) 'Wireless network capacity investment', *Proceedings of the 7th Annual Real Options Conference*, Washington DC, USA.
- Damodaran, A. (2002) *Investment Valuation: Tools and Techniques for Determining the Value of Any Asset*, 2nd ed., Wiley Finance Publishers, New York.
- Economides, N. (1999) Real Options and the Cost of the Local Telecommunications Network, in Alleman, J. and Noam, E. (Eds.): *The New Investment Theory of Real Options and its Implications for the Cost Models in Telecommunications*, Kluwer Academic Publishers, Norwell, Massachusetts, pp.207–214.
- Edelmann, J., Kyläheiko, K., Laaksonen, P. and Sandstorm, J. (2002) 'Facing the future: competitive situation in telecommunications in terms of real options', *Proceedings of the IAMOT2002 11th International Conference of Management of Technology*.
- Harmantzis, F. and Tanguturi, V.P. (2004a) 'Delay in the expansion from 2.5G to 3G wireless networks: a real options approach', *Proceedings of the International Telecommunications Society 15th Biennial Conference*, Berlin, Germany, available from: <http://userpage.fu-berlin.de/~jmueller/its/conf/berlin04/index.html>.
- Harmantzis, F. and Tanguturi, V.P. (2004b) 'Real options analysis for GPRS network with Wi-Fi integration', *Proceedings of the 31st Annual Conference of the Northeast Business and Economics Association*, New York City, NY.
- Herbst, P. and Walz, U. (2001) *Real Options Valuation of Highly Uncertain Investments: Are UMTS-licenses Worth their Money?*, Department of Economics, University of Tuebingen, Mohlstr. Working paper, Available from: <http://www.wiwi.uni-frankfurt.de/Professoren/walz/umts.pdf>.
- Hull, C.J. (2003) *Options, Futures, and Other Derivatives*, Prentice-Hall, Upper Saddle River, New Jersey.
- Iatropoulos, A.D., Economides, A.A. and Angelou, G.N. (2004) 'Broadband investments analysis using real options methodology – a case study for Egnatia Odos SA', *Communications and Strategies*, Vol. 55, 3rd Quarter, pp.45–55.
- Ipsos, R. (2004) *Research Study: Analyzing the Return on Investment of a BlackBerry Deployment*, White Paper, Available from: <http://www.blackberry.com/select/roi/index.shtml>.
- Katz, R.L. and Junqueira, C. (2003) *Managerial Strategies and The Future of ROIC in Telecommunications*, Working Paper, Columbia Institute for Tele-Information, Columbia Business School, Columbia University, New York, NY, <http://www.citi.columbia.edu/home/>.
- Kulatilaka, N. (2001) *A Real and Better Option for Valuing Highly Speculative Investments Focus: The 3G Spectrum Auction*, Working Paper, Available from: <http://people.bu.edu/nalink/points.htm>.
- Kulatilaka, N. and Lin, L. (2004) 'Strategic investment in technology standards', *Proceedings of the 8th Annual Real Options Conference*, Montreal, Canada.
- Lin, B. and Vassar, J.A. (2004) 'Mobile healthcare computing devices for enterprise-wide patient data delivery', *International Journal of Mobile Communications*, Vol. 2, No. 4, pp.343–353.
- McMohan, R.A., Devries, P.D. and Chong, P.P. (2005) 'Building a wireless network infrastructure under budget constraints', *International Journal of Mobile Communications*, Vol. 3, No. 4, pp.445–456.
- Mun, J. (2002) *Real Options Analysis-Tools and Techniques for Valuing Strategic Investments and Decisions*, Wiley Finance Publishers, Hoboken, New Jersey.
- Paxson, D. and Pinto, H. (2004) 'Third generation mobile games – an application of real competition options', *Proceedings of the 8th Annual Real Options Conference*, Montreal, Canada.

- Schwartz, E.S. and Trigeorgis, L. (2001) *Real Options and Investment under Uncertainty: Classical Readings and Recent Contributions*, 1st ed., The MIT Press, Cambridge, Massachusetts.
- Tanguturi, V.P. and Harmantzis, F. (2005) 'Real options for migration to 3G wireless broadband internet: the case of an operator in India', *Proceedings of the 9th Annual Real Options Conference*, Paris, France.
- Trigeorgis, L. (1996) *Real Options: Managerial Flexibility and Strategy in Resource Allocation*, The MIT Press, Cambridge, Massachusetts.
- Varshney, U., Malloy, A., Ahluwalia, P. and Jain, R. (2004) 'Wireless in the enterprise: requirements, solutions and research directions', *International Journal of Mobile Communications*, Vol. 2, No. 4, pp.354–367.
- Wickramasinghe, N. and Goldberg, S. (2004) 'How M=EC² in healthcare', *International Journal of Mobile Communications*, Vol. 2, No. 2, pp.140–156.
- Young, B.C., Jeffrey, M., Christopher, V.K. and Jennifer, M.M. (2006) 'Corporate wireless LAN security: threats and an effective security assessment framework for wireless information', *International Journal of Mobile Communications*, Vol. 4, No. 3, pp.266–290.

Websites

AirDefense, <http://www.airdefense.net>.

IEEE 802.11, *The Working Group Setting the Standards for Wireless LANs*, <http://www.ieee802.org/11/>.

SK Telecom, <http://www.sktelecom.com>.

T-Mobile, <http://www.t-mobile.com>.

US Department of Treasury, www.ustreas.gov.

Notes

¹From Wireless Evolution: Application, Services and Content Expo NJTC 2006 Conference, Keynote presentations.

²With the technology found on the Nokia 6136, operators can deliver voice and data services to subscribers over WLAN access networks, dramatically increasing mobile service availability while decreasing the costs related to network deployment. Consumers, meanwhile, are able to enjoy the benefits of voice calls via the internet using WLAN radio access. The Nokia 6136 phone is expected to be available during the second quarter of 2006. Press Release available at <http://www.nokiausa.com/about/newsroom/article/1,1046,3845,00.html>.

³Average from the most predominant high-rise buildings in the area.

⁴This limitation has a lower impact in rural and suburban areas. A high-density metropolitan area scenario is a challenging one for cellular service operators.

⁵Observation based on experience.

⁶For 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.

⁷The IYZ index has as major constituents (70%) public companies that offer cellular telephony services.

⁸The 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.

⁹Estimated for a fraction of OA&M costs of the base stations serving the subscribers out of premises.

¹⁰AT&T Wireless, now www.cingular.com

¹¹In 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.

Appendix: cash flows for case study framework

Investment cost projections for cellular with DAS solution, operator's perspective (Table 3)

capital expenditure (CapEx) = 2.5G Equipment + DAS System

CapEx = 5 buildings × (\$500,000/site + \$900,000/site) = \$7000000

annual operational expenditure (OpEx) = 5 sites × 12 months × \$10000/site/month

OpEx = Annual outflow × Discount factor = 600000 × (1/(1.108)ⁿ)

Annual revenue = 5000 users × \$50/month × 12 months

Annual revenue = Annual inflow × Discount factor = \$3000000 × (1/(1.108)ⁿ).

Investment cost projections for cellular solution with no DAS, operator's perspective (Table 4)

annual operational expenditure(OpEx) = Similar to case Cellular with DAS solution, Operator's perspective

annual revenue = 5000 users × \$20/month × 12 months

Annual Revenue = Annual inflow × Discount Factor = \$1200000 × (1/(1.108)ⁿ).

Investment cost projections for hybrid solution, corporate customer's perspective (Table 5)

capital expenditure (CapEx) = WLAN APs + Wireless Devices + WLAN security platform + Antenna system

CapEx = \$1100/floor × 55 floors × 5 buildings + 5000 users × \$366/unit × 2 units (5 yr) + \$180000 antenna system/building × 5 buildings

CapEx = \$5,112,500

annual operational expenditure(OpEx) = Annual payments/user for data services + Total cost of ownership based number of devices + WLAN equipment OA&M cost for 5 building

OpEx = 5000 users × \$20/month × 12 months + 5000 users × \$544 cost of ownership/user + 5 × \$10000/building/month × 12 months

OpEx = Annual overflow × Discount factor = \$4520000 × (1/(1.108)ⁿ)

annual revenue = Annual savings due to increase in productivity

$$\text{Annual Revenue} = \text{Annual inflow} \times \text{Discount factor} = \$27900000 \times (1/(1.108)^n).$$

Investment cost projections for cellular solution, corporate customer's perspective (Table 6)

capital expenditure (CapEx) = Cost of Wireless Devices (2/user within 5 yr period)

$$\text{CapEx} = 5000\text{users} \times 366 \times 2 = 3660000$$

annual operational expenditure(OpEx) = Monthly payments/user + Total cost of ownership based on number of devices + Base Station OA&M cost for 5 sites

$$\text{OpEx} = 5000 \text{ users} \times \$50/\text{month} \times 12 \text{ months} + 5000 \text{ users} \times \$544 \text{ cost of ownerships/user} + 5 \times \$10000/\text{building/month} \times 12 \text{ months}$$

$$\text{Annual OpEx} = \text{Annual outflow} \times \text{Discount factor} = \$6320000 \times (1/(1.108)^n)$$

$$\text{annual revenue} = 5000 \text{ users} \times \$5,580/\text{user/year}$$

$$\text{Annual Revenue} = \text{Annual inflow} \times \text{Discount factor} = \$27900000 \times (1/(1.108)^n).$$