2010 IEEE Symposium on Industrial Electronics and Applications (ISIEA 2010), October 3-5, 2010, Penang, Malaysia

A Pricing Model and Sensitivity Analysis for MVNO Investment Decision Making in 3G UMTS Networks

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***Abstract*—In this article we propose a pricing model for MNO and MVNO's investment in 3G UMTS networks. We also investigate and conceptualize the relationship among MNO, MVNO, and other related variables in the proposed pricing model. Next, we develop the influence diagrams representing MNO and MVNO and use them to explore the relationship of total costs, total revenues, and net profit. This diagram is used to find optimal decisions which maximize the expected profit values. Finally, we suggest a simple way of sensitivity analysis to identify the most critical parameters affecting the performance of the MVNO in the 3G wireless network market. An illustrative example of one-way sensitivity analysis is presented. The analysis of the results obtained from the model focuses on of MVNO's customers and its profits in an attempt to provide recommendations which may be utilised and made a greater contribution in the MVNO's investment decision making process.**

***Keywords*— a pricing model, Mobile Network Operator, Mobile Virtual Network Operator, second-generation cellular network, 3G UMTS network, sensitivity analysis**

I. Introduction

Third-Generation Universal Mobile Telecommunications System network (3G UMTS) was developed mainly for countries with Global System for Mobile communications network (GSM), because these countries have agreed to free new frequency ranges for UMTS networks. 3G UMTS network are intended to provide a global mobility with wide range of services including telephony, paging, messaging, Internet and broadband data. International Telecommunication Union (ITU) started the process of defining the standard for third generation systems, referred to as International Mobile Telecommunications 2000 (IMT-2000). The reasons of using 3G instead second-generation (2G) cellular network are higher speech quality that current networks, addition to speech traffic UMTS, together with advanced data and information services, will be a multimedia network. UMTS is above 2G mobile systems for its potential to support 2Mbit/sec data rates and UMTS is a real global system, comprising both terrestrial and satellite components. One of the main objectives of the third-generation (3G) network architecture is to support mobile virtual network operator (MVNO) requirements in terms of flexibility, rapid deployment, and cost reduction over the infrastructure of 3G mobile operators. In fact, the first MVNOs were mobile operators that had no physical infrastructure and/or spectrum; they were hosted by the traditional network operators and had no control over equipment. They could only manage the marketing, billing, and customer services [1]. A techno-economic approach has been used to identify business opportunities and quantify the potential profitability of different kind of business players [2].

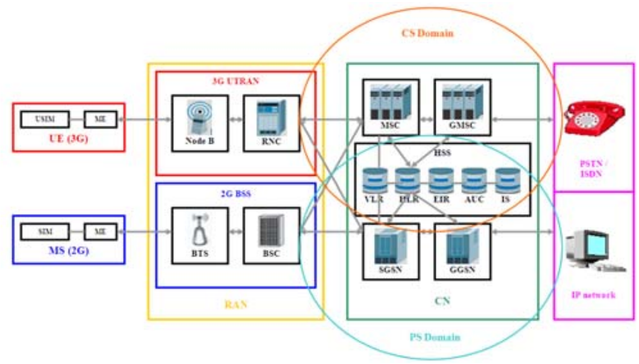

Figure 1. 3G UMTS network architecture model.

Fig. 1 shows some more detail about 3G UMTS network architecture model. The 3G UMTS network consists of three interacting domains; User Equipment (UE), UMTS Terrestrial Radio Access Network (UTRAN), and Core Network (CN). UE is the separation between Mobile Equipment (ME) and the UMTS Subscriber Identity Module (SIM) card (USIM). UTRAN is subdivided into individual Radio Access Network (RAN), where each RAN is controlled by a Radio Network Controller (RNC). The RNC is connected to a set of node B elements. The Core Network consists of Circuit Switched (CS) and Packet Switched (PS) domains. There are several elements such as Mobile services Switching Centre (MSC), Visitor location register (VLR) and Gateway MSC in the circuit switched domain. Packet switched domain consists of Serving GPRS Support Node (SGSN) and Gateway GPRS Support Node (GGSN). The other network elements such as Home Subscriber Server (HSS), Home Location Register (HLR), Equipment Identity Register (EIR), Authentication Center (AUC) and Information System (IS) are served for both domains. The competing 3G technology here was in the early study period loosely defined as Orthogonal Frequency Division Multiplexing (OFDM), the characteristics of which include full internet protocol compatibility throughout the network, and an effective OFDM radio frequency utilization. The Asynchronous Transfer Mode (ATM) is defined for UMTS core network [2].

In this article, we present both theoretical and practical pricing model to explain the incentive of (i.e., sufficient conditions for) profit MVNOs to enter on investment, strategic partnerships based on several fixed and variable costs and revenue on the telecommunications industry. We demonstrate that, under the right circumstances, an MNO's strategy to voluntarily provide wholesale access to an MVNO is justified by the net economic benefits produced. In particular, the two key factors in that relationship are (1) the value of the MVNO's brand reputation and (2) the level of the wholesale discount in the resale transaction between the MNO and the MVNO. In addition to the proposed pricing model, we also introduce a tool in economical risk estimation, namely sensitivity analysis, for MVNO in decision making for an investment in 3G UMTS network. They are primarily used to identify the most critical parameter values affecting the performance of the MVNO and to find the impact of specific uncertainties regarding market inputs and business agreements such as access charges and number of MVNO's customers, which could be the turning point for the business case. The article is organized as follows: Section II presents some more detail about the background of the 3G MNO and MVNO networks. Section III presents the proposed pricing model for MVNO. Section IV describes a modeling approach for sensitivity analysis. Section V presents a conclusion and discusses some perspectives and ideas for future work.

II. BACKGROUND

This section is intended to describe the background of 3G MNO and MVNO's networks and the basic network infrastructure investment among MNO and MVNOs on 3G UMTS networks. MVNO is characterized by neither having their own mobile license nor own mobile infrastructure, but the MVNO has the direct customer relationship with the end user. MVNOs buy spectrum and possibly also infrastructure from primary providers, referred to as Mobile Network operators (MNOs). MNO is a telephone company that provides services for mobile phone subscribers. The process of becoming a mobile network operator within a country usually begins by acquiring a radio spectrum license from the government. The precise spectrum obtained does depend on the type of mobile phone technology the operator intends to deploy. MVNOs Classification and Marketing strategies [3] are defined as follows: (1) Discount MVNOs provide cut-price call rates to market segments. Their strategy is based on cheap prepaid or post-paid tariffs with basic voice and SMS services; and (2) Lifestyle MVNOs focus on specific niche market demographics.

The 3G architecture needs then to be distributed in order to fulfill this evolutionary separation between the domain management of the MVNO and the wireless host operator. Fig. 2 illustrates a3G's MNO and MVNO network in more detail. Nowadays, MNOs are willing to outsource many parts of the mobile value chain to concentrate on their core business. Therefore, a market entry of many vendors from outside the mobile industry and the emergence of new sales and marketing co-operations can be observed. One business model, which will be discussed in this article, is the MVNO. The term MVNO in general is used for different business models, which sell mobile services under their own brand without possessing own network licenses and mobile infrastructure (RAN, MSC, SGSN and VLR), but providing its own mobile services to customers and possessing own Mobile Network Code (MNC), UMTS Subscriber Identity Module (USIM) cards, Gateway Mobile Switching Center (GMSC), and Home Subscriber Server (HSS), like Home Location Register (HLR), Equipment Identity Register (EIR), Authentication Center (AUC), Information System (IS), Intelligent Network (IN) and business support sections [1], [4].

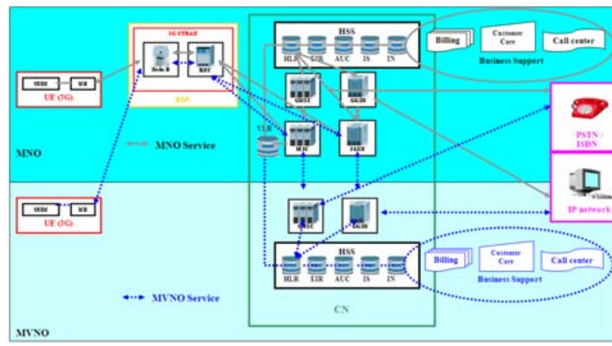

Figure 2. Illustration of a 3G MVNO network.

As there are a number of firms already doing business or interested in entering the mobile sector, which have been left without a 3G license and on the other hand, license fees may act as an economic burden for the "winning" companies, a new business channel to enter the mobile market and participate in the 3G UMTS network is the MVNO channel [3]. MVNO models mean lower operational costs for mobile operators (billing, sales, customer service, and marketing), help fight churn, grow Average Revenue Per User (ARPU) by providing new applications and tariff plans and also can help with difficult issues like how to deal with fixed-mobile convergence by allowing MVNOs to try out more experimental projects and applications. The opportunity for mobile operators to take advantage of MVNOs generally outweighs the competitive threat. However, the total traffic they can transport is limited because they share a common resource (i.e. spectrum because MNOs consumers and MVNOs consumers are in the same coverage area) [7].

There are three primary motivations for mobile operators to allow MVNOs on their networks. They are generally: (a) Segmentation-Driven Strategies – mobile operators often find it difficult to succeed in all customer segments. MVNOs are a way to implement a more specific marketing mix, whether alone or with partners, and they can help attack specific, targeted segments. (b) Network Utilisation-Driven Strategies – Many mobile operators have capacity, product and segment needs, especially in new areas like 3G. A MVNO strategy can generate economies of scale for better network utilisation. (c) Product-Driven Strategies – MVNOs can help mobile operators target customers with specialised service requirements and get to customer niches that mobile operators cannot get to.

In this article, a representative set of possible business scenarios have been selected. A fundamental decision based on investment of MVNO in 3G UMTS networks are described in the next chapter. We also propose a pricing model and a sensitivity analysis approach for making flexible investment and pricing decision for MVNOs. The ultimate aim is to highlight the potential MVNO's business profitability by utilizing various types of business strategies, pricing models and decision models.

III. The Proposed Pricing Model for MNO and MVNO

In this section, we propose a pricing model for MNO and MVNO's investment in 3G UMTS networks based on the economic point of view. MNO provides the dedicated resources for MVNOs. MVNOs have to pay to MNO those provided sources. The price is called an access charge and it could be used as the turning point for this business case, and the MVNO must negotiate hard with the MNO in order to keep access charges as low as possible. On the other hand, the national regulating authorities in telecommunications should protect the new companies and ensure that the access charge level will boost the overall competition. Fixed/variable costs and revenue have been identified in the proposed pricing model as shown in Fig. 3. However, most of these costs are quite inelastic since they are related to personnel costs, and the operator does not usually have much leverage to reduce them significantly. The marketing cost in some cases is of major importance [5].

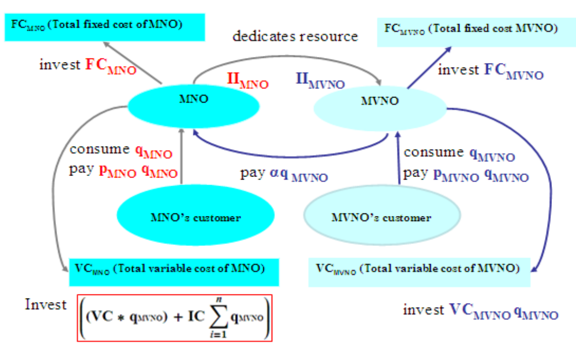

Figure 3. A Pricing Model for the MNO and the MVNO: description of the interactions.

Fig. 3 describes the interactions between the MNO and MVNO in 3G UTMS network. MNO and MVNO's business provides several services to the customers. The simplified business objective would be to maximize the profit of the total business [6]. The profit is simply calculated using the equation below:

Profit = Total Revenue (TR) – Total Cost (TC)
= ARPU * Customers – {(Total variable cost* Customers) + Total fixed cost}

(II: profit, p: ARPU (average revenue per user), q: number of customers, FC: total fixed cost, VC: total variable cost)

$$II = p*q - \{(VC*q) + FC\} \quad (1)$$

To be able to offer services to its customers, the MVNOs pay to the MNO for the network capacity it utilizes. The contract between MNO and MVNO is bilateral and usually based on the total traffic (can also include a fixed fee per MVNO in the same price).

The cost structure of an MNO is biased heavily towards fixed costs. The main fixed cost elements of the MNO are:

- Network operations and maintenance costs (NOMC)
- Sales costs (SC)
- Customer service and billing costs (CSBC)
- Marketing and communications costs (MCC)

$$FC_{MNO} = \text{Total fixed cost of MNO}$$
$$FC_{MNO} = NOMC + SC + CSBC + MCC \quad (2)$$

The main variable cost elements (per user) of the MNO are:

- Interconnect costs (IC)
- Customer acquisition costs (CAC)
- Customer retention costs (CRC)

$$VC_{MNO} = \text{Total variable cost of MNO}$$
$$VC_{MNO} = IC + CAC + CRC \quad (3)$$

The cost structure of the typical MVNO is almost completely the opposite of a facilities based network operator. The main fixed cost elements are relatively small. They are:

- Customer care and billing costs (CCBC)
- Sales, marketing and communications costs (SMCC)

$$FC_{MVNO} = \text{Total fixed cost of MVNO}$$
$$FC_{MVNO} = CCBC + SMCC \quad (4)$$

The main variable cost elements (per user) for the MVNO are:

- Customer acquisition costs (CAC)
- Customer retention costs (CRC)
- Access charges to MNO (α)

$$VC_{MVNO} = \text{Total variable cost of MVNO}$$
$$VC_{MVNO} = CAC + CRC + \alpha \quad (5)$$

The variable cost of MVNOs that depends on MNO [9] is:

$$\alpha q_{MVNO} = \text{access charges (pay to MNO)}$$

Implementation of a new mobile network including new services and applications will generate uncertain cost estimates. The main input is demand forecasts for the total market and estimates for lost market shares because of competition. If the forecasts turn out to be completely wrong, then the investments will also be out of scale. Since forecasts for new services are uncertain substantial cost risks are generated. The model used here assumes that an existing carrier is a monopoly in the upstream market and that the existing and new companies (full-MVNO) will compete in the downstream market. In this article, we apply and expand the independent models used. In this case, we assume n MVNOs in downstream market (when n is the number of MVNOs) (p_{MNO} (q_{MNO}, q_{MVNO}), p_{MVNO} (q_{MNO}, q_{MVNO})), and the profits for existing companies and new entrants are as follows [8]. MNO has the number of 1 to n MVNOs (when i = 1, 2, 3… n). The profit of MNO and MVNO is shown in (6) and (7), respectively.

$$\Pi_{MNO} = \left(p_{MNO}\, q_{MNO} + \alpha \sum_{i=1}^{n} q_{MVNO}\right) - \left(\left((VC * q_{MNO}) + IC \sum_{i=1}^{n} q_{MVNO}\right) + FC_{MNO}\right) \quad (6)$$

$$\Pi_{MVNO(n)} = p_{MVNO(n)}\, q_{MVNO(n)} - \{(VC_{MVNO(n)} * q_{MVNO(n)}) + FC_{MVNO(n)}\} \quad (7)$$

In the above profit equation of existing companies, Π_{MNO}, $p_{MNO}\, q_{MNO}$ and $\alpha \sum_{i=1}^{n} q_{MVNO}$ are the income of the upstream market, $p_{MVNO}\, q_{MVNO}$ is the income of the downstream market, $\alpha \sum_{i=1}^{n} q_{MVNO}$ is access charges paid by new entrants, $\left((VC * q_{MNO}) + IC \sum_{i=1}^{n} q_{MVNO}\right)$ is the cost incurred by the upstream market, and FC_{MNO} is total fixed cost of MNO. In (7), $\Pi_{MVNO(n)}$ is new entrant MVNO profits, $p_{MVNO(n)}\, q_{MVNO(n)}$ is the income of the downstream market, $\alpha q_{MVNO(i)}$ is access charges disbursed to existing companies, and $VC_{MVNO(n)}$ $(q_{MVNO(n)})$ is the cost incurred by the downstream market, and $FC_{MVNO(n)}$ is total fixed cost of MVNO. In (6) and (7), VC_{MNO} is the variable cost of MNO and $VC_{MVNO(i)}$ is the variable costs of MVNO. These two variables depend on the number of q_{MNO} (MNO's customers) and $q_{MVNO(i)}$ (MVNO's customers). In this article, we focus only on the economic factors and adopt them for the construction of an economic based modeling approach based on sensitivity analysis.

IV. Sensitivity Analysis for the Investment in the MVNO Operation

In this section, we describe a methodology to use sensitivity analysis for decision making on MVNO investment. Sensitivity analysis methods are well-known in the engineering literature. They have been used across various disciplines such as weather forecasting, chemical engineering and economics [10]. Sensitivity analysis is a basic tool in economical risk estimation and is used to identify the most critical parameters affecting the performance of the MVNO but also to find the impact of specific uncertainties regarding market inputs and business agreements such as access charges, which could be the turning point for this business case and the MVNO must have hard negotiation with the MNO in order to keep access charges as low as possible [11]. As a consequence, parameters with a large sensitivity coefficient have a strong influence on the state variable. This identifies which factors should be identified and measured most carefully to assess the state of the environmental system, and which environmental factors should be managed preferentially. Sensitivity analysis relies on two assumptions: (1) As the parameters are generally varied by a linear proportion, the state variable must linearly depend on the parameters, and (2) as the parameters are varied one at a time, different model parameters must not interact in their influence on the state variable [12].

We use sensitivity analysis to identify the most critical parameters affecting the performance of the MVNO. We gather the data from one of several MVNOs in Thailand. The data we obtained were used as input variables for sensitivity analysis and decision making on investment. We apply the information mentioned above to sensitivity analysis for identifying the most critical parameters affecting the performance of the MNO for MVNO's investment.

A) *A Modeling Approach for MNO and MVNO*

Sensitivity analysis is used to determine how "sensitive" a model is to changes in the value of the parameters of the model and to changes in the structure of the model. Before we describe the sensitivity analysis, we firstly introduce an influence diagram for the MNO and MVNO.

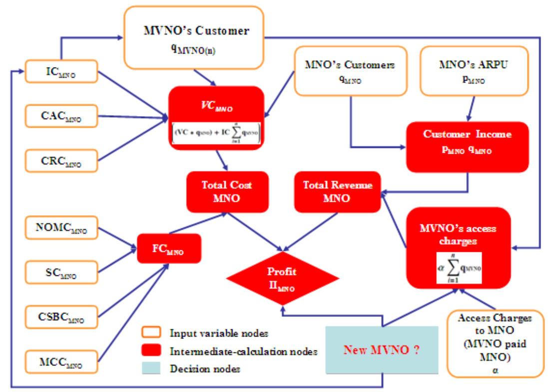

Figure 4. Influence diagram representing MNO.

Fig. 4 shows an initial influence for MNO. Note that the diagram consists entirely of decision nodes and rounded rectangles. "Profit" is obviously the consequence node and "Total fixed cost of MNO," "Total variable cost of MNO," "Total Cost," "Customer Income," "MVNO's Access charges," and "Total Revenue" are intermediate-calculation nodes. All of the other rounded rectangles ("Access Charges to MNO" "MNO's ARPU," "MNO's customers," "MVNO's Customers" "Interconnect costs (IC)," "Customer acquisition costs (CAC)," "Customer retention costs (CRC)," "Network Operations and Maintenance Costs (NOMC)," "Sales Costs (SC)," "Customer Service and Billing Costs (CSBC)," "Marketing and Communications Costs (MCC)") represent inputs to the calculation, and for now we represent these inputs as being constant. The model from the previous section, the annual profit of MNO would be the total annual revenue minus the total cost:

Total Revenue = Customer income + MVNO's Access charges

TR_{MNO} = MNO's ARPU * MNO's customers + $\alpha \sum_{i=1}^{n} q_{MVNO}$

$$TR_{MNO} = p_{MNO} * q_{MNO} + \alpha \sum_{i=1}^{n} q_{MVNO} \quad (8)$$

Total Cost = Total variable cost + Total fixed cost

TC_{MNO} = [{(Interconnect costs + Customer acquisition costs + Customer retention costs) * MNO's customers} + (Interconnect costs *MVNO's customers)] + (Network operations and maintenance costs + Sales costs + Customer service and billing costs + Marketing and communications costs)

$$TC_{MNO} = [\{(IC + CAC + CRC) * q_{MNO}\} + (IC * \sum_{i=1}^{n} q_{MVNO})] + (NOMC + SC + CSBC + MCC) \quad (9)$$

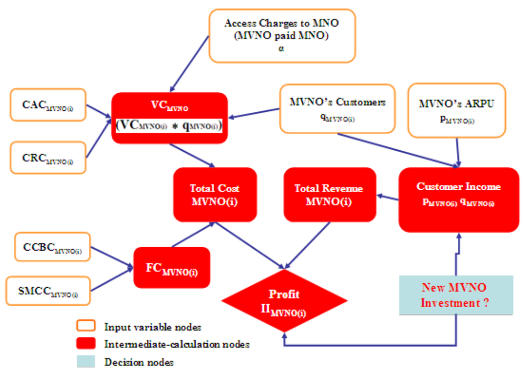

Figure 5. Influence diagram representing MVNO

Fig. 5 shows an initial influence for MVNO. "Profit" is obviously the consequence node and "Total fixed cost of MVNO," "Total variable cost of MVNO," "Total Cost," "Income's customer," and "Total Revenue" are intermediate-calculation nodes. All of the other rounded rectangle s ("MVNO's ARPU," "MVNO's Customers," "Customer Acquisition Costs (CAC)," "Customer Retention Costs (CRC)," "Access charges to MNO," "Customer Care and Billing Costs (CCBC)," and "Sales, Marketing and Communications Costs (SMCC)," represent inputs to the calculation, and for now we represent these inputs as being constant. The model from the previous section, the annual profit of MVNO would be the total annual revenue minus the total cost:

Total Revenue = Customer income

TR_{MVNO} = MVNO's ARPU * MVNO's customers

$TR_{MVNO} = p_{MVNO} * q_{MVNO}$ (10)

Total Cost = Total variable cost + Total fixed cost

TC_{MVNO} = {(Customer acquisition costs + Customer retention costs + Access charges to MNO) *MVNO's customers} + (Customer care and billing costs + Sale, Marketing and communications costs)

$TC_{MVNO} = \{(CAC + CRC + \alpha) * q_{MVNO}\} + (CCBC + SMCC)$ (11)

B) An Illustrative Example of One-Way Sensitivity Analysis of MVNO's Customers for MVNO

Table I. provides a description of the inputs and decision variables. This table also includes estimates (base values) and reasonable upper and lower bounds obtained from the reports. The upper and lower bounds represent MVNO's ideas about how high and how low each of these variables might be. MVNO might specific upper and lower bounds as absolute extremes, beyond which MVNO is absolutely sure that the variable cannot fill. MVNO is not at all sure, for example, what number of customers each year might turn out to be, and that it can vary from 100,000 to 300,000 customers. What does this imply for profit? The simplest way to answer this question is with a one-way sensitivity graph as shown in Fig. 6 for explanation.

TABLE I. INPUT VARIABLES AND RANGES OF POSSIBLE VALUE FOR MVNO INVESTMENT DECISION

Variable's MVNO (per year)	Base Value	Lower Bound	Upper Bound
MVNO's Customers	200,000	100,000	300,000
MVNO's ARPU	$250	$200	$275
Access Charges to MNO	$75	$75	$75
Customer Acquisition Costs	$48	$46	$60
Customer Retention Costs	$20	$18	$26
Customer Care and Billing Costs	$4,000,000	$3,750,000	$5,000,000
Sales, Marketing and Communications Costs	$2,600,000	$2,400,000	$3,500,000

The "Base Value" column in Table I indicates MVNO's initial guess regarding the 7 input variables. We can use these to make an estimate of annual profit (ignoring taxes for simplicity). The annual profit would be the total annual revenue minus the total annual cost from (10) and (11):

$$TR_{MVNO} = p_{MVNO} * q_{MVNO} = \$250 * 200{,}000 = \$50{,}000{,}000$$

$$TC_{MVNO} = \{(CAC + CRC + \alpha) * q_{MVNO}\} + (CCBC + SMCC) = \{(\$48 + \$20 + \$75) * 200{,}000\} + (\$4{,}000{,}000 + \$2{,}600{,}000) = \$35{,}200{,}000$$

Thus, using the base values, MVNO's annual profit is estimated to be $50,000,000 - $35,200,000 = $14,800,000. This represents a return of approximately 52.56% on his investment of $28,160,000. We use 80% of the total cost for calculating a return on investment.

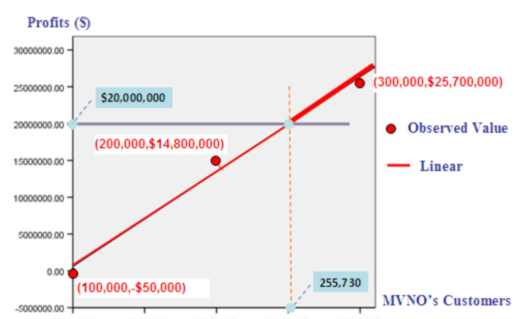

Figure 6. One-way sensitivity analysis of MVNO's Customers

The upward-sloping line in the figure above shows profit as MVNO's Customers varies from 100,000 to 300,000 to create this line, we have substituted different values for MVNO's Customers into the calculations using (7) detailed below:

$$\Pi_{(MVNO's\ Customers = 100{,}000)} = \$200 * 100{,}000 - \{(\$139 * 100{,}000) + \$6{,}150{,}000\} = -\$50{,}000$$

$$\Pi_{(\text{MVNO's Customers} = 300{,}000)} = \$275 * 300{,}000 - \{(\$161 * 300{,}000) + \$8{,}500{,}000\} = \$25{,}700{,}000$$

From the year report, MVNO expects to have the profit of $20,000,000 by next year. The horizontal line represents the amount of money ($20,000,000) that MVNO could earn from an investment. Based on linear regression, the point where the lines across is the threshold at which the two alternatives each yield the same profit ($20,000,000), which occurs when MVNO's customers equals 255,730 approximately. The heavy line indicates the maximum profit MVNO could obtain at different values of MVNO's customers, and the different segments of this line are associated with different strategies. MVNO might believe that MVNO's customers could be above or below 255,730. This number is a crucial variable and MVNO may need to consider more carefully about the uncertainty associated with it.

A *tornado diagram* allows us to compare one-way sensitivity analysis for many input variable at once. Suppose we take each input variable in Table I and "wiggle" that variable between its high and low values to determine how much change is induced in Profit. Fig. 7 graphically shows how annual profit varies as the input variables are independently wiggled between the high and low values.

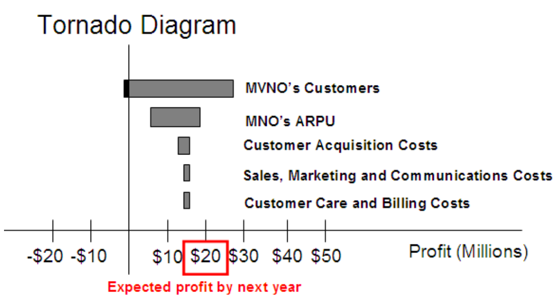

Figure 7. Tornado diagram for MVNO Point of View. The bars represent the range for the annual profit when the specified quantity is varied from one end of its range to the other, keeping all other variables at their base value.

Interesting insights can be gleaned from Figure 7. For example, MNVO's uncertainty regarding the number of MVNO's Customers is extremely important. On the other hand, the annual is very insensitive to Customer Care and Billing Costs and Sales, and Marketing and Communications Costs. The results shown in the figure above can tell us which variables we need to consider more closely and which ones we can leave at their base value. In this case, annual profit is insensitive to Customer Care and Billing Costs and Sales, and Marketing and Communications Costs, Network Operations and Maintenances Costs, so in further analyzing this decision we simply can leave these variables at their base values.

V. Conclusion and Future Work

We propose a pricing model for MNO and MVNO's investment in 3G UMTS networks. We also investigate and conceptualize the relationship among MNO, MVNO, and several other related variables. The main fixed and variable cost elements and revenue for the MNO and MVNO have been identified and described in the proposed pricing model. Next, we develop the influence diagrams representing MNO and MVNO and use them to explore the relationship of total costs, total revenues, and net profit. These influence diagrams are used to find optimal decisions which maximize the expected profit values. Finally, we use sensitivity analysis to identify the most critical parameters affecting the performance of the MVNO in the 3G wireless network market. An illustrative example of one-way sensitivity analysis is presented. The analysis of the results obtained from the model focuses on of MVNO's customers and its profits in an attempt to provide recommendations which may be utilised in the investment decision-making process. In future research based on this study, we will consider and analyse the competitions and strategic interactions among MNOs, MVNOs, other economic factors related to 3G wireless network investment and their economic consequences for flexible investment decision and study in two-way sensitivity analysis.

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