Individual Tariffs for Mobile Communication Services

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INDIVIDUAL TARIFFS FOR MOBILE COMMUNICATION SERVICES

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ABSTRACT

This paper introduces a conceptual framework and a computational model for individual tariffs for mobile communication services. The purpose is to provide guidance for implementation by communication service suppliers or user groups alike. The paper first examines the sociological and economic incentives for personalized services and individual tariffs. Then it introduces a framework for individual tariffs which is centered on user and supplier behaviours. The user, instead of being fully rational, has "bounded rationality" and his behaviours are subject to economic constraints and influenced by social needs. The supplier can belong to different types of entities such as firms and communities; each has his own goals which lead to different behaviors. Individual tariffs are decided through interactions between the user and the supplier and can be analyzed in a structured way using game theory. A numerical case in mobile music training is developed to illustrate the concepts.

KEYWORD

Individual tariffs, mobile communication services, computational games, risks

1 INTRODUCTION

Individual tariffs existed at the dawn of the telecommunication history. Due to the limited supply and demand, tariffs were negotiated between the individuals and the telephone companies in a bilateral way. Individual tariffs faded out when the telecommunication industry began to thrive in the early 20th century under economies of scale. Users started to pay same prices for standard services. [1]

Recent rapid developments in technologies, policy, regulations and law as well as other aspects in social environments have brought a lot of changes to the mobile communications industry and to the lives of individual users. Mobile services are no longer limited to voice; other value-added services and applications (e.g. location based services) are quickly gaining ground. Secondly, the power of individuals is rising both from the demand side and the supply side. These have been facilitating the movement toward personalized mobile services. Differentiated services need individual tariffs, where the pricing of mobile services are connected to the different requirements for service attributes and willingness-to-pay of each individual.

This paper intends to develop a theoretical framework for individual tariffs by putting microeconomic pricing principles and full deregulation in a sector still governed by public tariffs and monopoly thinking. Mobile services not only have functional values, but most of the time are associated with social values, e.g. friendship. By incorporating social dimensions, our framework aims to provide a better understanding of individual tariffs. Furthermore, our framework intends to provide guidance to build computational models for implementation, where the determination of individual tariffs can be automated or semi automated so that the provisioning overhead is not prohibitive.

This paper is organized as follows: section 2 introduces basic concepts of individual tariffs; Section 3 starts with the incentives for individual tariffs both from sociological (section 3.1) and economic perspectives (section 3.2); it then brings out the theoretical framework which is built on user (section 3.3) and supplier (section 3.4) behaviors and their interactions. The framework uses game theory as an analytical design tool (section 3.5). Section 4 introduces a computational model based on the conceptual framework, where the supplier is a profit-oriented firm and the user is an individual; a numerical case of mobile music training is developed to illustrate the concepts. The paper concludes in section 5.

2 BASIC CONCEPTS AND RESEARCH PERSPECTIVE

2.1 INDIVIDUAL TARIFFS

We define mobile (communication) services as those that are provided through a mobile or wireless user equipment, through a ubiquitous connection to facilitate communications anytime anywhere, between human beings, between humans and machines and between machines[1].

In order to define individual tariffs, the opposite is defined first. ***Public tariffs*** in telecommunication refer to the regulatory protected ability for an identified user to obtain from a service provider, by a bilateral contract, a set of standard prices for a set of standardized services. Public tariffs are common practice of current incumbent telecom operators. The number of services is limited and so are the choices of tariffs. A typical mobile operator offers 5-10 service bundles, each corresponds to a category of tariffs. User chooses a bundle, signs a contract (usually for 1 or 2 years) and pays a fixed monthly fee, which may cover some free voice minutes, SMS, MMS or certain amount of data traffic, plus limited customer support. Tariffs for usage exceeding the “free” offer vary among bundles; very often, the operator provides a subsidized mobile terminal. There is no interaction between operators and customers when signing the contracts. A customer has to choose/predict one category of

[1] Our discussion in the paper does not include the “machine to machine” communication.

services and tariffs which fit his/her needs best or reject the offer. The limited segmentation leaves a significant amount of demands from the users unsatisfied [2].

Individual tariffs in telecommunications refer to the regulatory protected ability for an identified user to obtain from a service provider, by a bilateral specific contract, a set of service specific prices corresponding to a request or a proposal from the user specified with a service demand profile and some duration.

Per this definition, individual tariffs do not in essence include pre-paid service usage, or service prices offered by traffic or service aggregators or resellers. Likewise, they are not covered in the service consumption derived from a user-specific mix of publicly offered and tariffed services. One could also use the term “individual ratings” to express the same.

The ***users*** of individual tariffs are the recipients of services; if there is a subscription, the user can also be called a subscriber.

The ***service provider/supplier*** is defined in a broad sense as the entity that provides access, content and applications, or a combination of them to users. Benkler [3] had pointed out that in addition to the two common forms to organize economic production, which are either through a firm under the direction of a manager, or through individuals themselves in the market following price signals, there is a third model of production. Benkler called it “common-based peer production”. The distinguishing characteristic of this model is that groups of individuals *collaborate* on large-scale projects following a diverse cluster of motivational drives and social signals rather than market prices or managerial commands. A well-known example is the Linux kernel project (see www.kernel.org) where thousands of people around the world collaborate to develop the core of an operating system. The third model of production is becoming more common and important in today’s information society. Already, there are mobile services created and provided following this model. For example, a service called cellphedia (see http://www.cellphedia.com) allows users to send and receive encyclopaedia-type inquiries between specific, pre-defined groups, through Text messaging. Since the group of individuals sharing a common goal can also be characterized as a community of mind [4] or a community of interest. We suggest that the “common-based peer production” can also be characterized as “community-based production”. We identify four types of service providers:

a.) Firms. To distinguish them from communities as suppliers (see below), we name them operators. There are public operators and private operators. The former (e.g. most public mobile operators) are subject to a universal service obligation under the regulatory regime. The latter sell services to customers under only the restrictions of commercial laws (e.g. WiFi operators). The concept of universal service was straightforward in the past, which consisted of post, telegraph and some basic (fixed) telephone services. But the advent of mobile and Internet are demanding more components in the universal service system and expanding the definition of universal service. Here we just simply assume that some mobile operators are subject to the obligation. What of concerned is the economic implication of universal service for an operator. Any universal service inherently introduces substantial economic distortions by the interruption of market mechanism. Therefore a public mobile operator with universal service obligation will have to bear higher cost than a private operator.

b.) Closed communities where membership is required. Only the members can contribute their efforts, and consequently the usage of the services is only limited to the members. The contributions from members of a community vary from knowledge, information, expertise, time, even empathy and sometimes money.

c.) Open communities which do not require a formal membership; but certain level of registration and authentication are still needed to meet privacy policies and regulation. At the same time, open communities are also subject to liability risks and IPR issues.

d.) And ultimately, individuals.

3 A CONCEPTUAL FRAMEWORK FOR INDIVIDUAL TARIFFS

3.1 INTRINSIC DRIVERS OF INDIVIDUAL TARIFFS

From a sociological perspective, a post-modern society is characterized by its lack of dominant ideology, culture or fashions [5]. This is also reflected in the diversity of personal values which give meanings and directions to an individual's behaviors. Not all individual users are willing to consider personalized services and tariffs. Some prefer a pre-determined bundle with little transparency and limited choices. But there are values held by a growing population inviting personalized services and individual tariffs. Here is a non-exhausted list of drivers that we consider to be fundamental.

Individualism. We adhere to the individualism defended by Hayek [6] as the theoretical foundation of our research. Under this individualism, there are universally accepted principles under which man makes his own choices and take full responsibility; he is free to follow his own will, to make full use of his knowledge and skill, and he is guided by his concerns for the particular things of which he knows and he cares. Personalized services and tariffs of mobile services are reflections of Hayek's individualism; where a person in a free society has the freedom of choices of services, at anytime and anywhere. It is also reflected in the freedom of service creation and provision, either to a family, a small community and group, or to the whole society.

Self-identity, in a late modernity setting with rapid social changes, has to be routinely created and sustained in the reflexive activities of the individual [7]. "How shall I live?" has to be answered in day-to-day decisions about how to behave, what to wear and what to use, et cetera. Modernity opens up the project of the self, but under strong influence of standardization of commodities from market. Market promoted individualism first out of the concerns the freedom of contract and mobility intrinsic to capitalistic employment, next in order to extend the concept to consumption to designate individual's wants. A good example is the corruption of the notion "life style", where the project of self has been associated with the possession or consumption of certain pre-determined products and services. The consequence is the suppression of the genuine development of the self. To move away from this predicament created by commodified consumption, an individual should surround himself with personalised experiences. Service personalization and individual tariff promote user's autonomy by encouraging the user to define what he wants, not just selecting or accepting the pre-defined services, as part of a "framed" style of life.

Innovation was defined by Rogers [8] as an idea, practice or object that is perceived as new by an individual or other unit of adoption. Innovation in the context of individual tariffs is user-centric, which is in sharp contrast with the supplier-centred tradition in telecommunication industry. The latter often innovates in a closed form, and uses patents, copyrights or trademark to prevent others from imitation. The former often uses open source (software or tools), shared knowledge to creative new products or services to accommodate users' unique demands; user-centric innovations are often freely revealed [9]. In addition to the products or services they have developed, participants of user-centric innovations gain rewards from the innovation processes [10]. More generally, innovation is a specific expression of creativeness. Maslow [11] distinguishes "special talent creativeness" from "self-actualization creativeness". The former refers to the level of creativity that belongs to geniuses such as Einstein, Edison and Mozart, which is exceptional. The latter refers to the creativity that is latent universally in ordinary people, which springs much more directly from personality and shows itself widely in ordinary affairs of life, not only in great and obvious product but also in a tendency to do everything creatively. The creation of personalized mobile services used to be inhibited by technology, knowledge and economic constraints. With the first two being greatly pushed forward nowadays, the research in individual tariffs aims to alleviate the last constraint and ultimately unleash the spirit of creativity from ordinary people.

The ***recognition*** from others also plays an important role in our value as we are all social animals. In a networked society where physical boundary is disappearing, a little effort may harvest lots recognitions from people around the world. Recognitions from community members provide positive feedbacks to creative activities; it helps an individual establish self-esteem, which leads to the feeling of self-confidence, strength, capability and adequacy, of being useful and necessary in the world [11].

3.2 ECONOMIC INCENTIVES OF INDIVIDUAL TARIFFS

A second angle we choose to look at individual tariffs is from economic perspectives. Specifically, we examined theories in the areas of price discrimination, willingness-to-pay and risk hedging, which justify the economic incentives to engage in personalized mobile services and individual tariffs for both the users and suppliers.

3.2.1 PRICE DISCRIMINATION

Price discrimination or price differentiation is a common practice in today's business world. The concept was coined by A.C Pigou [12], who distinguished three types of price discrimination. In first-degree (perfect) price discrimination, each unit of commodity will be sold at a difference price, which is the maximum the user wants to pay. In second degree price discrimination (nonlinear pricing), commodities will be divided into n groups and be sold at n different prices. In third degree price discrimination consumers will be divided into n different groups and each group will be charged a unique price. Different types of price discrimination have different welfare effects in terms of maximizing consumer plus supplier surplus. Theoretically, first-degree price discrimination leads to a Pareto efficient outcome; Second and third degree price discrimination improve overall welfare in general, with some users receiving insufficient amount of product or service. Nevertheless, these users are better off than if they are never served.

Early analyses of price discrimination were done under monopolistic settings and about physical goods; the supplier's technologies involve no economies of scope, and usually possess constant or decreasing return to scale. Varian [13] provided a good overview of these researches. The general impression is that the firms conduct price discrimination have some market power, they may only shuffle the prices paid by pre-existing users without serving extra user groups, neither increasing the amount of product or service. In this case, overall welfare falls.

On the other hand, Eden [14] has observed that price discrimination and price dispersion can occur in a competitive environment, where a price dispersion equilibrium can be achieved when competitors all charge discriminatory prices but the mix of prices vary among firms. Levine [15] argued that price discrimination is not necessarily the evidence of market power. In more situations, it is the optimal strategy for a firm to allocate common costs among buyers. This line of argument provides an alternative way to look at price discrimination. Furthermore, Varian [16] demonstrated that for industries that involve technologies which exhibit increasing return to scale, large fixed and sunk cost and significant economies of scope, the rule of setting prices at marginal cost is no longer economically viable: the marginal cost is close to zero. Pricing principle under this context should be that marginal willingness to pay equal to marginal cost.

Current technologies already permit suppliers to track and trace user behaviours and infer their preferences so as to provide services accordingly. But most users dislike the feeling of being (passively) traced and concern it as erosion of privacy [17]. Individual tariffs invite users to be actively involved in service personalization and pay according to their willingness. It provides a possible approach to implement the idea of first-degree price discrimination[2] and push the market to Pareto efficiency, under a fully competitive environment.

3.2.2 WILLINGNESS-TO-PAY

Willingness-to-pay (WTP) is the maximum amount of money the user is prepared to pay for a service, which is a measurement of value that the user put to the service. WTP is higher when attributes of a service meet precisely the user demands, which is also one of the economic reasons that call for personalized services and individual tariffs.

It is quite unlikely, if not impossible that the supplier can identify all the demands of users simply by observations and offer every possible choice. Even if the supplier does, the burden of having to choose from too many options may lead simply to information overload and

[2] Reselling the services can be prevented by personalization, where each consumer receives the service tailored exactly to his needs. Each consumer is receiving different services to a certain degree.

frustrate the user. A plausible solution is to introduce interactions and change the role of user from passive audience to active players in co-creating value [18]. This has been facilitated by the rapid advances in IT and operation flexibility.

By involving the consumers in a service design through interactions, users' specific demands are identified and integrated to the service. User's willingness-to-pay is higher than the comparable standard services, *ceteris paribus*. Franke and Piller [19] studied the online design of watches with over 700 participants and found that the user WTP even exceeds the best-selling standard watches of the same technical quality. More empirical studies which provide similar results can be found in [20].

3.2.3 RISKS

The term risk is often used vaguely describing the presence of uncertainty. The four possible ways to provide individual tariffs for mobile services lead to different risks, not only to service providers but sometime to the end-users.

User's risks:

Individual tariffs introduce more risks to end-users who bear little risks under public tariffs. Specifically, the risks can be over-committing or over-consumption which may lead to a service disruption. As a consequence, the individual may be denied access from others or access to the information society. However, unlike the supplier, individual alone has no means to hedge these risks as he does not alone have access to risk pooling or aggregation other than savings. He can only rely on the planning or replanning of his own resources, till used up or replenished.

Supplier's risks:

Suppliers, be them firms, communities or even individuals, share a common goal when providing individual tariffs: to minimize risks. The thinking of sure/certain profit from users is currently dominant in mobile as well as other telecommunication industry. Individual tariffs are calling for a change to allow uncertainty in revenue from each individual user. The guiding principle, which has already been recognized in insurance industry for hundreds of years, is to have a positive profit *on average*. Insurance alleviates financial losses by transferring risk of loss from one entity to another by method such as pooling. Various models and computational techniques have been developed over years for life and non-life insurances/reinsurance [21]. Although has long been used in telecommunication, pooling was only limited to capacity estimation. There is no research applying the "pooling" thinking to *differentiated* telecommunication services and tariffs, where the focus will be on pooling the user demands and willingness-to-pay for a service. At individual level, each user's demands for a service may seem unique and serving them may be costly. But for a supplier who serves many users, the pooling of the demands offer market potential. Furthermore, by pooling, the negative profits from individual users are allowed as long as the aggregate profit remains positive, which generates an overall robust business.

Risk hedging for firms and closed communities, which have exclusion mechanisms to reduce the free-riding problem, can focus on the degree of heterogeneity of demands, the degree of heterogeneity of willingness-to-pay across members, the size of membership, et cetera. For open communities, the non-exclusiveness characteristic allows free-riding to kick in.

3.3 USER BEHAVIOUR

The concept *Homo economicus* or economic man describes a model of man who seeks to attain specific and predetermined goals to the greatest extent with least costs. Homo economicus can be characterized as fully rational and self-interested. The model is used broadly in economic and other social sciences. However, many researchers have found limits in this model [22, 23].

3.3.1 BOUNDED RATIONALITY

The strict definition of rationality states that, an individual's preference relation is rational if it possesses the properties of completeness and transitivity [24]. It means the individual is able to compare all the alternatives and the comparisons are consistent. Furthermore, rationality implies that the individual has complete information of all alternatives and knows about the consequences of his choices; he also has unlimited time and unlimited computational power to pick his most preferred option. In reality, such perfectly-rational person never exists. Over the past decades, a large mass of empirical data have shown violations of the rationality assumption (see [25] for a detailed review.)

Herbert Simon [26] has pointed out that most of the time, an individual does not know all the alternatives. Neither does he have perfect information regarding the consequences of choosing a particular alternative both because of limited computational power and because of the uncertainty in the external world. The individual's preferences do not possess the rational prosperities when comparing heterogeneous alternatives. Simon characterized this as "bounded rationality". Model construction under bounded rationality assumption can take two approaches. First is to retain optimization, but to ***simplify sufficiently*** so the optimum is computable. Second is to construct ***satisficing*** model which provides decisions good enough, with reasonable computational cost [27]. Neither approach dominates the other.

Following the pioneering work of Simon on bounded rationality, Kahneman and Tversky conducted a series of research on various types of judgment about uncertain events. Their conclusion was that people rely on a limited number of heuristic principles which reduce the complex tasks of assessing probabilities and predicting values to simpler judgment operations [28]. A recent revisit on these studies by Kahneman and Frederick [29] proposed a formulation in which the reduction of complexity is achieved by an operation of "***attribute substitution***". A judgment is said to be mediated by a heuristic when an individual assesses a specified *target attribute* of a judgment object by substituting another property of that object, the *heuristic attribute*, which comes more readily to mind. Heuristics share this common process of attribute substitution; furthermore, the usage of heuristics is not limited to judgment under uncertainty.

3.3.2 A SOCIAL DIMENSION

The self-interested property implies that economic man is amoral and has no sense of right or wrong. He ignores all social values unless adhering to them gives him benefits; his preferences are exogenous and not affected by societal environment at all. However, this is never true. In choosing to act, individuals commonly consider the consequences of actions not only for themselves but others as well; they have social preferences [30]. This other-regarding (in comparison with self-interested) property of social preferences often embodies as altruism, fairness, teamwork, spite, etc.

Mobile services, by bringing mobility to time[3] and space, enable lots of social interactions which were hardly possible in the past [31, 32]. We contend that the social preferences of mobile services are decided by benefits that an individual elicits from the interactions under different social environments and with different people. Major factors affecting social preferences are:

a.) Access to service, which is an individual’s obligation or rights.

b.) Social context, by which we mean the social environment that an individual lives in, such as social location and social relationships. Under different locations and accompanied by different people, an individual’s preferences are affected by specific social norms and social relationships [33]. This is further complicated by a possible absent presence effect introduced by a mobile service, where a person is physically present but absorbed by a technologically mediated world of elsewhere [34].

c.) Content. The content of a communication service could be categorized as time critical and non time critical according the perceived importance of a timely service. Individual’s intertemporal preference is usually decided by a value function on the subject and a discount function on time. Empirical research indicates that the discount function is a generalized hyperbola [35]. Moreover, content could be categorized based on whether the communication is directly or indirectly motivated. In directly motivated communication, the action satisfies a need; the content is important to the individual, which can be ideas and thoughts, feeling and emotions, comfort and supports. In indirectly motivated communication, the action satisfies an intermediate goal, which can in turn lead to the satisfaction of a need; content is less significant in indirectly motivated communication, what is important is the fact that the communication has occurred. It occurs just to confirm a relationship [36].

3.3.3 MODIFIED BEHAVIOUR MODEL

The differences in behaviour among users can be studied by analyzing the decision rules, which lead to different choices. Decisions are made based on preferences. The art of decision making is to obtain a complete ranking of the alternatives that reflect the preferences [37]. Very often, this is done by assigning a numerical value to each alternative. The number is usually called utility. Specifically, we consider two types of utilities of mobile communication

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[3] On one hand, mobility in time means communication can happen at times which used to be impossible. On the other hand, it means that a communication can happen whenever there is a motivation.

services, namely economic utility and social utility. Economic utility in a given situation is derived from the various service attributes, or from the transactions that the mobile service enables, either with an economic agent, or with a machine (E.g. an application server). An individual elicits social utility from the social interactions that mobile service enabled. A preference relation can be represented by a utility function only if it is rational [24], where the preference must satisfy completeness and transitivity. Many preferences, especially social preferences, are partially rational or irrational. Therefore many situations can not be described by utilities but only by preferences. Here we assume that there are partial preferences, which can be mapped out by types and contexts. If a selection of a subset of preferences leads to a locally monotonic function, then there exists a utility function that can be used for computational purposes.

A mobile service normally has multiple attributes, the utility function is then constructed by following the method from multiple attribute utility theory [38]. First, a utility function for each service attribute is assessed. Then a multiple attribute utility function determines how the level of one attribute affects overall utility vis-à-vis a set of assessed weights of relative importance.

The individual tries to optimize his utility. Due to his bounded rationality, his optimizations are carried out in a much simpler way. We propose that the user builds his utility function based on a set of "perceived attributes" of a mobile service. The "perceived attributes" are different from the service attributes defined by the service provider using full technical specifications. For an individual user, an operation of "**attribute substitution + simplification**" takes place in such a way that it not only simplifies the understanding of service attributes but also significantly reduces the number of them. As a consequence, the individual optimizes on a much simpler utility function.

The individual does not have complete information of all the alternatives; neither does he have full information of the supplier. Indeed, the individual learns from the service personalization and tariff negotiation process. He acquires more information through the interactions with the service provider, either explicitly or through inference.

When making a decision, the individual uses satisficing rules and tries to achieve an acceptable level of utility before he stops.

3.4 SUPPLIER BEHAVIOUR

We also take a utilitarian approach when modelling a supplier's behaviour.

When the supplier is a single firm, economic utility is elicited from economic benefits such as profit or market share, which is generated by service offering. If we expand the analysis further, a supplier also has social preferences for his decisions (e.g. environmental preferences). There may be conflicting goals over a supplier's economic utility and social preferences; he will try to achieve equilibrium/equilibria between them. But the equilibrium/equilibria is seldom computation-based but mostly based on ranking of preferences. It is because none of the existing models provides measurement or calibration instrument to quantify the social preference of a supplier. Therefore in this research, we assume that the supplier derives only economic utility from service offerings. A firm seeks to achieve maximum economic benefit and at the same time minimum risks.

The goals of a community, when offering mobile services, are to achieve financial breakeven and minimize service provisioning risks. On one hand, community can buy or exchange services with a firm or a community. In a way, it plays the role of an aggregator who accumulates demands from its members and acts as an entity with more bargaining power than a single individual while negotiating with other suppliers. On the other hand, the services can be created, maintained and used by the members of the community. In this setting, users themselves act as a supplier. In this research, we are interested in the latter.

When a single individual is the supplier, he can either choose to seek profit and acts as a firm, or to achieve financial breakeven.

3.5 AN ANALYTICAL DESIGN TOOL: COMPUTATIONAL GAME THEORY

Game theory, as a formal analytical approach, has applications in a variety of fields including evolutionary biology, political science, and military strategy. We limited our usage of game theory under economics scope. The main advantage of game theory is that it provides structured analysis of decisions, which are made as reactions to another player's decisions. Over years, game theory has evolved to incorporate "bounded rationality" in its analyses [39]. Further, the cooperation between disciplines such as computer sciences, artificial intelligence and economics gave birth to computational game theory which enables richer ways of modelling complex problems of interactions in an efficient way by computers.

Generally, the bilateral contracting procedure between the user and the supplier can be modelled by an imperfect information game, where the payoffs are the utilities that both parties receive from the service. Specifically, the negotiation process can be modelled by a recursive Stackelberg game, where the first player has a dominant influence over the follower. We empower the user by letting him move first. Different decision rules and constraints can be applied to investigate the equilibrium, if it exits, when the individual sets his service and price requirement to the supplier. Furthermore, different supplier strategies such as bundling can also be studied.

4 A COMPUTATIONAL MODEL

In this section, we introduce a computational model where the suppliers are profit-oriented firms and users are individuals. The overall goal is to determine equilibrium between a user and a supplier when the individual sets his service and price requirements to the supplier. A training service in the field of singing using mobile technologies for the instruction is studied as a case.

4.1 A SERVICE DESIGN SPACE & A PERCEPTUAL SPACE

As mobile and computing technologies evolve, technical specifications of a mobile service become much more complex. From a supplier's perspective, it is common to define tens or even hundreds service attributes in a single service. We characterize a space that is constructed by these *technical attributes* as a ***service design space*** (or an explicit space). Each dimension in this space corresponds to a technical attribute of the service, including price/tariff.

When reaching an agreement with a supplier, the user wants the details to be specified in text or a specification form. Service Level agreements (SLAs), which use to be a way to ensure quality of service (QoS), are becoming increasingly common to set commercial and business terms of service provisioning [40]. SLAs generally take the form of a structured template, with specific QoS metrics that are evaluated over a specific time interval or to a set of defined objectives. Thus SLAs are often written in technical language.

However, an ordinary user usually does not understand most of the technical details of the service specifications. Even given a complete literal translation and additional explanations of the attributes, it is unlikely that the user has the patience to go through all the details. More importantly, user needs to balance among the value of each attribute and the constraints so as to optimize his payoffs. Such perfectly-rational user never exists. Instead, user demands are often expressed in plain (natural) language which involves little technical details. His perception of the service is usually much simpler. We define a ***perceptual space*** as a space constructed by the ***perceived attributes*** of a service (e.g. 'a fast connection'). The perceived attributes are actually the results of a reduced mapping or an "attribute substitution plus simplification". The reduced mapping is based on certain heuristics or as a result of learning of the technical attributes into features that the user in general can relate to. To reach a concrete SLA, a translation or a mapping between the explicit space and the perceptual space is necessary.

4.2 MODELING THE USER

Suppose users can be divided into groups which share similar preferences for a specific class of services. We employ a statistical method called principle component analysis (PCA) to find out the mapping between an explicit space and a perceptual space for a specific group interested in the same class of services. We assume the mapping is valid for a new user, who can be placed in a same group.

Denote the explicit space as x space; the technical attributes as a vector $x = [x_1, x_2 \ldots x_n]$. The samples are the users' revealed target values of service attributes in x space. PCA generates new vectors which are linear combinations of $x_1, x_2 \ldots x_n$. Denote the PCA space as z space, the PCA components as $z = [z_1, z_2 \ldots z_n]$, and the principle component coefficient matrix as p (each column containing coefficients for one principal component), we have $z=x\,p$. The PCA method has two advantages:

1. The first PCA components often explain more variance than the rest of the components, which can be left out without losing much information.

2. The generated PCA components are orthogonal to each other [41].

Interpretation of the PCA components is service specific. In reality z space has much smaller dimensionality than x space due to user's perceptual capabilities. For a given service, we analyze the first few components which cover +/-80 % of variance.

The next step is the elicitation of a utility function. User's utility function, if it exists, is derived based on the reduced set of (PCA) components. Following the multiple attribute utility theory approach, a utility function for each of the perceived attribute is derived first. The second step is to determine how the level of one attribute affects overall utility vis-à-vis a set of assessed weights of relative importance. Multiple attribute utility functions usually take a multilinear form because of the mutual utility dependency among attributes. PCA components are orthogonal to each other, meaning that the value of one attribute is independent of the value of the other. Therefore our multiple attribute utility function can be simply reduced to an additive form.

As mentioned in the beginning, mobile services involve lots of social aspects and individual's preferences are most of the time context and content dependent. User's revealed preferences may not possess the completeness and transitivity property, which are the necessary conditions to find a utility function. On the other hand, by working only in a perceptual space, it is easy for the user to set where he would like to be, and that is called a target point (actually a vector of values), which mixes economic and social aspects of the service. In this paper, we assume the user's utility function is the inverse of the Euclidean distance from a user's best reachable points (because of constraints) to his target point. A user maximizes his utility by approaching as close as possible to his target point. This is also a simplified decision process. The utility function has its limitations but to a certain degree, it also reflects certain 'irrational' aspects: a user may not prefer lower prices than his target value *ceteris paribus*, or his social interaction preferences may overshadow better price.

4.3 MODELING THE SUPPLIER

The supplier, as a profit-oriented company, is assumed to make decisions based only on his economic utility. We define this utility, in the context of the negotiation of an individual tariff, as the expected marginal profit that the supplier receives from serving a specific individual user. The utility function is defined in terms of attributes in the explicit space including price and service provisioning costs. The supplier maximizes his utility, under certain constraints.

4.4 THE NEGOTIATION PROCESS – A RECURSIVE STACKELBERG GAME

During service personalization, a user and a supplier negotiate on a set of service attributes and their values, including tariffs/price in view of a service level agreement (SLA). The negotiation process has a non-cooperative and recursive nature. It is modelled as an n-stage user-lead Stackelberg game. The individual user is the leader as he sets forth first his wishes in the context of individual tariffs, and not the supplier as it in supplier driven public tariffs. During each stage, each player tries sequentially to optimize his own utility taking into account what the other has proposed under his own constraints. Players update their constraints based on what others proposed as variable tolerance bounds as a learning process.

Payoffs & constraints: the players' payoffs are expressed in their utility functions. User's utility function is expressed in a perceptual (z) space while the supplier's in a explicit (x) space. Optimization of the user utility is carried out in z space and optimization of the supplier utility in x space. Players set their constraints separately in x space. The final SLA is expressed in x space in view of provisioning by the supplier. Since the user's utility function, constraints, optimization and SLA are expressed in two different spaces, transformations from one space to another is carried out when necessary.

Equilibrium: A one-stage Stackelberg game can be solved to find a Nash equilibrium, which is a profile of actions with the property that no player can deviate to achieve a better payoff, given the actions of the other player. In the recursive Stackelberg game used in our model, we define an equilibrium point as a point where no player can elicit a higher utility by deviation or entering a new stage of the game; furthermore, the point should also provide the supplier a non-negative payoff.

Negotiation process: It has several steps.

Step 0: In the beginning, the supplier advertises the offering of a class of mobile services. The service attributes (including price) and their values are expressed in x space (denoted as x_offer^0). The service attributes are translated into perceptual attributes, thanks to a pre-existing survey amongst potential users of the service, serving as a learning function. The individual user sets his target values for the perceptual attributes based on his preferences. The values of the attributes of the public offer from the supplier are also mapped into the user's perceptual space: it serves as an initial reference point for the user (denoted as z_offer^0).

Step 1: User optimizes his utility in z space, under his own constraints and taking into consideration the supplier's offer. Denote the user's choice in z space as z_user, which is a vector. User's objective at stage *i* is to maximize his utility $z\_user\_utility(z\_user^i)$, subject to $z\_constraint\_user(z\_user^i, z\_offer^{(i-1)}) \leq 0$. The constraints can be linear and nonlinear. *i=1, 2 … k*, represents the round of negotiation (*i-th* stage of the game). $z\_offer^{(i-1)}$ represents the supplier's offer in the *(i-1)-th* round. The result of user's optimization at stage *i* is denoted as $z\_user\_result^i$; it is then transformed into x space as $x\_user\_result^i$.

Step 2: User decides whether to stop or not, based on his own decision rules. In case of the former, he may opt out to take the public offer or to negotiate with another supplier. If the user decides to continue the present negotiation, he communicates with the operator about his request, which is $x\_user\_result^i$. The user may at the same time signal to the supplier a possible tolerance region in x space.

Step 3: The supplier updates his constraints regarding the proposed value $x\_user\_result^i$ and the possible tolerance region signalled by the user. He then calculates his own optimum under the updated constraints. Denote the supplier's choice in x space as x_operator, which is a vector. The supplier maximizes at stage *i* his utility $x\_operator\_utility(x\_operator^i)$, subject to $x\_constraint\_operator(x\_operator^i, x\_user\_result^i) \leq 0$. The constraints can be linear and nonlinear. *i=1, 2… k* represents the round of negotiation. The result is denoted as $x\_operator\_result^i$. The supplier then decides whether to accept the proposal, or to propose back his last optimized values. He may stop the game based on his own decision rules.

Recursion and Stopping rules: the procedure repeats from (1)--(3) until it satisfies one of the following conditions: $z\_user\_result^{(m+1)} = z\_user\_result^{m}$ or $x\_operator\_result^{(m+1)} = x\_operator\_result^{m}$. Either player can stop the game when the results show a non-convergence trend, which either appears as an oscillation (e.g. $\|z\_user\_result^{(m+1)} - z\_user\_result^{m}\| = d, d \neq 0$) or an amplification (e.g. $\|z\_user\_result^{m} - z\_user\_result^{(m-1)}\| < \|z\_user\_result^{(m+1)} - z\_user\_result^{m}\|$). Furthermore, the supplier will stop the game when the result of his optimization leads him to negative profit.

4.5 IMPLEMENTATION AND PRELIMINARY RESULTS

We have developed a tool to automate the numerical calculation of utilities and the negotiation process of tariff and service personalization. One off-line part calculates the PCA mapping between the explicit space and the perceptual space from a group-survey of potential users with latent interest in the service. The other on-line part decides if an equilibrium/equilibria exists based on the utility functions, constraints and decision rules set by both players (see Figure 1), and computes the equilibrium if it exists. The tool is implemented in a Matlab® environment (www.mathworks.com).

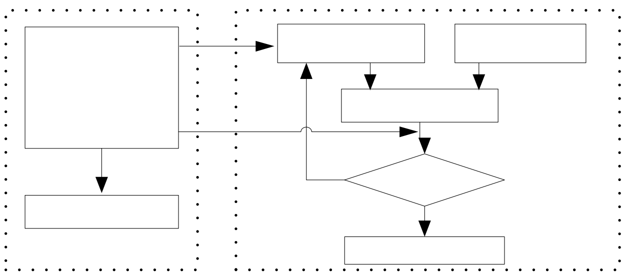

Figure 1: Functional blocks of the implementation.

We have created a mobile music service with limited service attributes to illustrate the computational model and to test the tool. The service is inspired by recent deployments of mobile music services by operators worldwide [42]. While operators are reporting quick acceptance of the services, some analysis has pointed out the unsuitability of current mobile music pricing mechanism [43]. By creating the numerical case in mobile music, we wish to demonstrate that the concepts and computational model can be directly applied to real practice. The service is called "mobile singing classroom" where the users can improve their singing performance by following the courses and getting instructions and content. Users are supposed to be students from a music college; the supplier is an operator assisted by teachers.

Service Description and Service Attributes

The user carries out a search (e.g. by sending SMS) in a database and finds out which music lessons he would like to follow. (e.g. Verdi' opera: Otello, Attila). After selection, he can download the music and other instructional materials to learn and to practice. He can send

Constraints update

Utility determinat

Statistical analysis (PCA mapping)

Optimization

questions to the operator during his lessons and will receive professional answers. The attributes of the service to be negotiated are listed in Table 1.

Utility functions

User's utility is expressed in PCA space. Denote the generated PCA components as $z = [z_1, z_{2 \ldots} z_m]$, we choose the first components which cover 80+% of variance. The utility function takes the form $U(z) = [\Sigma(z-z_i)^2]^{1/2}$. The user maximizes his utility by minimizing U(z).

We define operator's utility as the incremental profit from serving the additional user, which is the expected profit minus costs from provisioning the personalized services. Operator's utility takes the form U(o) = revenue-costs.

Besides the value added "mobile singing classroom" service, the user also has a basic subscription with the operator. He pays a monthly fee for a bundle of basic services such as voice minutes, SMS, MMS and data traffic (all with capacity ceilings). There are several bundles for the user to choose amongst. Since the value added singing classroom service is based on the basic services, we assign a coefficient (k) to user's bundle. This coefficient assumes that the user will use certain percentage of basic services ceilings for the mobile singing classroom. When calculating operator's cost, we first subtract k*(user bundle) amount of services because they are already paid.

Constraints and decision rules

Both user and operator's constraints are expressed in the technical space. The user has boundary constraints which are the region of tolerance for the technical attributes. Moreover, the user has budget constraints. The cost of total usage includes the cost of subscription for basic services, the cost of contract of the singing classroom service, the cost of investment on a mobile device which supports high end music functions. Further, the user has time constraints. He needs time to learn and practice. Finally, the user may have some specific preferences which can also be translated into constraints. Some of these constraints are fixed; the rest change during the negotiation process as the user adjusts his constraints according to the operator's offer. The operator has boundary constraints. He also has constraints which guarantee the minimum the quality of his services. In addition, the user also indicates a possible negotiation space during the negotiation. Most of operator's constraints are updated with user's proposal in each round of the negotiation.

The user stops when one of the two criteria is satisfied, i.e.: 1) the distance from one of the optimization results to his target point in his perceptual space is less then a relative value when compared to the initial situation (e.g. less than 5% of the initial distance). 2) the difference between two consecutive optimization results (user utilities) is less than a relative value when compared to the initial situation (e.g. less than 0.1 % of the initial distance). Operator can either accept the request from the user and sign the contract or quit the game without signing the contract.

An equilibrium is defined as: 1) user wants to stop the negotiation and 2) operator makes positive profit. Then the negotiation stops. SLA will be signed.

Numerical results

We have three users which represent three types of students:

User a: Just wants to listen to the music and wants to know how to perform or improve his background knowledge on certain types of music; does not want to ask questions to the teacher. The number of songs available is important to him. Due to the fact that it takes much less time to just listen to the music than actively learn how to perform, the user can basically take a lesson everyday.

User b: Studies in an active mode and takes a lot of time to practice according to the instructions; eager to ask questions to improve his performance skill. The user would like to focus on a certain series of songs. The number of lessons the user will take each month is small but at the same time, the user tends to ask a lot of questions.

User c: Represents the type of users who wants relatively medium level of services when compared to the other two types of users. Takes moderate number of lessons and subscribes to moderate number of instructions and asks moderate number of questions.

Table 1 shows the users' revealed preferences, the operator's public offer as well as the results of each negotiation[4]. Figure 2 shows the negotiation process between the user-a and the operator. Point 1 represents user-a's first proposal; its position shows user's (inverse) utility and the operator's utility from this proposal correspondingly. Point 2 represents the operator's counter offer and the utilities of each player. The final point is the user's proposal 7.

Gains and losses (when compared to the public offer) are analysed for each player; the results can be a win-win or win-loss situation. The user, as the leader of the game, achieves gains. The differences in gains across users stem from their different preferences and constraints. The operator achieves better results in two cases but a worse result in one case. In our simulation, the operator uses a same set of constraint update mechanism and therefore treats all the users similarly.

Table 1: User revealed preferences, operator's public offer and negotiation results

Name	Initial points			Pubic offer	Final EQ Point		
User names	a	b	c		a	b	c
Dbsize (ksongs)	6	1	3	2	5.6	1.9	2.6
Instructions from the teacher per lesson	2	8	4	4	2.1	6.2	3.2

[4] Due to the limitation of our computational tool, the negotiation results are not in integer.

Coding rate of songs (kbps, 96/128/144)	128	144	144	114	130.78	119.3	122.45
SMS searches/lesson	7	1	3	2	6.27	1.9	3.0
Distribution method (mobile/fixed/mixed) - here the user should choose a value between 1-10	3	9	7	5	5.89	7.3	5.6
Number of questions student asks in contract period	2	60	30	10	1	58.3	21.3
Length of contract in months	2	4	3	2	1.6	5.2	2.5
Number of lessons/month	20	8	10	5	19.1	6.1	8.4
User's bid for the service (euro)	100	100	70	30	63.7	98.64	53.6

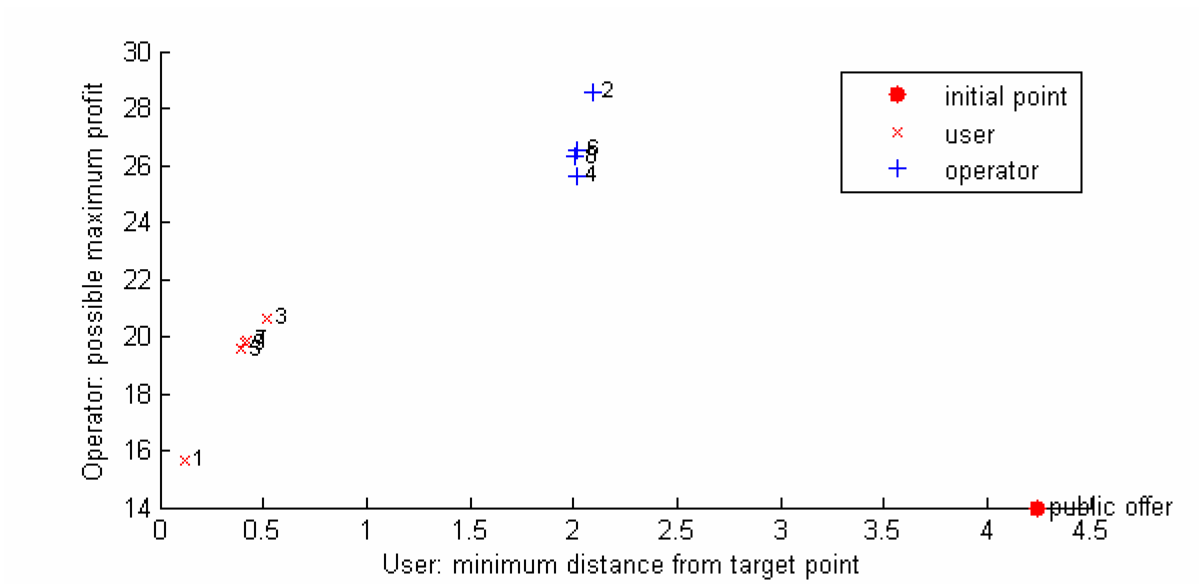

Figure 2: The negotiation process of user and the operator.

5 CONCLUSIONS

This paper tries to carve out a small piece of land out of the uncharted area of individual tariffs in mobile communication services. It aims to provide a theoretical framework to assist the development of computational models which can be implemented in real world applications. The framework is built centred on user and supplier behaviours. The user, instead of being fully rational, has "bounded rationality" and his behaviours are not only subject to economic constraints but also influenced by social needs. The supplier, which can be a firm, a community, or an individual, has different goals which lead to different behaviors. Individual tariffs are decided by the interactions between users and suppliers.

We developed a computational model based on the conceptual framework. The model can be used to determine the individual tariffs between a profit-oriented supplier (firm) and an individual user. Preliminary results show individual tariffs can be beneficial to both the users and the supplier. Our next steps of work involve comparing different types of equilibria when the user and the supplier use different strategies and decision rules. Risk will also be incorporated in the model by linking individual's utility with random distributed parameter. Furthermore, the computational model may be extended to the situations where the user can be a community instead of an individual, and also the supplier can also be a community or even an individual.

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