Multi-Attribute Auction Model for Agent-Based Content Trading in Telecom Markets

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Abstract. The advent of the Internet and the development of the Next Generation Network (NGN) have enabled the development of value added services (VAS), while operators' investments in licenses and their desire to stay competitive on the market have triggered the development. When forming VAS, special attention needs to be paid to the purchase of resources (e.g., transport capacity and content) needed for the service creation. As the number of participants on the telecom market increases, the need for automation of transactions carried between them arises. In this paper, we identify stakeholders on the telecom content e-market and propose an appropriate model which captures their transactions. Since content is not a commodity we propose a multi-attribute auction model for content trading which prevents sellers from manipulating the auction outcome by offering unnecessarily high values of some (often less important) attributes in order to compensate for unreasonably low values of other (more important) ones. A multi-agent system which uses the multi-attribute auction model as a negotiation protocol is presented and an illustrative example of content trading in telecom markets is provided.
Keywords: content trading, B2B telecom e-market, multi-attribute auctions, multi-agent system

1 Introduction

Provisioning of basic telecommunication services (i.e., fixed and mobile communication, data transfer) is no longer enough to keep existing customers, let alone attract new ones [1] so telecom operators are pursuing innovations and launching new value-added services (VAS) [2] in order to increase revenue. There are two types of resources needed for the creation of VAS. They are the information resources (i.e., content) the service is based on and the transport capacities needed for service provisioning [3]. The term content encompasses movies, songs, news, images and text, in other words data and information within various fields [4]. The Next Generation Network (NGN) brings its own new added value into the market and one of these added values is multimedia content composed of several types of content (e.g., audio, video, data…) [5].

The telecom market is divided into two submarkets, the B2B (Business-to-Business) market and the B2C (Business-to-Consumer) market. Telecom operators buy resources on the B2B market [6], from those resources they create VAS which are then sold to users on the B2C market [7]. The research problem addressed in this paper concerns the automation of business processes related to content trading on the B2B telecom electronic market (e-market) by using multi-attribute auctions.

The paper is organized as follows. Section 2 identifies stakeholders on the telecom content e-market and presents the phases of the proposed Content e-Trading Transaction Model. Section 3 presents a Multi-Attribute Auction Model used during the content trading negotiation process. Section 4 illustrates the use of the Multi-Attribute Auction Model and compares it with a few other multi-attribute decision making approaches, while Section 5 concludes the paper and gives an outline for future work.

2 Telecom e-market

The telecom content e-market includes participants from the media, Internet, advertising and telecom world [8, 9]. *Media companies* provide professionally produced content (e.g., music videos, movies, TV shows) which is used to create VAS. New business models enable *advertisers* to sponsor content and receive valuable feedback from the users. Also, since mobile phones carry diverse context information about their owners, the opportunity for target advertising arises. *Internet companies* (e.g., search engines) help users to find potentially interesting content. They also have the possibility to create a new generation of applications which use context information from users' mobile phones. *Telecom operators* generate new revenue streams by increasing the number of VAS which they offer to their users and at the same time they increase the traffic going through their network. *Users* profit from a greater selection of VAS and from the rise of payment opportunities for the use of VAS. So we can say that on the telecom content e-market, shown on Figure 1, all participants are on the win.

The users buy content packed in VAS from Telecom operators on the *B2C e-market* while all the other previously mentioned companies do business on the *B2B e-market*. The proliferation of e-business and the dynamic nature of business transactions conducted on the Internet, argues for the development of intelligent trading agents which act on behalf of human traders (i.e., buyers and sellers) [10–12]. Intelligent trading agents can also be used to impersonate stakeholders in the environment of the NGN in order to enable automated interactions and business transactions on the telecom markets [7].

2.1 CeTT Model

The CeTT (Content e-Trading Transaction) Model systematically analyses process of content trading on the telecom content e-market. It was made by adjusting

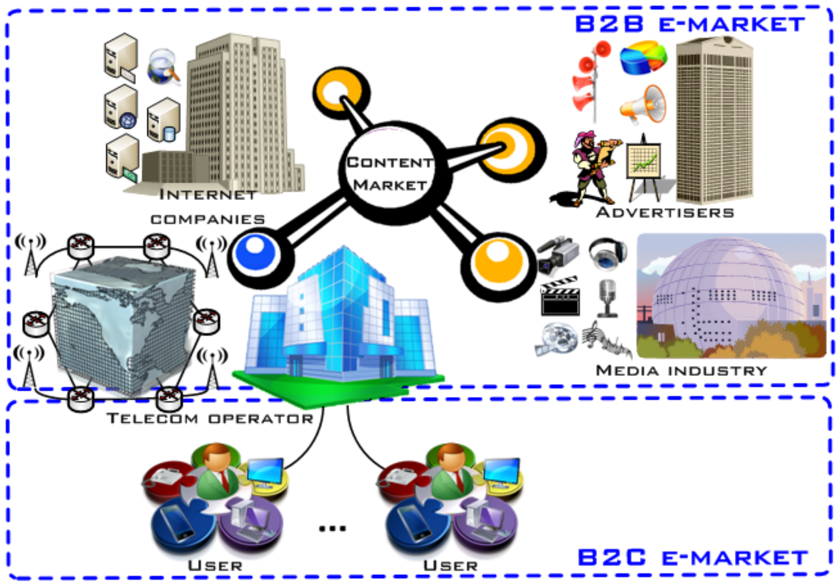

Fig. 1. Telecom content market

the BBT (Business-to-Business Transaction) Model [13], CBB (Consumer Buying Behaviour) Model [13] and the Sourcing Process [14] to the specifics of the telecom content e-market. We can formally identify five steps which must be executed in order to successfully complete one content trading transaction on the B2B e-market. These steps are as follows (Figure 2): 1) need identification, 2) brokering, 3) negotiation, 4) contracting, and 5) content and supplier evaluation.

The goal of the *need identification* phase is to specify the type and the appropriate values of the content that the telecom operator would like to purchase. Both the type and the parameters are determined based on the history of users' content consumption as well as on market research concerning latest releases of new and popular content. In the CeTT Model the *Service Provider Agent (SPA)* which represents the telecom operator's department for creating and providing VAS, contacts various *User Agents (UAs)* which represent operator's users in order to find out their preferences. The SPA also searches through operator's database with past transactions and tries to predict which kind of content would users like.

The main role of the *brokering* phase is to match the SPA with content providers that sell the type of content needed for the creation of a new service or upgrades of an old one. The SPA searches the market and identifies a group of potential business partners which are represented by their *Content Provider Agents (CPAs)*.

When studying B2B e-markets, a special intention is paid to the *negotiation* phase since the outcome (i.e. financial efficiency) is still the premier performance

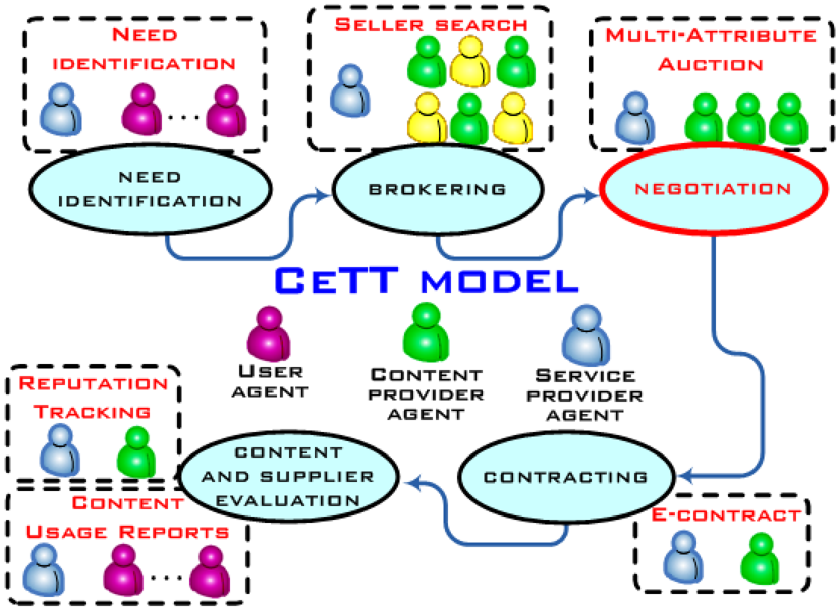

Fig. 2. Content e-Trading Transaction Model

measure for most businesses [15]. Negotiation is a process which tries to reach an agreement regarding one or more content attributes (e.g., price, quality, etc.). Each stakeholder in the negotiation process is represented by an intelligent trading agent that negotiates in his behalf (e.g., SPA trades in behalf of telecom operator) [10]. We use the Multi-Attribute Auction Model described in Section 3 for content trading in the CeTT Model since multiple issues need to be settled and the parties involved have different preferences towards these issues.

In the *contracting* phase the negotiated terms are put into legally binding electronic contract [16] and the conditions, clauses and activity sets that satisfy those negotiated terms are specified [17]. The contracting phase of the CeTT Model starts with the contract preparation activities which are then followed by the contract fulfilment process which includes contract execution and execution monitoring. The SPA and the winning CPA agree on the content delivery terms, payment deadlines and penalties in case that one of the parties does not respect the negotiated terms. Later, the SPA checks if the parameters of the delivered content match the negotiated ones and are all deadlines met.

In the *content and supplier evaluation* phase the SPA uses the information from the monitoring part of the contracting phase in order to calculate CPA's reputation based on his fulfilment of the negotiated terms [18]. Content is evaluated after a certain period by tracking its popularity with telecom operator's users. UAs report back to SPA with the latest users content consumption information.

3 A Multi-attribute Auction Model for Content Trading

Due to their well defined protocols, auctions are suitable enablers of negotiations in e-markets and as such will be used in the negotiation phase of the CeTT Model. Participants in the auction (i.e., telecom operator and media companies) will be represented by their agents (i.e., SPA and CPAs). Complex items (i.e., content) often require negotiation of several attributes, and not just the price [19]. They are sold in multi-attribute auctions [20] which are a special case of procurement auctions. Procurement auctions are also called reverse auctions since there are multiple sellers and only one buyer that purchases items.

Existing models of multi-attribute auctions use different approaches to determine the winning offer (e.g., by defining various utility functions [20–22], by using fuzzy multi-attribute decision making algorithms [23], by introducing pricing functions and preference relations for determining acceptable offers [24], by calculating the ratio of deviation from the ideal offer and the deviation from the anti-ideal offer [25]).

The prerequisite for conducting the multi-attribute auction is for the SPA to specify the preferences of the content he wishes to purchase. This step is conducted in the need identification phase of the CeTT Model. Preferences are usually defined in the form of a scoring function based on the SPA's utility function [22]. The SPA sends a request to all CPAs identified as potential business partners in the brokering phase of the CeTT Model. The CPAs then reply by sending bids. The winner of the multi-attribute auction is the CPA that provided the highest overall utility for the SPA. Our model is based on reverse auctions and takes into account the price, as well as other non-monetary attributes of the purchased content.

A multi-attribute auction can be defined as a tuple $< b, S, t >$, where

- b is the buyer agent (i.e., SPA);
- S (of size s) denotes the set of all seller agents (i.e., CPAs) that participate in buyer b's multi-attribute auction;
- $t : \mathbb{R}^s \rightarrow \mathbb{R}$ is the winner determination function.

The winner determination function ranks CPAs' offers based on the values assigned to them and determines the auction outcome. A description of all negotiable content attributes as well as the functions that assign values to CPAs' offers are defined in the *content evaluation model* which is represented with a tuple $< x, w, U, d_p >$, where

- $x = (x_1, \ldots, x_j, \ldots, x_n)$ is the set of attributes used to describe the content; each attribute j has a reserve and aspiration value, denoted as x_j^r and x_j^a, respectively, determined by the SPA;
- $w = \{w_1, \ldots, w_j, \ldots, w_n\}$ is a set of weights that determines the importance of each attribute from x for the SPA, where w_j is the weight of attribute j;
- $U : \mathbb{R}^{s \times n} \times \mathbb{R}^n \rightarrow \mathbb{R}^s$ is a utility function that calculates the SPA's utility of CPAs' offers;

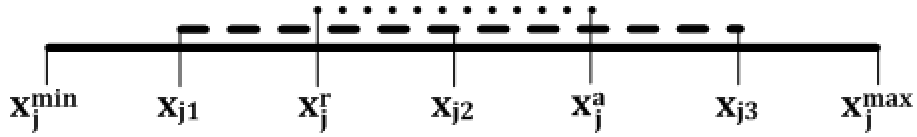

Fig. 3. Attribute values

- $d_p : \mathbb{R}^{s\times n} \times \mathbb{R}^n \rightarrow \mathbb{R}^s$ is a deviation function that calculates the SPA's positive deviation of CPAs' offers.

As shown in Figure 3, there are several relevant values of an attribute that can be used to determine SPA's utility for that attribute. An attribute j has the lowest and highest possible value, x_j^{min} and x_j^{max}, respectively. The CPAs place offers between those values (e.g., x_{j1}, x_{j2}, x_{j3}). Reserve value x_j^r marks the lowest value of an attribute j that is acceptable to the SPA while the aspiration value x_j^a is the highest value of an attribute j that the SPA is interested in. An offer with at least one attribute value worse than the reserve value (e.g., x_{j1}) is disqualified. In a single attribute auction, a value better than the aspiration value (e.g., x_{j3}) is usually accepted since it clearly brings additional benefit to the SPA (e.g., lower price than the one that the SPA was ready to pay presents clear savings for the SPA). To the best of our knowledge, the existing multi-attribute auction models do not distinguish between x_j^a and x_j^{max} and accordingly do not consider the situation where $x_j^a < x_j \leq x_j^{max}$.

The utility function $U(x)$ was designed in such a manner to prevent CPAs from significantly increasing the total utility of their offers by assigning unnecessarily high values to some (often less important) attributes in order to compensate for unreasonably low values of other (more important) ones. However, the additional benefit that the SPA gets from the value higher than the aspiration value x_j^a is not completely ignored. After determining the utility of an offer the winner determination function t also takes into account additional gain that the SPA obtains from each offer before declaring the winner of the auction.

Utility function $U(x_i)$ takes as input an offer x_i placed by CPA_i and, together with the set of weights w maps it to a real value. Function $U(x_i)$ can be defined as an additive scoring function that assumes the existence of mutual *preferential independence* between attributes [22]. In order to calculate the utility of offered content, reserve values and weights for each attribute need to be considered [21]. Function $U(x_i)$ is defined as follows:

$$U(x_i) = \sum_{j=1}^{n} w_j U(x_{ij}),\ where \sum_{j=1}^{n} w_j = 1 \tag{1}$$

$$U(x_{ij}) = \begin{cases} \frac{x_{ij} - x_j^r}{x_j^a - x_j^r},\ x_j^r \neq x_j^a\ and\ x_j^r \leq x_{ij} < x_j^a \\ N.A.,\ x_{ij} < x_j^r \\ 1,\ x_{ij} \leq x_j^a \end{cases} \tag{2}$$

In our model, $U(x_{ij})$ depends on the reserve and aspiration values, x_j^r and x_j^a, respectively, that the SPA defines for each attribute j. Value N.A. in Equation (2) marks a non-acceptable value for an attribute, i.e., it is worse than the reserve value x_j^r. An offer is rejected if the utility of at least one attribute is N.A. Values offered higher than the aspiration value are acceptable, but their utility cannot be higher than 1. Positive deviation function $d_{p,i}$ compares an offer x_i placed by CPA_i with the aspiration offer $x^a = (x_1^a, \ldots, x_j^a, \ldots, x_n^a)$ and maps the comparisons to a real value. Function $d_{p,i}$ is defined as follows:

$$d_{p,i} = \sqrt{\sum_{j=1}^{n} d_{p,ij}^2},\; d_{p,ij} = \begin{cases} w_{ij} \frac{x_{ij} - x_j^a}{x_j^{max} - x_j^a},\; if\ x_{ij} > x_j^a\ and\ x_j^a \neq x_j^{max} \\ 0,\; otherwise \end{cases} \quad (3)$$

In our model, the $d_{p,i}$ depends on the aspiration and highest possible attribute values, x_j^a and x_j^{max}, respectively. It calculates the SPA's additional benefit as the positive deviation of an offer x_i from the aspiration offer x^a. The function $d_{p,i}$ takes into account only attributes with values higher than the values of the aspiration offer x^a. An offer with $d_{p,i} > 0$ brings additional benefit to the SPA beyond the utility he expects to get.

The primary objective of the winner determination function is to maximize SPA's utility while the secondary objective is to maximize additional benefits that some offers bring. The problem arises when the objectives are in conflict so the function t tries to find the compromise between them by setting the weight of additional benefits w_{bonus} low enough to prevent CPAs with average offers from manipulating the auction outcome in their favour, but at the same time w_{bonus} should be high enough to reward the CPAs with very good offers which also bring additional benefit to the SPA. The t is defined as follows:

$$t = \max_i\ T(i),\ where\ T(i) = w_{bonus} d_{p,i} + (1 - w_{bonus}) U(x_i) \quad (4)$$

4 An Illustrative Example

The proposed Multi-Attribute Auction Model for determining the auction winner was implemented and the results are presented in this section. The application domain of the model was content trading on the B2B telecom e-market. One buyer (SPA) and 5 sellers (CPAs) participated in a sealed-bid multi-attribute reverse auction. The SPA needs to buy new and popular songs which he sells to his users as a ringtone or a music video. First, he gathers information from UAs and does some market research. The SPA determines that it already offers the first five songs from the music charts so its aspiration value is set on the 6th place on the charts. It also does not want a song ranked under the 60th place so the reservation value is 60. Since songs from more popular artists are sold more often than the ones from new or less popular artists, when purchasing new content, the SPA also takes into account the popularity of the artist that is performing the song.

After the SPA found CPAs that provide the kind of content it wants to purchase, the negotiation phase begins. The agents negotiated on the following attributes: x_1 - the percent of the profit from each sold ringtone or music video that the SPA will get, x_2 - the current position of the song on the music charts, x_3 - the popularity index of the singer in the previous year, x_4 - the music reviwers' grade of the song and x_5 - the time period that the SPA has the right to sell the song. The Table 1 contains the minimum (i.e., worst) and maximum (i.e., best) possible attribute values as well as SPA's valuations (i.e., weights), reservation and aspiration values for each attribute. We assume that the song will not be on the music charts (i.e., interesting enough to users for them to buy the ringtone or music video) longer than 100 days (roughly three months) so we set the x_5^{max} on 100 days even though x_5^{max} can actually be indefinite.

Table 1. Attribute values and SPA's attribute valuations

	x_1	x_2	x_3	x_4	x_5
minimum value (x_j^{min})	0	100	100	1	1
maximum value (x_j^{max})	100	1	1	10	100
weight (w_j)	0.30	0.25	0.20	0.15	0.10
reservation value (x_j^r)	20	60	60	2.5	30
aspiration value (x_j^a)	50	6	6	6.5	75

The Table 2 contains the offers placed by CPAs, utilities and positive deviations of those offers as well as ranking of offers according to our model and previously mentioned winning offer determination approaches ([22, 24, 25, 23]). After a set of experiments we determined that $w_{bonus} = 0.05$ is low enough to prevent compensation of attribute utilities. From the rankings with other approaches we can see that CPAs were able to compensate the lower utility of a certain attribute with the higher utility of anther attribute and win in the auction due to SPA's lack of distinguishing between x_j^a and x_j^{max}. Since our Multi-Attribute Auction Model prevents CPAs with average offers from manipulating the auction outcome in their favour we plan to use it in the negotiation phase of the CeTT Model.

Table 2. Sellers' offers and offer rankings

	x_1	x_2	x_3	x_4	x_5	$U(x)$	d_p	$T(i)$	Rank	Rank[22]	Rank[23]	Rank[24]	Rank[25]
CPA_1	35	12	10	9.5	95	0,807	0,151	0,775	3	1	2	2	2
CPA_1	40	20	12	6.5	80	0,812	0,020	0,773	4	4	4	1	4
CPA_3	45	25	14	7.5	100	0,832	0,109	0,796	2	2	1	4	1
CPA_4	35	7	6	6.5	85	0,845	0,040	0,805	1	3	5	3	5
CPA_5	75	46	33	2.5	100	0,564	0,180	0,546	5	5	4	5	4

5 Conclusion

In this paper, we identified stakeholders on the telecom content e-market and proposed a model which captured all stages related to transactions carried out on the telecom content e-market. Phases of the introduced CeTT (Content e-Trading Transaction) Model are described and the roles and tasks of intelligent software agents in the model are defined. The Multi-Attribute Auction Model which defines a protocol for content trading conducted in the negotiation phase of the CeTT Model is presented. A comparison of the proposed model with several other multi-attribute auction models which use different approaches to determine the winning offer was conducted. An example presented in Section 4 illustrated how, unlike the other models, our Multi-Attribute Auction Model prevents sellers (e.g., Content Provider Agents) with average offers from manipulating the auction outcome in their favour. The model maximizes the buyer's (e.g., Service Provider Agent's) utility of placed offers while taking into account additional benefits that some offers bring and it also discourages sellers from offering unnecessary high values of some attributes with the purpose of compensating for unreasonably low values of the other ones.

For future work, we plan to implement the remaining phases of the CeTT Model and integrate them with the Reputation Tracking Reverse Auction Model [18] used in the content and supplier evaluation phase of the CeTT Model.

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