A Multi-Agent System for Game Trading on the B2B Electronic Market

Ana Petric, Gordan Jezic

University of Zagreb
Faculty of Electrical Engineering and Computing
Unska 3, HR-10000, Zagreb, Croatia
{ana.petric, gordan.jezic}@fer.hr

Abstract. In order to provision content-based services to their users, service providers need to purchase content distribution rights from various content providers. Sometimes the creation phase of certain content categories can last longer than planed so content providers deliver the content to service providers with delays. The delayed delivery can cause financial damages and inconveniences to service providers which have already announced the appearance of new content to their users. In this paper we propose a multi-agent system which is used to model an electronic market for trading the rights to distribute video and computer games. On the proposed market, a service provider agent uses the multi-attribute reputation decision making mechanism to purchase content distribution rights from content provider agents. Several sets of experiments were conducted to demonstrate the efficiency of the multi-attribute reputation decision making mechanism.
Keywords: content trading, B2B content e-market, reputation tracking auctions, multi-agent system

1 Introduction

The ability to transfer various video and audio data as well as other forms that carry certain information into digital form so it can be deployed across multiple technologies is considered to be one of the fundamental enablers of convergence between different domains (i.e., telecommunications, the Internet, information technology, broadcasting and media) that are involved in the content service provisioning process [3, 13]. The appearance of digital content was followed by the development of (digital) content market while the advances in the ICT (Information and communication technologies) industry enabled the development of (digital) content electronic market (e-market).

Service providers (i.e., network operators, internet service providers, cable television operators) recognized the potential of the content e-market and started to develop new business models for provisioning content-based services to their users [1, 5, 6]. The term content encompasses movies, songs, games, news, images and text, in other words data and information within various fields [12]. Since content production is not in service providers' primary business domain, in order to provision content-based services, they have to buy content distribution rights from various content providers (i.e., media companies, copyright holders) on the content e-market [1, 4]. Content providers sell content distribution rights to service providers on the Business-to-Business (B2B) content e-market, while service providers provision content-based services to users on the Business-to-Consumer (B2C) content e-market [7, 10].

Games are one of the youngest content categories while the (digital) games market is considered to be one of the most advanced content markets when it comes to digital distribution and exploitation [11]. Some content categories, such as games, have longer and/or expensive creation phases so content providers can sell content distribution rights on the B2B content e-market during the creation phase even before the content is finished (e.g., game distribution rights can be sold once the story line has been created and the visuals of the game have been designed). If the creation phase lasts longer than anticipated by the creation deadlines, games can be delivered to service providers with delays causing financial damages and inconveniences to service providers.

The paper is organized as follows. Section 2 presents the architecture of a multi-agent system for game trading while section 3 presents the settings of the conducted experiments and the obtained results. Section 4 concludes the paper and gives an outline for future work.

2 Architecture of the Multi-Agent System

Figure 1 shows the architecture of the proposed multi-agent system for game trading that is defined as $MAS_{gt} = \{SPA, CPA_1, \ldots, CPA_i, \ldots, CPA_M\}$. The Service Provider Agent SPA represents a network operator which acts as a service provider on the content e-market while M Content Provider Agents CPAs represent game publishing companies which publish (and produce) games and act as content providers on the B2B content e-market. On the B2C content e-market, the SPA provides game-based services to users which are represented by their User Agents (UAs).

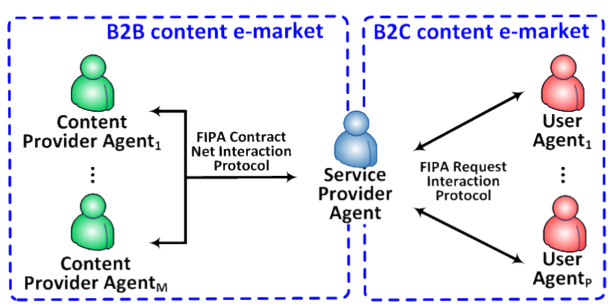

Fig. 1. Architecture of the multi-agent system for games trading

2.1 Content Provider Agent

The content provider agent CPA_i sells game distribution rights to the SPA. The CPA_i is defined as follows $CPA_i = \{\boldsymbol{X_{cpa_i}}, dem, r_c(i)\}$ where $\boldsymbol{X_{cpa_i}}$ represents the current CPA_i's games offer, dem stands for the delivery evaluation mechanism which is used to calculate the on-time delivery probability for a certain game, while the $r_c(i)$ is the CPA_i's risk taking policy which represents the lowest acceptable value of the on time delivery probability defined by the game publishing company's business strategies.

The CPA_i receives a Call For Proposals (CFP) from the SPA and decides will it participate in an auction held by the SPA. If the CPA_i does not have at its disposal any games ready for distribution, it calculates the on-time delivery probability $p(t_c(\boldsymbol{x_i}))$ that the creation phase of a certain game $\boldsymbol{x_i} \in \boldsymbol{X_{cpa_i}}$ will be completed by the deadline t_c which is defined in the CFP. If the probability $p(t_c(\boldsymbol{x_i}))$ is higher than its risk taking policy $r_c(i)$, the CPA_i sends an offer $\boldsymbol{x_i}$.

2.2 Service Provider Agent

The SPA is defined as follows $SPA = \{th, gc, cem, rtm, mrdm\}$, where the th is the trading history with CPAs, the gc contains information about prior users' games consumption, the cem is the content evaluation mechanism, the rtm is the reputation tracking mechanism while the $mrdm$ is the multi-attribute reputation decision making mechanism. The information from the th is gathered from prior transactions with CPAs and used by the rtm. The information contained in the gc is gathered from users' consumption behaviour on the B2C e-content market and used to determine reserve and aspiration values used by the cem.

After analysing the information from the gc, the SPA determines relevant game attributes $\boldsymbol{A} = \{a_1, \ldots, a_j, \ldots, a_n\}$ as well as their reserve and aspiration values necessary for the evaluation of games offered by CPAs. Reserve value x_j^r marks the lowest value of an attribute a_j that is acceptable to the SPA while the aspiration value x_j^a is the highest value of an attribute a_j that the SPA is interested in. The SPA starts an auction by sending CFPs to CPAs. The SPA acts as a buyer while CPAs act as sellers in the auction. The required delivery deadline t_c as well as a list of relevant attributes $\boldsymbol{A}$ and their reserve values $\boldsymbol{x^r} = \{x_1^r, \ldots, x_j^r, \ldots, x_n^r\}$ are sent within the CFP. The SPA receives $m \leq M$ offers $\boldsymbol{X_m} = \{\boldsymbol{x_1}, \ldots, \boldsymbol{x_i}, \ldots, \boldsymbol{x_m}\}$ from CPAs that decided to participate in the auction where the CPA_i offers to sell distribution rights of the game $\boldsymbol{x_i} = \{x_{i1}, \ldots, x_{ij}, \ldots, x_{in}\}$.

Content Evaluation Mechanism The cem [9] is represented with a tuple $< \boldsymbol{X_m}, w_c, u_c, d, u >$, where each offer $\boldsymbol{x_i} = \{x_{i1}, \ldots, x_{ij}, \ldots, x_{in}\}$ from the set of offers $\boldsymbol{X_m}$ is described with n attributes, $w_c = \{w_{c1}, \ldots, w_{cj}, \ldots, w_{cn}\}$ is a set of weights that determines the importance of each attribute from $\boldsymbol{x_i}$, u_c is a utility function that calculates the SPA's utility of CPA_i's offer $\boldsymbol{x_i}$; d is a deviation function that calculates the SPA's additional benefit of CPA_i's offer

$\boldsymbol{x_i}$; u is a utility function that calculates the total utility of the offer $\boldsymbol{x_i}$ and it is defined as follows:

$$u(\boldsymbol{x_i}) = (1 - w_{c,bonus})u_c(\boldsymbol{x_i}) + w_{c,bonus}d(\boldsymbol{x_i}). \tag{1}$$

The primary objective of the $u(\boldsymbol{x_i})$ is to maximize content utility $u_c(\boldsymbol{x_i})$ of the offered content $\boldsymbol{x_i}$ while the secondary objective is to maximize additional benefits $d(\boldsymbol{x_i})$ that an offer brings. The weight of additional benefits $w_{c,bonus}$ should be low enough to prevent a CPA with an average offer from manipulating the auction outcome in its favour, but at the same time it should reward a CPA with a very good offer which also brings additional benefits to the SPA.

The content utility function $u_c(\boldsymbol{x_i})$ is an additive scoring function that assumes the existence of mutual *preferential independence* between attributes [2]. It is defined as follows:

$$u_c(\boldsymbol{x_i}) = \sum_{j=1}^{n} w_{cj} u_c(x_{ij}),\ where \sum_{j=1}^{n} w_{cj} = 1 \tag{2}$$

$$u_c(x_{ij}) = \begin{cases} \frac{x_{ij} - x_j^r}{x_j^a - x_j^r},\ x_j^r \neq x_j^a \ \&\ x_j^r \leq x_{ij} \leq x_j^a \\ N.A.,\ x_{ij} < x_j^r \\ 1,\ x_{ij} > x_j^a \end{cases} \tag{3}$$

Value N.A. in (3) marks a non-acceptable value for an attribute. Values offered higher than the aspiration value are acceptable, but their utility cannot be higher than 1. The positive deviation function $d(\boldsymbol{x_i})$ compares an offer $\boldsymbol{x_i}$ placed by the CPA_i with the aspiration offer $\boldsymbol{x^a} = \{x_1^a, \ldots, x_j^a, \ldots, x_n^a\}$ taking into consideration highest possible attribute values x_j^{max} as follows:

$$d(\boldsymbol{x_i}) = \sqrt{\sum_{j=1}^{n} d(x_{ij})^2},\ d(x_{ij}) = \begin{cases} w_{cj} \frac{x_{ij} - x_j^a}{x_j^{max} - x_j^a},\ if\ x_{ij} > x_j^a \ \&\ x_j^a \neq x_j^{max} \\ 0,\ otherwise \end{cases} \tag{4}$$

Reputation Tracking Mechanism The rtm [8] is represented with a tuple $< y, w_r, V, r >$, where $y = \{y_1, y_2, y_3\}$ is a set of attributes used to calculate CPAs' reputation, $w_r = \{w_{r1}, w_{r2}, w_{r3}\}$ is a set of weights that determines the importance of each attribute from y for the SPA, V is the SPA's sliding window which is used to store information regarding the last v auctions the SPA held; and r is a utility function that calculates CPAs' reputation.

Three attributes relevant for calculating CPA_i's reputation are: y_1 – the average utility of games the CPA_i offers; y_2 – the share of total transactions carried out by the CPA_i; y_3 – the share of financial damages inflicted on the SPA due to CPA_i's late delivery. The formulas for calculating reputation are as follows:

$$r(CPA_i) = \textstyle\sum_{l=1}^{3} w_{rl} y_l = \begin{array}{l} w_{r1} \frac{1}{a_i} \sum_{k=1}^{v} \frac{a_i^k u(\boldsymbol{x_i^k})}{u(\boldsymbol{x_{win}^k})} + \\ w_{r2} \frac{\sum_{k=1}^{v} c_i^k n_k p_k x_{i1}^k}{\sum_{k=1}^{v} n_k p_k x_{win,1}^k} + \\ w_{r3}(1 - \frac{\sum_{k=1}^{v} c_i^k d_i^k}{\sum_{s=1}^{m} \sum_{k=0}^{v} c_s^k d_i^k}) \end{array},\ where : \sum_{l=1}^{3} w_{rl} = 1 \tag{5}$$

$$a_i = \sum_{k=1}^{v} a_i^k,\ a_i^k = \begin{cases} 1,\ if\ CPA_i\ participated\ in\ auction\ k \\ 0,\ otherwise \end{cases} \tag{6}$$

$$c_i^k = \begin{cases} 1,\ if\ CPA_i\ won\ in\ auction\ k \\ 0,\ otherwise \end{cases} \tag{7}$$

$$d_i^k = n_{k1} p_k x_{i1}^k \tag{8}$$

In (5), $\boldsymbol{x_{win}^k}$ denotes the winning offer in auction k, n_k denotes how many times has the SPA sold a certain game, p_k denotes the selling price of a game, while x_{i1}^k is the percentage of the income from selling games that the SPA will get, a_i^k in (6) denotes CPA_i's participation in auction k; c_i^k in (7) denotes whether the CPA_i won auction k. In (8), d_i^k denotes the estimated financial damage inflicted to the SPA due to the CPA_i's late delivery while n_{k1} denotes the estimated number of users that would have bought the game in the period between the arranged and actual delivery date.

Multi-attribute Reputation Decision Making Mechanism The *mrdm* is defined as a tuple $< cem, rtm, w_t, t >$ where *cem* and *rtm* are previously described content evaluation mechanism and reputation tracking mechanism, respectively, $w_t = \{w_{t1}, w_{t2}\}$ denotes a pair of weights where w_{t1} and w_{t2} determine the importance of *cem* and *rtm*, respectively, and t is the total score function. The winner of the SPA's auction is the CPA_i with the highest total score $t(\boldsymbol{x_i})$ which is determined as follows:

$$t(\boldsymbol{x_i}) = w_{t1} u(\boldsymbol{x_i}) + w_{t2} r(cpa_i),\ where\ w_{t1} + w_{t2} = 1 \tag{9}$$

3 Case study: Games trading

The proposed multi-agent system was implemented using the Java Agent DEvelopment Framework (JADE[1]) and it consists of one SPA and 8 CPAs. The SPA conducts auctions by using the *FIPA Contract Net Interaction Protocol*[2].

In this case study publishing companies announce the appearance of new games roughly one month earlier while the service provider offers few new games to its users every day what comes up to 25 games in one week. So, each week the SPA conducts 25 sequential auctions and purchases the rights to distribute games which the service provider is going to start offering to his users during one week in the next month. Since the service provider announces the appearance of new games to its users it is important that the games are delivered on time.

Before the beginning of an auction, the SPA determines relevant attributes and their appropriate (i.e., reserve and aspiration) values which are going to be used for the evaluation of offered games. Those attributes are: a_1 - a percentage

[1] `http://jade.tilab.com`
[2] `http://www.fipa.org/specs/fipa00029/index.html`

Table 1. Range of attribute values and SPA's attribute valuations

	a_1	a_2	a_3	a_4	a_5
minimum value (x_j^{min})	0	t_1	0	0	1
maximum value (x_j^{max})	100	t_8	100	100	100
weight (w_j)	0.30	0.25	0.20	0.15	0.10
reservation value (x_j^r)	15	t_1	50	15	30
aspiration value (x_j^a)	40	t_8	90	45	75

of income from each sold game that the SPA will get, a_2 - game type, a_3 - a percentage of mobile phone types which have the necessary software and hardware support to run the offered game, a_4 - a percentage of income from selling various advanced game options that the SPA will get, and a_5 - the time period during which the SPA has the right to sell the game.

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. Minimum and maximum values as well as SPA's valuations of all attributes remained the same during the experiment. We assume that the game will not be interesting to users longer than three months so we set the x_5^{max} on 100 days even though x_5^{max} can actually be indefinite. Game types are taken from Ovi[3]: t_1 - action, t_2 - arcade, t_3 - education, t_4 - card & casino, t_5 - adventure, t_6 - puzzle and trivia, t_7 - sports, and t_8 - strategy.

After the CPA_i receives a CFP it determines the probability that the game $\boldsymbol{x_i}$ will be completed on time. If the probability is higher than its risk taking policy $r_c(i)$, the CPA_i offers the game $\boldsymbol{x_i}$ to the SPA. In this case study the CPA_i's on time delivery probability for a game $\boldsymbol{x_i}$ in the auction k is determined by (10) while the CPAs' risk taking policies are listed in Table 2.

$$p_k(t_c(\boldsymbol{x_i})) = p_{k-1}(t_c(\boldsymbol{x_i})) + random[-0.05, 0.05] \tag{10}$$

Table 2. Content providers' risk taking policies

$agent$	CPA_1	CPA_2	CPA_3	CPA_4	CPA_5	CPA_6	CPA_7	CPA_8
$r_c(i)$	0.6	0.65	0.7	0.8	0.55	0.6	0.65	0.7

Aspiration and reserve values are determined from game sales records. Since we do not model users behaviour, in this experiment reserve and aspiration values were chosen randomly from intervals $[0.95x_j^r(nominal), 1.05x_j^r(nominal)]$ and $[0.95x_j^a(nominal), 1.05x_j^a(nominal)]$, respectively, after each set of 25 auctions. The values $x_j^r(nominal)$ and $x_j^a(nominal)$ are given in Table 1. The SPA

[3] `https://store.ovi.com/#/games`

accepted offers containing all game types. The utility of a certain game type t_j was equal to its market share in the last period δt (i.e. last week) as follows:

$$u_c(x_{i2}) = n_{t_j}(\delta t) / \sum_{j=1}^{8} n_{t_j}(\delta t), \tag{11}$$

while the number of games sold in one week $n_{t_j}(\delta t)$ for each game type t_j was chosen randomly from the interval $[0.8 n_{t_j}(nominal), 1.2 n_{t_j}(nominal)]$ where $n_{t_j}(nominal)$ for all games type was 12500.

CPAs also calculate their reserve and aspiration values from game sales records so those values do not differ significantly from the values calculated by the SPA. CPAs' reserve and aspiration values are chosen randomly from intervals $[0.95 x_j^r(nominal), 1.05 x_j^r(nominal)]$ and $[0.95 x_j^a(nominal), 1.05 x_j^a(nominal)]$, respectively, while their nominal values are given in Table 3. The CPAs offer values that are chosen randomly between CPAs' reserve and aspiration values.

Table 3. Content provider agents' weights, reserve and aspiration values

Attribute	a_1	a_2	a_3	a_4	a_5	a_1	a_2	a_3	a_4	a_5
	Content Provider Agent CPA_1					Content Provider Agent CPA_2				
w_{cj}	0.35	0.21	0.15	0.20	0.09	0.34	0.19	0.145	0.21	0.115
x_j^r	37.5	t_1	38	90	45	36	t_1	34	88	41
x_j^a	12.5	t_8	24	60	85	14	t_8	16	61	86
	Content Provider Agent CPA_3					Content Provider Agent CPA_4				
w_{cj}	0.33	0.18	0.175	0.19	0.125	0.36	0.24	0.16	0.175	0.085
x_j^r	38	t_1	33.5	92	49	37.5	t_1	34.5	87	43
x_j^a	13	t_8	14	58	90	15.5	t_8	13	63	91
	Content Provider Agent CPA_5					Content Provider Agent CPA_6				
w_{cj}	0.345	0.22	0.14	0.165	0.13	0.335	0.21	0.155	0.185	0.125
x_j^r	39	t_1	33	85	47	36.5	t_1	37	83	46
x_j^a	16	t_8	12	54	88	13	t_8	11	57	89
	Content Provider Agent CPA_7					Content Provider Agent CPA_8				
w_{cj}	0.36	0.23	0.13	0.15	0.13	0.375	0.19	0.21	0.115	0.11
x_j^r	38.5	t_1	35.5	94	44	37.5	t_1	38.5	92	48
x_j^a	13.5	t_8	15	67	87	14.5	t_8	16	59	90

Once the SPA chooses the winning CPA_i of auction k, whether the CPA_i will deliver the game on time or with a delay is determined as defined in Listing 1. In case the delivery delay occurs, the number of users $n_{k1}(\boldsymbol{x_i})$ that would have bought the game $\boldsymbol{x_i}$ in the period between the agreed and actual delivery time is calculated as follows:

$$n_{k1}(\boldsymbol{x_i}) = n_k(\boldsymbol{x_i}) * (1 - e^{(1-temp)}), \tag{12}$$

where the variable *temp* is taken from Listing 1 while the total number of users $n_k(\boldsymbol{x_i}$ that would have bought the game $\boldsymbol{x_i}$ if it was delivered on time is deter-

Listing 1 The on time delivery occurrence

$temp = random[0, 1]$
if $temp < p_k(x_i)$ **then**
  on time delivery
else
  delivery delay
end if

mined by (13) where t_j is the game type of game $\boldsymbol{x_i}$.

$$n_k(\boldsymbol{x_i}) = \frac{\sum_{l=((k \bmod 25)-1)\cdot 25+1}^{(k \bmod 25)\cdot 25} n_l(\boldsymbol{x_i^l})}{\mid n_l(\boldsymbol{x_i^l} \mid x_{i2} = t_j) \mid} \cdot \frac{u(\boldsymbol{x_i^l})}{\frac{1}{25}\sum_{l=((k \bmod 25)-1)\cdot 25+1}^{(k \bmod 25)\cdot 25} u_l(\boldsymbol{x_{i|i=winner}^l})} \tag{13}$$

The total SPA's income from selling a game $\boldsymbol{x_i}$ bought in auction k is:

$$income_{r/nr,k}(\boldsymbol{x_i}) = (n_k - n_{k1}) \cdot p_k \cdot x_{i1} \tag{14}$$

where the label r/nr specifies whether the SPA took the CPA_i's reputation into account (label r) when it determined the winner of the auction, or did not (label nr), p_k is the game unit price while the x_{i1} is the percentage of the total income that the SPA keeps from the game sales.

For each auction in the experiment we determined the winner of the auction by using the multi-attribute reputation decision making mechanism and calculated the income $income_r$ from the game sales by using (14). For each auction we also determined the winner by using just the content evaluation mechanism (i.e., the weight w_{t2} in (9) was set to 0 so the CPAs' reputation was not taken into account) and calculated the accompanying income $income_{nr}$. The efficiency η of the reputation tracking mechanism is determined by comparing the previously defined incomes as follows:

$$\eta = \frac{\sum_{k=1}^{T} income_{r,k}(\boldsymbol{x_i^k}) - \sum_{k=1}^{T} income_{nr,k}(\boldsymbol{x_j^k})}{\sum_{k=1}^{T} income_{nr,k}(\boldsymbol{x_j^k})}, \forall k \text{ } when \text{ } cpa_i \neq cpa_j. \tag{15}$$

where T is the total number of reputation tracking auctions in one experiment.

We conducted nine sets of experiments as follows. We changed the values of reputation attribute weights (i.e., w_{r1}, w_{r2} and w_{r3}) in each set and conducted 100 series of experiments per set. Each series of experiments is conducted with different total attribute weights (i.e., w_{t1}, w_{t2}). In the first series the weight w_{t2} is set to 0.01 and it is increased in each following series by 0.01. One series of experiments consists of 100 experiments while one experiment includes 2800 seal-bid multi-attribute reverse auctions held sequentially one after the other. Since the reputation in an ongoing auction was calculated from the trading history gathered from previous 300 auctions, the first 300 out of 2800 auctions did not take reputation into account when determining the winner of an auction but they were used to calculate CPAs' reputations later. The remaining 2500 auctions

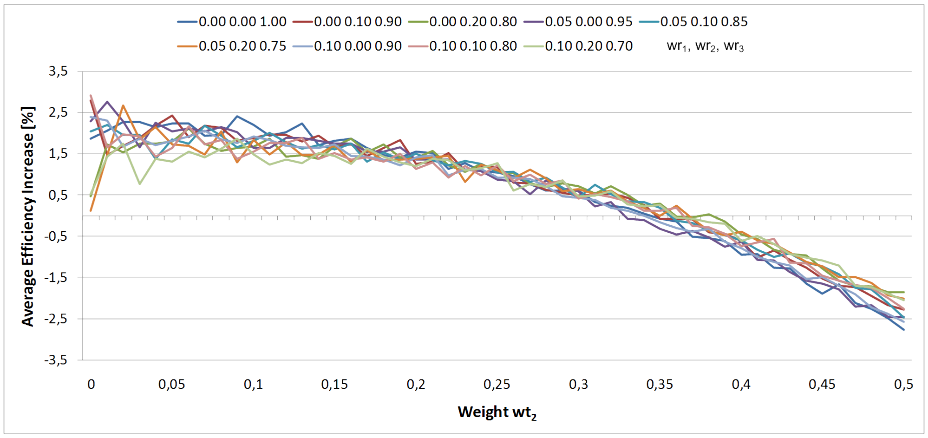

Fig. 2. Efficiency of the reputation tracking mechanism

took reputation into account when determining the winner of the auction. In the conducted experiments we tried to increase SPA's income by reducing the damages inflicted to the SPA as a consequence of CPAs' late deliveries. The emphasis was put on the reputation attribute y_3 by setting a higher value of reputation attribute weight w_{r3}.

In Figure 2 we can see the results of the conducted experiments. At the end of each experiment the efficiency of the reputation tracking mechanism is calculated by using (15). Since one series consists of 100 experiments, Figure 2 shows a mean value of efficiency for each series. The efficiency of the reputation tracking mechanism varies between 1.5 and 2.5% for weights $w_{t2} \in [0.05, 0.15]$ and continues to decrease afterwards. Approximately after the w_{t2} rises above 0.35 the reputation tracking mechanism becomes inefficient (i.e., $\eta < 0$).

4 Conclusion and Future Work

The presented multi-attribute reputation decision making mechanism enables service providers to negotiate the purchase of content distribution rights by taking into account content attributes as well as the content providers' reputation. The reputation is based on: i) the utility of content providers' offered content in previous auctions what gives a certain advantage to content providers which offer high quality content; ii) the ratio of incomes realized from selling content of a certain content provider and service provider's total income; and iii)the ratio of damages that a certain content provider caused with its delayed content deliveries and the total damages caused by all content providers. We implemented a multi-agent system in which the Service Provider Agent uses the proposed multi-attribute reputation decision making mechanism to purchase game distribution rights from Content Provider Agents on the B2B e-content market.

From the conducted experiments we can see that the efficiency of the proposed mechanism varies between 1.5 and 2.5% when the importance of the reputation in the decision making process varies between 5 and 15% while the mechanism becomes inefficient when the importance of the reputation rises above 35%.

For future work we plan to model several strategies which content providers will use to prepare offers and continue our work with modelling users behaviour to get a complete content electronic market.

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