VONEX: A Novel Approach to Establishing Open Virtual Money Exchange Regime

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ABSTRACT

Establishing an open virtual money exchange regime is a novel idea but rarely discussed. This paper provides a pioneer research on *virtual money exchange* (VONEX) approach, aiming to facilitate the exchange of virtual currencies among a variety of heterogeneous virtual communities. It has defined the intrinsic value and exchangeable value of virtual currencies and suggested a redistribution strategy, constituting the theoretical foundation of the virtual exchange rate system, by which a novel *VONEX exchange rate algorithm* is derived. Further to the introduction of the algorithm, a proof is given to ensure its correctness.

Categories and Subject Descriptors

H.3.5 [**Online Information Services**]: Commercial services, Data sharing, Web-based services; K.4.4 [**Electronic Commerce**]: Payment schemes; H.4 [**INFORMATION SYSTEMS APPLICATION**]: General

General Terms

Algorithms, Design

Keywords

Payment, virtual payment, virtual world, virtual money, virtual exchange system, redistribution, exchange rate, VONEX

1. INTRODUCTION

Virtual money is one of the by-products produced from the evolution of virtual world, and is one of the proofs of the similarity between the virtual world and the real world. As defined in [1][11], virtual money (v-money) is similar to traditional money (t-money). It is transferred from t-money, created in virtual world, and spent in both virtual and real worlds. Virtual currency is a type of virtual money that intends for online use. It provides users (e.g. online players) the purchasing power for virtual commodities in order to enhance their character skills and thus has a definite advantage over others. Yamaguchi [12] pointed out an important fact that a virtual currency is valid only in the corresponding virtual community, possessing the same properties as the real world currency.

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Despite virtual money was intended to use within the virtual world, it does not imply that they influence only the virtual world. The usage of virtual money is extended from purchasing virtual weapons to exchanging for real world products, including real world money, which may seriously interfere the real world economic system. The usage of virtual money is thus a controversial issue and has arisen a lot of discussion. Virtual world and real world are indeed two different economic systems. The former one is closed and messy as no regulations are built so far. The closeness of the virtual economic system is partly due to the non-interoperability between various virtual communities, which constitute the virtual world. One or more dedicated virtual currencies are minted in each virtual community. Unfortunately, they were not expected to use in other virtual community, or intended to prohibit the liquidity of the currency so as to hinder the PLAYERS from leaving that virtual community to others. Even being in the same virtual community, spending the same virtual currency, it is troublesome to transfer money among different game servers. Obviously, it may protect that virtual community in some areas, but hinder the development of the virtual economic system. In addition, what will happen to those users when that virtual community collapses? With no doubt, all the virtual currency will become valueless. Also, as an important fact, even if a player plays well in a single virtual community, all the reputation, moneys or skills need to be rebuilt when he comes to a new v-community. All his efforts made before are meaningless. The above indicates a need of new solution to improve existing virtual communities and protecting the virtual wealth of all players.

Establishing an open virtual money exchange regime is a means of protecting the virtual wealth of players. It is also a demand of virtual community development for more business. According to Niko Partners [7], the online revenue of MMOGs in China reaches US $2.5 billion in 2008 and will be $6 billion in 2012. Noted that these figures were measured for China only, the actual number for the worldwide must be much more significant.

To establish the open virtual money exchange regime, this paper explores how to transfer virtual wealth across heterogeneous virtual communities. Apparently, this implies a need of building up a virtual money exchange rate system that can help virtual wealth transfer when virtual money is used to represent virtual wealth. Its success will consequently protect players' virtual wealth accumulated before and enhance trading efficiency across many virtual communities.

A key concern of virtual money exchange rate system is how to generate a virtual currency exchange rate, at which one virtual currency can be bought for another. A critical research issue found here is how to measure the worthiness of one virtual currency against another. The toughness of the issue is: virtual world is comparatively closed, where the values of virtual wealth measured by individual virtual currencies of closed virtual communities have no way to compare. Virtual world is different from the real world that is open like a single system. In real world, standard baskets of goods, services or currencies can be used as the measurement bases of value comparison to determine and adjust the exchange rates between real currencies. This is because information for goods, services and currencies are available to the money issuers of all currencies and thus exchange rate mechanism between real currencies can be devised.

The above research issue can be separated into three research problems. One is how to turn the closed virtual world into an open virtual world, so that needed information is available for value measurement among virtual currencies. Second, how to use the available information to determine virtual currency exchange rates for virtual wealth transfer between virtual communities. Third, how to stabilize the virtual exchange rates so that people involved in buying and selling virtual currencies feel reasonable for the value changes of virtual currencies.

The research scope of this paper is how to determine virtual currency exchange rates. It assumes an open virtual world where virtual currency information is freely available. It also assumes that the solution to stabilizing any virtual currency exchange rates must be based on a ready solution to the determination of virtual exchange rates. Thus, the discussion of this stability is second and out of the research scope of this paper.

By observation [1], the demand and supply regarding virtual currencies exist in virtual world. This makes it possible to establish a *floating exchange rate regime* for virtual currency exchange, that is, virtual exchange rates are constantly floating due to the changes of demand and supply of virtual currencies.

This paper aims to establish an open virtual money exchange regime by investigating on the supply and demand of virtual currencies. To establish the new regime, a novel Virtual Money Exchange (VONEX) approach is proposed. It features with the characteristic of *self-adjustment* such that virtual currency exchange rates could be automatically adjusted as the demand and supply of virtual currencies change under the market force.

The rest of paper is organized as follow. Section 2 proposes a novel virtual money exchange regime, where theoretical foundation and technical approach to virtual currency exchange are described and the algorithm of generating virtual currency exchange rates are given. Section 3 provides a proof of the algorithm. Section 4 discusses related works. Finally, a conclusion is made with contributions and future works.

2. AN OPEN VIRTUAL MONEY EXCHANGE REGIME

This section describes a novel *virtual money exchange* (VONEX) approach to the establishment of an open virtual money exchange regime. To technically discuss this approach, the theoretical foundation of VONEX is first described, followed by the detailed discussion of VONEX Exchange Rate Algorithm (VERA)

2.1 Theoretical Foundation of VONEX

The labor theory of value [3] argues that any product (money is a special type of products) has its intrinsic value that can be measured by its labor cost. Thus any product should be traded based on its intrinsic value. However, in reality, it is not much practical because a product may not be desirable by people in market and thus away from its intrinsic value in trade. Utility theory [4][5] argues that, although intrinsic value that has materialized the labor cost is important, the utility of using a product determines the exchangeable value of the product in market. Thus, extending the utility theory, demand and supply of a product determines the exchangeable value of the product.

As a special type of products, virtual money agrees with the utility theory, which can be used to explain the phenomena of virtual money and to build virtual exchange rate system.

Adopting utility theory, we propose a *redistribution strategy* based on the dynamic re-valuing of the intrinsic values of virtual currencies. The process of dynamic re-valuing is a way of re-assessment of intrinsic values of virtual currencies based on the supply (intrinsic value) and the demand (exchangeable value) of all virtual currencies. A crucial idea behind is the definition of intrinsic value and exchangeable value. *Intrinsic value* is the actual value of the product, which is extended to be the sum of supply of that currency. It quantifies the worthiness of an arbitrary currency in the simplest way. Nevertheless, no matter how valuable of an arbitrary currency is, if there is no buyer, i.e. no demand, it is useless. Therefore, the total demand of that virtual currency can be regarded as the *exchangeable value* of it.

Due to the market force, demand and supply for each virtual currency are in constant changes. Some virtual currencies may be depreciated against their intrinsic values due to their lower exchangeable values and some others may be appreciated because of their higher exchangeable values. The result is that, in any equilibrium point for any virtual currency, its total supply to other virtual currencies always equals to its total demand from all other currencies.

To find an equilibrium point between demand and supply, we can make demand and supply equal for any virtual currency with a set of assumed floating virtual exchange rates between all virtual currencies. When considering all virtual currencies as a whole, the total supply of all virtual currencies always dynamically equals the total demand of all virtual currencies in any equilibrium point.

Computing the outcomes for all virtual currency exchange rates in any dynamic equilibrium point forms the theoretical foundation of the proposed VONEX approach, which states as follows:

In any dynamic equilibrium point, the sum of the supply of a set of virtual currencies from an arbitrary virtual currency, considered as the intrinsic value of that currency, always equals to the sum of the demand on that virtual currency from a set of other currencies, considered as the exchangeable value of that currency. The inequality between the supply and demand in terms of quantity can always be adjusted by a set of floating exchange rates, which guarantees the return to the equilibrium.

Particularly, in t=0, there is neither supply nor demand for any virtual currency, the value of exchange rate cannot be calculated. In t=1, 2… *n*, due to the utility changes in each virtual community, the exchangeable value of each virtual currency has changed from its previous time point. This requires to change the virtual exchange rates between different virtual currencies in order to gain a dynamic equilibrium of exchangeable values between virtual currencies.

The process of obtaining new virtual exchange rates between different virtual currencies is fulfilled by the above redistribution strategy, which states the mechanism of the re-balance of exchangeable values among virtual currencies originating from the market force. By acquiring the information of the demand and supply of virtual currencies, a set of virtual currency exchange rates is computed, using any dynamic equilibrium points.

2.2 VONEX Exchange Rate Algorithm

2.2.1 Central Idea of VERA

An important part of VONEX approach is the VONEX Exchange Rate Algorithm (VERA), which computes the dynamic exchange rates between virtual currencies. It serves the virtual currency exchange on behalf of PLAYER (requestor) whose virtual currency has been deposited to appropriate account before request can be made. VERA is designed based on the demand and supply of all virtual currencies from PLAYERS. Applying the redistribution strategy of section 2.1, VERA computes the expected virtual currency exchange rates at all time points by building a series of dynamic equilibriums between supply and demand for each virtual currency. To obtain the desired computational results, VERA assumes that:

(1) the inputs of both demands and supplies of all virtual currencies are always available in practice;

(2) the total supply of a virtual currency to different virtual currencies always equals to the total demands of that virtual currency from all other virtual currencies.

The computational result of VERA is a series of virtual currency exchanges rates at different time points.

2.2.2 Data Capture for VERA

Practically, supply and demand of a virtual currency can be obtained, using Buy Lead and Sell Lead, shown in Figure 1, which forms two types of virtual currency exchange requests.

Name of currency	
Amount to sell/buy (supply/demand)	
Desired currency exchanged back	
Estimate amount of return (computing result after exchange rate has been computed)	

Figure 1. Sample interface of exchange request

Buy Lead and *Sell Lead* can be regarded as demand from buyers and supply from sellers. For Buy Lead, the buyer issues the demand of a virtual currency that he desires for; in Sell Lead, the seller posts the supply of a specific virtual currency in exchange for another type of virtual currency, as shown in Figure 1. Therefore, the demands and supplies of all virtual currencies can be obtained as the input for VERA algorithm. Buy Lead and Sell lead are two different concepts, and are regarded as two separate operations.

According to the inverse characteristic of exchange rate between two currencies and the supply and demand relation (i.e. a supply of X to Y is the same as the demand of Y for X if the supply and demand matches), we have *demand of currency Y = supply of X × exchange rate (Y/X)*. In general, we have:

$$Sell\ Lead: demand = supply \times exchange\ rate \quad (1a)$$

$$Buy\ Lead: supply = demand\ /\ exchange\ rate \quad (1b)$$

2.2.3 Assumptions and Notations

Before discussing the pre- and post-conditions of the algorithm, some notations are made beforehand as described below.

Let C be the set of virtual currencies that are eligible for exchange. $C = \{c_1, c_2, \cdots, c_n\}$. In *Sell-Lead*, sellers provide an arbitrary currency c_x in order to exchange for another currency c_y, which forms the supply of c_x to c_y and is denoted by s_{xy}. It is presented in the unit of currency c_x. As depicted in formula (1a), the demand in the exchange is unknown, denoted by ud_{yx} and presented in the unit of currency c_y, regarded as the *offer* of the transaction. In *Buy-Lead*, buyers desires to get currency c_x by currency c_y, which forms the demand of c_x , denoted by d_{xy} and presented in the unit of currency c_x. By formula (1b), the unknown is the supply, denoted by us_{yx} and presented in the unit of c_y. Followed the above assumption, the total amount of supply of currency c_x is denoted by $\sum_{y=c_1}^{c_n} s_{xy}$. Likewise, the total amount of demand of currency c_x is represented by $\sum_{y=c_1}^{c_n} d_{xy}$. Let e_{xy} be the exchange rate of currency c_x to currency c_y. Assume there are n currencies, their exchange rates are denoted by the set E_{xy} such that $E_{xy} = \{e_{11}, e_{12}, \cdots, e_{1n,} \cdots e_{nn,}\}$ where its cardinality of E_{xy}, i.e. the number of elements $|E_{xy}| = n^2$. Based on the above definitions, formula (1a) and (1b) are rewritten as follow:

$$\text{Sell-lead: } ud_{yx} = s_{xy} \cdot e_{xy} \quad (2a)$$

$$\text{Buy-lead: } us_{yx} = d_{xy} \cdot e_{xy} \quad (2b)$$

Let IVc_x and EVc_x be the intrinsic value and exchangeable value of c_x respectively. As defined in section 2.1, IVc_x is the total supply of c_x such that $IVc_x = \sum_{y=c_1}^{c_n} s_{xy}$ in sell-lead or $IVc_x = \sum_{y=c_1}^{c_n} us_{xy}$ in buy-lead; EVc_x denotes the total demand of c_x, such that $EVc_x = \sum_{y=c_1}^{c_n} ud_{xy}$ in sell-lead or $EVc_x = \sum_{y=c_1}^{c_n} d_{xy}$ in buy-lead. Based on the redistribution strategy, the demand of any virtual currency should be fulfilled by the supply of that currency so that all currencies on-hand can be sold at whatever price, that is, SUPPLY equals DEMAND. Thus, the following relationship always holds.

$$\forall c_x \in C$$
$$\sum_{y=c_1}^{c_n} s_{xy} = \sum_{y=c_1}^{c_n} d_{xy} \quad (3)$$

where:

$$\text{Sell-Lead: } \sum_{y=c_1}^{c_n} s_{xy} = \sum_{y=c_1}^{c_n} ud_{xy} \quad (3a)$$

$$\text{Buy-Lead: } \sum_{y=c_1}^{c_n} us_{xy} = \sum_{y=c_1}^{c_n} d_{xy} \quad (3b)$$

Noted that formula (3), (3a) and (3b) denotes the only the equality in terms of value between two concepts, supply and demand. The value of the supply and demand can be represented by different currency unit. Thus, unit conversion is necessary and will be discussed shortly.

2.2.4 Conditions when t=0

Assume when t = 0, there is no request made through the system, regarding the exchange between any virtual currency c_x and c_y such that $c_x \in C$ and $c_y \in C$. Therefore, the amount of supply and demand of each $c_x \in C$ equals 0. Thus, $IVc_x = EVc_x = 0$, which means that each virtual community is isolated and its supplied virtual currency has no exchangeable value. Consequently, no exchange rate exists among different virtual currencies (NULL value). Formally, Formula (4a) and (4b) expresses this idea. In this situation, we have:

Precondition:

$$\forall x \in C \land \forall y \in C$$
$$ud_{xy} = 0,\ s_{xy} = 0 \quad (4a)$$
$$d_{xy} = 0,\ us_{xy} = 0 \quad (4b)$$

Postcondition:

$$e_{xy} = \text{NULL} \quad (4c)$$

In VERA design, we call the state of t=0 as the *initial state* of VONEX system. When the above condition is satisfied, the VONEX system is said to be *initialized*.

2.2.5 Conditions when t = 1, 2, … , k, …, m

Assume when t = 1 such that $t_1 - t_0 = f$ milliseconds, there are requests made through VONEX system, regarding the exchange of any currency c_x *and* c_y such that $c_x \in C$ and $c_y \in C$. Therefore, there exists some s_{xy} and d_{xy} such that both of them are greater than zero, i.e. $s_{xy} > 0$ and $d_{xy} > 0$. The requests are made through either *Buy Lead* or *Sell Lead*. All requests issued between *t=k-1* and *t=k* are grouped according to their type of business, and the type of currency as well, just right before *t=k* in the system. Particularly, for all time points $t = k, k \in \mathbb{N}$ (ℕ is the set of natural number), we defined it as a *cutoff* point of the system since it clears all the exchange requests made between *t=k*-1 and *t=k* after computation

Based on redistribution strategy, $IVc_x = EVc_x$ for all $c_x \in C$, which means that each virtual community is now open and its corresponding virtual currency has exchangeable value that is forced to equal to its intrinsic value, as shown in formula (3a) and (3b) . This leads to having exchange rates between different virtual currencies such that $e_{xy} \geq 0$. Formally, the pre-condition of the VERA algorithm is the same as formula (4a) and (4b) while the post-condition is:

$$e_{xy} \geq 0; \quad (5c)$$

To satisfy the above precondition, s_{xy} and d_{xy} can be retrieved from the requests made by various Players who issues exchange requests no matter in form of *Buy-Lead* e-biz or *Sell- Lead* e-biz.

2.2.6 Computing e_{xy}

Now, we step to the computation methods for the exchange rate. As stated before, the cardinality of E_{xy} equals n^2. Here, *n* denotes the number of virtual currencies that participate in the exchange. Apparently, based on the ideas given by formula (1a), (1b) and (3) e_{xy}can be computed. Nevertheless, we also face two problems:

(1) Computation of the sum of demand $\sum_{y=c_1}^{c_n} d_{xy}$ and supply $\sum_{y=c_1}^{c_n} us_{xy}$ involves different virtual currencies, which amounts cannot simply be summed due to different units.

(2) At least n^2 equations must be available and solved to compute the e_{xy}.

To solve the above two problems, an intermediate currency called CONEY is introduced in the computation. The main idea of problem solving is that we convert all different currencies into a single currency CONEY and also reduce the equation number that is required. CONEY is meaningful only during the virtual currency exchange rate computation.

Let e_{xo} be the exchange rate of currency c_x to CONEY c_o and e_{yo} be the exchange rate of currency c_y to CONEY c_o. Then, the exchange rate of currency *x* to currency *y* is:

$$e_{xy} = e_{xo}/e_{yo} \quad (6)$$

Therefore, the variables (exchange rates) remain become:

$$E'_{xo} = \{e_{1o}, e_{2o}, \cdots, e_{no}\}$$

where its cardinality $|E'_{xo}| = n$. To find out all exchange rates, we have to build n equations, which will be deduced later.

Let z_p be the amount of CONEY supply converted from the supply of virtual currency c_x, which is normally found in Sell-Lead e-biz and let z_q the amount of CONEY demand converted from the demand on virtual currency c_x, which is found in Buy-Lead e-biz. Then, we have:

$$z_p = s_{xy} \cdot e_{xo} \quad \text{or} \quad (7a)$$

$$z_q = d_{xy} \cdot e_{xo} \quad (7b)$$

Let $z_{p'}$ be the amount of CONEY demand converted from the unknown demand of virtual currency c_y as found in Sell-Lead e-biz and let $z_{q'}$ be the amount of CONEY supply converted from the unknown supply of virtual currency c_x as found in Buy-Lead e-biz, we have

$$z_{p'} = ud_{xy} \cdot e_{xo} \quad \text{or} \quad (7c)$$

$$z_{q'} = us_{xy} \cdot e_{xo} \quad (7d)$$

As mentioned before, z_p and $z_{p'}$ are regarded as the intrinsic and exchangeable value of currency c_x, respectively, in Sell-Lead e-biz. Thus, by the Formula (3a), (7a) and (7c), we have:

$$z_p = z_{p'} \quad \text{or} \quad (7e)$$

$$s_{xy} \cdot e_{xo} = ud_{xy} \cdot e_{xo} \quad (7f)$$

where all supply and demand of any virtual currency c_x can be converted into CONEY.

Similarly, for Buy-Lead e-biz and by Formula (3b) , (7b) and (7d), we have

$$z_q = z_{q'} \quad \text{or} \quad (7g)$$

$$d_{xy} \cdot e_{xo} = us_{xy} \cdot e_{xo} \quad (7h)$$

To generalize, we assume there exists a series of dynamic equilibrium points at *t* = 1, 2… *k*… *m*. At any time point *t* = *k*, Formula (7e) to (7h) hold. At t = k, there exists a *cutoff point*, where all the demand and supply are initialized to zero such that all elements inside E'_{xo} equals NULL. Thus, for any time point at t = k + 1, Formula (7e) to (7h) also hold. Thus, at any equilibrium points, there exists *n* exchange rates denoted by the set E'_{xo}. Each element in the set is a variable. Hence, *n* equations are required to obtain the solution.

Next, we have to set up *n* equations to find out the value of elements e_{xy} inside E'_{xo} . At all equilibrium points *t* = *k* (*k* ∊ 1…*n*), Formula (8a) and (8b) can be deduced by formula (2a), (7f) and formula (2b), (7h), respectively.

$$e_{po} \cdot \sum_{x=c_1}^{c_n} s_{px} = \sum_{x=c_1}^{c_n} e_{xo} \cdot s_{xp} \quad (8a)$$

$$\sum_{x=c_1}^{c_n} e_{xo} \cdot d_{xp} = e_{po} \cdot \sum_{x=c_1}^{c_n} d_{px} \quad (8b)$$

where *p* denotes an arbitrary currency c_x such that $p \in C$. Formula (8a) denotes the total supplied amount from a currency presented in CONEY (at converter's side) equals the total supplied amounts from many other currencies to that currency presented in CONEY (at convertee's side). It can be applied to Sell-Lead exchange request group while formula (8b) is for Buy-Lead exchange group. Therefore, followed by formula (8a) and (8b), we could build up a set of linear equations, as shown in formula (9a) and (9b), in order to find out the variables $E'_{xo} = \{e_{c_1o}, \cdots, e_{c_no}\}$. Formula (8a) and (9a) are applied to Sell-Lead e-biz computation while Formula (8b) and (9b) are applied to that of Buy-Lead e-biz.

$$\begin{cases} e_{c_1o}\cdot\sum_{x=c_1}^{c_n} s_{c_1x} = \sum_{x=c_1}^{c_n} e_{xo}\cdot s_{xc_1} \\ e_{c_2o}\cdot\sum_{x=c_1}^{c_n} s_{c_2x} = \sum_{x=c_1}^{c_n} e_{xo}\cdot s_{xc_2} \\ \vdots \\ e_{c_no}\cdot\sum_{x=c_1}^{c_n} s_{c_nx} = \sum_{x=c_1}^{c_n} e_{xo}\cdot s_{xc_n} \end{cases} \quad (9a)$$

$$\begin{cases} \sum_{x=c_1}^{c_n} e_{xo}\cdot d_{xc_1} = e_{c_1o}\cdot\sum_{x=c_1}^{c_n} d_{c_1x} \\ \sum_{x=c_1}^{c_n} e_{xo}\cdot d_{xc_2} = e_{c_2o}\cdot\sum_{x=c_1}^{c_n} d_{c_2x} \\ \vdots \\ \sum_{x=c_1}^{c_n} e_{xo}\cdot d_{xc_n} = e_{c_no}\cdot\sum_{x=c_1}^{c_n} d_{c_nx} \end{cases} \quad (9b)$$

By solving *n* equations suggested in formula (9a) or (9b). We obtain the exchange rates $e_{xy} = e_{xo}/e_{yo}$. Let $RET = \{r_1, r_2, \cdots, r_m\}$ be the set of estimated returns, shown in Figure 1, where $r_k \in$ RET is the sum of *m* exchange requests for $c_k \in C = \{c_1, c_2, \cdots, c_n\}$ at each equilibrium point *t* = *k*-1 and *t* = *k*.

By following formula (1a) and (1b), all estimated returns RET can be computed and virtual currency selling and buying offer can be sent back to the Players.

3. CORRECTNESS PROOF ON VERA

In this Section, we will prove that the computational method of VONEX Exchange Rate Algorithm (VERA) is correct. As stated before, the strategy of the virtual exchange rate regime is redistribution. That is,

Given that the exchangeable value and intrinsic value of an arbitrary virtual currency are equal; Then, the total demand of an arbitrary virtual currency, in terms of its money value, and in the unit of that virtual currency, can be fulfilled by the total supply of that virtual currency, in terms of money value, and in the unit of that virtual currency.

The above statement formulates the *proposition* of the proof. It can be interpreted as a formal Proposition (11):

$$\left(EV_{c_k} = IV_{c_k} \right) \Longrightarrow \left(\sum_{y=c_1}^{c_n} ud_{c_ky} = \sum_{y=c_1}^{c_n} s_{c_ky}\right) \quad (11)$$

EV_{c_k} denotes the exchangeable value of an arbitrary virtual currency c_k such that $c_k \in C$. Likewise, IV_{c_k} denotes the intrinsic value of the currency. ud_{c_ky} represents the unknown demand of c_k in terms of money value while s_{c_ky} is the supply of c_k in terms of money value. The notation $p \Longrightarrow q$ denotes a *conditional implication relationship* such that the truth of *p* implies the truth of *q*.

We will apply mathematical induction to prove the above proposition. Equilibrium reached once it is proved. In addition, since the VONEX system consists of different states, the proposition should be valid for all states. Therefore, the proof is separated into two parts.

(1) Proof of formula (11) by mathematical induction

(2) Proof of equilibrium at t=0, t=1, t=2 and t=n.

Firstly, we prove the proposition by induction. The complete proof should consist of both the Sell-Lead and Buy-Lead. Due to page limitation, only the proof of Sell-Lead is illustrated as follows but they are equivalent. The proof of Buy-Lead biz can be constructed in a similar fashion.

Let $f(n) = (EV_{c_k} = IV_{c_k}) \Rightarrow (\sum_{y=c_1}^{c_n} s_{ky} = \sum_{y=c_1}^{c_n} ud_{ky})$

PART A: When n=1,

1. $\because ud_{c_1c_1} = s_{c_1c_1}\cdot e_{c_1c_1}$ (def. (2a))
2. $\therefore ud_{c_1c_1} = s_{c_1c_1}$ ($e_{c_1c_1} = 1$)
3. $\because EV_{c_1} = IV_{c_1}$ (given condition, *see* Section 2.1)
4. $\therefore (EV_{c_1} = IV_{c_1}) \Rightarrow (\sum_{y=c_1}^{c_1} ud_{c_1y} = \sum_{y=c_1}^{c_1} s_{c_1y})$

is always true.

PART B: Assume when n=m, the following is valid

$$(EV_{c_k} = IV_{c_k}) \Rightarrow \left(\sum_{y=c_1}^{c_m} ud_{c_ky} = \sum_{y=c_1}^{c_m} s_{c_ky}\right) \quad (12)$$

PART C: When n=m+1

1. $\because EV_{c_k} = IV_{c_k}$
2. $\therefore s_{c_{m+1}c_k}\cdot e_{(m+1)o} = s_{c_kc_{m+1}}\cdot e_{ko}$ (def.(8a))
3. $\because s_{c_{m+1}c_k} = ud_{c_kc_{m+1}}/e_{(m+1)k}$ (def. (2a))
4. $\therefore s_{c_{m+1}c_k}\cdot e_{(m+1)o} = (ud_{c_kc_{m+1}}/e_{(m+1)k})\cdot e_{(m+1)o}$
5. $\therefore s_{c_{m+1}c_k}\cdot e_{(m+1)o} = ud_{c_kc_{m+1}}\cdot e_{ko}$ (def. (6))
6. $\therefore s_{c_kc_{m+1}}\cdot e_{ko} = ud_{c_kc_{m+1}c_k}\cdot e_{ko}$ (step 2 and 5)
7. $\therefore s_{c_kc_{m+1}} = ud_{c_kc_{m+1}}$
8. $\because \sum_{y=c_1}^{c_m} ud_{c_ky} = \sum_{y=c_1}^{c_m} s_{c_ky}$ (12)
9. $\therefore \sum_{y=c_1}^{c_m} ud_{c_ky} + ud_{c_kc_{m+1}} = \sum_{y=c_1}^{c_m} s_{c_ky} + s_{c_kc_{m+1}}$
10. $\therefore \sum_{y=c_1}^{c_{m+1}} ud_{c_ky} = \sum_{y=c_1}^{c_{m+1}} s_{c_ky}$
11. $\therefore (EV_{c_k} = IV_{c_k}) \Rightarrow \sum_{y=c_1}^{c_{m+1}} ud_{c_ky} = \sum_{y=c_1}^{c_{m+1}} s_{c_ky}$

Thus, the proposition (11) holds for n=m+1. Proof finishes.

There are several things that are worth to emphasize. **(1)** Intrinsic value of currency c_k is defined to be the supply of c_k, i.e. the amount of c_k that is "leaving" the virtual community of c_k. **(2)** Exchangeable value of currency c_k is defined to be equal to the supply of other currency that is to be exchanged to c_k, i.e. the amount of non c_k currency that are "entering" the virtual community of c_k. The total amount also equals to the unknown demand of c_k , as mentioned in section 2.2.6. **(3)** The introduction of CONEY is to ensure that all virtual currencies are of same unit. As a result, the equality between the intrinsic value and the exchangeable value of currency c_k implies the corresponding values in the unit of CONEY are equal.

Since the Proposition (11) is proved to be valid by induction, the correctness of VERA algorithm has been proved to hold for all *t*=*k* where *k* is a non-negative integer. Alternatively, we can prove VERA algorithm by contradiction. Assume Proposition (11) is not true for *t*=*r* such that r is a non-negative integer. Thus, it implies $\sum_{y=c_1}^{c_n} s_{ky} \neq \sum_{y=c_1}^{c_n} ud_{ky}$ and $EV_{c_k} \neq IV_{c_k}$ as a consequent. This contradicts with the hypothesis that $EV_{c_k} = IV_{c_k}$. Therefore, Proposition (11) is proved to be always valid.

4. RELATED WORKS

In literature, there is not much research on virtual money. This phenomenon is slightly improved only in recent years resulted from the fact that a dramatically increasing number of people joining virtual communities (including MMORPGs). Nevertheless, most of these researches are economics-oriented (e.g. [9][10][12]). Few researches focus on technical point of views on virtual money exchange. A significant part of population devoted their time in the virtual world. They are not purely teenagers but also a group of well-educated adults. A current estimate shows MMORPG players reach approximately 17 millions [6]. Moreover, there are increasing concerns in psychological areas. Guo and Barnes [2] point out the determinants of individual's purchase of virtual items. Research in [8][11] analyzed the psychological and social factors that may improve software design or improve customer-loyalty. In this section, we will analyze existing virtual money exchange system in order to gain an insight to what an exchange system should look like, and their pros and cons as well.

A latest research on virtual money is the work of Guo and Chow [1], which made a phenomenal analysis on the existing virtual money systems, classified the existing virtual money systems into four types, and proposed a common money system model.

4.1 CONCLUSION

In this paper, we have established a virtual money exchange regime through a novel virtual money exchange (VONEX) approach. In this approach, intrinsic value and exchangeable values are discussed to lay the theoretical foundation for virtual money exchange; VONEX Exchange Rate Algorithm (VERA) is designed to support virtual money exchange, and its correctness has been proved.

The focal point of the paper is the floating exchange rate regime used in virtual currency exchange, where only supply and demand are considered during the computation. The spirit of the exchange rate system tied to the redistribution strategy such that the total supply of any virtual currency on-hand could be distributed to others who have demand on it. An important fact is that the deduced exchange rates are floating and varying over time. A new comer in the system implies a new re-balancing process. The re-balance state of the system is the equilibrium point of the system under redistribution strategy.

By applying VONEX approach, the business risk of VONEX System owner or virtual payment provider is almost zero since VONEX System is only a mediator but not the buyer or seller of virtual money. As such, by introducing transaction fees or whatever similar to the extra service charges, VONEX becomes a definitely profitable business provided that there are demands of exchange. We would like to emphasize that exchange in VONEX refers to not only the transaction between different virtual currencies of different virtual world, but also same virtual currency that originated from the same virtual world but different game server (e.g. WoW). This exchange is impossible currently but it is feasible via VONEX.

Virtual money exchange is an important research issue yet rarely discussed before in both industries and academia. There is no virtual money to virtual money exchange (V-V exchange) solution was found so far. This paper provides a pioneer research on attempting to initiate the idea of how a V-V exchange rate system could be built. The key contributions of this paper can be dedicated to the following points:

(1) Provided a novel approach to establishing a novel virtual money exchange regime.

(2) Applied floating rate regime to the virtual world economy

(3) Defined intrinsic and exchangeable value of virtual currency where standard basket of goods, services and currencies is absent

(4) Defined a redistribution strategy so as to re-allocate virtual wealth from among various virtual communities.

(5) Illustrated the correctness proof of VONEX exchange rate algorithm.

VONEX approach presented in this paper is still evolving. More stringent implementation level evaluation for it is required. In addition, there is a further matter that has to be handled, which is the exchange rate stabilization. As mentioned before, one of the barriers among virtual communities is the heterogeneous communication protocols, virtual currencies, etc. How to overcome this problem is another interesting area that is worth to explore.

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