New directions in Computing on Demand (CoD)

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***Abstract* -- Today, utility computing and Computing on Demand (CoD) could be parallelized to Grid computing because the latter is the best available technology to enable computing power as a massively available utility. In the present paper, iWatt, a naïve linear measurement for CoD services is introduced. The innovative feature of iWatt is considered to be the fact that facilitates both a consumption assignment to a Grid-ready service and a producing capability to CoD infrastructure in an analogous way to electric power device-network interaction. Experimental and benchmarking work need to be done in order to test practical issues for the proposed metric.**

***Index Terms* – computing on demand, iWatt, Grid computing, economics, Grid Economic Services Architecture Working Group.**

I. INTRODUCTION

FIRST to foresee the emergence of Computing on Demand (CoD) was John McCarthy, at MIT Centennial in 1961. He declared that "If computers of the kind I have advocated become the computers of the future, then computing may someday be organized as a public utility just as the telephone system is a public utility... The computer utility could become the basis of a new and important industry". Since then many scientific terms emerged in order to describe new trends and directions in utility computing [41] or on demand computing [15] or computing on demand [23]. But CoD to flourish needs resources, applications and standards. In this direction, they have been developed concurrent, multiprocessor, multicore and multicomputer systems and scientific concepts like parallel computing [55], [40], cluster computing [8], distributed computing [7], autonomic computing [33], [24], pervasive computing [43], ubiquitous computing [44], [45], sentient computing [1]. The decisive boost of CoD during the last decade came from Grid computing [16], Internet, Web and Semantic Web technologies [5]. Grid computing put together and promoted the major advantages of related existing technologies by providing a theoretical and practical framework in which (a) computing resources are not administered centrally, (b) open standards are used and (c) non-trivial quality of service is achieved [16]. Internet [11] and Web technologies provided a common communication platform accelerating the physical and virtual connection between machines, digital content and people. In this direction, Tim Berners Lee states that [5] "By analogy to the Semantic Web, the Grid has spawned the Semantic Grid, where information and computing resources are annotated with metadata (and as with the SW RDF is the language of choice), allowing the exploitation of machine-readable specifications for the automatic coordination of resources to solve particular large-scale problems. The Grid and Semantic Grid raise a number of old questions in a new guise. Given that one's computing resources are given over to outsiders, trust and security will require reconsideration. Socially, an interesting issue is the understanding whether the Grid will actually change science, or merely allow the processing of more and more data". In this direction, Vafopoulos et al [51], [52], [53], [54] have introduced g-work, a holistic analytical framework advancing CoD benefits. In addition, a step in the commercialization of CoD based on Grid technologies have been provided by GGF's "Grid economy use cases" setting an operational framework on computational providing, reselling and brokerage [30]. In subsection A, a brief theoretical background for the economic issues arising in the CoD services market is presented. Subsection B describes a comprehensive implementation framework for the "economy-Grid" projects. Section III refers to the applied work done for CoD and it is divided into two subsections, Grid projects and business research and products. A "two-way" metric for CoD, iWatt, is been introduced in the fourth section of the paper. Subsection IV.A provides the general framework behind iWatt formation logic. A review of the major existing CoD metrics and currencies is discussed in subsection IV.B. Subsection IV.C involves the definition of iWatt and is composed of the analysis of supply and demand side for CoD services. At the end of the section an example CoD service XML schema is provided. Section V concludes.

II. ECONOMICS

Today as Grid computing technologies advance in a fast pace, global deployment of CoD is primarily a decision based on economic principles rather than a technological one. It has not been done yet much research in applying economics to CoD services. The three major sources of academic and practical research in CoD economics comes from NASA [34], [35], HP [29] and the Grid Computing and Distributed Systems (GRIDS) Laboratory [56]. Previous and resembling work could be consider the research conducted for bandwidth pricing [26], [27], [28], Internet economics [47], [38], [2], pricing and allocation of computer time [58], [36].

A. Theoretical background

CoD services market despite the fact that small and short-lived, as every market, is characterized by demand (consumption) and supply (provision). Let us introduce a basic problem and two sub problems definitions for the CoD services market set up.

The basic problem. The problem of choice in producing, pricing, distributing and utilizing computing resources on demand, by an effective way in personal, business and social level.

Sub problem 1: *Provider's choice*

For a CoD service provider the primary problem is defined to be the choice of quantity and price level of the provided CoD service.

Sub problem 2: *Consumer's choice*

For a CoD service consumer the primary problem is defined to be which (and in what extent) operations to outsource in a CoD provider.

The basic characteristics of the emerging CoD services market could be summarized in the following list:

- Absence of a unique measurement unit and widely adopted standards
- Small and immature market

- Not storable units of service
- Not user-friendly operational interfaces
- Limited number of e-services
- Absence of flexible and market driven pricing
- Not trivial accounting procedures
- Inelastic demand
- Trust and security issues
- Lack of forward markets
- Potential exercise of market power
- Network externalities [20]
- Free riding [20]
- Economies of scale and scope [20]
- Fully virtualized markets are highly dynamic and harder than physical markets [29]
- High transaction rate [29]
- Large scale [29]
- Low reaction time [29]
- Over-provisioned resources expire quickly [29].

The thematic areas of economic theory exploited or should be exploited in order to facilitate an analytical framework for CoD commercialization are considered to be General Equilibrium Theory [3], [4], [14], Theory of Finance, Network Economics and Economic Theory of Digital Goods.

General Equilibrium Theory. General equilibrium theory is a branch of theoretical microeconomics. It seeks to explain production, consumption and prices in a whole economy. General equilibrium tries to give an understanding of the whole economy using a bottom-up approach, starting with individual markets and agents. General equilibrium models typically involve a multitude of different goods markets. Modern general equilibrium models are usually complex and require computers to help with numerical solutions. In a market system, the prices and production of all goods and services, including the price of money and interest, are interrelated. A change in the price of one good or service, say CoD services, may affect another price, for example, the wages of IT consultants. If IT consultants differ in tastes from others, the demand for CoD services might be affected by a change in IT consultants' wages, with a consequent effect on the price of CoD services. Calculating the equilibrium price of just one good or service, in theory, requires an analysis that accounts for all of the millions of different goods or services that are available. In this context, Nakai and Van Der Wijngaart [34] concluded that “The general equilibrium theory is inadequate as a detailed description of the mechanism that allows an economy to function in the manner we observe daily. Thus, a global scheduler for Grids whose mechanism is based on the theory would not behave like the markets we casually encounter.”

Theory of Finance. Due to the fact that CoD services are not storable, contracts for future delivery are the most popular financial engineering tools for pricing this type of diachronic uncertainties. This lack of inventory drives producers and consumers to anticipate the resulted price/availability uncertainty by fixing the price and availability of a resource in advance [58]. A forward contract is an agreement between two parties to buy or sell an asset or a service (which can be of any kind) at a pre-agreed future point in time. Therefore, the trade date and delivery date are separated. It is used to control and hedge risk, for example currency exposure risk (e.g. forward contracts on USD or EUR) or commodity/service prices (e.g. forward contracts on CoD). One party agrees to sell, the other to buy, for a forward price agreed in advance. In a forward transaction, no actual cash changes hands. If the transaction is collaterised, exchange of margin will take place according to a pre-agreed rule or schedule.

Otherwise no asset of any kind actually changes hands, until the maturity of the contract. The most well known method for pricing forward derivatives, the Black-Scholes formula [26] has not yet applied in pricing options for CoD services.

Network Economics. Network Economics refers to business economics that benefit from the network effect. This is when the value of a good or service increases when others buy the same good or service. For instance, when someone buys a telephone, it makes other phones more useful, because other people who own a phone now have a larger network. Internet analysis, based on foundations of network economics, has been initiated by Hal Varian [46], [31], [32] and among others examines internet pricing and new economy analysis in general. Network economics have not yet been applied in CoD services.

Economic theory for digital goods. According to Danny Quah [39] "Digital goods are bitstrings, sequences of 0s and 1s, that have economic value. They are distinguished from other goods by five characteristics: digital goods are nonrival, infinitely expansible, discrete, aspatial, and recombinant. The New Economy is one where the economics of digital goods importantly influence aggregate economic performance." His research considers such influences not by hypothesizing ad hoc inefficiencies that the New Economy can purport to resolve, but instead by beginning from an Arrow-Debreu general equilibrium perspective and asking how digital goods affect outcomes. It has been applied with great success to open source software and digital rights management [39]. In our point of view Quah's analysis can be extended for CoD services economic analysis.

B. *Implementation framework*

Economic theory exploitation in Grid (the term is used interchangeably to CoD) is in a primitive state resulting sometimes obscure definitions and categorizations. A useful presentation of "economy Grid" projects is been provided by the economy-Grid (EG) layer model which was introduced in the context of the BIG project and is composed by four concrete layers (Figure 1). The Integration Layer: Grid using economic principles [EG1] includes the projects that integrate economic principles, concepts, and experience into the Grid and influence developments of Grid infrastructure, e.g. resource usage can be optimized by adaption of auction principles.

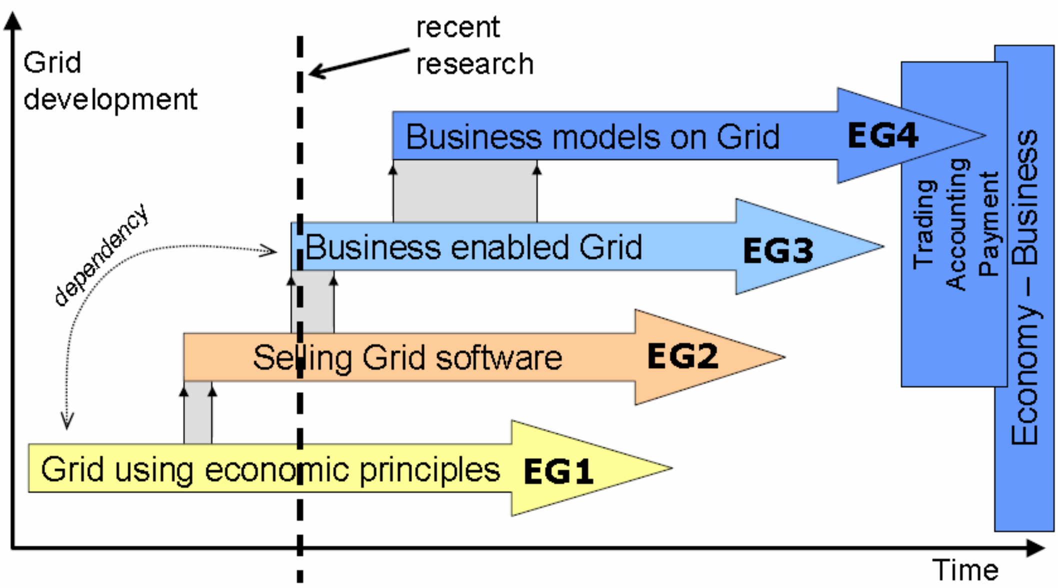

Fig. 1. Economy Grid Layer Model Economy Model [the BIG project]

The Commercialization Layer: Selling Grid software [EG2] deals with companies creating products or services for "homogeneous" organizations using Grid software or some components. The third Enabling Layer: Business enabled Grid [EG3] consists of the appropriate services which establish an open Grid, with similar properties as the Internet for information today. The emerging Grid market will be providing trading, accounting and payment mechanisms. Indicative parts of EG3 could be the GridBank, an OGSA-Based Accounting System, and the GGF GESA-WG [21]. The last component is the Modelling Layer: Business Models on Grid [EG4] and refers to the new e-business paradigm will emerge from Grid infrastructure extensive usage.

III. APPLICATIONS

Grid computing is rapidly growing in popularity. Forrester Research reports that 37% of enterprises are piloting, rolling out or have implemented some form of Grid computing [18]. IDC calls Grid computing the fifth generation of computing, after client-server and multi-tier [25]. The rapid development of Grid computing literature and applications revitalize the idea of Application Service Provider (ASP) [12], Software as a service (SaaS) [49] and Service-oriented Computing [38] in general, by providing a powerful implementation platform. SaaS is a software application delivery model where a software vendor develops a web-native software application and hosts and operates (either independently or through a third-party) the application for use by its customers over the Internet. Customers pay not for owning the software itself but for using it. They use it through an API accessible over the Web or standalone Web Services. In section A we provide an indicative list of "economy Grid" projects around the world. Section B is devoted to the major business applications of CoD.

A. Projects

Last decade Grid computing is the major IT infrastructure investment for U.S.A., E.U., China, Japan and Australia (a list of some Grid projects can be retrieved from GridsWatch webpage at Gridswatch.com). In the next subsection we briefly discuss GridBus in Australia, Grid Market in UK, China National Grid, Grid Consortium Japan, Market-based Resource Allocation for Grid Computing with Real Demand Data and Grid Market Hub at the National Grid of Singapore.

GridBus in Australia - Gridbus.org. The Gridbus project is engaged in the creation of open-source specifications, architecture and a reference Grid toolkit implementation of service-oriented Grid technologies for eScience and eBusiness applications.

Grid Market in UK - lesc.imperial.ac.uk/markets. The Computational Markets project is funded under the DTI e-Science Core Technology programme and is concerned with the development of mechanisms to support the trading of Grid services.

China National Grid - ssc.net.cn/en/index.asp. The China National Grid (CNGrid) Project supports various applications including scientific research, resource and environment research, advanced manufacturing and information service by sharing resources, collaborating and service mechanism.

Grid Consortium Japan. This consortium aims at contributing the society by promoting R&D of Grid technology, spreading of research results and by researching the trend of international technological standardization.

National Grid of Singapore - ngp.org.sg. The scope of the most multi-thematic Grid infrastructure in the world is to facilitate the seamless use of an integrated cyber infrastructure in a secure, effective and efficient manner to advance scientific, engineering and biomedical research and development, with the longer term goal of transforming the Singapore economy using Grid computing technologies. The two projects concerning Grid economics and business models are the “Market-based Resource Allocation for Grid Computing with Real Demand Data” and the “Grid Market Hub”.

- **Market-based Resource Allocation for Grid Computing with Real Demand Data - sis.smu.edu.sg/Grid**. The project aims to create an empirical data set of Grid usage information (i.e. computing resources, network, storage, etc.) and a test bed based on the HP Labs’ Tycoon system.
- **Grid Market Hub.** The deliverables are a Grid Exchange prototype and underlying interoperability architecture in order to enable a Grid Market Hub. The Grid Exchange will have functions for resources, metering, accounting, licensing, certification and discovery.

BOINC - boinc.berkeley.edu/trac/wiki. BOINC is a software platform located at the University of California for volunteer computing and desktop Grid computing.

B.Business

The leading global indirect CoD services are the Google applications (spreadsheet, writely, calendar etc.) since it is estimated that Google database and AJAX-oriented [19] applications are distributed in more than 600.000 Grid components around the world. In addition, all the rest global IT market leaders have been installed and/or selling Grid-oriented technologies (for a detailed analysis see [56]). In the following paragraphs, six major and three minor IT companies which have deploy Grid technologies are presented.

HP - tycoon.hpl.hp.com. Tycoon is a market-based system for managing compute resources in distributed clusters like HP PlanetLab, the Grid, or a Utility Data Center. The basic idea is that users have a limited supply of credits. Consuming users pay providing users to use computer resource. Users who provide resources can, in turn, spend their earnings to use resources later.

IBM – zurich.ibm.com/Grideconomics. The IBM Zurich Research Laboratory at 2002 introduced the concept of “Grid economics”. Their vision is summarized in the following paragraph. “Grid computing is seen as the next step for the Internet: a vision of large-scale, heterogeneous, distributed systems assembled at will across organizational boundaries (within or between companies) promising ultra-fast ubiquitous utility computing, always available at the flip of a switch. Grid computing aims to offer for computation what the Internet delivered for communication.”

Amazon EC2 – amazon.com. Amazon Elastic Compute Cloud (Amazon EC2) is a web service that provides resizable compute capacity in the cloud. Prices start at $0.10 per hour and can be combined with storage access.

Sun – network.com. The Sun Grid Compute Utility is a simple to use, simple to access data center-on-demand. Sun Grid delivers enterprise computing power and resources over the Internet, enabling developers, researchers, scientists and businesses to optimize performance, speed time to results, and accelerate innovation without investment in IT infrastructure. No matter the size of a business or the size of a job, there is no barrier to entry and exit.

Oracle – oracle.com. Oracle Corporation has introduced Oracle 10g infrastructure software, the first specifically designed for enterprise Grid computing. Oracle Grid computing is platform independent.

But there are also many small innovative companies that offer CoD services, mainly in the business sector. In the following lines three of them are briefly presented.

Appro computing on demand - appro.com. Appro has a Compute on Demand Center (CODC) in Houston, Texas. The service is targeted at the oil and gas industry. The CODC is located in the CyrusOne data center.

HPCPortal - hpcportal.de. T-Systems is providing an on-demand service of a variety of hardware systems for many years. Systems include Cray Opteron, NEC SX8 vector supercomputers and HP Clusters. Prices are in the order of 5 euro per CPU hour.

Tsunamic Clusters on Demand - tsunamictechnologies.com. Tsunamic offers raw computing power on demand, ranging from $0.85 per cpu/hour for pay-as-you-go with no commitment. A subscription for 4,000 CPU hours per month costs $1,000.

IV. iWATT: THE "TWO-WAY" METRIC

In this section, a "two-way" metric for CoD, iWatt, is been introduced in the third section of the paper. Subsection 3.1 provides the general framework behind iWatt formation logic. A review of the major existing CoD metrics and currencies is discussed in subsection 3.2. Subsection 3.3 involves the definition of iWatt and is composed of the analysis of supply and demand side for CoD services. At the end of the section an example CoD service XML schema is provided.

A. General framework

We strongly believe that the extensive commercialization of CoD is directly depended to the satisfaction of potential consumers' preferences. In other words, demand for CoD services can substantially increase only when effective, cheap and user-centric services will be developed. The central goal of an Open Grid infrastructure should be the provision of a powerful problem-solving mechanism for citizens, government and businesses. An open Grid all spare bandwidth, storage, and computational resources are purchasable on demand by anybody from anybody. In this context, Foster and Kesselman, two of the Grid computing pioneers state that: "The real and specific problem that underlies the Grid concept is: coordinated resource sharing and problem solving in dynamic, multi-institutional virtual organizations" [17]. The information and software on-demand layer is the intermediate step between infrastructure and problem-solving mechanisms (Figure 2).

For a example, if a household or a company wants to make a financial decision which involves vast and complicated amount of data, taps into a CoD financial web service and receive in real time the answer of the specific problem.

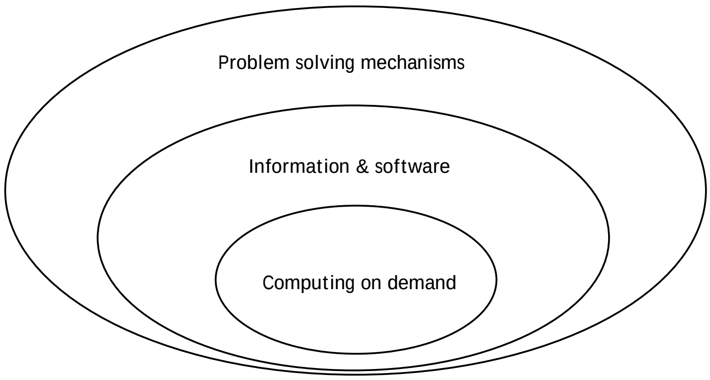

Fig. 2. The central goal of an Open Grid infrastructure should be the provision of a powerful problem-solving mechanism through the

exploitation of information and software

B.Metrics and currencies

Consumers buy electricity by the kilowatt-hour, telephone service by the minute, and gasoline by the liter. But in what unit will consumers buy CoD services when companies turn them into a directly consumed utility? Cheliotis et al [10] empahasize that "Grids and resources are generally heterogeneous and potentially of arbitrary scale. Scale and heterogeneity are exactly the drivers which led to the establishment of standard monetary units and currency exchange rates in the real economy". Next we describe five CoD metrics except the trivial CPU cycles.
Computon. HP is working on its utility-computing unit, the computon. Unlike the kilowatt, an agreed-upon way to measure the pure consumption of electricity, the computon will measure several different services—such as data-storage capacity and processing power—to reflect computer usage.
Sun Power Unit. Sun introduced the Sun Power Unit, which measures processing power based on the work performed by a 1-GHz UltraSPARC III processor core in one second and measures storage consumed in gigabytes. The company will refine the Sun Power Unit through a series of real-world pilot projects that will help identify and define the real drivers of cost in actual application and production environments.
Cobblestone. A BOINC project gives you credit for the computations your computers perform for it. BOINC's unit of credit, the Cobblestone, is 1/100 day of CPU time on a reference computer that does both (i) 1,000 double-precision MIPS based on the Whetstone benchmark and (ii) 1,000 VAX MIPS based on the Dhrystone benchmark.
GridCredit. GridCredit is a linearly defined currency used in the economic transactions between producers (the computing resources) and consumers (the Grid users) on the DataGrid project [13].
Grid dollar. According to Rajkumar Buyya [9] the resource price in terms of G$ can be assigned arbitrarily. The G$ can be equated to real money or tokens charged to users for accessing resources.

C. Definition of iWatt

For utility computing to fulfill its promise, there has to be a standard pricing model that all users can apply to their operations. Until then, on-demand computing will be just another complex, proprietary pricing strategy vendors use to keep you from fairly and accurately comparing one service to another. Without a pricing standard, CoD is one more way for vendors to lock in users to their technology and services. Once we have an industry wide CoD pricing model, CoD will be real.
Analogically to Watt for electric power, we introduce the iWatt (infoWatt because everybody is familiar with the word Watt) measurement unit as a "two-way" metric since every CoD service is been assigned a specific amount of iWatts (demand side) and each CoD infrastructure is designed to have a certain amount of iWatts (supply side).
Let us parallelize a CoD service as an electric device which is plugged into the CoD infrastructure and operates in an analogous way to electric network plugs. Identifying and quantifying the supply and the demand quantity of a product or a service is considered to be the first step in the market pricing mechanism. IWatt CoD measurement unit is introduced as a linear combination of resources and a discount factor for middleware inefficiencies will be included.

Supply side. Our use case scenario describes the simplest possible global Grid which is composed of three resources (processing power, storage and bandwidth) and two independent Grid installations. Each Grid plant has –unrealistically- a single component, but it is trivial to expand it for as many as we wish. Initially, a standardization process takes place in order to get unit-free measurement units for each resource (Table 1).

TABLE 1

A STANDARDIZED VALUE FOR EACH RESOURCE IS SET

RESOURCE STANDARDIZATION MATRIX	
PROCESSING POWER	MHZ
STORAGE	GBYTE
BANDWIDTH	MBIT/S

For example, the first Grid has 180 MHz of computing power, 20 GB of storage and is connected through an 80 Mbit/s line. Respectively, Grid2 has 210 MHz of computing power, 40 GB of storage and is connected through a 50 Mbit/s line (Table 2).

TABLE 2

RESOURCE QUANTITY VECTORS [RQ] FOR GRID1 AND GRID2

	RQ[1]	RQ[2]	
RQ[1,1]	180	210	RQ[2,1]
RQ[1,2]	20	40	RQ[2,2]
RQ[1,3]	80	50	RQ[2,3]

Let us now define the resource quantity vector [dimensions mx1] for the i^{th} grid as:

$$\mathbf{RQ[i]_{mx1} = (rq[i,1], rq[i,2], \ldots rq[i,m])^T} \qquad \textbf{(1)}$$

where **rq[1,1]** is the quantity of the first resource (processing power in our scenario) located of the first Grid, and so on and so forth, with **n** the different Grid plants and **m** the different resources. In this way, a resource quantity matrix can be defined, **RQ**= {RQ[i,j] | (i,j)∈[1,m]×[1,n]} combining all the resources of all grids.
The resource combination vector for a positive resource i ∈ [1,…,m] is defined as

$$\mathbf{RC[i]_{1xm} = (0, 0, \ldots 1, \ldots, 0)} \qquad \textbf{(2)}$$

where the quantity of all resources except i are 0.
The role of the resource combination vector is essential since it is capturing the contribution of resources for each Grid plant. The specific definition offers a flexible analytical framework because a Grid installation could offer, for instance, only one of the resources (i.e. storage). Furthermore, is the basic construct of the resource combination matrix, which summarizes all the information, provided by each resource combination vector.
The resource combination matrix RC [dimensions m×m] equals the identity matrix I_m if all resources are available for all Grid plants (Table 3).

TABLE 3

THE RESOURCE COMBINATION MATRIX

RC[1]	1	0	0
RC[2]	0	1	0
RC[3]	0	0	1

The Grid resource quantity matrix [GRQ] is calculated as the following product:

$$\mathbf{GRQ}_{mxn} = \mathbf{RC}_{mxm} \times \mathbf{RQ}_{mxn} \quad \textbf{(3)}$$

TABLE 4

GRID RESOURCE QUANTITY MATRIX [GRQ] FOR GRID1 AND GRID2

	GRQ[1]	GRQ[2]	
GRQ[1,1]	180	210	GRQ[2,1]
GRQ[1,2]	20	40	GRQ[2,2]
GRQ[1,3]	80	50	GRQ[2,3]

In our example, the Grid resource quantity matrix [GRQ] for Grid1 and Grid2 are presented in Table 4. The market resource quantity matrix [MRQ] is defined as:

$$\mathbf{MRQ}_{mx1} = \mathbf{GRQ}_{mxn} \times \mathbf{1}_{nx1} \quad \textbf{(4)}$$

where $\mathbf{1}_{nx1}$ is the n^{th} dimensional column vector containing ones

TABLE 5

THE MARKET RESOURCE QUANTITY MATRIX [MRQ]

MRQ[1]	390
MRQ[2]	60
MRQ[3]	130

In our case, the market resource quantity matrix [MRQ] is given in Table 5. Each resource has a different price per unit and a different contribution to a completed task and consequently its proportional share to the infoWatt price (iP) should differ. In this context, the weight row vector for each resource of the i^{th} Grid plant is denoted as:

weight[i] = (weigth[i,1], weight[i,2], … ,weight[i,m]) **(5)**

for $1 \le i \le n$ and where weight[i,1] +weight[i,2]+ … +weight[i,m] =1 and 0 < weight[i,j] < 1, for all $(i,j) \in [1,n] \times [1,m]$. In a similar way, the weight matrix is defined for each resource of each Grid plan as **weight** = $\{w[i,j]) \mid (i,j) \in [1,n] \times [1,m]\}$

The quantity of infoWatts for the i^{th} Grid installation is given by the following product:

$$\mathbf{Gi[i]_{1x1}} = \mathbf{weight[i]_{1xm}} \times \mathbf{RQ[i]_{mx1}} \quad \textbf{(6)}$$

Or equivalently, in matrix form: $\mathbf{Gi[i]} = (\mathbf{weight_{nxm}} \times \mathbf{RQ_{mxn}})[\mathbf{i,i}]$ **(6a)**

We have arbitrary set weights to weight[1] =0.3, weight[2]=0.2, weight[3] =0.5 for both Grids in order to calculate iWatt quantity for Grid1 (Table 6) and Grid2 (Table 7).

TABLE 6

CALCULATIONS FOR THE AMOUNT OF INFOWATTS FOR GRID1

WEIGHT[1]	RQ[1]	PRODUCT
0,3	180	54
0,2	20	4
0,5	80	40
	TOTAL	98

TABLE 7

CALCULATIONS FOR THE AMOUNT OF INFOWATTS FOR GRID2

WEIGHT[2]	RQ[2]	PRODUCT
0,3	210	63
0,2	40	8
0,5	50	25
	TOTAL	96

The quantity of infoWatts for the whole market [Mi] is given by the summation of each Grid's infoWatt quantity:

$$\mathbf{Mi = Gi[1] + Gi[2] + \ldots + Gi[n]} \qquad \textbf{(7)}$$

or equivalently, in matrix form:

$$\mathbf{Mi}_{1x1} = \mathbf{1}_{1xn} \times \mathbf{weight}_{nxm} \times \mathbf{RQ}_{mxn} \times \mathbf{1}_{nx1} \qquad \textbf{(7a)}$$

with weight=$(w[i,j])_{(i,j)\in[1,n]x[1,m]}$
In our example this sum equals to 194 iWatts. Assuming that the weight vector is the same for all grids (weight = weight[i] for all i $\in$[1,n]), a simplistic way to calculate it, is to obtain from the actual market prices from all resources (Pr) and iWatt price (iP) and to substitute them in the general formula for the resource price (see also Table 8):

$$\mathbf{Pr[j] = weight[i,j]} \times \mathbf{iP} \qquad \textbf{(8)}$$

TABLE 8

THE RESOURCE PRICE VECTOR

PR	WEIGHT	IP
300	0,3	1.000
200	0,2	1.000
500	0,5	1.000

The hypothesis that the price of an iWatt is obtained from the market is a valid assumption if the market is efficient and market power is not exercised from a group of companies (oligopoly) or a single company (monopoly). This naïve linear model for infoWatt calculation can be extended in order to capture the realistic hypothesis that middleware algorithms and network transfers cause inefficiencies in Grid-oriented code execution. Not very often is the case that software will run ten times faster if it is executed in a ten times more powerful Grid. Consequently, a possible extension to the linear model could be the introduction of a ***discount factor*** $\boldsymbol{d_{nx1}}$ for every discrete Grid installation. Hence, equation (6) is transformed to:

$$\mathbf{Gi[i]_{1x1} = d[i] \{weight[i]_{1xm} \times RQ[i]_{mx1}\}} \qquad \textbf{(9)}$$

where $0 \leq$ **d[i]** ≤ 1, while d is defined to zero when a Grid plant is out of order and equals to one when it has a perfect performance and d is a data-driven parameter which could be estimated dynamically through standard benchmark tests for each Grid plant.
Equivalently, in matrix form:

$$\mathbf{Gi[i] = (d \times weight_{nxm} \times RQ_{mxn})[i]} \qquad \textbf{(9a)}$$

Demand side. The second way of the "two-way" metric of a CoD service is based on the assignment of a specific amount of iWatts in every e-service executed for each Grid component. This proposal could be feasible through an implementation of the XML schema produced by the Grid Economic Services Architecture Working Group of the Global Grid Forum (GESA-WG) [21]. The GESA-WG is designing OGSA-style services that will allow Grid services to be charged in a flexible and parameterized way. The Open Grid Services Architecture (OGSA) provides an infrastructure for virtualising resources of many types (compute, storage, software, networking etc.) as Grid Services. The infrastructure for building these basic Grid services is being defined elsewhere within the Global Grid Forum. Although mechanisms will exist for defining these services it is unlikely that any sustainable infrastructure will be provided by any non-research organization without financial compensation. For Grid Services to be provided on demand, organizations will want to be paid for providing these resources. The purpose of GESA-WG is therefore to define the additional service data and ports needed to describe the economic Grid services – the enabling infrastructure – rather than to describe the economic models that will be built on such an infrastructure. Its work is supplemented by the Usage Record Working Group (UR-WG) [50] which is specifying the basic information that needs to be gathered when a resource is used and the Resource Usage Service Working Group (RUS-WG) [42] which is designing an OGSA-style service which will access usage record information.
Our innovative idea is that every e-service in order to be implemented in the Grid should have been assigned a certain amount of iWatts through a series of standardized benchmark tests. So, if you want to buy, for instance, a financial CoD service you know that is consuming 30 iWatts per hour of use. In such case, the market will operate in two alternative business models. The first case will be to buy a CoD-ready service from an IT company assigned with X number of iWatts and you can choose a different CoD service provider to run it. The second case is to buy a CoD service packaged from a single CoD vendor. The CoD service market will be operating as the heating options in a rented house, where you have option A to pay a monthly rate for central heating or option B to use a heating device plugged into the preferred electric or gas network. Most probably a CoD service provider may only be interested in a small subset of resources for the purposes of deciding the supply price. The UR-WR have defined an introductory subset of base properties, including (1) Network, (2) Disc, (3) Memory, (4) Wall Clock Time, (5) CPU Time, (6) Node Count and (7) Processors which could facilitate the service pricing policy. Even if it is possible to press together a CoD service that is being sold within the price mechanism schema, this does not always fully apprehends the behaviour of the service being sold [21]. For instance, a CoD service may sell access to a set of financial analysis tools through a web-based service which analyses and combines historical and individual economic data. The proposed structure of solution in this kind of problems given by GESA-WG is to encapsulate each CoD service and pricing mechanism within a separate Grid Service.

V. CONCLUSIONS AND FUTURE WORK

Last decades thousands of billions euros, dollars, and yens have been invested in Grid computing infrastructure from central governments and IT companies. Major and small companies introduce innovative Grid-oriented products and services and the associative academic research has a steady high growth. One of the next cornerstones for Grid computing to become a massively available commercial utility is considered to be the creation of global Grid market with a single measurement unit and common standards.
In the present paper, we have introduced a "two-way" naïve linear definition of iWatt, a measurement unit for CoD services. The innovative feature of iWatt is considered to be the

fact that mimics the "plug-and-play" philosophy of electric devices and network. As it was mentioned before, we need to work hard in order to build the theoretical and practical prerequisites for a massively available CoD service market. It is essential to conceive the stylized facts and the driving forces of the CoD service economy. Theory and practice of Statistics could help us to find accurate estimates for the weight of each resource and the discount factor for every Grid plant. In addition through the experimental use of the linear pricing model for iWatt, non-linearity and extra explanatory variables could be emerged.

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