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Expert Grid: New Type of Grid to Manage the Human Resources and Study the Effectiveness of Its Task Scheduler

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Abstract Grid systems are the federation of resources from multiple locations to reach a common goal. In previous researches, the focused resources were only CPU, electronic devices, storage devices, network, and software applications, but till now, human resource (HR) has not been considered as Grid resources in details, despite its importance in many fields of science and society. HR is one of the important assets of organizations and plays a significant role in their success. Common and local methods to share and manage the human's skills and knowledge in large geographically dispersed organizations are almost centralized, not reconfigurable and are based on the structure of organization; therefore, the optimal trade-off between the HR and job demands is a challenging problem. In addition, these methods did not consider some important parameters such as security issues, load balancing, organizations costs, unnecessary overtime, and employment issues. In order to overcome these defects, in this paper the new Grid architecture, named Expert Grid (EG), is proposed to find, employ, exploit, share, and manage the HR, its skills and knowledge effectively. EG provides infrastructure to increase the customer satisfactions by optimal distributions of requested jobs from customers. Experimental results show that the EG decreases the HR free time, customers delay time, and HR overtime in order to achieve high level of customers satisfaction and better performance of organizations.

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الخلاصة

إن أنظمة الشبكة هي اتحاد الموارد من مواقع متعددة للوصول إلى هدف مشترك. وفي البحوث السابقة كانت الموارد مركّزة فقط في وحدة المعالجة المركزية والأجهزة الإلكترونية وأجهزة التخزين والشبكة والتطبيقات البرمجية ، ولكن حتى الآن لم تؤخذ الموارد البشرية بعين الاعتبار كموارد شبكة بالتفاصيل على الرغم من أهميتها في العديد من حقول العلم والمجتمع. إن الموارد البشرية هي واحدة من الأصول الهامة للمنظمات وتلعب دوراً كبيراً في نجاحها. إن الطرق الشائعة والمحلية لتبادل وإدارة المهارات والمعرفة البشرية في المنظمات الكبيرة الموزعة جغرافيا هي تقريباً مركزية وغير قابلة لإعادة التشكيل وتقوم على هيكل المنظمة، ولذلك فإن المفاضلة المثالية بين الموارد البشرية وطلبات العمل هي مسألة صعبة. بالإضافة إلى ذلك، إن هذه الطرق لا تأخذ بعين الاعتبار بعض المعلمات الهامة مثل القضايا الأمنية وموازنة الحمل وتكلفة المنظمات والعمل الإضافي غير الضروري وقضايا التوظيف. ومن أجل التغلب على هذه العيوب تم في هذه الورقة العلمية عرض بناء شبكة جديد يدعى شبكة الخبير، وذلك لإيجاد وتوظيف واستغلال ومشاركة وإدارة الموارد البشرية من حيث مهاراتها ومعرفتها بشكل فعال. وتزود شبكة الخبير البنية التحتية لزيادة رضى العملاء من خلال التوزيع المثالي للأعمال المطلوبة من العملاء. وتظهر النتائج التجريبية أن شبكة الخبير تقلل من الوقت الحر للموارد البشرية ووقت تأخير العملاء والوقت الإضافي للموارد البشرية ، وذلك من أجل تحقيق مستوى عالٍ من رضى العملاء وأداء أفضل للمنظمات.

1 Introduction

Nowadays, Information Technology (IT) affects everything from communication to management and industry to business [1–8]. IT uses the electronic and digital devices such as storage media, computer networks, computer hardware, and computer software to convert, store, protect, process, transmit, and retrieve information. Grid systems are relatively new concept in IT which can be used not only for providing high-performance computations, but also for efficient service and data management. The Grid system was initiated in the mid-1990s [9] as it consists of an aggregation of computer networks performing as a distributed system to solve computational and data centric problems [10] in dynamic, multi-institutional virtual organizations [11]. The main goal of Grid system is combining the power of widely distributed resources to provide requested services [12–14]. Grid systems depending on functioning and aims are divided into three main categories: computational Grid, data Grid, and service Grid [15]. Grid systems have many applications such as the MAGIC-5 (Medical Applications on a Grid Infrastructure Connection) to develop a research plan to study models and algorithms for a distributed analysis of biomedical images [16]; BioSim Grid for developing the Grid-enabled bimolecular simulation database providing the data accessible to the biological community; ZetaGrid which is an open source and platform-independent Grid system using free CPUs; Green Grid which is an open industry consortium of end-users, policy-makers, technology providers, facility architects, and utility companies collaborating improvement of the resource efficiency of data centers and business computing ecosystems. In Grid, there are many types of resources such as computers, cluster of computers, online tools, storage space, data, and applications [17], which are widely distributed and heterogeneous in comparison with traditional and cluster systems. One of the most important resources in Grid systems which has not received enough attention recently is human resource (HR).

HR is the most valuable asset of any organization but very few organizations are able to fully harness its potential [18,19]. However, the organization's success and prosper crucially depend on how to manage the HR optimally. Therefore, organizations in today's competitive world can perform at peak levels only if each HR is committed to the organization's objectives and goals [20]. HR management (HRM) is a strategic approach to manage and exploit the skills and knowledge of HR in order to increase the efficiency and success of organization [21]. In geographically dispersed organizations, the trade-off between HR and job demands is very difficult since the HR may be located in different physical places. Static dispreading of the HR in these organizations leads queue of customers to receive the services in some branches, yet some others may be free in other branches.

The main contribution of this paper is introducing the special type of Grid named Expert Grid (EG) to find, share, exploit, manage, and employ the HR in large and geographically dispersed organizations. Here, we develop architecture, policies, tools, and methods to manage and share the HR optimally by using current technologies such as computer networks and Grid systems. To the best of our knowledge, EG is the first attempt to provide architecture and policies to find, share, exploit, manage, and employ the HR, their skills and knowledge in the Grid environments. To show the effectiveness of the proposed method, we considered three parameters: HR free time, customer delay time, and HR overtime.

The rest of this paper is organized as follows: The related works are reviewed in Sect. 2; EG and its layered architecture are discussed in Sect. 3; the task scheduler component as one of the important components of EG is disrobed in Sect. 4; in Sect. 5, the experimental results are provided; and in the last section, we will conclude the paper.

2 Related Works

HR being a comparatively modern management term was introduced in the 1960s [22]. HRM refers to the effective use of HR in order to improve organizational performance [23]. Employment relationship is presented in 1965 from the late medieval period systems [24]. HR and their knowledge are often considered to be crucial to the success of the automotive producers [25]. Employment asset in any organization attracted an increasing attention in the HRM [26–29]. In [30–32], authors claim that employing the best people will not be enough to compete with the other organizations, and efficient and effective management of people plays critical role in this competition. In [33], the authors introduced the contextual approach in HRM. This approach declares that the size of an organization has large impact on its management method. In [34], three aspects of HR management systems were considered, leading the way of exploiting the human assets and knowledge: first, employing people with particular skills and knowledge; second, planning the continuous learning; third, rewarding based on their performance. There are some models to manage the HR, which include Michigan model, Harvard model, and Contingency model. Michigan model [35] declares that people should be counted as a resource of organization like other resources, and utilization of these resources is based on the strategic aims of the organization. Also, this model is called hard model of HRM [36]. In Harvard model [37], people are the most valuable, serious, and critical resources in any organization. According to this model, organization strategies always depend on the employees. In Harvard model, it is assumed that if the employees are dedicated to an organization, they will work better [37]. Harvard model is called soft model of HRM [36]. Contingency model as another model to manage the HR has been applied to obtain a complementary view, but it is not true that all organizations have the same connection among HRM practices [38,39].

Nowadays, technologies have a deep effect on the HRM and provide a new direction for it. Some works such as [40–42] used electronic human resource (eHR) systems in organization. eHR allows people to change their job-related benefits and enhance their knowledge, skills, and abilities through web-based training systems [42]. eHR increases the efficiency of HR processes, reduces administrative costs, and decreases transaction times [43], but there is not a formal architecture involving all issues related to HRM such as security, and in large geographically dispersed organization, it suffers from inefficient load balancing. eHR may also decrease the degree of perceived control of incumbents and increase the degree to which the systems are viewed as invasive of privacy. As a result, system acceptance may suffer, leading to reduced organizational efficiency and effectiveness [42]. Some works such as [44,45] were introduced to search the people with specific knowledge and skills in the social networks as popular types of vast and complex systems that millions of people use to communicate with friends, family, and colleagues. Zhang et al. in [44] compares Breadth First Search, Random Walk Search, Best Connected Search, Weak Tie Search, Strong Tie Search, Hamming Distance Search, and Information Scent Search in social networks by simulating on an email dataset. Ehrlich et al. in [45] proposed a social-context-aware expertise search system that can be used to identify experts, see dynamic profile information, and get information about the social distance to the expert, before deciding how to initiate contact. The system uses an innovative approach to infer content from email and chat logs [45]. But these papers introduced only a simple search in social network and are much more about finding people than managing their expertise in an organization. Few papers such as [46] explain social search mechanisms to find individuals by considering the social relationships among people. All of these approaches did not consider some important parameters such as security issues, load balancing, real organizations, costs of organizations, unnecessary overtime, and employment issues. Therefore, they cannot be useful and practical for real organizations.

Grid system is an important emerging technology where distributed organizations can gain much advantage from it [47]. The Grid system as a new paradigm for scientific applications [48] is based on computational and networking infrastructure that are providing pervasive and reliable access to data and computational resources over a wide-area network [49]. The main idea of the Grid is to connect resources from different locations, organizations, and multiple heterogeneous platforms to build a distributed and scalable system to enable users to access the resources transparently [50]. Grid systems in [15] depending on the functionality and aims are divided in to three main categories: computational Grid, data Grid, and service Grid. Computational Grid is the Grid system with high computational capacity [15], which shares computing resources. This will be a good replacement for supercomputer allowing applications run faster than before. Computational Grid is developed to manage and deal with computational centric problems [51]. Some examples and projects of computational Grids are Health Care Organization, Materials Science Collaboratory, and Computational Market Economy [13]. Data Grid provides an infrastructure to store, analyze, and synthesize new information from data warehouse, which involves the complete dynamic life cycle of service deployment, provisioning, management, and decommissioning. The main idea of data Grid is to store and manage huge amounts of data, which is naturally similar to computational Grid. Some examples and projects of data Grids are as follows: the Biomedical Informatics Research Network, Grid Community Research Group, the Large Hadrons Collider, EU Data Grid which is switched to enable Grids for EGEE (Enabling Grids for E-sciencE) [52], the International Virtual Observatory Alliance, Grid community Research Group and physics Data Grids. Service Grid is a system that provides computing services which is not available from a single machine. It provides on-demand service to the user, such as collaborative conferencing and interactive multimedia [15]. Resources with complicated intellectual property issues are wrapped as Web services and shared on the service Grid, which enables service providers to provide services while protecting intellectual property of their resources. Service Grid is expected to be applied in different domains, such as Language Grid to share resources and services in the language domain, Agricultural Service Grid to provide agricultural knowledge and field information sensor as services, Education Service Grid to share open courseware and e-Learning systems as services, and so on.

In all previous works on Grid systems, the resources were CPU, electronic devices, network, software application components, and so on [53]; but in these works, the HR has not been considered in details as a Grid resources, although these resources are very important in many fields of science and society.

The main goal of this paper is to introduce EG as a special type of Grid system to find, share, exploit, and employ the HR in large geographically dispersed organizations. EG not only benefits from advantages of previous managing and searching mechanisms but also adds some new electronic-based features such as expert managing, load balancing, task managing, salary, and security issues to manage the HR optimally on Grid infrastructure. These components and layered architecture of EG are introduced and discussed in the next section.

3 Expert Grid

In today's world, Internet has emerged as an information hub to facilitate data transfer and sharing [54]. Therefore, many

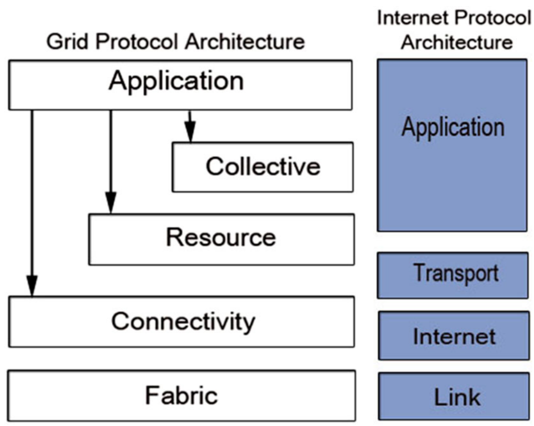

Fig. 1 The layered Grid protocol architecture compared with Internet protocol architecture [55]

projects and systems such as Grid system used Internet concepts and protocols to share data and information. The Grid system utilizes a layered structure that corresponds to the Internet protocol architecture (Fig. 1). The Grid architecture consists of five layers: application, collective, resource, connectivity, and fabric layer. The application layer is similar to the internet application layer comprises the user applications [55]. The collective layer contains protocols, services, and APIs to implement interactions across collections of resources and coordinate multiple resources [56]. Resource layer provides communication and authentication protocols to define protocols for the secure negotiation, initiation, monitoring, control, accounting, and payment of sharing operations on individual resources [55]. The connectivity layer defines core communication and authentication protocols required for Grid-specific network transactions [55]. The fabric layer in this structure refers to a set of resources or devices, including computers, storage systems, networks, and various types of computer-controlled instruments and devices.

The architecture of EG is inspired from the Grid architecture. As shown in Fig. 2, this architecture is depicted as four layers: interface, management, tools, and infrastructure layer. The interface layer provides the relation between EG and customer, HR and manager. The management layer manages the HR, jobs, and quality-related issues. The tools layer develops the infrastructure layer to provide essential tools for management layer and handles the organization rules and policies. The infrastructure layer provides information transfer, security, data resources, and storages media.

The components of this architecture and their duties are described as follows.

3.1 Interface Layer

Interface layer facilitates creating and relation between EG and customer, HR and manager. The Interface layer is also related to the aspects of data representation. This layer has 3 components: manager, expert, and customer as described below.

Manager provides the connection between EG and managers to import some managing policies, rules and laws that must be observed. Expert provides a connection between a person with specific skill and ability in a particular part of the organization and EG. Customer provides connection between people who are the recipients of a service from EG. Also, this layer involves the authorization of access to EG, which is controlled by the EG administrator. Users (managers, customers, and HR) are assigned an ID and password that allows them to access to data, information, and programs within their authority.

3.2 Management Layer

Management layer includes two managing components: HR management and Job[1] management to provide requested services from interface layer by using the tools of tools layer. The relations between the components of management layer and interface layer are illustrated in Fig. 3.

Human resource management (HRM) handles the HR activities based on the strategy and goals of organization. Also, it facilitates the utilization of information coupled with HR's skills, knowledge, ideas, commitments, and motivations. HRM adapts the HR managing strategies and policies with the organization's goals and objectives. It manages and handles HR education, as well as its discovery and employment. It maximizes the efficiency of an organization by optimizing the effectiveness of its HR while improving the work time of HR. Moreover, it is responsible for HR trust and expertise evaluation, which is very important for future actions and managing the expert of HR to achieve high efficiency. The HRM fulfills these duties by means of set of expert tools, which are provided by tools layer.

Job management exploits and classifies the jobs according to the requested services and the execution time. Job management not only divides and classifies jobs to tasks but also manages them relating to their nature and required services. This component considers all aspects of a job, including its status, priority, requested time, and requested HR. In addition, this component keeps the record of each resource, for example average use of HR, HR being busy or idle, and the cost of HR. Also, it is responsible for processing a job, submitting the created tasks to the task scheduler, and making sure that all of the tasks corresponding to the job will be completed in a timely manner. After dividing the job into many independent tasks, job management submits the task to the task scheduler. In the mean time, the available HR is reported

[1] Job made of several tasks that could have different HR requirements and task represents a request from customer to one HR.

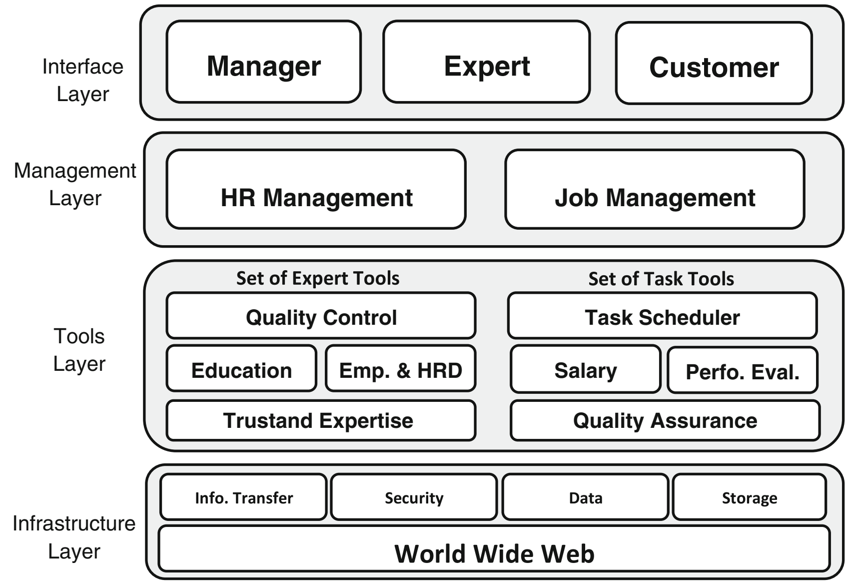

Fig. 2 Layered architecture of Expert Grid

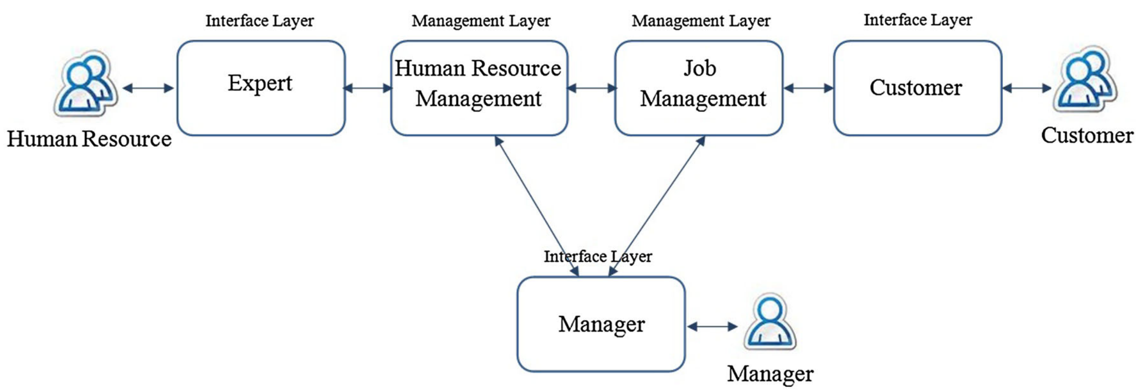

Fig. 3 The relations between the components of Management and interface layer

by HR Management and its related components. Also, customer component in interface layer, to provide the summary and wrap-up the customer's job, can monitor the progress of a job and all of its tasks via this component. The job management starts, controls, and monitors the job according to its requested HR, deadline, and cost of service. Job management utilizes four components, (1) quality assurance, (2) task scheduler, (3) salary and (4) performance evaluation in tools layer to fulfill these deities.

3.3 Tools Layer

Tools layer monitors and manages the HR and job factors in order to improve the utilization, performance, and availability of HR and increase the satisfaction of customers. Furthermore, it provides required information and services to management layer by using the infrastructure layer. In this layer, two sets of tools are used: set of expert and task tools. These sets and their components will be discussed briefly below.

3.3.1 Set of Expert Tools

Since the main goal of EG is to exploit and share the skills and knowledge of HR, some expert-related tools are provided in tools layer. This section elaborates on this set and its components.

Quality control (QC) is a process employed to ensure a certain level of quality in service provided by organization, which is also used in many field of sciences and technologies such as [57–64]. The basic goal of QC in EG is to make sure that the provided services meet a defined set of quality criteria and satisfy specific requirements of customer. QC includes all the prepared techniques, methods and activities used to complete quality requirements. Customer satisfaction (CS) is one of the topics, which can be considered as one of the duties of quality control component in which customers judge about the quality of provided service and express their satisfaction. We used Berger et al. method [65] to define a CS. They defined the CS coefficient to improve service quality.

As the processes and techniques of service providing by organization are becoming more and more complicated, it is being increasingly realized that the education is very important. Education increases the skills and knowledge of the employees to improve the performance and efficiency of organizations. Its purpose is to improve the performance of HR and to enable them to improve their knowledge and skills in their fields to do the assigned jobs better. Also, when a new plan is introduced in any organization, to improve efficiency and productivity of an organization, HR must adapt themselves to the new situation, which is not possible without education. However, HR education is a continuous process and never stops. Education must affect knowledge, skills, and ability of HR to help them increase their knowledge and facts and teach them technical and manual skills, which are necessary to do their job efficiently. Also, it should form the manner of HR toward other HR and the organization. It should also create in it a sense of responsibility, interest in the job, and appreciation of enterprise's goals and policies. Education increases the efficiency and throughput of organization as well as adaptability and effectiveness of HR.

Employment and human resource discovery (Emp. & HRD) are one of the most important issues in HRM [21]. This component not only provides some methods and policy to discover the appropriate HR with specific skills and knowledge, but also hires the new employees in order to employ their knowledge, skills, and abilities. Here, we used an ontology-based mechanism to classify and discover the HR regardless of their geographical location, which is adopted from of [66]. Li [66] proposed an efficient discovery framework which organizes a Grid by a semantically linked overlay representing the semantic relationships between Grid participants. Specifically, she used a semantics-aware topology construction method to group similar nodes to form a semantic small-world. With the small-world topology, resource-discovery queries will be propagated only between semantically related nodes, which greatly improve the efficiency and accuracy of resource discovery in Grid. The ontology represents knowledge of HR as a set of concepts and the relationships between pairs of concepts. In particular, a semantic link between two ontologies can be *Equal-to, Similar-to, Reference, Implication, Subtype,* and *Sequential* [66]:

To classify HR between these types of semantic links, the *Similar-to* is very important and applicable. To measure the semantic similarity between HR, we need to extract each HR's semantic characteristics. To compare two ontologies, we define an ontology similarity function. The similarity function is based on the normalization of Tversky's model to give a numeric measurement of ontology similarity. Assume A and B are two peers, and their extended ontology signature sets are S(A) and S(B), respectively. The semantic similarity between peer A and peer B is defined as equation (1) [66]:

$$\mathrm{Sim}(A,B)=\frac{S(A)\cap S(B)}{S(A)\cap S(B)+\alpha S(A)-S(B)+\beta S(B)-S(A)} \quad (1)$$

where "∩" denotes set intersection, "–" is set difference, "||" represents set cardinality, "α" and "β" are the parameters that provide for differences in focus on the different components.

Node A and node B are semantically equivalent if sim(A, B) = 1. Node A is semantically related to node B, if sim(A,B) exceeds the user-defined similarity threshold t ($0 < t \leq 1$). Node A is semantically unrelated to node B if sim(A, B)< t [66]. Then, the HR classified based on their similarity and equality values. Therefore, the HR with same skills and abilities are in same group and the discovering process can be significant. Also, it can find the HR more efficiently than flooding and centralized mechanisms.

Trust has become important topic of research in many fields including sociology, psychology, philosophy, economics, business, law, and IT. Trust is a characteristic that is considered in all types of Grid system for its open and decentralized nature. Trust is also a subject relating to belief in honesty, dependability, trustfulness, competence, and reliability of HR. It plays an important role in enabling trusted infrastructure to perform the tasks over Expert Grid. Trust can be viewed as an assumption about the expected quality or reliability of a HR based on existing information or observations about its past behaviors. In EG, we adopted multicriteria trust model, which is introduced in [67]. If any interaction between two HR occurred, a trust value is stored based on the satisfaction of requester entity in its own DTL (direct trust level) table. After any interaction between HR_i and HR_j, the DTL is updated by equation (2).

$$\begin{aligned}\mathrm{DTL}\left(\mathrm{HR}_i,\mathrm{HR}_j,c\right)_{\text{after interaction}} &= (1-\theta)\times \mathrm{DTL}\left(\mathrm{HR}_i,\mathrm{HR}_j,c\right)_{\text{before interaction}}\\ &\quad+\theta\times \mathrm{STL}\left(\mathrm{HR}_i,\mathrm{HR}_j,c\right) \end{aligned}\quad (2)$$

where DTL $(\mathrm{HR}_i, \mathrm{HR}_j, c)_{\text{before interaction}}$ is the direct trust level, which is assigned by HR_i to HR_j in context c before interaction. STL $(\mathrm{HR}_i, \mathrm{HR}_j, c)$ is the satisfaction value that HR_i evaluates for HR_j in context c and θ shows the priority factor in range of [0, 1], for example, if $\theta > 0.5$, DTL priority is greater than STL priority.

Expertise shows the type of skill, expertise, and dexterity of any HR. This information is very important for other components in order to optimize self-decisions making, for example, the task scheduler uses this information to assign the tasks to appropriate HR. We define expertise as the opinion or view of some HR about the skill and ability of another HR, which provides some service for them. We suppose that HR_i can rank HR_j after receiving its service. The ranking numbers are in the range of [0,1] and represent to service customer by excellent (1), very good (0.8), good (0.6), average (0.4), bad (0.2), or very bad (0). Service customer ranks the HR by one of these adjectives based on some factors such as: its skill, ability, attitude, talent, and knowledge. By these preliminaries, Eq. (3) evaluates the expertise value of HR_i (Ei).

$$E_i = \frac{1}{x} \sum_{n=1}^{|Fi|} Wn \times EAni \tag{3}$$

$$F_i = \{\text{HR}|\text{HR is the friend of HR}_i\} \tag{4}$$

where EA_{ni} denotes the answer for expertise of HR_i from HR_n. λ is in the range of [0, 1], for example, if $\lambda = 0.4$, only the HR can contribute in expertise evaluation process whose E value is not less than 0.4. X denotes the number of HR, which HR $\in F_i$, and its E value is less than λ.

3.3.2 Set of Task Tools

Task management in EG is one of the most important and significant issues. Set of task tools in tools layer provide some tools to manage and control the received job by using four components.

Task scheduler in Grid system assigns tasks to suitable resources to execute them [68]. The goal of task scheduler is to minimize the overall execution time for a collection of tasks. In EG, task scheduler determines which HR must do which task at a period of time. The main purpose of task scheduler is to shorten the response time to customer and enhance the HR utilization to increase organization efficiency. It matches the computational needs with the available resources and then distributes the task to appropriate HR.

Salary plays an important role in HR satisfaction and pleasure. Salary is granted to any HR based on their performance, which is obtained from performance evaluation's component. The salary must be calculated in order to increase the motivation of HR, which can result in promoting the performance and throughput of the organization.

Performance evaluation evaluates the performance of any HR. This component enables the managers to recognize the sluggard and hardworking HR. Task scheduler and salary component use this information to make appropriate decision.

Quality assurance (QA) is an old concept (from World War II), but it is still a useful tool in many fields of science and technologies such as [64,69–74]. QA is the process of monitoring and assessing a product, service to ensure that it is of sufficient quality. In other word, QA is the process of verifying or determining how the services are met. Also, it is the planned and systematic activities which are implemented in a quality system so that quality requirements for service will be satisfied. In organizations, QA is an approach with specific steps to define the goals of organization by considering design, development, and service. In addition, QA is a process-centered approach to ensure that requirements of organization are fulfilled, and the best possible services are provided for customer. Therefore, it refers to all the things that are made within an organization in order to achieve a preferred level of quality.

3.4 Infrastructure Layer

Infrastructure layer enables the communication between terminals of customers and HR based on World Wide Web and computer networking to provide reliable data transfer. This layer includes four components: information transfer, security, data resources, and storage.

Information transfer is used to transfer the information between the components of EG by using some network protocols to transfer information and data. Transport control protocol (TCP), DiskRouter [75], and GridFTP [76] protocols can be used to transfer data between two nodes of EG. DiskRouter [75] provides the mechanisms to move large amounts of data efficiently and uses disk as a buffer to aid in large-scale data transfers. GridFTP [76] is a FTP[2]-based, high-performance, secure, high-speed, and reliable data transfer protocol optimized for high-bandwidth wide-area networks such as Grid. Also, this component can be improved by use of some new protocols such as High-Speed Transport Control Protocol (HSTCP) [77] and Quick Transport Control Protocol (QTCP) [78].

Security component does some decryption and encryption to transfer the data and information between the EG components. Security consists of the rules and policies adopted by the EG administrator to prevent and observe unauthorized access, abuse, illegal modification, and attack. It secures the network, protects the information, and supervises the operations being done. Secure communication is enabled using asymmetric encryption.

Data resource is a component of infrastructure layer that represents all the data and information accessible to EG. It is expanding collection of structural and functional data and information about the components of EG, organization, HR, and customers. It represents all the data which are accessible and available to an organization. Also, it can be a chunk of data that can be shared by customers and HR.

Storage stores data and makes it available to other components. Also, it operates as a server and provides a possibility to store and retrieve the shared data and information used by components of tools layer.

4 Tasks Scheduler

Task scheduler as the most important component of EG allocates a set of tasks, which are received from job management

[2] File transfer protocol.

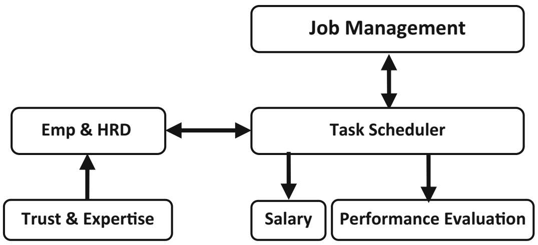

Fig. 4 The relation between the task scheduler and the components that have the role on the scheduling process

TID	Exp	T	PET	P

Fig. 5 The characteristics of the tasks

HRID	Exp	T	R	QL

Fig. 6 The characteristics of HR

to the appropriate set of HR based on their skills and knowledge in order to increase HR's utilization and decrease the total execution time of tasks. Task scheduler must provide facilities that each HR with same skills and knowledge has the equal task loads. The main purpose of task scheduler is to shorten the response time to customers and enhance the HR utilization to increase organization efficiency. Figure 4 illustrates the relation between the task scheduler and the components that have the role on the scheduling process.

In the scheduling process, job management divides each job to some independent tasks while each task needs only one HR to perform and then delivers the tasks to the task scheduler. Each task is determined by 5 properties which are shown in Fig. 5. TID is the unique identification number of task; Exp is the type expertise that is needed to perform this task; T is the minimum required level of trust value in the range of [0, 1]; PET is the predicted execution time to perform the task which is approximated by job management; P is the value in the range of [0, 1] showing the priority of the task which is determined by job management.

Then, HRD finds the HR and sends its information to the task scheduler. Each HR is determined by 5 characteristics presented in Fig. 6. HRID is the unique identification number of HR; Exp is the type of HR's expertise; T is the trust value of HR in the range of [0, 1], 1 means the HR is very trustworthy and 0 means is very untrustworthy; and QL is the queue length of HR and shows the numbers of tasks waiting to receive service from HR.

For example, if $J = \{J_1, J_2, J_3\}$ is the set of job received by job management, job management divides these jobs to some tasks; suppose $J_1 = \{T_{1,1}, T_{1,2}\}$, $J_2 = \{T_{2,1}, T_{2,2}, T_{2,3}\}$ and $J_3 = \{T_{3,1}, T_{3,2}, T_{3,3}, T_{3,4}, T_{3,5}\}$ are the sets of tasks which are sent to task scheduler. Table 1 shows the characteristics of these tasks.

Table 1 The characteristics of ten tasks which is delivered to task scheduler

TID	Exp	T	PET	P
$T_{1,1}$	S_1	0.10	10	0.81
$T_{1,2}$	S_2	0.50	20	0.70
$T_{2,1}$	S_1	0.70	15	0.60
$T_{2,2}$	S_1	0.35	22	0.45
$T_{2,3}$	S_1	0.30	25	0.98
$T_{3,1}$	S_2	0.10	20	0.95
$T_{3,2}$	S_3	0.55	35	0.41
$T_{3,3}$	S_1	0.15	30	0.50
$T_{3,4}$	S_2	0.50	14	0.32
$T_{3,5}$	S_3	0.60	20	0.39

Table 2 The discovered HR with skill on S1, S2, and S3

HRID	Exp	T	QL
HR_{01}	S_1	0.35	5 min
HR_{02}	S_1	0.70	15 min
HR_{03}	S_2	0.50	5 min
HR_{04}	S_3	0.60	10 min
HR_{05}	S_2	0.30	30 min
HR_{06}	S_3	0.30	0
HR_{07}	S_1	0.10	15 min
HR_{08}	S_3	0.55	40 min

For instance, $T_{1,2}$ needs the HR with skills on S_2 and at least 0.5 level of trust; it has 20 min predicted execution time with the priority of 0.70. After sending the tasks to the task scheduler, task scheduler delivers the required skills to the Emp & HRD component and gets the characteristics of the available HR. Table 2 shows the discovered HR by Emp & HRD component.

Now, the task scheduler considers the type of HR and trust level of each task, sorts the tasks based on their priority and then determines candidate HR to perform the tasks. Table 3 shows candidate HR to perform the tasks.

Then, task scheduler calculates STNHR_i (Set of Tasks can Run on HR_i) which is obtained from Eq. (5). Equation (6) shows the sum of execution time of tasks which can run on HR_i (SETHR_i). Table 4 shows the STRHR and SETHR for HR.

$$\mathrm{STRHR}_i = \{T \,|\, T \ni \text{TID and } \mathrm{CHR}_T = \mathrm{HR}_i\} \tag{5}$$

$$\mathrm{SETHR}_i = \sum_{k \in \mathrm{STRHRi}} \mathrm{P.E.T.}(k) + \mathrm{Q.L}\,(\mathrm{HR}_i) \tag{6}$$

Task scheduler first considers $T_{2,3}$ because of its priority. $T_{2,3}$ can be run by HR_{01} or HR_{02}, but because $\mathrm{SETHR}_{01} < \mathrm{SETHR}_{02}$, task scheduler assigns $T_{2,3}$ to HR_{01}. Then, $T_{2,3}$ is removed from the queue of HR_{02} ($\mathrm{STNHR}_{02} = \{T_{1,1}, T_{2,1},$

Table 3 Candidate HR to perform each task

TID	Priority	CHR
$T_{2,3}$	0.98	HR_{01}, HR_{02}
$T_{3,1}$	0.95	HR_{03}, HR_{05}
$T_{1,1}$	0.81	HR_{01}, HR_{02}, HR_{07}
$T_{1,2}$	0.70	HR_{03}
$T_{2,1}$	0.60	HR_{02}
$T_{3,3}$	0.50	HR_{01}, HR_{02}
$T_{2,2}$	0.45	HR_{01}, HR_{02}
$T_{3,2}$	0.41	HR_{04}, HR_{08}
$T_{3,5}$	0.39	HR_{04}
$T_{3,4}$	0.32	HR_{03}

$T_{3,3}$, $T_{2,2}$}), and $SETHR_{02}$ is updated ($SETHR_{02} = 70$). $T_{3,1}$ can be run by HR_{03} or HR_{05}, and because $SETHR_{05} < SETHR_{03}$, task scheduler assigns $T_{3,1}$ to HR_{05}. Then, $T_{3,1}$ is removed from the queue of HR_{05}($STNHR_{05}$ ={}) and $SETHR_{05}$ is updated ($SETHR_{05} = 30$). $T_{1,1}$ can be run by HR_{01}, HR_{02}, or HR_{07}, because $SETHR_{07} < SETHR_{02} < SETHR_{01}$, task scheduler assigns $T_{1,1}$ to HR_{07}. Then, $T_{1,1}$ is removed from the queue of HR_{02}($STNHR_{02}$ ={$T_{2,1}$, $T_{3,3}$, $T_{2,2}$}), and the queue of HR_{01} ($STNHR_{01}$ = {$T_{2,3}$, $T_{3,3}$, $T_{2,2}$}) and $SETHR_{02}$, $SETHR_{01}$ are updated ($SETHR_{02} = 60$, $SETHR_{01} = 82$). $T_{1,2}$ can only be performed by HR_{03}; therefore, it assigned to HR_{03}. $T_{2,1}$ can only be done by HR_{02}; therefore, it assigned to HR_{02},. $T_{3,3}$ can be performed by HR_{01} or HR_{02}, and because $SETHR_{02} < SETHR_{01}$, task scheduler assigns $T_{3,3}$ to HR_{01}. Then, $T_{3,3}$ is removed from the queue of HR_{01} ($STNHR_{01}$ = {$T_{2,3}$,$T_{2,2}$}, and $SETHR_{01}$ is updated ($SETHR_{01} = 52$). $T_{2,2}$ can be performed by HR_{01} or HR_{02}, and because $SETHR_{01} < SETHR_{02}$, task scheduler adds $T_{3,3}$ to the queue of HR_{01}. Then, $T_{3,3}$ is removed from the queue of HR_{02} ($STNHR_{02}$ = {$T_{2,1}$, $T_{2,2}$}, and $SETHR_{02}$ is updated ($SETHR_{02} = 30$). $T_{3,2}$ can be performed by HR_{04}, HR_{08}, and because $SETHR_{04} < SETHR_{08}$, task scheduler adds $T_{3,2}$ to the queue of HR_{04}. Then, $T_{3,2}$ is removed from the queue of HR_{08} ($STNHR_{08}$ = {}, and $SETHR_{08}$ is updated ($SETHR_{08} = 40$). $T_{3,5}$ can only be performed by HR_{04}; therefore, it will be assigned to the queue of HR_{04}. $T_{3,4}$ can only be performed by HR_{03}; therefore, task scheduler adds $T_{3,4}$ to the queue of HR_{03}. The pseudocode of the task scheduler is shown in Fig. 7.

Task Scheduler

```
// Q is a task queue in task scheduler
Begin
    Sort Q by priority DESC
    Sends the required HR to Emp. & HRD component
    Receive the discovered HR from Emp. & HRD component
    For each HR
        Calculate STRHR
        Calculate SETHR
    EndFor
    For each Task Ti∈Q
        Find CHR for Ti
        If CHR=empty write "not executable" end exit
        Find the HRk with lower SETHR and assigns to Ti
        Remove Ti from all STRHR except STRHRk
        Update SETHR
    EndFor
End
```

Fig. 7 Pseudocode of the task scheduler

5 Experimental Results

Nowadays, local service provision (LSP) methods are a common way to provide specific service for customers of organization. In these methods, each branch of organization has independent manager providing the services. Therefore, only local HR and their knowledge can be used to meet customers' needs. The concepts of LSP are discussed completely in [79–82]. Since the concept of EG is very broad and is bound to be expanded in the near future, in this section we simulate the task scheduler component and obtained very excitement results over LSP methods. Tasks scheduling plays a vital role in achieving the skills and knowledge of HR. In the next subsection, a case study is presented to illustrate the effectiveness of EG over LSP methods.

5.1 Case Study

To help evaluate the efficiency of Expert Grid, twenty geographically dispersed organizations (available at: www.DSet.csasrb.ir) are supposed. Each organization has different types of HR, branch numbers, and customer reference ratio. The number of customers reference in organization is based on Poisson distribution with predefined $\lambda_{i,j}$ where i is the branch's number and j is the type of requested HR. The time between each customer referring is based on exponential distribution with μ which describes the time between events in a Poisson process. The service time is based on exponential

Table 4 The STRHR and SETHR for each HR

HR	1	2	3	4	5	6	7	8
STRHR	{$T_{2,3}$, $T_{1,1}$, $T_{3,3}$, $T_{2,2}$}	{$T_{2,3}$, $T_{1,1}$, $T_{2,1}$, $T_{3,3}$, $T_{2,2}$}	{$T_{3,1}$, $T_{1,2}$, $T_{3,4}$}	{$T_{3,2}$, $T_{3,5}$}	{$T_{3,1}$}	{}	{$T_{1,1}$}	{$T_{3,2}$}
SETHR	92	95	59	65	50	0	25	75

distribution with predefined μ_i where i is the type of required HR.

With the use of EG, each customer can contact any HR in any branches, whereas without EG, by use of LSP method, customers will face two shortcomings: first, they can use only those HR in their own cities and second, they only find the local HR. In the next subsections, we consider three factors to evaluate the performance of EG; HR free time, customer delay time, and HR overtime. In all cases in the next section, EG is compared with traditional local method.

5.2 Preliminaries Equations

The number of customers reference in organization is based on Poisson distribution with predefined $\lambda_{i,j}$ where i is the branch's number and j is the type of requested HR. The time between each customer reference is based on exponential distribution with μ, which describes the time between events in a Poisson process. The service time is based on exponential distribution with predefined μ_i where i is the type of required HR. The obtained results show the better performance of EG in HR free time, customers delay time, and HR overtime, which are discussed in this section.

First experiment was set up to evaluate the free time improvement ratio (FTIR), which is defined by Eq. (7):

$$\text{FTIR} = \sum_{k=1}^{20} \text{FT}_k^{\text{EG}} \Big/ \sum_{k=1}^{20} \text{FT}_k^{\text{LSP}}, \tag{7}$$

with

$$\text{FT}_x^{\text{EG}} = \sum_{j=1}^{h} \text{FT}_{x,j}^{\text{EG}}, \tag{8}$$

$$\text{FT}_x^{\text{LSP}} = \sum_{j=1}^{h} \text{FT}_{x,j}^{\text{LSP}}, \tag{9}$$

where FT_x^{EG} is the summation of HR free time at organization x after implementing the EG, FT_x^{LSP} is the summation of HR free time at organization x by means of local method, before implementing the EG, $\text{FT}_{x,j}^{\text{EG}}$ is the HR free time in branch j at organization x after implementing the EG, $\text{FT}_{x,j}^{\text{LSP}}$ is the HR free time in branch j at organization x by means of local method, before implementing the EG, and h is the number of branches at organization x.

Second experiment was set up to evaluate the delay time improvement ratio (DTIR), which is defined with Eq. (10):

$$\text{DTIR} = \sum_{k=1}^{20} \text{DT}_k^{\text{EG}} \Big/ \sum_{k=1}^{20} DT_k^{\text{LSP}}, \tag{10}$$

with

$$\text{DT}_x^{\text{EG}} = \sum_{k=1}^{h} \text{DT}_{x,j}^{\text{EG}}, \tag{11}$$

$$\text{DT}_x^{\text{LSP}} = \sum_{k=1}^{h} \text{DT}_{x,j}^{\text{LSP}}, \tag{12}$$

DT_x^{EG} is the summation of customers delay time at organization x after implementing the EG, DT_x^{LSP} is the summation of customers delay time at organization x by means of local method, $\text{DT}_{x,j}^{\text{EG}}$ is the customers delay time in branch j at organization x after implementing the EG, and $\text{DT}_{x,j}^{\text{LSP}}$ is the customers delay time in branch j at organization x by means of LSP method.

Third experiment was set up to evaluate the overtime improvement ratio (OTIR), which is defined with Eq. (13):

$$\text{OTIR} = \sum_{k=1}^{20} \text{OT}_k^{\text{EG}} \Big/ \sum_{k=1}^{20} \text{OT}_k^{\text{LSP}}, \tag{13}$$

with

$$\text{OT}_x^{\text{EG}} = \sum_{k=1}^{h} \text{OT}_{k,j}^{\text{EG}}, \tag{14}$$

$$\text{OT}_x^{\text{LSP}} = \sum_{k=1}^{h} \text{OT}_{k,j}^{\text{LSP}}, \tag{15}$$

where OT_x^{EG} is the summation of HR overtime at organization x after implementing the EG, OT_x^{LSP} is the summation of HR overtime at organization x by means of local method, before implementing the EG, $\text{OT}_{x,j}^{\text{EG}}$ is the HR overtime in branch j at organization x after implementing the EG and $\text{OT}_{x,j}^{\text{LSP}}$ is the HR overtime in branch j at organization x by means of LSP method.

5.3 Results

In this subsection, three experiments in terms of HR free time, customers delay time, and HR overtime on proposed scenario are evaluated. MATLAB is used to determine the performance of EG in scheduling the received tasks.

5.3.1 HR Free Time

HR free time is the most direct metric to evaluate the efficiency of the task scheduler. If HR free time is decreased, the load balancing of the system is increased. High load balancing achieves optimal HR utilization, maximizes throughput of organization, and minimizes response time for customer. Figure 8 shows the HR free time in the organizations by use of LSP and EG.

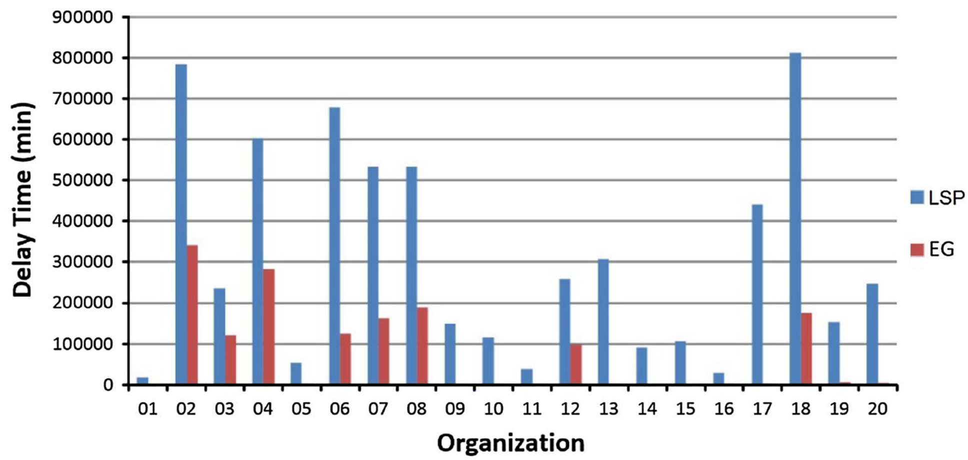

Fig. 8 HR free time in the organizations by use of LSP and Expert Grid

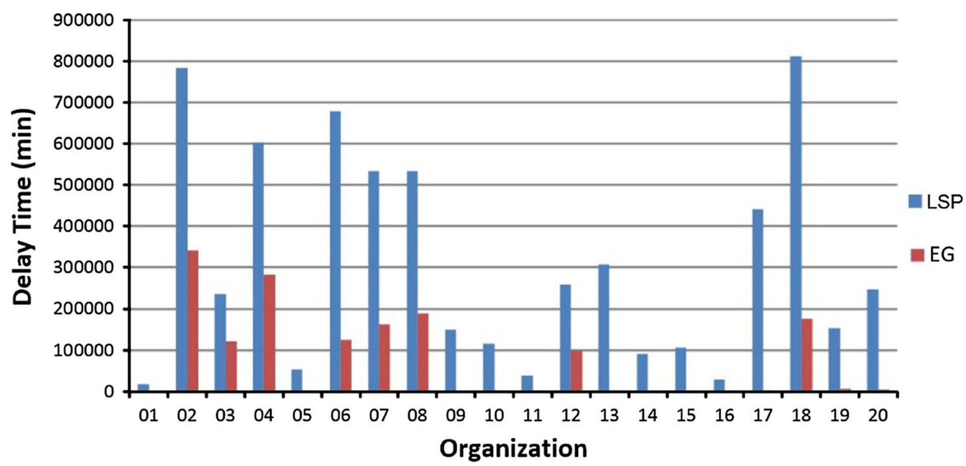

Fig. 9 Customers delay time in the organizations by use of LSP and Expert Grid

This experiment shows the FTIR is 74.3 % which means the EG reduces the HR free time in each organization significantly. This result shows that all HR with same expertise have similar workloads in any branch of the organizations.

5.3.2 Customers Delay Time

The second experiment was set up to evaluate the customers delay time. Customers delay time has a significant impact on the customer satisfaction. Figure 9 shows the effect of the EG on the customers delay time in the organizations by use of LSP and EG.

Figure 9 shows the customer delay time in all organization are decreased significantly. This experiment shows in DTIR is 41 %, means the EG increases the customer satisfaction considerably.

5.3.3 HR Overtime

The third experiment was set up to evaluate the HR overtime. HR overtime shows extra work time of each HR in its organization. Unnecessary overtime can be costly for organizations. Figure 10 shows the effect of EG on the overtime of HR in the organizations by use of LSP and EG.

This experiment shows OTIR is about 27.7 % which means EG reduces the HR overtime and organizations' costs in each organization. Therefore, EG reduces unnecessary overtime significantly.

Briefly, these results show EG can effectively balance the task loads of organization, reduce overtime of HR and cost of the organizations, and also increase the efficiency of large-scale organizations.

6 Conclusions and Future Works

HR is the most important and crucial asset in any organization; therefore, management of these assets has great role in any organization to increase their performance. Grid systems enable the sharing of a wide variety of distributed resources such as hardware, storages, and computing equipment. One of the most important resources in Grid systems which has not received enough attention recently is HR. In this paper, the new architecture based on Grid system named Expert Grid (EG) to manage the HR, increase customer satisfaction,

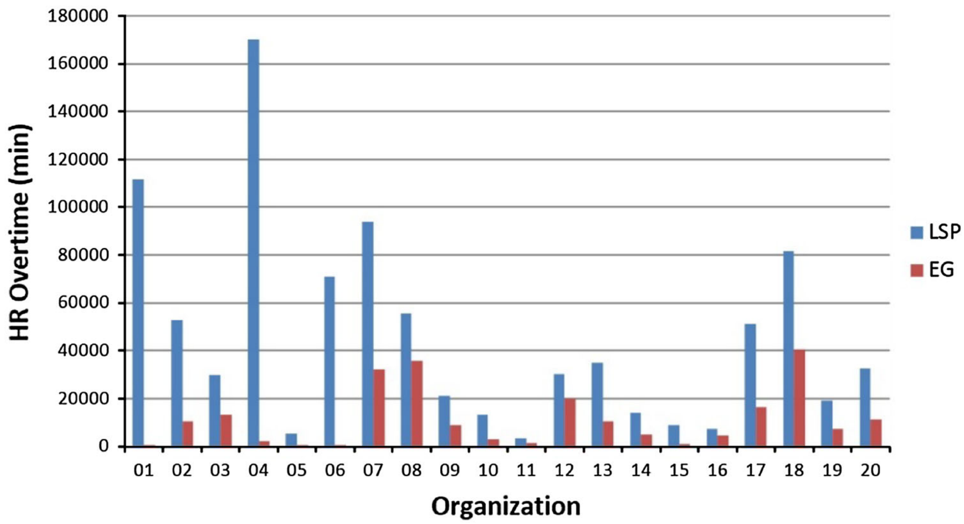

Fig. 10 Overtime in the organization by use of LSP and Expert Grid

and improve performance of organization is introduced. EG is depicted as four layers: infrastructure layer, tools layer, management layer, and interface layer. The interface layer provides the relation between EG and customer, HR and manager. The management layer manages the HR, jobs, and quality factors. The tools layer handles the organization rules and policies by means of three sets of tools. The infrastructure layer provides information transfer, security, data resources, and storages media. Obtained results showed the better performance of EG in twenty various organizations in terms of HR free time, customers delay time, and HR overtime over LSP methods. In addition, load balancing between organizations is achieved efficiently. Furthermore, EG improves the performance of organization by decreasing the overtime and free time of HR, and improves the customers' satisfactions by decreasing the customer delay time.

This work is the first attempt to investigate effectiveness of Grid systems in HRM. Future studies in this domain will be twofold: first, due to the characteristics of EG and their components nature, there are still many open issues for EG including improving their layers and related components; second, task scheduler will be interesting to be extended in order to consider some other constraints, such as response time and cost of service which we plan to study them in our future works.

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