The Sensing Enterprise: Towards the Next Generation Dynamic Virtual Organisations

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Abstract. In today's dynamic and volatile global environment, established legacy concepts such as Virtual Organisations (VOs) need to be evolved to enhance their agility in order to promptly adapt to changes. This paper proposes the use of the Sensing Enterprise concept and properties, supported by the paradigms of the Internet of Things, Cyber-Physical Systems and Future Internet Enterprise Systems, as an essential enabler towards the advancement of the current 'dynamically created' VO concept towards a Next Generation of agile and genuinely Dynamic Virtual Organisations (DVOs), displaying awareness, perceptivity, intelligence and extroversion. The properties and benefits of the Next Generation 'sensing' DVO are defined and then illustrated in a scenario that typically requires utmost agility and dynamism.

Keywords: Virtual Organisations, Breeding Environments, Sensing Enterprise, Internet of Things, Collaborative Networks, Disaster Management.

1 Introduction

In the context of increasingly competitive global environments in market and society, enterprises and organisations are often compelled to take on project opportunities requiring competencies beyond their individual resources and knowledge. As a result, organisations become so-called Collaborative Networked Organisations (CNOs) that act as 'breeding environments' (BEs) for Virtual Organisations (VOs) [1]. VOs are temporary associations between BE members, created in order to bid for, win and complete projects requiring resources and know-how above those available in any BE member alone. However, in an increasingly volatile market and society environment, successful VOs are required to become dynamic and agile, i.e. to constantly perceive changes and adapt to them in a timely manner.

In this paper, the authors argue that the new 'Sensing Enterprise' (SE) concept, supported by the paradigms of the Internet of Things [2], Cyber-Physical Systems, [3] and Future Internet Enterprise Systems [4], is able to assist in the evolution of current VOs and dynamically created VOs within a VO Breeding Environment (VBE) [5], towards a next generation of genuinely Dynamic and agile VOs, hereafter referred to

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as 'Dynamic VOs' (DVOs). As a result, DVOs will be able to sense and promptly adapt to changes in their environment during their entire lifecycle.

A brief review of current research in the SE area is followed by defining the capabilities of the future SE. Next, the SE paradigm is applied to the current VO concept so as to transform it into a genuine DVO. Finally, the practical application of the new DVO concept is exemplified through a case study in disaster management - an environment that would greatly benefit from higher levels of dynamism and agility, present in the next generation DVOs.

2 The Sensing Enterprise

As the economy and society is becoming increasingly networked and digital, there seems to be a need to redefine the notion of enterprise[1], especially as new social and technology tools are provided by recent advances in new research paradigms, such as Internet of Things [2], Cyber-Physical Systems [3], Future Internet Enterprise Systems [4] and others. Such paradigms facilitate the pervasiveness of the enterprise, blurring its traditional boundaries to the point where internal and external stimuli (coming from within and outside of the enterprise) cannot be distinguished. As pervasiveness implies a federation of processing capabilities and knowledge resources, the new paradigms will also make collective intelligence more accessible and coordinated.

In an attempt to reconsider the notion of the enterprise, the FInES cluster [6] has identified so-called *Qualities of Being* as properties of the future enterprise as being humanistic, community-oriented, cognizant, people-centred, inventive, agile, environmentally aware, and 'glocal' (with local and global perspective). An enterprise displaying the above properties becomes a so-called Sensing Enterprise (SE).

The SE is also described as "an enterprise anticipating future decisions by using multi-dimensional information captured through physical and virtual objects and providing added value information to enhance its global context awareness" [7]. In fact, it is not characterised only by awareness (as the term implies), but also by decentralised intelligence. This does not only concern collaboration in decision making, but also purposefulness evaluated in its environment. Thus, an SE is in fact a social enterprise, sometimes also described as 'liquid' to suggest its pervasiveness.

The 'liquid' character of the SE is supported by the anticipation that sensors will become a commodity in the future [8]. Thus, the ownership of an enterprise on the sensors will not necessarily restrict other organisations to provide value-added services, based on observations of these sensors. Santucci et al. [ibid.] point out that "the Sensing Enterprise will be a sort of radar in perfect osmosis with an ecosystem of 'objects' supported by several private area networks and delivering in real time a wealth of unstructured data, not only more data but also new data".

Presently, the main technical obstacle for 'de-solidification' of the conventional enterprises is the 'verticalisation' of the existing technical solutions, e.g. Cyber Physical Networks - the trend of manufacturing devices initially customized to the specific applications. This leads to application silos with fragmented architectures, incoherent unifying concepts, and as a result, a lack of interoperability.

[1] The terms 'enterprise' and 'organisation' are used interchangeably throughout this paper.

2.1 The Sensing Enterprise Capabilities

In terms of technical architecture, the SE is considered as a system-of-Cyber Physical Systems (CPS) where these CPSs do not necessarily operate within the boundaries of the enterprise, nor even in its domain of interest or operation. The SE will also encompass the CPSs owned and governed by the other enterprises.

In order to access, combine, use and act upon the extensive, multi-dimensional, multi-modal data (now at the disposal of the enterprise), an SE needs to maintain the capabilities to seamlessly sense this data, perceive its meaning, make decisions and articulate a response (whether this articulation refers to acting (actuating), requesting the additional data, transferring an information to another enterprise, etc.). The stimulus for this cycle may originate from within or outside the enterprise and within or outside its domain of interest.

The cycle above can be explained in terms of semantic interoperation of two enterprises. Note that hereby, the term 'enterprise' is used in this explanation only to illustrate the ownership on the specific CPS, which one enterprise could exploit. In order to illustrate this cycle, we extend Sowa's [9] formal definition of semantic interoperability of systems; thus, an enterprise S is semantically interoperable with enterprise R, if and only if the following condition holds for any stimulus p that is articulated by S and sensed by R: For every statement q that is implied by p in the enterprise S, there is a perception of p, namely q', in the enterprise R that: (1) is implied by p in the enterprise R, and (2) is logically equivalent to q (see Fig. 1.).

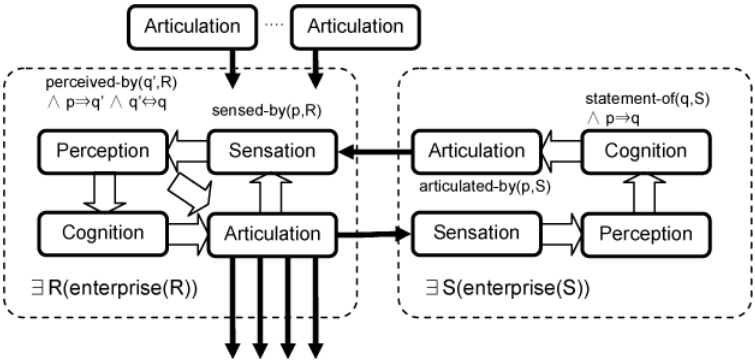

Fig. 1. Illustration of the interoperable SE

Based on the assumptions above, we identify awareness, perceptivity, intelligence and extroversion as the key capabilities of the Sensing Enterprise [10].

Although the core concept of SE does not distinguish between the internal and external stimuli, there is a need to separately consider the self-awareness and environmental awareness of one SE. While the latter is crucial for exploiting the pervasiveness of one SE, the former is relevant for maintaining its multiple identities (e.g. towards suppliers and customers, but also on web or a social network). The pervasiveness of an SE extends the conventional domains of interest of an enterprise (e.g. typical channels for detecting new business opportunities). Hence, now one has to consider not only the functional environmental awareness, but also the universal

one concerning observations of any stimuli, even from unknown and unanticipated sources. When arbitrary stimuli are taken into account, it becomes important for the enterprise to achieve the capability to perceive any stimulus, be it multi-modal, multi-dimensional, discrete or continuous. Perceptivity is a capability of an SE to assign a meaning to the observation from its environment or from within itself. Then, based on the perception, the SE should be able to decide on the consequent action. This decision is a result of a cognitive process, which consists of identification, analysis and synthesis of the possible actions to perform in response to the "understood" observation. The intelligence also encompasses assertion, storing and acquisition of the behaviour patterns, based on the post-agreements on the purposefulness of the performed actions.

The last desired attribute of an SE, extroversion, is related to the willingness and capability of the SE to articulate the above action/s and demonstrates the SE's business motivation and/or a concern about its physical and social environment.

3 Towards Next Generation Dynamic Virtual Organisations

3.1 Virtual Organisation Evolution

The development of VO and VBE management models, methods, systems and tools [11] addressing challenges in CNOs management, supported by the progress in Information and Communication Technologies (ICT) [12], is on-going given the dynamic environments in which organisations exist. Thus, 'first generation' VOs were created from an 'open universe' of organisations considering a number of important factors in the process so as to quickly and reliably establish an interoperable environment between trusted partners. This approach was limited by the possibility of rapidly finding a set of suitable partners that best fit a collaboration opportunity and quickly configure them into a VO. 'Second generation' VOs called for a more effective VO creation process [13] to enable having dynamically created VOs in response to the requirement to capture short-time windows of collaboration opportunity. Therefore, VBEs (as 'nesting' environments) emerged in order to increase the preparedness of organisations towards rapid configuration and creation of VOs by negotiating in advance a set of cooperation agreements and common operation principles, interoperable systems and ontologies [13].

Nevertheless, market dynamics have made collaboration opportunities not only short-time windows, but also collaborative projects with evolving features induced by the fluctuations in the continuously changing environments that may surround a VO collaborative project operation. This calls for a 'third (next) generation' VO type, with an emphasis not only on a dynamic VO creation process, but also on VO's 'agile' behaviour during its lifecycle. A third generation, truly dynamic VO (DVO) would be capable to recognise and promptly react to changes in the environment during its operation, and therefore survive and even thrive on change. This organisational behaviour matches that of what has been described above as the 'Sensing Enterprise' [7], on which authors believe DVOs should be based on.

3.2 Next Generation Dynamic Virtual Organisation Properties

During the last years, advances in ICT have been facilitating more effective, agile, flexible and trustworthy collaborative environments and networks, enabling organisations to collaborate and negotiate, systems/services to adapt and interoperate, information to be exchanged and retrieved, and resources to be discovered and shared [14]. In this context, organisations need to acquire new *Qualities of Being* [6] (see Section 2) which are strongly related to the properties that define an SE*:* aware, perceptive, intelligent, and extroversive. Authors propose the adoption of these properties for the next generation VOs (DVOs).

Thus, a genuine DVO must display *self-awareness* and *environmental awareness* capabilities in order to cope with dynamic and sometimes turbulent market conditions. *Self-awareness* is related to the capability of the DVO or DVO partner to sense a phenomenon or event within itself; for example, the DVO should be able to forecast, based on its own internal performance a possible need for re-engineering during its operation and proactively react with the required changes/adaptations to maintain the time-, cost- and quality frames constraining its mission/goal. *Environmental awareness* is related to the capability of the DVO or DVO partner to sense a phenomenon or an event from its environment, extended by the capability to receive messages from its environment; for example, to detect an external driver or inhibitor in the market and/or society that may trigger an internal DVO change process to take advantage of the driver or mitigate the risk of the inhibitor.

A second important Next Generation DVO property would be *perceptivity* as the capability to assign a meaning to an observation internally or in its environment and decide on possible action - for example, real-time continuous monitoring, assessment and adjustment aiming to sustain DVO efficiency.

The third property of a Next Generation DVO would be *intelligence*, as a capability encompassing assertion, storing and acquisition of behaviour patterns (best practices), based on post-mortem analyses in regards to the purposefulness of the past performed actions; for example the use of past DVOs heritage (experience and other assets) for improving future or current DVOs operation performance.

Fourth and last property that a Next Generation DVO would need to exhibit is *extroversion,* related to the willingness and capability of the DVO or DVO partner to articulate its actions in case of a request or need for change (e.g. VO evolution); for example, a DVO partner willing and capable to change its position in the DVO topology or modify the initial role, rights and responsibilities assigned to it, or a DVO capable of reconfiguring, rescheduling, reallocating or optimising the resources involved in its operational plan.

4 Case Study: Dynamic VOs in Disaster Management

The increasing rate and intensity of natural and man-made disasters demands more than ever effective prevention, preparation, prompt response and recovery from catastrophic events. Governments worldwide respond to this challenge by putting in place various disaster management policies, departments, agencies and organisations providing emergency management and services. Typically however, such organisations display a high organisational diversity due to their complex historic, traditional,

geographical, cultural and political environments. In addition, there is a plethora of other participants (e.g. non-governmental organisations, volunteers etc.) that need to be included in the disaster relief effort. These factors significantly increase the complexity involved in cooperation.

The collaborative operation of emergency services is often promulgated at state, national and international levels (e.g. [15-18]). However, such directives alone have proven insufficient, bringing about increased response times, sub-optimal cooperation on the ground and even dispute as to who, where and when is 'in charge'[19].

In order to address these issues, previous research has argued for and modelled the establishment of so-called 'Disaster Management Collaborative Networks' (DMCN) as strategic alliances of governmental and non-governmental organisations which are aimed to act as BEs facilitating the *prompt* establishment of Disaster Management Task Forces (DMTF) and Disaster Response Teams (DRT) in order to handle complex search, rescue and/or relief mission [20].

The models previously proposed relied on the dynamically created, second generation VO paradigm; while this approach improves response times and cooperation, it does not address well the degree of autonomy and interoperability required of the DMTFs and DRTs during operation on the ground. Independence and resilience are crucial in emergency situations where some response teams may fail, with the rest of the teams having to promptly reorganise or find replacements (with or without BE/DMCN assistance) in order to recover missing functionality; this would require prompt, ad-hoc interoperation with potentially new partners [21]. Response teams should also be able to perceive and promptly adapt to changes to their operating environment, to ensure the safety and efficiency of their partners and of other teams.

4.1 Sensing, Agile Disaster Management Task Forces and Response Teams

It is hereby argued that the previously defined DVO concept featuring 'Sensing Enterprise' properties could address the shortcomings of the previous models.

Thus, *self-awareness* (perceiving a phenomenon or event within itself) would help DMTFs and DRTs to continuously monitor the status and performance of their human, software and hardware components (e.g. monitoring the vital signs of team members, functionality of equipment etc.). *Environmental* awareness would enable the task forces and response teams to sense events and receive information from other sources in the operating environment - e.g. data from wireless sensor networks (WSNs) or other teams and compensate for fluctuations, within pre-determined limits. This capability, currently restricted to a functional aspect (i.e. matching pre-determined interests of the team) could be subsequently evolved to *ubiquitous (universal) awareness*, enabling the team to receive and interpret messages beyond agreed interests and formats. This would allow a heterogeneous set of response teams to interoperate seamlessly and share data essential to their mission and safety.

The *perceptivity* of the Next Generation DVO concept employed in disaster management would allow the DMTF or DRT to assign a *meaning* to an internal or environmental observation and decide on possible action; for example, location information provided by an internal GPS sensor combined with radiation, temperature etc. readings from the environment (e.g. via a WSN) would create a percept that may lead to certain action (proceed, evade, etc.). Should the envisaged action be beyond predetermined autonomy level, contact the DMCN or BE for mission reconfiguration.

In disaster management, a timely, suitable response is crucial in saving lives and property. Therefore, the DMTF/DRT decision to act based on a percept must be based on a cognitive process, consisting of identification, analysis and synthesis of the possible actions to perform in response to the understood observation (i.e. the percept). Therefore, the DVO-based agile response teams must also possess *intelligence*, possibly in the form of a knowledge management/expert system that would provide possible actions based on rules established by using disaster management best-practice, previous disaster response actions and outcomes and importantly, by externalising relevant human tacit knowledge. The DMTF/DRT would become a learning organisation that constantly learns, stores, and improves its response to external challenges in an agile manner.

The social effect of *extrovert* DMTFs and DRTs, materialised by transparency towards other teams, disaster relief participants (e.g. community, non-governmental and faith groups, etc.) and general public would bring significant benefits. In large scale catastrophic events, trust and communication are paramount in an effective response and minimising negative effects [19, 22]. Often, in a disaster situation, the population self-organises in novel and efficient ways; response teams must tap into this resource and use it to optimize their operations; for this to happen however, in addition to gaining community trust, the response teams must also be able to interoperate at short notice and without previous preparation and negotiation - in effect, displaying interoperability as a unilateral property [21].

5 Conclusions and Further Research

The aware, perceptive, intelligent and extrovert Sensing Enterprise holds the promise to revolutionise all areas of the current market and society landscape.

Following a brief review of the SE research state of the art and the description of the typical SE capabilities, the paper has described the evolution of the VO concept from its origins up to the current, dynamically *created* VO. Next, the SE capabilities have been applied to the current VO concept in order to enhance its agility and evolve it into a next generation, genuinely real-time Dynamic Virtual Organisation (DVO).

Furthermore, it has been exemplified how the DVO concept could be employed in an area demanding extreme agility and dynamism, namely disaster management. A brief review of the current problems in disaster management and shortcomings of the previous models based on the legacy VO concept was performed. This was followed by the application of the new DVO paradigm to disaster management task forces and response teams in order to improve collaboration, safety, response time and efficiency.

The SE and VO areas are continuously evolving. Therefore, further research is necessary in order to update and refine the Next Generation DVOs SE-related attributes and to test them in various case studies.

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