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Supporting Coordination in Dynamic Virtual Enterprises

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Abstract

Dynamic virtual enterprises (VE) involve rapid, on-demand, teaming of business partners in pursuit of specific business objectives defined by the customer. Current literature confirms the need for new coordination structures and tools to be used to support management of a shared business process in these emerging forms of organisations. The main objectives of this paper are to investigate coordination requirements in dynamic VE and to propose a mechanism called the time-map that can be used to support coordination during all phases of the VE life cycle.

1. Introduction

The need for global scale and reach, short development and manufacturing cycles, reduced time-to-market and operational costs, increased customer satisfaction and rapid adoption to new market changes has forced companies to intensify collaboration, automation and distribution of their business processes (Ouzounis and Tschammer, 2001). Consequently, the new forms of organisations have emerged called virtual enterprises (VE).

The first generation of virtual enterprises is considered to be “static” because the models of shared business processes (including tasks, roles, resources etc.) are pre-defined and agreed among all participants at the time when the VE is formed. Business processes are then executed repetitively with very small (if any) variations. This is not a new and particularly challenging concept. For example

some of the big manufacturing companies have already business relationships with their suppliers and customers based on electronic procedures and protocols such as EDI. This type of e-commerce is usually referred to as B2B e-commerce.

Dynamic virtual enterprises are the latest development in e-commerce that involves rapid teaming of business partners (in particular small and medium enterprises) in pursuit of specific business objectives. Business partners are linked dynamically (on-demand) according to the requirements made by the customer. Thus, the partners collaborate on a short-term basis (during the VE lifecycle) to solve a particular business problem. Once the problem is solved cooperation ends and the virtual enterprise ceases to exist. Note, that in general companies forming dynamic coalitions to pursue market opportunities are not a new concept - many examples can be found in construction industry, telecommunications, film industry, software engineering etc. However, "the manual and tedious process required to form these coalitions limits the number of market opportunities that can be pursued" (Nayak et. al. 2001, pg.2).

In these more open kinds of circumstances where trading partners do not know or fully trust each other, they require more control information about execution of their transactions in order to coordinate and monitor their activities (Lee et al, 2001). There is a need to specify coordination structure explicitly (van der Aaslast, 2000).

However, current research efforts in the area of dynamic virtual enterprises are more oriented towards technical issues (i.e. integration of various technical platforms and systems) rather than design of value-added services and tools that are necessary for successful design, implementation, monitoring and coordination of shared business processes. So far little systematic knowledge and hardly any tools are available to support management of business processes in virtual enterprises (CETIM, 2001).

The main objectives of this paper are to investigate coordination requirements in dynamic VE and describes a coordination mechanism that can be used in all phases of the VE life cycle including:

(i) forming of a dynamic VE; (ii) monitoring of business process execution; (iii) exception handling; and (iv) analysis of the accumulated experience after the dynamic VE ceases to exist.

The paper is organised as follows. Section 2 discusses various coordination theories and in particular challenges and opportunities related to coordination support in a dynamic VE. Related work is described in Section 3. Section 4 analyses coordination requirements in a dynamic VE and introduces a coordination mechanism called the time map that is based on formal modeling of temporal constraints and estimates. Section 5 illustrates by an example from tourism industry, how the time map can be used to support coordination in all phases of a dynamic VE.

2. Coordination in Dynamic Virtual Enterprises – Challenges and Opportunities

Coordination is the process of integrating work activities and determining their dependencies to accomplish organisational goals and objectives (Malone and Crowston, 1994). Work activities can be coordinated in many ways. Consequently, many diverse coordination theories exist as well as information systems used to support coordination.

For example, Malone (1987) describes four coordination mechanisms based on concepts of markets and hierarchies. The two market-based mechanisms include centralised markets (where decision making is centralised and communication takes place via the broker) and decentralised markets (where all buyers are in a direct contact with all potential sellers). The two hierarchical mechanisms include product hierarchy (where different divisions exist for different product lines) and functional hierarchy (where a number of processes are grouped into functional departments). However, these coordination mechanisms are specialised (and optimised) for a particular scenario rather than flexible. Therefore, they are not suitable for dynamic VE where a high degree of flexibility is required.

Another possible approach is to coordinate work activities by predefined formal organisational concepts such as structures, policies, plans and contracts among participants. However these traditional mechanisms for implementing coordination are no longer satisfactory in rapidly changing business environments. In a dynamic VE, in some cases trading partners may rely on mutual trust to regulate and coordinate their activities, simply because there is not enough time for contract implementation prior to the beginning of a shared business process (Lee et al, 2001).

When it comes to computer supported coordination, the systems that exist in practice range from fully automated coordination to systems that facilitate/support coordination performed by human decision makers. For example job-shop scheduling systems fully automate coordination by delivering the tasks to agents (humans/machine) at the right point of time. The main objective of this coordination mechanism is to maximise effectiveness and efficiency of the overall process while removing human decision making.

At the other end of the spectrum is human-driven coordination. Here, various computer applications (for synchronous/ asynchronous collaboration and communication) are used to support work activities that need to be coordinated while the actual coordination is left to humans. Human-driven coordination is useful in situations where work activities cannot be fully specified in advance such as in the case of ad-hoc processes (e.g. crisis management). On the down side, human-driven coordination could be very complex, time-consuming and error prone process.

Somewhere in the middle are the latest applications of workflow technology. Here, coordination is automated but humans still participate (for example by selecting a

task from a to-do list etc.). However, workflows are not suitable for dynamic VE as all the coordination rules have to be fully specified in advance and cannot be changed during workflow execution.

Coordination in virtual enterprises offers a set of completely new challenges different from those in traditional organisations.

- Business processes in virtual enterprises are driven by customer goals. As different customers are likely to have different goals a whole variety of business process models have to be created on demand.
- Dynamic VE are by nature distributed. Therefore coordination mechanisms have to provide for distributed work (both in terms of location and time).
- Dynamic nature of VE requires a dynamic and flexible coordination mechanism that can be easily changed to suit the current situation at any time during execution of a business process.
- A business process model is only partially known in advance, thus coordination mechanism has to support rather than restrict the evolution of a business process.

At the same time, the effective coordination support in dynamic virtual enterprises is likely to open completely new opportunities for execution of shared business processes. For example, duration of a business process “development and marketing of a new product” can be reduced significantly by shifting the project from one virtual partner (or team) to another that reside in three different time zones (CETIM, 2001). In this way, sharing the same business process between Europe-, US- and Asia-based teams can generate a 24-hour working environment. Technical infrastructure has already made this transfer possible. However we still lack methods and tools that will support coordination and effective management of such a business process.

3. Related Work

This section briefly describes various approaches to business process modeling and coordination with the special emphasis on coordination.

When it comes to coordination support and business process modeling, workflow technology is currently one of the most influential business technologies. It is used to specify, execute, manage, monitor and streamline business processes. Among other features, this technology offers effective coordination support mainly through the use of control-flows. However, conventional workflow management systems have a number of limitations in the relation to the dynamic VE concept. They are more suitable to support business processes within an organisation /business unit where individual tasks are executed and coordinated via the central workflow

engine. More importantly, models of shared business processes are inflexible and require all tasks, resources and participants to be specified in advance. Consequently, this approach is only suitable for static virtual enterprises. On the other hand, in a dynamic VE the partners that are to provide parts of the shared business process may not be known in advance and may be selected dynamically after negotiation during business process execution.

In order to support business processes spanning more than one organisation, the concept of interorganisational workflows has emerged. Workflow Management Coalition (2001) is working on standards for workflow interoperability. However, the real issue here is not to connect technical systems but to develop fundamentally new concepts and architectures to support execution and management of interorganisational processes. In interorganisational workflows, the business partners and all tasks of a shared business process are still specified statically and in advance making this concept more suitable for static virtual enterprises.

The latest development in dynamic VE is to model business processes as a set of coordinated e-services. E-services are applications offered by different companies that can be wrapped and presented as independent services that, in turn, could be further composed to create new e-services (Durante et. al., 2001). For example (Benatallah et. al. 2001) uses a concept of self-coordinated e-services. Here the responsibility of coordinating the providers participating in composite service execution is distributed across several lightweight software components hosted by participants themselves. However, the coordination support is still limited.

There are several other projects such as eFlow (Durante, 2001) that are also based on the concepts of e-services. However, the main emphasis of this work is still on technological architectures for e-services rather than coordination support.

4. Coordination in Dynamic Virtual Enterprise

Dynamic VE, considered in this paper, are also based on the concept of dynamic e-services. Thus, a business process is a collection of integrated e-services offered by different (independent) providers who form a temporary coalition/team in order to pursue specific business objective(s). Basic e-services can be combined to form composite services, and they in turn, can be combined even further to offer more complex composite services. As Durante (2001) pointed out, in order to provide added-value to the user, customisation and deployment of composite e-services has to be very flexible and efficient.

It is not hard to imagine that integration of e-services poses a set of unique challenges as it has to occur both at the conceptual and technical levels. Currently, there are many companies that already offer or are in the process of development of technical platforms and solutions to support dynamic composition of e-services (see for example Kuno, 2001). As technical solutions are becoming available, the

research focus is shifting from technical issues and platforms to conceptual integration i.e. business process modeling and new tools for business process management. This paper focuses primarily on coordination support.

Another interesting aspect of dynamic e-services composition is which party performs the integration and where coordination support is needed. One option is to have a single provider of a composite e-service. In this case, the service provider is in charge of selection of individual e-service providers (in consultation with the customer) and is in charge of monitoring and coordination. This option relies on knowledge the composite service provider has about local markets, service providers, their quality and availability as well as the experience in designing composite services for the customer (i.e. in meeting their goals and objectives).

Another option is to have the customer in charge of composition and coordination of individual e-services. In this case the customer has to have knowledge about e-service providers and how to integrate their services. In many cases this is not a realistic expectation. Additionally, service integration could be very complex, error prone and time consuming for inexperienced customers.

The third option assumes self-coordinated e-service providers. Thus, there is not a single (centralised) provider of the composite e-service. Rather coordination is distributed across all service providers as well as responsibility for meeting customer's goals. While the first option (centralised coordination) is more suitable for the situation where individual service providers are totally independent and not expected to collaborate directly, the third option requires service providers that are ready to collaborate, exchange information directly and adjust their performance to meet the common goal.

This paper considers primarily coordination in dynamic VE where a composite e-service is offered by a single service provider (i.e. the first option). Consequently, the coordination problem resides with the service provider. However, the coordination mechanism described here can be also extended to cover the other two cases.

4.1. A Coordination Mechanism

Individual e-services can be described in terms of their preconditions (that need to be satisfied for the service to occur) and various service parameters (such as service provider, cost, resources etc.) as well as temporal constraints and estimates. In order to determine the actual values of some parameters (such as for example cost) and temporal constraints (such as the expected beginning and finish time) for an individual e-service, it is necessary to create a model of a composite e-service first. This process requires coordination of individual e-services.

Preconditions specified for each e-service indicate the order in which they have to be scheduled. Obviously, if the result of one service is a pre-condition for another service, these two services have to be scheduled to commence one after another.

However, preconditions alone are not sufficient as they do not provide enough information for coordination purposes. It is necessary to know when exactly each e-service has to start and finish in order to satisfy user requirements. Therefore, to coordinate individual e-services we have to use temporal constraints and estimates.

Temporal constraints are different rules that regulate the order, timing and duration of individual e-services. The following are the most common temporal constraints applicable to e-services.

- *An absolute deadline constraint* limits when an e-service must begin/end.
- *A relative deadline constraint* limits when an e-service *must begin/end* relative to the *beginning/end* of an e-service.
- *A periodic deadline* is used to prescribe the occurrence of an e-service in terms of repetitive time (e.g. every second Friday)

Temporal constraints are specified by the customer (e.g. they want a composite e-service to be completed by a particular date), individual service providers or are derived after scheduling of individual e-services.

When integrating individual e-services into a composite one, a set of resulting temporal constraints has to be *mutually consistent*. This means that it is possible to find an assignment of temporal attributes for all individual e-services such that all corresponding temporal constraints can be satisfied. If it is not possible to find such an assignment, temporal attributes of individual services have to be adjusted until a possible schedule is found and all temporal constraints are satisfied. This process usually takes several iterations.

Temporal estimates describe estimated duration and order of individual e-services. They are usually provided by individual service providers or derived from the accumulated experience (they are not constraints).

- *Estimated occurrence* is used to express the fact that an e-service could occur after/before some absolute time or periodically every d time.
- *Estimated order* is used to express when an e-service could start/end relative to the beginning/end of another action.

To start integrating e-services at the conceptual level, it is necessary to formally describe all temporal constraints and estimates and then use an algorithm to find out when each service should occur (i.e. to find its expected begin/end date and time).

Let $S_i, S_j, S_k \dots$ etc. identify a set of e-services to be integrated into a composite service. The following examples illustrate how the above temporal constraints and estimates can be specified formally. An absolute deadline constraint:

$$A_{Deadline}(S_i, e, \preceq Date1)$$

prescribes that e-service S_i must be completed no later than $Date1$.

A relative deadline constraint:

$$RDeadline(S_j, b, \leq, S_i, e, d)$$

prescribes that e-service S_j must start no later than d time after e-service S_i is completed.

Similarly, a relative deadline constraints can be used to specify duration of an e-service. For example,

$$RDeadline(S_i, b, \leq, S_i, e, d)$$

prescribes that e-service S_i must take no more than d time to execute.

Note that relative deadline constraints can be also used to prescribe order of individual e-services. For example,

$$RDeadline(S_j, b, =, S_i, b, -)$$

prescribes that e-services S_i and S_j should start at the same time. “=” indicates that the parameter that corresponds to the time distance between the two time points is not applicable in this case (i.e. it is zero).

A periodic deadline constraint:

$$PDeadline(S_i, e, d, Date1, Date2)$$

prescribes that e-service S_i must be completed every d time starting from $Date1$ until $Date2$ is reached.

Temporal estimates are described in a similar way. For example, a temporal estimate

$$EDuration(S_i, =, d)$$

is interpreted that e-service S_i takes (usually) d time to complete.

Similarly,

$$EOccurrence(S_i, b, <, Date1)$$

indicates that S_i could start before $Date1$.

Finally,

$$EOrder(S_i, b, <, S_j, b)$$

is interpreted that e-service S_i could start before e-service S_j starts.

Obviously, the above formal description of temporal constraints and estimates is not a user-friendly mechanism for specification and coordination of e-services. Instead, this paper proposes a time visualisation method called the time map (as depicted by Figure 1). Nodes of this map are absolute time points that correspond to the beginning/end time of individual e-services. Arcs are relative time values that correspond to a distance between the corresponding two time points (e.g. duration of an e-service or time between two e-services). All arcs are labeled by temporal operators (e.g. “<”) and some by relative time values indicating time limits (e.g. “<d1” means that the distance between two time points should be less than d1). An absolute time value attached a node correspond to a deadline or estimated occurrence. To indicate repetitive time, a set of absolute time values is attached to a node. To distinguish temporal constraints from estimates, a darker font/colour is used.

For example, Figure 1 indicates that the estimated duration of S_i is less than $d1$ time. Service S_j must start before S_i . Service S_j is expected to occur on $Date2$, $Date3$ or $Date4$. Service S_k is expected to start after or at the same time (no earlier) when service S_i ends. Service S_k must take no more than $d2$ time to complete. Services S_k and S_l must start at the same time (i.e. $Date1$).

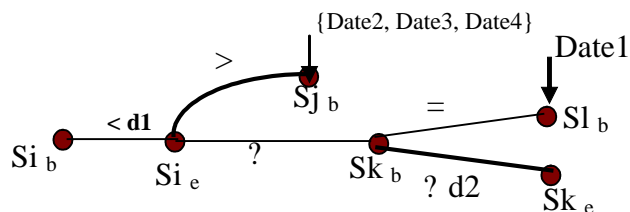


Figure 1: An Example of a Time Map

Coordination of individual services within a composite e-service is an iterative process. Hence, the initial time map may not contain all e-services. To add to the complexity of the coordination problem, some providers of individual e-services may not be known in advance and can be dynamically selected at the run-time. The challenge of proper e-service coordination is to find out how these additional e-services can be linked with the rest of the time map while still keeping all temporal constraints and estimates consistent. So to determine the order, duration and expected beginning/end times for all e-services, we propose to modify and apply the Floyd-Warshal all pair shortest path scheduling algorithm (Dechter et. al. 1991) that is used in artificial intelligence for temporal constraint networks. The algorithm has to be modified to take into account time estimates and repetitive time. The actual specification of this algorithm is out of the scope of this paper.

5. Coordination of e-Services in Dynamic VE

This section illustrates how a time map can be used for coordination support in each phase of a dynamic VE lifecycle.

5.1 An Example of Dynamic VE

Tourism industry is a good candidate for implementation of a dynamic VE due to the large number of small- to medium- size service providers whose services can be easily integrated into a complex composite service. Moreover, in order to get

involved into a dynamic VE, individual service providers are not required to have sophisticated IT infrastructure so even the smallest operators can benefit from joining a virtual enterprise.

Suppose that a composite e-service called eVisitor is offered to a tourist visiting a city. A service provider can be, for example, another independent provider or a city council. Suppose that the following is a sample of e-services offered to the visitor.

S1: car rental,

S2: hotel accommodation,

S3: sightseeing tour

S4: dinner and show

S5: chocolate factory tour etc.

Each visitor is likely to have different requirements and thus a large number of composite e-services can be designed. Even, if a number of visitors use the same e-service (e.g. accommodation) they may prefer different e-service providers (e.g. expensive or budget). Some visitors may require new e-services not originally offered (e.g. an aerobic session in a local health & fitness centre).

5.2 Supporting the Life Cycle of a Dynamic VE

This section illustrates how the time map can be used for coordination support in all phases of the life cycle of a dynamic VE.

- **Forming a Dynamic VE**

The provider of a composite service designs a model of a business process by integrating individual e-services (stored in a service repository) to suit the needs and requirements of a particular visitor. In this process, the provider uses their knowledge and experience (about different local services and providers). As they accumulate more and more experience on composite e-service provision, they are likely to have ready-made models (i.e. business process templates) that can be adopted or modified to suit a particular customer.

During the forming phase of a dynamic VE, the time map is used as a decision support tool that facilitates the selection of service providers and scheduling of individual parameters (cost, temporal constraints etc.). The actual selection of individual service providers is left to the composite service provider and is out of the scope of this paper.

For example, suppose that the visitor specifies the following temporal constraints. They will arrive at the International airport at 8.30 on 15th of January 2002. They would like to pick up the rental car at the airport and drive to a hotel to check-in. They require hotel accommodation for one night and car rental for 2 days. They

would like a guided city sightseeing tour (preferably in the afternoon) and diner and dance in the evening (at least one hour after the sightseeing tour).

The above requirements can be formally represented by using the language introduced in the previous section of this paper.

ADeadline (S1, b, ≥, "15-Jan-2002:09:00:00")	ADeadline (S1, e, ≤, "16-Jan-2002:15:00:00")
ADeadline (S2, b, ≥, "15-Jan-2002:12:00:00")	ADeadline (S1, e, =, "16-Jan-2002:10:00:00")
EOrder (S2, b, >, S1, b)	EOrder (S2, b, ≤, S3, b)
EOccurrence (S3, b, "15-Jan-2002:11:00:00")	EOccurrence (S3, b, "15-Jan-2002:15:00:00")
EDuration (S3, =, 2hours)	ADeadline (S4, b, =, "15-Jan-2002:20:00:00")
EDuration (S4, ≤, 3 hours)	RDeadline (S3, e, ≤, S4, b, 1 hour)

The corresponding time map is depicted by Figure 2.

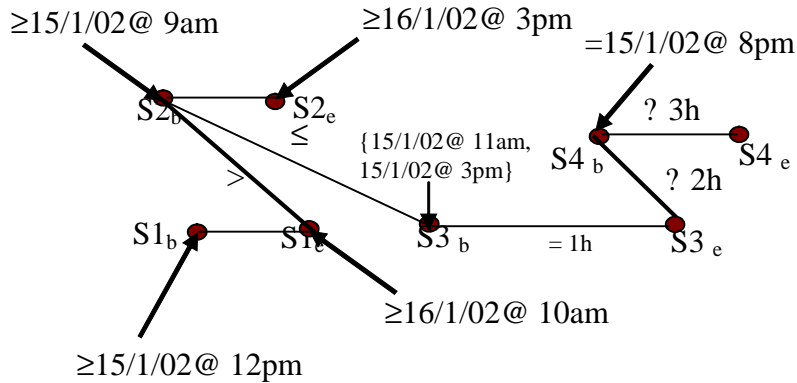


Figure 2: An Example of a Time Map

The provider of the composite service uses this time map to schedule services of individual providers. Every time when a new service provider is selected, new temporal constraints and estimates are added to the existing time map.

Hence, scheduling of individual services is an iterative process where temporal constraints and estimates of potential service providers are removed, added and modified until the time map is consistent and a schedule is found that satisfy all user

requirements. To find a schedule for each potential combination of e-services, the same scheduling algorithm is used. When the right schedule is found all bookings and confirmations will be done electronically. The visitor gets his/her schedule of activities and individual service providers receive requests for their respective services.

In the case that a satisfactory schedule cannot be found, the customer is contacted and some of the initial temporal constraints are removed/modified and the whole process is repeated again.

Therefore, in this case the selected service providers (i.e. hotel, car-rental agency and the local restaurant) form a dynamic virtual enterprise for this particular visitor. Furthermore, the provider of the composite e-service has insight into all business processes composed for different customers and may be able to even coordinate activities of different customers (e.g. organise a group discount if more than 10 customers are interested to attend the same local attraction at the same time).

- ***Executing a Shared Business Process***

In this phase, the actual execution of each composite service is monitored. Note that providers of individual e-services are independent and as such they are not expected to directly coordinate their activities. To support the monitoring process a set of check points for some (critical) services can be negotiated with the individual providers (e.g. to enable customers to return to the airport on time). This means that providers of these services are obliged to inform the provider of the composite service about the current status of their services at some point of time. Checkpoints can be also easily visualised on the time map. They can be also used to fine-tune execution of individual services.

If the checkpoints are not defined then the provider of the composite service has no information about the execution of individual e-services until they are completed. This means that it is not possible to visualise the stage of execution of each individual e-service provider by using for example the expanding bar (time) chart, as it would be the case in project management.

- ***Handling Run-Time Exceptions***

During business process execution for each customer, different types of exceptions can occur e.g. a service provider is no longer available, e-service is temporarily suspended, a new e-service is introduced, duration of an existing e-service is extended etc. Exception handling in dynamic VE is much more complex than in a single organisation due to its dynamic nature. Furthermore, an exception can affect execution of more than one business process (i.e. more than one customer at the same time).

When an exception occurs, the main objective is to still meet user requirements (if possible) but at the same time, minimise propagation of the problem to other e-services within the same process.

During exception handling, the time map is used as a simulation tool to find an alternative schedule and accommodate new services or replace service providers. In this process checkpoints play a very important role to prevent possible escalation of the problem.

For example, a sightseeing tour gets cancelled due to the bad weather. So a number of alternative services can be offered to the visitors affected by this cancelation. For example our visitor may decide to join a tour of the local chocolate factory (S5) and refuses a complementary aerobic session after the tour. Time constraints and estimates for e-service S4 will be removed and the new constraints for e-service S5 will be added to the time map.

- ***Analysis of the Accumulated Experience***

After the same service has been executed a number of times, the accumulated experience, stored in the time maps of different customers, can be analysed to provide better services in the future. This includes finding suitable service providers, creating a composite e-service to suits the needs of a particular customer, to fine tune checkpoints for individual e-services and to offer new services. One of the research challenges here is to apply data mining techniques to mine process templates for different customer profiles and consequently design a composite e-services that will better suit their needs.

5.3 Meeting the Coordination Challenges

Although the previous example is relative simple, it illustrates the complexity of coordination in dynamic virtual enterprises. Having in mind a number of customers a good provider of composite services is likely to have, and the ever increasing number of different service providers and services, the importance and complexity of the coordination problem becomes more apparent as well as the need for tools such as the time map.

Section 3 identified a number of coordination challenges in dynamic VE. The previous example illustrates how the time map meets these challenges. More precisely,

- Customer's goals and objectives are used as a starting point to compose a business process (i.e. integrate individual e-services) that will satisfy their requirements.
- The time map is suitable for distributed work as time constraints and estimates can be easily specified irrespectively of the time and place where an e-service provider resides.

- Coordination rules are not static and hard-coded prior to business process execution. Therefore, they can be adjusted as a business process progresses to suit the current situation.
- When dynamic VE is formed, the service provider can start from the subset of e-services and then expand the business process by adding the new services or changing the existing ones. Thus the model of a composite service is allowed to evolve during run-time.

The simplicity and above all flexibility of the time map makes it a good starting point for further exploration of the coordination problem in a dynamic VE.

6. Conclusion

The main objectives of this paper were to investigate coordination requirements in dynamic VE and to describe a coordination mechanism that can be used in all phases of the VE life cycle.

The paper argues that the coordination challenges in dynamic VE are different from those in traditional organisations. Consequently, traditional coordination theories and implementations need to be redesigned to suit the highly dynamic nature of a dynamic VE. The paper describes a coordination tool called time map and illustrates its use by an example from the tourism industry.

Current and future work include further investigation of the coordination in virtual enterprises in particular data mining techniques that could be used to mine a business process templates for a specific customer profile from the stored time maps. By storing and reusing the accumulated experience on service coordination, service providers will be in a position to offer better service to their customers and form more efficient dynamic virtual enterprises in the future.

Dedicated to the loving memory of my father Bosko Krusevac (2. 12. 1935 – 13. 4. 2002)

References

- Benatallah, B., Dumas, M., Fauvet, M.-C, Paik, H.-Y, (2001), “Self-coordinated and self-traced composite services with dynamic provider selection. Technical Report, The University of New South Wales, School of CSE, 2001.

- CeTIM – Center for Technology and Innovation Management (2001), Virtual Enterprise Lab Description (available at <http://www.cetim.org/velab.html>)
- Dechter, R., Meiri, I., Pearl, J. (1991), “Temporal Constraint Networks”, *Artificial Intelligence*, 49, 61-95.
- Durante, A. et. al. (2001), “ A Model for e-Services Market Place”, Hewlett-Packard Company Publishing.
- Kuno, H. (2000), “Surveying the E-services Technical Landscape”, Hewlett-Packard Company.
- Lee, R.M., Bons, R.W.H, Wagenaar, R.W. (2001) “Pattern-directed Auditing of Inter-organisational Trade Procedures”, *Towards the e-Society: E-Commerce, E-Business, and E-Government*, Proc. of the First IFIP Conference I3E 2001, October 3-5, 2001, Zurich, Switzerland, Kluwer Academic Publishers.
- Malone, T.W. and K. Crowston (1994), *The Interdisciplinary Study of Coordination*. {ACM} Computing Surveys, 26(1): 87-119.
- Malone, T.W., (1987) Modeling coordination in organizations and markets. *Management Science*, 33: 1317-1333.
- Nayak, N. et al. (2001), “Virtual Enterprises – Building Blocks for Dynamic e-Business”, *Workshop on Information Technology for Virtual enterprises (ITVE)*, Gold Coast, Australia.
- Ouzounis, V. and Tschammer, V. (2001), “Towards Dynamic Virtual Enterprises”, *Towards the e-Society: E-Commerce, E-Business, and E-Government*, Proc. of the First IFIP Conference I3E 2001, October 3-5, 2001, Zurich, Switzerland, Kluwer Academic Publishers.
- Van der Aalst W. M.P. (2000), “Process-Oriented Architectures for Electronic Commerce and Interorganizational Workflow”, *Information Systems*, Vol. 24, No.8, pp.639-671.
- Workflow Management Coalition (2001), *Workflow Management Coalition Interface: Process Definition Interchange Process Model*.