Business Value Chains in Real-Time On-Line Interactive Applications

Justin Ferris, Mike Surridge, and E. Rowland Watkins

University of Southampton, IT Innovation Centre,
2, Venture Road, Chilworth, Southampton, SO16 7NP, UK
{jf,ms,erw}@it-innovation.soton.ac.uk

Abstract. Grid infrastructure are already being used in the on-line gaming sector to provide large-scale game hosting in a business context. However, the game platforms and infrastructures used do not take advantage of the potential for rich business networks to support indefinite scaling within single game instances, or to simplify the problem of managing the quality of experience and access rights for end customers. The European edutain@grid research project is developing an infrastructure for realising such business networks using bipartite Service Level Agreements. This paper describes the analysis of business value chains and SLA terms for the initial implementation, and provides insights into how these should be formulated, and what challenges this presents to Grid infrastructure implementers.

Keywords: Business models, Service Level Agreements, Grid, Trust, Security, Value chains.

1 Introduction

The recent maturation of Grid technologies [1] raises the possibility of improving the way that on-line applications such as games and e-learning courses are managed and provided to customers. These applications fall within the broader category of Real-Time On-Line, Interactive Applications (ROIA), a new class of 'killer' application for the Grid. The edutain@grid project [2, 3] is investigating how Grid can improve ROIA provisioning and is developing a novel, sophisticated and service-oriented Grid infrastructure to support secure, reliable and scalable provisioning of ROIA and that supports flexible value chains. To facilitate this work, the project is focusing on exemplar ROIA from two of its partners.

BMT Cordah Ltd provides training courses in search and rescue planning that are used by customers such as the UK Maritime and Coastguard Agency (MCA). The courses are used to train new search and rescue planning staff (around 10% of which leave and have to be replaced annually), and to update existing staff. Currently, courses are run twice per year at a dedicated facility, but it would be better to use distance learning options to reduce costs and the length of time staff have to spend away from their normal stations. This has not been possible up to now because the training depends on the interactive use of simulator models, but edutain@grid will

J. Altmann, D. Neumann, and T. Fahringer (Eds.): GECON 2008, LNCS 5206, pp. 1–12, 2008.

overcome this barrier by allowing students to access simulators securely from remote locations via the Grid.

Darkworks develops on-line multiplayer games for mainstream and niche game distributors. On-line games played over the Internet are a rapidly growing segment of the video games industry, now all the main console vendors support connection to the Internet as standard. It is predicted that in the next few years the on-line game market sector will grow rapidly to billions of Euros, which makes them a 'killer' application capable of justifying massive investment in the Grid. On-line games use virtualised interactive environments very similar to those used in on-line training simulators, posing similar technical challenges to deliver acceptable Quality of Experience. However, on-line games pose additional challenges for the Grid: the end-users are members of the public with little understanding of features such as Grid security and minimal access to technical support, and the number of users can vary by many orders of magnitude during the life of a single game title.

In general, ROIA are soft real-time systems with the potential for very high user interactivity between users. Large numbers of users may participate in a single ROIA instance, and are typically able to join or leave at any time. Thus ROIA typically have extremely dynamic distributed workloads in comparison to more typical Grid-based applications, making them very difficult to host cost-effectively. Also, like other mass entertainment media, on-line games may start out with a small number of users, and go through a very rapid period of growth in popularity whose timing and extent are very hard to predict and may depend on the quality of experience delivered. These factors make hosting ROIA a very challenging (and risky) undertaking. Grid middleware systems such as the Globus toolkit [4], gLite [5], and UNICORE [6], are not well suited to meeting this challenge cost-effectively, because they don't address soft real-time provisioning aspects, and they don't allow the rapid extension of business networks to allow scaling by several orders of magniture beyond the capacity of the initial hoster. Thus initiatives such as Butterfly Grid [7] and Bigworld [8] allows hosters to scale resources according to demand, but do not allow scaling of a single on-line game instance beyond a single hoster.

The edutain@grid project will address these challenges using so-called 'business Grid' developments such as GRIA [9, 10], which currently supports simple Service Level Agreements (SLA) for non-real-time data storage and processing [11]. The project is building on GRIA, extending the commitment models and corresponding resource management technology to address real-time application loads. These are then being used to support extended value chains allowing multiple hosters to participate in the same ROIA instance, and enabling more hosters to be recruited as customer demand increases. In addition, edutain@grid will support demand management mechanisms such as option or variable pricing, and user-friendly security and trust models which are critical for 'business-to-consumer' on-line gaming scenarios.

The rest of this paper is organised as follows. In section 2 we present the analysis of business actors and value chains from the edutain@grid project, and highlight some of the business scenarios that must be supported. Section 3 briefly describes an implementation of the edutain@grid framework to support these value chains, and discusses the initial results and their implications for SLA. Section 4 provides a summary of the overall work on edutain@grid value chains to date, and discusses the direction of future work.

2 Business Models in Edutain@grid

To ensure business models for Grid-based ROIA will be economically viable, it is necessary to analyse the value chains (i.e. business actors and value flows) in which ROIA (specifically on-line games and e-learning applications) will be operated and used. The goal of edutain@grid is to support value chains corresponding to commercially viable scenarios, preferably in such a way that the same ROIA application software need not become locked into one particular business scenario. The work of edutain@grid is thus related to efforts in the BEinGRID project, which is performing and analysing Business Experiments (some also using GRIA) to produce a generic value network for Grid [12]. In edutain@grid, this analysis is finer-grained and more focused on the specifics of ROIA provision.

2.1 Business Actors

The analysis of value chains revealed an extensive hierarchy of business roles that must be supported by the edutain@grid infrastructure to provide flexibility regarding the business models and value chains supported:

The three main classes of edutain@grid business user are 'providers' who host services through which the ROIA is delivered to users, 'consumers' who access the ROIA by connecting to these services, and 'facilitators' who play other business roles in the creation of ROIA application software, its distribution to providers and consumers, and the operation of ROIA instances. These three main classes and some of their important sub-classes are shown in the actor hierarchy diagram (Figure 1).

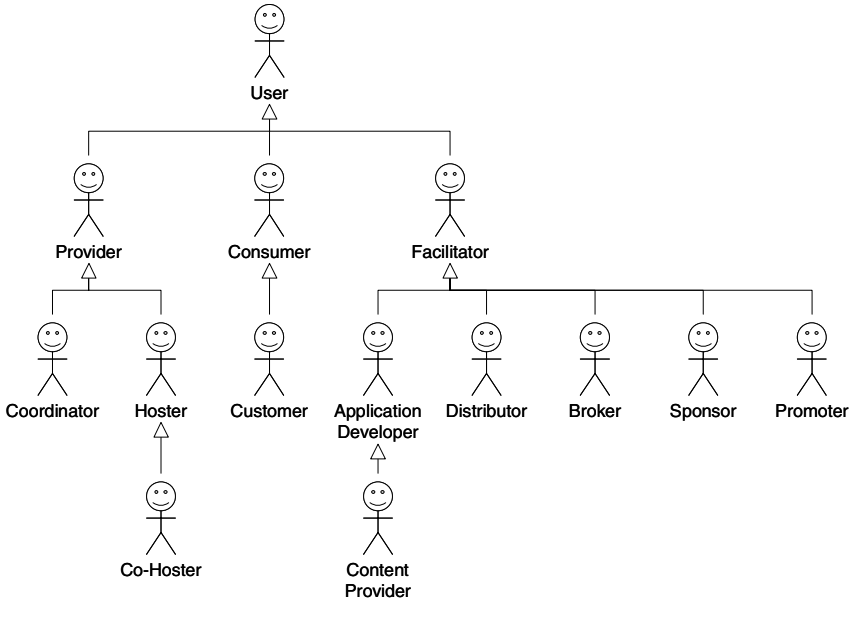


Fig. 1. Business Actors in edutain@grid

The providers in edutain@grid actually host servers on which ROIA processes run, thereby making the ROIA available to its users. Three important sub-classes of ROIA providers were identified and will be supported by the project:

- Hoster: is an organisation that hosts core, usually computationally intensive processes that support a ROIA virtual environment including interactions of users with this environment and with each other. In an on-line game, a hoster will run the game simulation processes to which players connect, while in the maritime e-learning scenario a hoster runs the search and rescue simulator.
- Co-hosters: are other hosters participating in the same ROIA instance – where more than one hoster is involved in a single ROIA instance, each hoster will regard the others as 'co-hosters' of the ROIA instance.
- Coordinator: is an organisation that makes a ROIA instance accessible to its consumers, and coordinates one or more hosters to deliver the required ROIA virtual interactive environment.

Note that a co-hoster should not be confused with a coordinator. There is nothing special about a co-hoster. Each hoster for a ROIA instance will consider each other hoster to be a co-hoster. In contrast, a coordinator has quite a different role, it coordinates a set of hosters to provide a ROIA instance to its consumers. Today, on-line game hosters exist, but there are no 'co-hosters' or 'coordinators' because there is only one hoster per game instance. The edutain@grid infrastructure breaks away from this limitation, enabling new business models to manage risks of ROIA hosting and delivery, and provide genuine scalability for ROIA provision.

A consumer in edutain@grid is someone who accesses a ROIA instance – e.g. a player in an on-line game, or a trainee using a search and rescue simulator. Because edutain@grid is not limited to a single application sector, few assumptions can be made about the IT skills or other characteristics of consumers. Indeed, there may be many specialised types of consumers reflecting application-specific roles within the ROIA – e.g. the difference between trainees and tutors using a search and rescue simulator. The edutain@grid framework does not distinguish these application-specific consumer roles, but it does distinguish one special type of consumer known as a 'customer'. The customer actually pays the coordinator to allow them (and in some applications, other consumers) to access the ROIA.

A facilitator in edutain@grid does not run or use ROIA processes directly, but plays some other role in the delivery of ROIA. The most important facilitators in edutain@grid are application developers, whose needs are addressed through the development of an edutain@grid API, and distributors who supply ROIA software to providers and consumers who need mechanisms for software licensing and (in some applications) distribution of run-time software updates.

2.2 Service Level Agreements (SLA)

It is important to note that the value chain analysis performed in edutain@grid, is quite different from the business analysis that has come out of other projects such as Gridbus [13]. Gridbus, for example, does not consider the use of value chains, nor

analyse the relationships between business actors, but focuses on algorithms for specific business decisions such as brokering within symmetric business networks such as resource-sharing virtual organisations. In edutain@grid, a different approach has been used following the architectural model proposed by the NextGRID project [14, 15] and used with GRIA in the SIMDAT project [11]. Here, each pair of business entities may have a distinctive relationship specified in a bipartite, bi-directional Service Level Agreement (SLA) which is private to the two participants and not exposed to other entities in the value chain. The format of the SLA used in these systems is based on the WS-Agreement specification [16], although a 'discrete offer' protocol is used to establish SLA, rather than using the full WS-Agreement negotiation protocol.

Given that each SLA is in principle different from all the others, it is important to distinguish and clarify the different types of SLA needed by edutain@grid:

- Agreements between customers and coordinators, in which the coordinator agrees to provide access to one or more ROIA global sessions, usually in exchange for payment. For convenience, an agreement of this type will referred to as a *customer account*, but keeping in mind this refers to the terms of use as well as the payment mechanism.
- Agreements between coordinators and hosters, in which the hoster agrees to host ROIA processes to support the coordinator's ROIA global sessions, and to provide accounting information on use of these processes by consumers. An agreement of this type will be referred to as a hosting SLA, but keeping in mind this refers to the payment mechanism as well as the terms of use.
- Agreements between distributors other actors, allowing other actors to receive and use ROIA software. An agreement of this type will be referred to as a software licence. Its terms typically cover how the software is used, rights to access source code or redistribute the software, and optionally payments to the distributor.

How these are used depends on the topology of the value chain through which funds flow from the customers (who ultimately pay for everything) to the other actors.

2.3 Value Chains

The simplest value chain considered in edutain@grid is one in which customers pay coordinators for access to the ROIA software as well as services, and the coordinator pays distributors to provide the software and hosters to run the ROIA processes and provide the virtual environment. All revenue thus flows through the coordinator. This topology is shown in Figure 2.

A value network representation of the relationships in this topology is shown in Figure 3. The customer pays the coordinator for access to a ROIA under the terms of the customer account, while the coordinator pays its hoster(s) to host the ROIA and provide accounting under the terms of a hosting SLA. In this value chain the coordinator also pays a distributor for access to ROIA software including the right to distribute it to hosters, and the distributor pays the application developer to produce ROIA software.

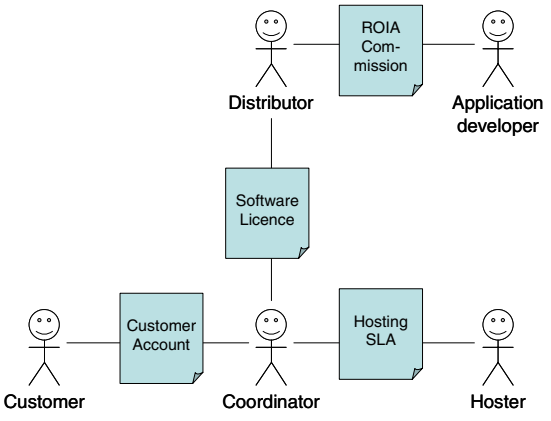


Fig. 2. Coordinator-based software licence value chain

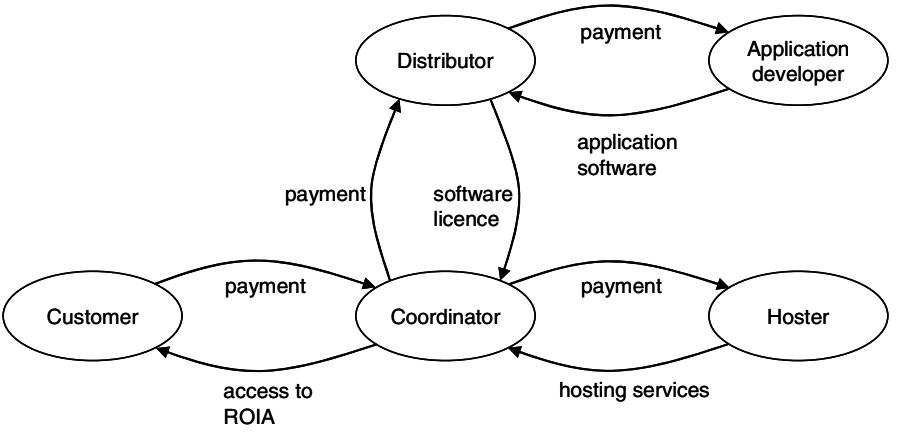


Fig. 3. Value network for coordinator-based software licence value chain

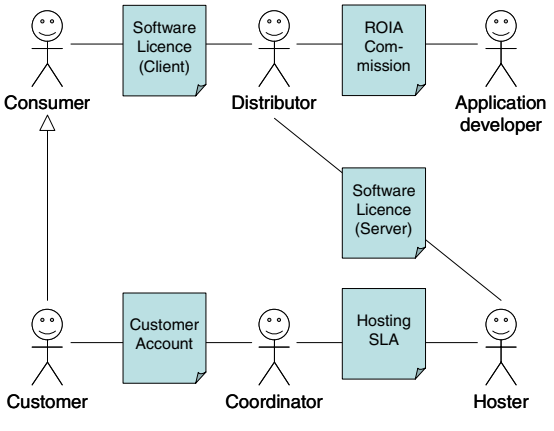
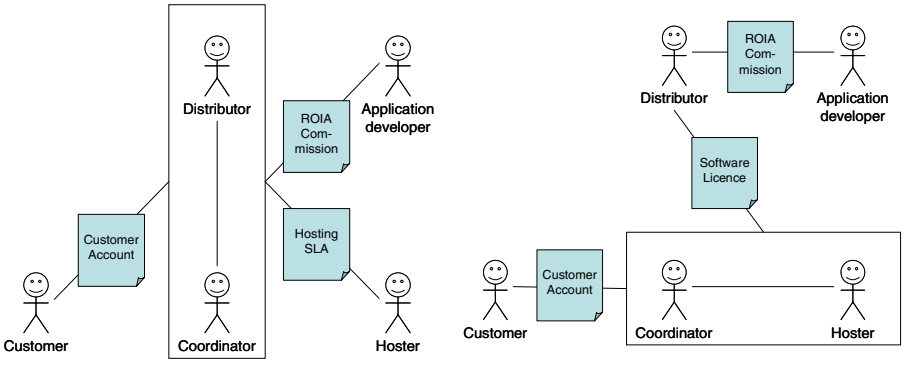


Fig. 4. Distributor-based software licence value chain



(a) Distributor-Coordinator (b) Hoster-Coordinator

Fig. 5. Collocation of business roles

A more complex topology arises when the distributor provides software to the other actors directly as shown in Figure 4. This topology is more typical of current on-line gaming scenarios in which the software is sold to customers who can then decide for themselves whether to connect to a hoster to join a particular on-line game instance.

Even within a single overall value chain topology there may be a wide range of business models can be encoded in the agreements. For example, in Figure 2 a distributor may charge the coordinator a fixed fee for using the ROIA software, a royalty on the income received from customers, or a percentage of the profits. In Figure 4 the distributor may provide software to hosters for free to encourage the provision of ROIA instances, increasing the value (and hence the price) of the client software for consumers. Thus a wide range of options can be used to balance risks and rewards between the distributor, coordinator and hosters in each case. These will be reflected in the specific terms of the SLA between them.

It is also possible for one business organisation to take more than one of the edutain@grid business roles, as shown in Figure 5. The distributor-coordinator topology shown in Figure 5(a) allows a distributor to form direct relationships with the consumers and hosters using their software, and retain a greater share of the revenue provided by customers. This only works if the distributor is able to market the ROIA to customers, find and negotiate terms with hosters, and run the services needed to support ROIA global sessions – i.e. if they have all the capabilities and relationships needed by edutain@grid coordinators. Similarly, the hoster-coordinator topology shown in Figure 5(b) allows a hoster to retain a greater share of the revenue by acting as their own coordinator. This topology is used by the current generation of on-line game hosters (though with variations in the software distribution), and depends on a hoster being able to market the ROIA directly to customers and take all the responsibility (and risk) of delivering the required Quality of Experience.

As noted in Section 1, one of the innovations provided by edutain@grid is to allow more than one co-hoster to cooperate in providing a single ROIA instance to consumers. Suppose a hoster begins selling access to a massively multiplayer on-line

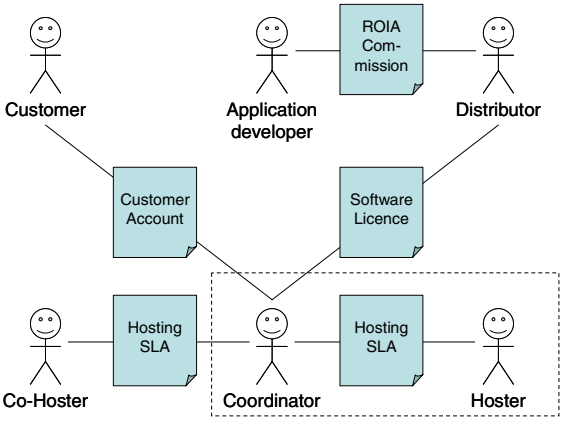


Fig. 6. A co-hosted edutain@grid ROIA

game, acting as their own coordinator and using the value chain shown in Figure 5(b). If the game reaches blockbuster status, the number of players may grow beyond the capacity of this hoster, which would lead to degraded Quality of Experience, and rapidly declining participation. The only way the hoster can avoid this is by installing enough capacity to meet the peak demand, but this is risky: if they over-estimate demand they will invest too much and profits will be too low, but if they under-estimate demand the customers will become dissatisfied and the game will only remain a hit and deliver high revenues for a very short time. The edutain@grid project allows a coordinator to split the ROIA instance between more than one hoster, leading to a value chain like the one shown in Figure 6. With this capability, a hoster finding they have a blockbuster on their hands can introduce a second co-hoster to maintain the customer Quality of Experience in exchange for a share of the revenue.

Note this means there is a clear distinction between the coordinator (who sells the game to customers and organises the hosters) and the hosters themselves, even if the same business is acting as the coordinator and one of the hosters (as indicated by the dotted line in Figure 6). The coordinator is the one taking the risk that it may be difficult to maintain customer QoE as demand grows. The share of the revenue they are willing to pass on to hosters (i.e. the price of the hosting SLA) will depend partly on how this risk is shared with hosters through the SLA terms. Hosters will need to focus on managing resources very efficiently, which may limit the number of service level options they can afford to offer [17].

Other value chains may also be created with more facilitator roles. For example, if the number of available hosters (or the number of different hosting options) were to become very large, it may be possible for a business to make money acting as a broker between the coordinator and the hoster. In this scenario, hosting SLA will be set up by the broker, matching the needs of coordinators to the terms offered by hosters. The broker extracts value by charging the hoster: either a commission for each negotiated SLA, or a fee for considering (advertising) the hoster at all. The broker role is economically viable only if the number of actors is too great for direct negotiation between coordinators and hosters to be cost effective. Since this will not be the case

initially, the edutain@grid framework is designed to work without brokers but to allow for them when the need arises.

Deciding which value chain topology and business model (SLA terms) makes sense depends on the details of each application and its business context. Even within each application sector, it is unlikely that one topology with one business model will suit every application. Therefore, the edutain@grid business infrastructure must provide sufficient flexibility to support a range of topologies and models, even if each application uses only a single agreement topology and business model.

3 Validation Experiments

The edutain@grid project has now produced a first implementation of the framework to support the business actors and value chains presented above for ROIA. The framework is based on a Service Oriented Architecture [18], using GRIA-based services to manage business relationships, along with real-time resource management services from U.Innsbruck and a real-time distributed application framework from U. Muenster. A detailed description of the implementation can be found in [19].

Presently, the framework is being used to perform experiments that investigate which terms in hosting SLAs are most useful for ROIA. The idea is to find terms that coordinators find useful in managing the risks of over/under-estimating user demand, yet allow hosters to retain control over their own resources and implement efficient, ideally autonomic management processes. Support for co-hosting in edutain@grid means that possible interactions and dependencies on co-hosters must be taken into account in this analysis. Consequently, this work must go far beyond existing (even Grid-based) on-line game hosting environments.

The SLA-based management technology used in edutain@grid is based on GRIA, but the SLA terms and metrics typically used with GRIA (based on disk storage and transfer, CPU time, etc [11]) are not very useful (or valuable) in a multi-hosted ROIA scenario. To make use of hosting services with metrics such as these, a coordinator would have to predict how a given ROIA will perform on systems they do not own and with which they are not familiar. To have any chance of doing this, the coordinator will certainly need to control how these systems are allocated and managed, which means the hoster would lose the ability to exploit the systems for other purposes during ‘off peak’ periods, or to outsource parts of the ROIA to co-hosters if they are unable to handle periods of increased load. Even if the hoster is willing to give up these operational advantages, the coordinator still has to optimise the use of resources not just at one hoster site, but across several co-hosters who will have quite different resources. In short, neither the coordinator nor the hoster is likely to be happy with a hosting SLA expressed in terms of resources. The coordinator will find it hard to manage customer Quality of Experience without deep knowledge of all the resources used by multiple co-hosters, and the hosters will be unable to manage their own resources to maximise returns on their investment from multiple SLA with different coordinators.

Fortunately, GRIA does not force SLA terms to use resource-based metrics – it provides a more general framework which is being further extended in edutain@grid to allow testbed deployments using a wide range of SLA terms. This allows the

project partners to conduct realistic experiments in which SLA terms are really used to manage services – the only aspect that is 'simulated' is the settlement of bills based on these terms between the partners. At this stage, edutain@grid experiments are focusing on quite different hosting SLA terms, chosen because they appear to offer the coordinator a good chance of managing ROIA Quality of Experience, but without needing to control (or even understand) the resources and management strategy at each hoster. The terms being investigated in current experiments include:

- the performance of connections between ROIA customers and the hoster, expressed in terms of the virtual environment update rate sustained by the hoster;
- the number of such connections to the hoster;
- the rate at which new connections are made to the hoster.

These metrics relate directly to the concerns of the coordinator – how many customers can their contracted hosters support, and how quickly can new customers join the ROIA? It is already clear that the coordinator can use such 'outcome-related' metrics to manage hosting capacity and control the Quality of Experience seen by their customers. Moreover, hosters can easily measure the number of connections and refuse service if the coordinator (or the application) causes the volume or rate of connections to exceed the limits specified in the hosting SLA.

What is not yet clear is whether the hoster can successfully manage their resources to deliver the required ROIA performance, when the limits on usage are defined in terms of customer behaviour. It is clear that if very few customers are connected to the ROIA, the hoster can use the freedom inherent in such an SLA to reduce the resources allocated – e.g. by running multiple ROIA processes on a single host. However, it is also possible that a ROIA may be come more computationally expensive without a massive increase in customer connections, and since the SLA doesn't specify a limit on resources, the hoster would then be obliged to allocate more resources to maintain the specified ROIA performance. It is also possible for the ROIA itself to induce SLA breaches. For example, imagine an on-line game with (say) 1000 customers provisioned by two co-hosters, each signed to an SLA with a 600 connection limit. It is possible for the ROIA to behave in such a way that all 1000 customers have to transfer their connections to only one of the hosters (e.g. if they all need to gather in one location in the virtual game environment). This would breach the connection limit agreed with that hoster, who would therefore be within their rights to refuse connections, destroying the QoE obtained by customers.

To address these challenges, the project is investigating advanced management models that use forecasts of application and resource load. For example, is may be possible to predict a gathering of on-line gamers in one location, allowing measures to be taken to counteract the negative effects on QoE. At this stage it is not clear what these measures might need to be. One option is to sub-divide the region where customers are predicted to be, and redistribute the pieces between the hosters. Another option is to use 'mirroring', in which replicas of the region are created and customers distributed between them. This technique is already used in single-hoster games to reduce the level of customer interactions, although this does degrade the customers' game experience. The simplest option may be to simply move the region of interest to another, higher-capacity hoster – but would the first hoster notify the coordinator of

an impending overload knowing that the work would then be switched to a competitor? To incentivise such behaviour will require a further radical extension of SLA terms beyond those previously used in Grid-based environments.

4 Summary and Future Work

The edutain@grid project aims to create a new class of 'killer application' for the Grid: Real-time On-line Interactive Applications (ROIA). This class spans several commercially important applications, including on-line gaming and simulator-based training, both of which are being used in validation case studies in the project.

The project is investigating the need for value chains between business actors, each playing its role to deliver the ROIA to end-customers in a Grid-based environment. The analysis leads to a separation between the roles of the hoster (who hosts ROIA services) and the coordinator (who sells ROIA access to customers and guarantees their Quality of Experience). This separation makes it possible to support co-hosted, and hence more scalable ROIA, as well as conventional single-hosted ROIA (in which a business acts as both hoster and coordinator). The edutain@grid architecture has been designed to be flexible enough to support a wide range of value chain topologies among the roles identified, and to accommodate facilitators such as brokers where such roles are economically viable.

The initial implementation of the edutain@grid framework is now complete, and experiments are being conducted to investigate how business values can be expressed in SLA terms that allow service providers to retain flexibility and control costs, while being attractive to service consumers. Initial findings suggest that the hosting SLA between ROIA coordinators and hosters should be expressed in terms of the outcomes for the coordinator, as more conventional SLA terms based on resource committed by the hoster are of limited value to the coordinator and force the hosters to cede control over aspects of their resource management.

Future work will focus on the analysis of business models constructed using these value chains and SLA terms, and operational management of ROIA and resources to address outstanding challenges such as dynamic ROIA-induced load customer load imbalances. These challenges are already faced in on-line gaming applications, but today the only solution is to restrict customer interactions in the game environment. The edutain@grid approach offers the prospect of Grid-based ROIA with few restrictions, which should also stimulate much greater commercial investment in the Grid itself.

Acknowledgments. The work described in this paper is supported by the European Union through EC IST Project 034601 'edutain@grid'.

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