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### **From Metaverse to MOOC: Can the Cloud meet Scalability Challenges for Open Virtual Worlds?**

**Authors:** Colin Allison\*<sup>1</sup>, Iain Oliver<sup>1</sup>, Alan Miller<sup>1</sup>, C.J. Davies<sup>1</sup>, John McCaffery<sup>1</sup>

**Affiliations:**

<sup>1</sup>School of Computer Science, University of St Andrews, St Andrews KY16 9SX, UK

\*ca@st-andrews.ac.uk

**Abstract:**

The use of immersive 3D virtual worlds for education continues to grow due to their potential for creating innovative learning environments and their enormous popularity with students. However, scalability remains a major challenge. Whereas MOOCs cope with tens of thousands of users downloading or streaming learning materials, the highly interactive, multi-user nature of virtual worlds is far more demanding - supporting even a hundred users in the same region at the same time is considered an achievement. However, if the normal number of concurrent users is relatively low and there is only an occasional need to have a large group in-world at the same time for a special event can the Cloud be used for supporting these high, but short-lived, peaks in de-

mand? This paper develops a context for the deployment of immersive education environments in the Cloud and presents performance results of Cloud-based virtual world hosting.

**One Sentence Summary:** Can the Cloud be used on a demand basis for meeting fixed periods of high load in virtual worlds?

## 1 Introduction

Several factors are contributing to the growth of the use of immersive 3D virtual worlds for education: the advances in capabilities and reductions in cost of widely available personal computers – their graphics performance for example; the emergence of open source platforms such as OpenSim [1] and RealXtend [2] for creating and deploying virtual worlds; the availability of free high quality client viewers such as Phoenix [3]; and the increase in suitable bandwidths for arbitrary connections to virtual world servers across the Internet. The educational potential of these technologies for creating innovative learning environments is evidenced by a growing number of case studies, publications, workshops and conferences on the topic; and most importantly, the popularity of virtual worlds with students and pupils. In addition, virtual world software is now being regarded as the vanguard of the 3D Web. The existing 2D Web has enabled major advances in many aspects of online learning – anytime, anywhere access, downloadable learning objects, online shared learning environments, collaboration tools for peer learning, global reach and, as MOOCs have recently demonstrated, a very significant scalability of courses which use a small number of well understood types of online learning resources.

To realize the potential of immersive education and progress towards virtual worlds for a 3D Web, as easy to access and use as the 2D Web, there are several challenges to overcome. These include suitable tools for content creation, programmability, support for the management of immersive environments in educational scenarios, initial download times on arrival, erratic accessibility due to firewalls, integration with the 2D Web, and the complexity of certain user interfaces [4].

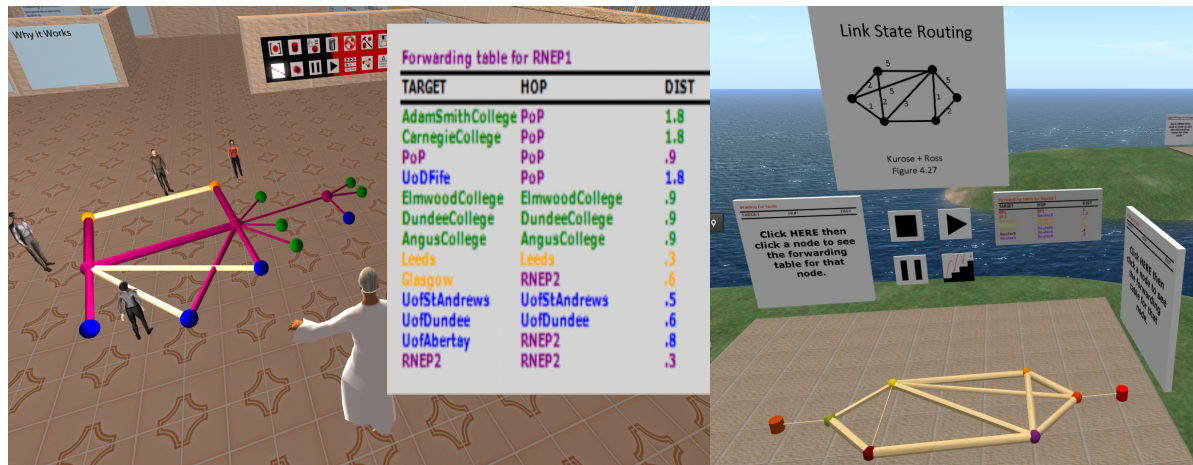
Scalability also presents a major challenge and is the main motivation for the work reported in this paper. Whereas in the case of MOOCs it is feasible to set up web sites that cope with tens of thousands of users downloading learning materials, the highly interactive, multi-user nature of virtual worlds is far more demanding; supporting even a hundred users in the same region at the same time is rarely possible. As is often the case with online learning environments the normal, or average number of users is relatively low – between one and ten for example – but the need to have a whole class in-world at the same time for an induction session, a demonstration or some other special event requires supporting an order of magnitude more users, albeit for a relatively short period. Provisioning sufficient hardware to meet peak demands is clearly not cost-effective, so how best to meet this recurring requirement?

One of the main attractions of Cloud computing is the flexibility of using varying amounts of computing resources in accordance with need. In particular, the Infrastructure as a Service (IAAS) model suggests that rather than having to provision local hardware that can cope with occasional high peaks in demand the Cloud can be used for obtaining large amounts of computing power for a few hours while it is needed, paying for it pro rata, then relinquishing it again.

The question naturally arises: can the Cloud IAAS model be exploited for relatively heavily attended events in a virtual world?

This paper proceeds by: i) giving some examples of how open virtual worlds are being successfully used for immersive education; ii) outlining the design of a suitable benchmark for predicting performance with different avatar loads; iii) applying these benchmarks on a local server hardware, virtual machines and the Cloud.

## 2 Open Virtual Worlds in Education



**Figure 1:** Routing Island: students can model and build networks and then interactively modify them to observe how routing algorithms recalculate forwarding tables.

We distinguish between virtual worlds in general and Open Virtual Worlds (OVW). The latter imply that like a MOOC, these are freely accessible educational resources available across the Internet. In addition the underlying software is typically open source and free to use. OVW for learning have been created to support a wide variety of topics including Internet routing [5](Fig. 1), cultural heritage [6] [7](Fig. 2), archaeology [8], WiFi experimentation [9], electro-magnetic theory [10], programming algorithms [11], HCI [12], space science [13] and humanitarian aid [14].



**Figure 2:** A 3D immersive reconstruction of St Andrews Cathedral circa 1318 (top) is used in the Schools History curriculum and for public exhibitions. The lower image is the Cathedral as it is today. School pupils combine trips to the ruins with visits to the virtual reconstruction.

Part of the motivation for using OVW is that students and pupils readily engage with them, often more so than with conventional learning materials and contexts [15]. Second Life was pioneering in its global reach but it was not designed for education and several commentators have highlighted problem areas that arise when using it for that purpose [16]. These include: commercial cost, code size restrictions, age restrictions, unwanted adult content and other distractions, difficulty of coursework marking due to the permissions system, quality of experience due to remote servers, firewall blocking by campus computing services, a lack of facilities for copying

and sharing content and backing up work outside of the virtual world. Other issues arise – those of ethics, trust, privacy – and the technological barriers to running a class with software which does not scale. In recent years OpenSim [1] has increasingly displaced Second Life (SL) as the platform of choice for developing immersive learning environments. OpenSim is an open source project which uses the same protocol as Second Life so is compatible with any SL compatible viewer/client including the SL viewer itself and others such as Phoenix [3]. This software compatibility has resulted in a de facto standard for Virtual Worlds and has meant that OpenSim offers a natural progression from Second Life for educationalists.

While OpenSim offers solutions to many of the significant drawbacks encountered with Second Life - commercial cost, age restrictions, land constraints, content sharing and backup - there are features (or the lack thereof) inherited from Second Life which act as barriers to a wider adoption of Open Virtual Worlds in education. In this paper we focus on the problem of *scalability*. The following section details the development of a testbed for OVWs that can estimate the number of simultaneous users a particular OVW can accommodate before the quality of experience for the users deteriorates below what is acceptable.

### 3 Development of a Framework for Testing Scalability

The key question is: how many avatars can any particular virtual world support before their quality of experience (QoE) degrades to the point of non-usefulness? In order to develop a framework for carrying out evaluations of scenarios that will answer that question we need to know: i) how to characterize typical avatar behavior; ii) how to simulate avatars; and iii) what is a meaningful metric to indicate QoE?

In order to capture typical avatar behaviour two sets of observations were made with 8 users and 33 users respectively. Each test had 3 runs and each run lasted for 10 minutes. In this experiment the users' avatars spend 80 to 90 percent of their time standing and doing nothing as described in [17]. The remainder of the time was spent walking around. Four measurements were derived from the traces: Frames per Second (FPS), Physics Frame Per Second (PFPS), Frame Time (FT), and Physics Frame Time (PFT). The data collected is summarized in [18] and strongly suggests the Frame Time better reflects the load escalation caused by increases in avatars than the FPS metric. Accordingly we chose a frame time metric as a better representation of the server load generated by numbers of users.

The next stage involved creating automated loads. Various different types of *bots* were created. These were modified Second Life clients that used libOpenMetaverse to connect to and interact with the OpenSim server. The two bots most closely aligned with human-controlled avatars behaved as follows:

Walk-2: a 20 second walk followed by an 80 second walk in random direction

Walk-Rest 1: a 20 second walk in a random direction followed by 80 seconds of standing still

In addition, the bots had inventories and were clothed to make the experimental environment closer to a human controlled experience. After detailed tests it was found that Walk-2 was the closest match to human controlled avatars.

The framework used the following methods, software and hardware. The software consisted of OpenSim version 0.7.1 running in Grid mode, using MySQL on Ubuntu Linux version 11.04. The server is started using a script before the bots are connected and is later stopped after all the bots have disconnected. The server had 10GB RAM, and an Intel Xeon 4-core X3430 quad processor running at 2.4 GHz.

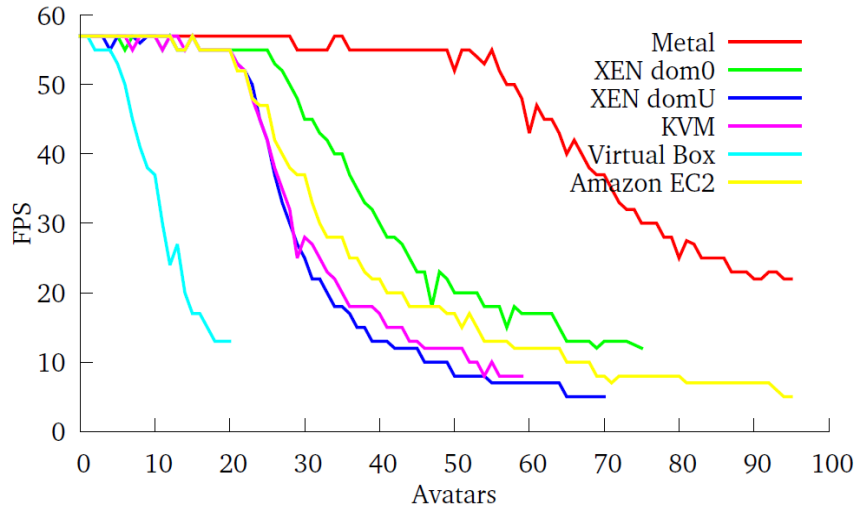
The in-world measures of load were gathered using a customised client built using the libOpenMetaverse library. The monitor and the simulators were run on separate workstations to eliminate overhead on server. The workstation OS was openSUSE 11.3 using Mono to run .Net components. The monitor workstation collected data from the OpenSim server every 3 seconds. (The statistics gathered by the monitor client are generated by the server and sent out to all clients.) The bots were distributed over a number of client workstations, so that the load on any one would not affect the behaviour of the bots or their load on the server. Through tests it was established that a maximum of 25 bots could be run on a single workstation. The maximum number of bots used in the experiments was 100, which required 4 workstations. The workstations had 4GB RAM and core-2 quad Q6600 processors running at 2.4 GHz. mined to most closely approximate the same load on

The bots used were of the type that mostly closely approximated the load on the server generated by a human-controlled avatar (Walk-2). In the experiments the number of bots was increased by 5 for each iteration. Each run was repeated 3 times. The bots were connected to the server with a 20 second gap between starting each bot. All of the bots for a run were connected to the server before the system was allowed to run for 700 seconds. This collected more than 200 values from the monitor. The monitor was then disconnected. The next section shows how results originally reported in [17] compare with new measurements from the Amazon ec2 Cloud.

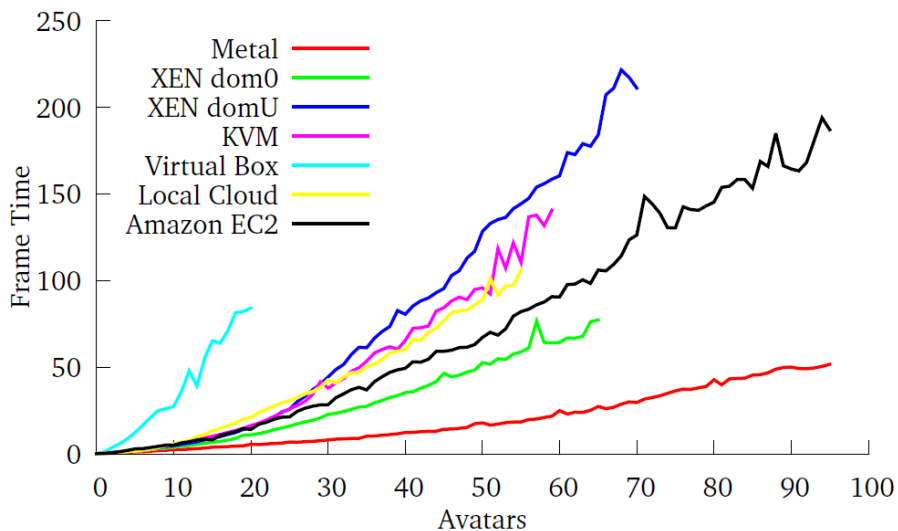
#### 4 OVW Performance in the Cloud

The following types of machine were used in these tests. *Metal* (Xeon 4-core as described above). *XEN Dom0* and *XEN DomU* – two variations of the XEN virtual machine [19] running on the Metal hardware. Xen is reportedly used in the Amazon Web Services (AWS) Cloud. *Kernel Virtual Machine* (KVM) a feature of the Linux kernel [20] that supports virtualization. Again, this was run on the Metal hardware. *Virtual Box* - an Oracle virtualisation product for “home and enterprise use”[21]. The AWS machine instance was picked to closely match the specification of the local *Metal* configuration. It is a “first generation” extra-large instance: “m1.xlarge”, running Ubuntu. OpenSim and MySQL were installed and the same eversion of Cathedral Island that was used in the non-Cloud test runs. m1.xlarge is described as: “15 GB memory, 8 EC2 Compute Units” (4 virtual cores with 2 EC2 Compute Units each) [22].

Figures 3 and 4 compare the measured performance in Frames per Second and Frame Time across these platforms using the framework described above. The OVW used was a version of Cathedral Island (see Fig.2).



**Figure 3:** FPS against numbers of avatars; less than 30 is generally regarded as a poor Quality of Experience for the user



**Figure 4:** Frame Time plotted against number of avatars

The graphs show that:

- The local Metal server performs the best by any measure.
- The AWS m1.xlarge instance, which approximates to Metal, only performs as well as Xen Dom0.
- KVM has slightly lower performance for this application than Xen DomU
- VirtualBox is not an attractive option, barely coping with 10 avatars before degrading beneath QoE thresholds. (It may not have been designed for scalable performance).

## 5 Conclusion

We have pointed to the great potential of open virtual worlds for immersive education but also highlighted some significant challenges to realizing that potential. The particular topic addressed in this paper is *scalability*. It is currently considered a great achievement to maintain good Quality of Experience for even a hundred avatars in the same region at the same time. Affordable commodity local servers can typically support up around sixty avatars comfortably. We asked the question “Can the Cloud be used for relatively short, fixed periods of much higher avatar density?” We have described the development of a framework for automating scalability testing of virtual worlds. Initial results have shown that our framework is producing consistent and useful measurements and that the AWS machine instance most closely corresponding to the local hardware does not perform as well. Work is in progress using larger AWS machine instances to see if the scalability barrier can at least be raised using the Cloud. We have not systematically analysed the financial cost of using AWS yet, but believe that if a machine instance can significantly outperform the local hardware, then running it for e.g. two or three hours for special events would be cost effective. The authors welcome communications about any aspects of this paper.

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