Metaverses as a Platform for Game Based Learning

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***Abstract*—This paper evaluates metaverses as a platform for game based learning. Metaverses such as *Second Life* are a relatively new type of Internet application. Their functionality is similar to that offered by 3D multi-player online games, but differs in that users are able to construct the environment that *avatars* inhabit and are not constrained by predefined goals of the type found within a game environment. From a quality of service (QoS) perspective metaverses are similar to games in that the timeliness of network communication is important, but differ in that their demands upon host server systems and network traffic are more bandwidth intensive.**

This paper contributes to our understanding of metaverses by presenting a case study of the application of Game Based Learning (GBL) within a metaverse environment, by situating the case study within a survey of the state of the art in GBL in metaverses and by analysing the QoS delivered by the widely used *Second Life* metaverse under a range of evaluator-induced network conditions.

***Index Terms*—Learning Technologies, Game Based Learning, Virtual Worlds, Virtual Excavation, Metaverse, Second Life, Archeology, Multi User Virtual Environment, MUVE.**

Fig. 1. Reconstruction of a Spartan Basilica

I. Introduction

This paper presents a framework which supports a group-based exploratory approach to learning that integrates 3D gaming methods and technologies with an institutional learning management system (LMS). The resultant framework provides learners with anytime-anywhere access to interactive learning materials which in turn empower learners to engage in self-paced and personalized learning exchanges.

A virtual simulation environment based on real world data has been developed (Figure 1), with a methodology derived from an analysis of computer games being adopted as the means by which a user's progression through the system is controlled. Within a virtual setting, users, or groups of users, are faced with a series of dynamic challenges with which they engage until such time as a certain level of competence is developed. Once a series of domain specific objectives have been met, users are then able to progress within the educational scenario.

This paper presents a case study based on the excavation of a real-world site of archaeological interest. A system has been developed which makes use of Internet and 3D visualisation technologies in order to allow learners to engage in a virtual excavation project. This enables them to gain experience in applying their knowledge to concrete scenarios and to reflect upon the implications of their decisions. Designed to deliver a cooperative environment, which encourages exploration, the excavation simulator enhances the educational process by enabling students to engage in a realistic archaeological excavation scenario. Not only are students provided with an opportunity to put some of the theories they have been learning into practice, but it also allows those responsible for teaching archeology to design resources which place a greater emphasis on the practical application of knowledge that occurs during the excavation process.

By leveraging the immersive nature of gaming technologies and metaverses, the case study highlights the ways in which technological innovation can be used to enhance the educational process by widening the types of learning behaviours that an LMS can support. This is of benefit as it encourages and motivates learning engagement, whilst also acting as an enabler for the introduction of exploratory learning practices within learning resources. In facilitating this change, the use of metaverse type technologies is able to widen the opportunities for exploration of environments which have historically been inaccessible due to barriers of space, time or cost, thereby helping to address a real-world problem by opening archaeological excavation work to a wider audience.

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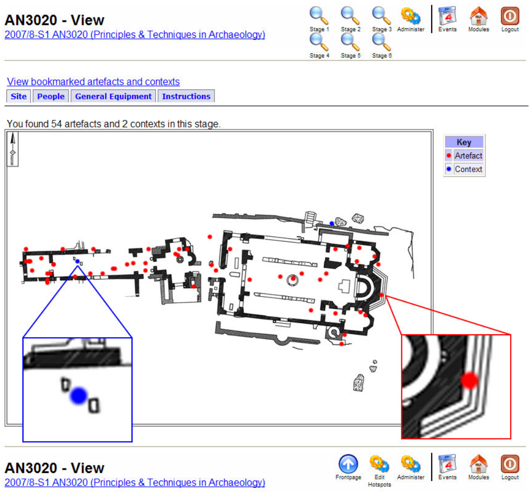
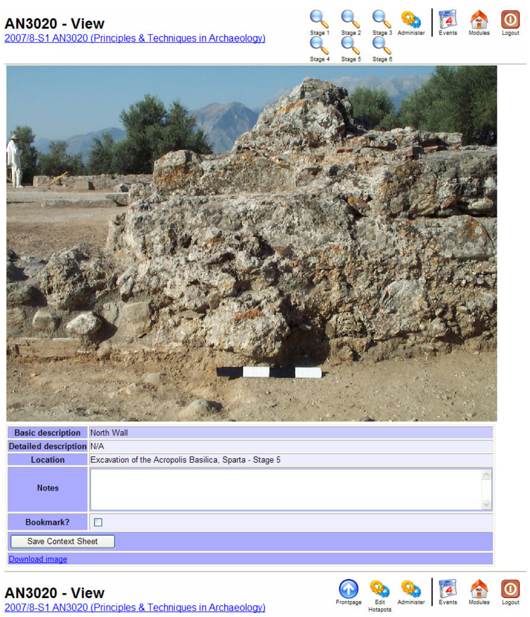


(a) Excavation Plan with finds and context



(b) Context for an excavated artifact

Fig. 2. Management of an excavation

II. Metaverses

As an emerging class of technologies, metaverses are a relatively new development, with some of the more mature examples such as *There* [1] and *Second Life* [2] being released within the last 5-6 years. By providing a simulated environment within which multiple users can interact through the use of avatars, the focus on metaverse deployment is centered around the enablement of social interactions.

Within a metaverse, each user has their own perspective on the virtual world, with the underlying environment presenting a consistent state to all users. Unlike games, the virtual environment of a metaverse is not fixed and can be modelled and altered by some or all of the users who inhabit it. In addition, each user's avatar can be enabled to portray the personality of the owner. As the environment is persistent, any changes to it, or a user's avatar, are long lived and are not reset each time a user logs in. This allows long term changes to the environment to be retained in perpetuity. It also allows users to form relationships by proxy, with each avatar being used to convey a user's in-world persona.

In many ways the environment presented by a metaverse is very similar to that of the real world, with the laws of physics often emulated to provide an environment that is representative of the real world; as such some of the behaviours we are familiar with (such as not being able to walk through walls, or objects falling down due to gravity) are mirrored in the virtual environment. There are, however, some notable exceptions which are designed to facilitate movement and exploration of the metaverse; users are often able to fly or teleport to different places within the metaverse.

Unlike games, metaverses do not impose any set rules or objectives. Instead the inhabitants of a metaverse are responsible for defining the rules and conditions that they wish to govern their environment. This makes it possible for metaverses to be used to host a variety of different activities including music concerts [3], [4], games [5] and university lectures [6]. In addition, this also means that metaverses can be used to develop environments which mimic the behaviours exhibited by *First Person Shoot'em'up* (FPS) [7], *Real Time Strategy* (RTS) [8] and *Action* type games. In this way metaverses are more adaptable than game engines which are traditionally designed to be able to support only a single gaming genre. As the underlying environment of a metaverse is not limited in size or the number of simultaneous users that can be supported, with multiple servers being used to host different regions of the world, there is a level of flexibility offered by metaverse technologies which allows the scale of the environment to be enlarged or reduced in line with demand.

Many metaverses also provide support for access controls which allow authorised users to define restrictions and policies on individual sections of land, thereby making it possible for private spaces to be introduced within the shared environment. In addition, metaverse clients often provide tools to enable synchronous and asynchronous textual communication between users to accompany the more obvious synchronous audio and visual communication in-world capabilities.

Several metaverse environments have been established, with each adopting a slightly different approach to the provision of the generic characteristics described above. Of those currently in routine use, Second Life and Open Simulator [9] are the most widely adopted platforms.

A. Second Life

Second Life is a popular commercial metaverse which provides accounts to anyone over the age of 18 years. Using a monthly subscription approach, SL *'residents'* can rent land to build upon. Using the Havok [10] physics engine to provide an approximation of the laws of physics within the virtual world, Second Life presents users with a broadly realistic representation of the real world. With an economy that is tied to that of the real world, Second Life is often used for commercial gain, with residents creating, buying and selling goods in order to earn currency in Second Life (SL) that can be exchanged for those of the real world.

Managed and hosted by Linden Labs, the virtual world presented by SL is broken up into a series of islands, with up to four separate islands hosted by a single server. Using a client-server model, all of the simulation in SL is conducted by the hosting servers, with the client application acting as a viewer which displays the resulting visualisations. Predominantly open source, the client application has been ported to a variety of platforms including: Windows, Mac OS X and Linux.

From an educational perspective, the adoption rates of SL are far higher than any other metaverse technology, with academia using the environment as a tool to support both teaching [11] and research [12]. In addition, many institutions actively use the platform as a marketing and recruitment tool, with a number of universities establishing sizable communities within the virtual world.

III. Archeology Case Study

A. Motivation

As the process of carrying out an archaeological excavation is destructive and unrepeatable, the opportunities for students to learn within the context of a real world excavation is naturally limited. In addition, there are significant financial and temporal costs associated with such involvement. Even when access to an excavation site is made possible, student participation is limited to following directions and undertaking prescribed activities, with few (if any) opportunities to experiment with alternative techniques and working practices. From an educational perspective it is desirable for these limitations to be removed, with the excavation process being opened to a wider audience. In this model, students are empowered to assume roles of higher authority so as to enable them to assess the suitability of different working practices in an effort to understand the impact that they may have on the excavation environment.

In much the same was as the properties of the *World Wide Web* (WWW) [13] opened up access to information through intuitive point and click graphical user interfaces, metaverses have the capacity to enable educators to offer new and innovative opportunities for the development of realistic and engaging educational scenarios based in previously inaccessible environments. By providing a rich multimedia environment which provides inherent support for presentation of multimedia content and collaboration between users, metaverses are well placed to enable the development of a new type of learning scenario in which exploratory learning is actively supported. Furthermore, through the development of realistic models of otherwise inaccessible environments, educators can develop environments to be examined and explored by students in ways not possible in the real world.

As part of this approach we contend that an important component of the learning process facilitated by metaverses is the ability to learn through doing. To highlight the ways in

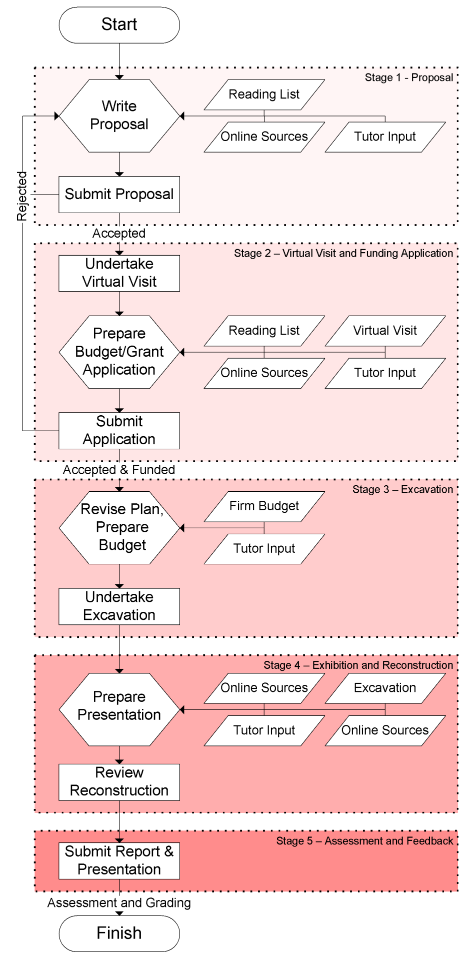


Fig. 3. Stages of an excavation

which metaverse technologies facilitate this type of approach, a virtual excavation has been developed based upon the excavation of a Byzantine basilica explored by the British School of Athens [14], [15]. The overarching aim of the case study is to allow students to engage with archeology and practice archaeological research methods in a meaningful way. Using a variety of techniques borrowed from the gaming world, the excavation process is broken down into a series of contiguous stages, with teams progressing between levels only once a certain level of competence is shown.

In this approach, students use a combination of 2D management interfaces delivered through an institutional LMS, the Module Management System (MMS) [16], [17], [18] (as shown in Figure 2) and a 3D reconstruction of the basilica hosted within SL (as shown in Figure 1). This allows students to plan, supervise and manage their excavation work within a detailed 2D environment, whilst the 3D metaverse is used to enable a first person perspective exploration of the archaeological site and the presentation of each team's findings in an intuitive and creative exhibit.

Using knowledge gained from lectures and third party

Fig. 4. Part of a Student Exhibition

sources, students work as part of a team and assume a variety of roles within their groupings. Not only does this variety provide opportunities for users to decide overall strategy and test out different excavation techniques and processes, it also encourages learners to develop transferable skills relating to budgeting, resource allocation and forward planning. With only limited financial resources available it is unlikely that teams will be able to excavate every area of the site. As such they must carefully consider the relative importance of areas and deploy resources as efficiently as possible.

Throughout the excavation, teams are able to adjust the levels of resourcing that they apply in an effort to balance the quantity and quality of material culture that they uncover. Remembering that excavation work is destructive in nature, teams will initially draw on knowledge gained from lectures to manage their excavation work. As they become more familiar with the requirements of the task in hand and the properties of the tools available to them, teams will slowly become more confident and rely more upon their own judgment.

Initially chance plays a relatively large role in determining the success of a team's efforts. However, as their procedural knowledge improves, so too will their ability to fine tune their personnel, equipment and time allocations. In turn this will improve the chances of more 'valuable' artifacts being discovered. However, it is important that an element of chance always exists within the interactions in order to reduce the likelihood of two excavation projects resulting in the uncovering of an identical selection of material culture. Not only does this make it possible for the progress of each team to be separately monitored, but it also acts to improve motivation and engagement, with randomisation being a technique frequently used within gaming communities to ensure varied and exciting game play.

Throughout the excavation process, teams uncover a rich variety of material culture which must be examined. Some of the artifacts found will be of archaeological interest, some will not. Depending on the resource allocated to each activity, teams will be given one of three levels of information, with the full information about an artifact only being revealed if the team has allocated the correct archaeological expert to the activity:

1) No information, just a photograph of the artifact.
2) Basic information accompanied by a photograph of the artifact.
3) Full information accompanied by a photograph of the artifact.

To make use of this data, teams need to maintain accurate context sheets and site logs, just as they would do on a real excavation project. Should teams neglect to do this, when they come to analyse and present their findings, they will quickly realise that they have lost all contextual information associated with each item that they failed to correctly catalog. This forces them to rely on external sources of information in order to determine the significance of the material culture uncovered, just as they would do in a real excavation. Whilst this process can be successful, it is likely to take longer and require more effort than maintaining the original contextual information gained during the excavation work.

After excavating the site and cataloging the finds that were made, teams present their research in a public forum. To do this they curate an exhibition in the Basilica Visitor Center (as shown in Figure 4) which features a variety of photographs, maps and drawings, 3D models and videos of the artifacts uncovered. These items are sourced directly from the finds held by each team. Each exhibition will feature a different subset of items which teams will have to accurately describe to both the module coordinator and other students enrolled on the course. To accompany the public exhibition, each team is also responsible for authoring an excavation report which describes the findings of the excavation work and highlights the successes of the approaches adopted.

B. Application of Gaming Methods

The concept of progression is the primary approach adopted by games to maintain player engagement and is based on the fulfillment of specific sub-goals and challenges. This approach is widely regarded as an effective way to both challenge and stimulate a player [19], [20] , with the smaller objectives acting as training exercises which allow players to develop the skills required to meet the increasingly complex challenges they encounter during the game. Within the case study, the concept of progression is maintained through the logical separation of the excavation scenario into a number of discrete stages (Fig. 3). From an educational perspective this approach offers benefits in allowing the excavation process to be more accurately modelled.

Randomisation within a game's artificial intelligence is frequently used to determine the outcome of a given situation based on the actions taken by a player. Within Civilization III [21] this approach can sometimes lead to counterintuitive results, with the occasional surprise victory of an ancient army unit (e.g. a spear man) over modern warfare equipment (e.g. battleships, tanks or fighter planes). Irrespective of any implementation level issues, the overall purpose of this randomisation is to maintain interest and encourage repeated use. Taking Sudoku [22] as an example, if each puzzle was identical, people would not spend hours playing multiple puzzles as each would share the same result thus, after completing one puzzle, there would be no challenge associated with completing further puzzles. By randomising the initial seed numbers, each Sudoku game is different, thereby offering a challenge to players. Within the case study, randomisation is used when determining the artifacts to be revealed to learners in order to introduce differences between each excavation simulation.

A policy of selective revelation allows game designers to control the rate at which in game information is released to players. Civilization III and Medieval: Total War [23] make use of this approach as a means through which to limit a player's ability to fulfil the requirements of battles against stronger opponents which feature later in the game. This has the effect of forcing players to engage in smaller battles with weaker opponents in order to build up the technical and social knowledge required to overpower larger settlements. The technique is most beneficial in games which have no physical barriers to prevent players from attempting to solve challenges out of sequence; whilst it is still possible for a player to meet the requirements of a later challenge, the likelihood of them doing so is naturally limited if players do not have the prerequisite prior knowledge. The stages concept used within the case study also relates to selectively revealing elements of the excavation site at different times within the excavation.

C. Case Study Evaluation

The core of the system (LAVA) supporting the case study has been deployed and evaluated over three consecutive academic years. Students in credit bearing archeology modules have completed virtual excavations both as part of a team and also individually. The trials, usually undertaken during class hours, have been voluntary, with students able to opt out as they wish. The uptake and completion rates of the trials have generally been high, with a sizable number of volunteers completing their participation in individual evaluation sessions focusing on specific components of the system.

When evaluating the system as a whole, a two pronged approach focusing on the usability of the system and the educational benefits that it offers has been adopted. The opinions of student participants have been collected using questionnaires broken down into three sections that included questions on system usability using the *DEC System Usability Scale* SUS [24], educational aspects of the system and open questions designed to allow respondents to provide feedback on any aspect of the system. In addition, group observations and individual interviews have been conducted to gain more specific information about key aspects of the system.

The initial findings of the evaluation process have been positive, with responses to the educational value and SUS sections of the evaluation indicating a broadly positive response to the system which has been consistent over each of the three years of evaluation [25]. In addition, encouraging user responses have been obtained which go some way to identifying specific aspects of the system that participants found engaging; the graphical and realistic nature of the visualisations presented being most noteworthy.

The following quote gives an account by a session observer:

> *"At the start of the evaluation session, once the users were logged in to the system the noise level in the room got louder and louder as the groups began to communicate with each other across the lab. The AN3020 lecturer kept trying to bring the noise level down, however these efforts were in vein. The noise level maintained a consistent plateau as the groups continued to communicate verbally. When the first group to complete stage 1 were shown the artifacts that they had discovered the room went silent, all of the groups focused on what the group to complete stage 1 had done, and then a wave of excitement and activity rolled over the lab as the other groups, spurred on by the outcome, began to try to complete the stage with renewed interest."* Quote from session observer.

It is promising that the initial findings indicate that the adoption of gaming methodologies have had a positive impact on the course. In addition, it is important to note that the evaluation process has played a significant role in shaping the instantiation of the system, with user feedback directly affecting the priorities adopted during the development process.

Given the heavy reliance placed on user opinion and other types of qualitative data, the evaluation process acts as an indicative guide to the applicability and suitability of LAVA as a teaching tool, with the process of deploying the system providing more concrete evidence of LAVA's fitness for purpose. The deployment and use of the system in a classroom environment proves the technical feasibility of the framework, architecture and current instantiation of LAVA.

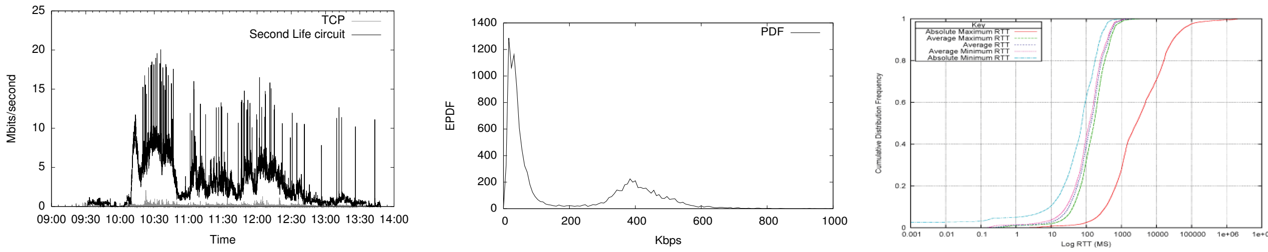
During deployment and evaluation LAVA worked well from a systems perspective. However a few issues of arose connected with network QoS, both for SL users and the possible impact upon other users:

- There was concern that SL is a greedy application which impacts badly upon the traffic it shares the network with, this acted as a barrier to deployment.
- Compared to state of the art computer games, metaverses are considerably less "slick". Whilst moving around the environment, buildings often take a while to appear, and when they do bits may be missing.
- Errors in avatar positioning can create odd effects: when bumping into walls it sometimes appears as though the avatar is halfway through the wall and movement is not as smooth as desired.

In order to investigate these issues further measurements of network conditions and SL traffic were collected and analysed. These are discussed in the next section.

IV. Evaluation of Network Communication

Metaverses rely upon network communication to allow distributed users to interact through the proxy of avatars. For an immersive experience it is important that network communication is timely [26]. Consequently, like most 3D games, using TCP is problematic. Unlike 3D games the client does not hold a model of the entire world. As avatars move around, their immediate environment is downloaded dynamically to the client.



(a) Throughput During a Lab Session (b) A User's Throughput Distribution (c) Inter Planet Lab RTTs

Fig. 5. Second Life Traffic Traces

Here we investigate the resource utilisation of Second Life, with regards to what resources it requires to operate and how this interacts with other traffic on the Internet.

1) Lab session: During a workshop for 30 learners the traffic between the SL clients and servers was captured. This allowed the network requirements of Second Life and the feasibility of using SL with a lab of students to be evaluated and the resources necessary to be measured. It also facilitates comparison between the demands placed upon the network by SL with computer games and TCP.

	Total	**UDP**	**TCP**
Bytes	5148894.385KB	5053021.063KB	95813.562KB
Packets	17042669	16632300	410225
bits/second	2569.309Kb/sec	2521.468Kb/sec	47.811Kb/sec
Connections	22192	332	21853

TABLE I
SUMMARY STATISTICS FOR THE TRACE AS A WHOLE.

First we present an overview of the traffic statistics before looking at particular aspects in more detail. Table I shows the summary statistic for the entire capture. Over 5 Gigabytes of data was monitored. Of that 98% was Second Life UDP traffic and 2% TCP traffic. The UDP traffic was distributed over 332 separate SL Circuits an average of 11 for each client computer. The TCP traffic was distributed over 21853 separate connections. The average amount of traffic per circuit was 15,219KB. The average size of TCP connections was 4 KB. Thus the UDP traffic counts for the overwhelming majority of SL traffic and it is organised into circuits.

How the throughput of TCP and UDP traffic for the Lab changes over time is shown in Fig. 2(a). At the start of the trace there is little activity. Then at ten past ten activity increases. This corresponds to the start of the "hands on" session, where each of the 30 participants is completing a worksheet. During this time total throughput averages 7 Mbps and reaches peaks of between 15 and 20 Mb/sec.

The traffic from each user was separated and analyzed. Fig. 5(b) shows the probability distribution of throughput per second for one user. The distribution is binomial. This lower bandwidth distribution corresponds to periods during which the Avatar is stationary and when there is little activity. The higher bandwidth distribution corresponds to when the avatar is walking or flying. These show that when the Avatar is active the bandwidth utilisation is around 400 Kb/sec significantly above the average levels. It also suggests that SL traffic distributions are made up of separate components which are worth measuring and analyzing separately.

During the workshop the number of packet drops was measured at 0.02% of the total. This indicates that the end to end bandwidth usage was within the capacity of the local network, the WAN and Linden Labs. The average round trip time was also measured as 153ms and the average packet size was 304 Bytes.

Computer games have relatively low bandwidth requirements, for example; First Person Shooters (Unreal Tournament) and massively multi-player role playing games (World of Warcraft), typically require less than 50 Kbps and 10 Kbps respectively. This is comparable to the bandwidth required by SL when the avatar is inactive (20 Kbps), but is a fraction of that SL requires when the avatar is moving (400 Kbps). Hence one consequence of metaverses requirement to dynamically download their environment is that they use much higher bandwidth than computer games.

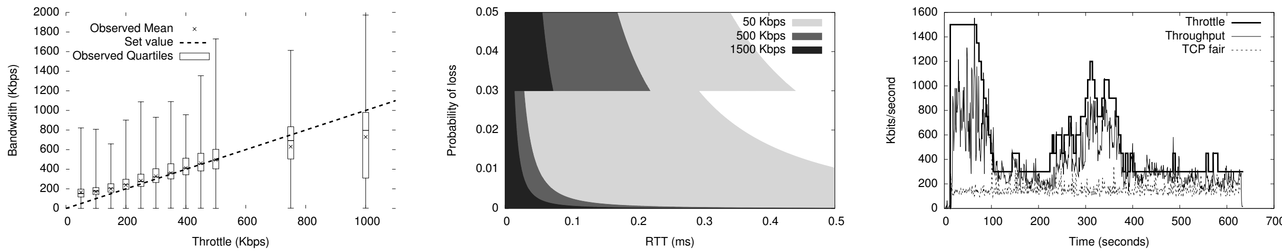
There are a wide range of applications which metaverse traffic has to share the network with. A comparison with traffic that is regulated by TCP is valid and important as over 80% of Internet traffic uses TCP as a transport protocol.

TCP's congestion control mechanisms limit the amount of data an application can send per round trip time. They have their origins in research conducted in the late eighties. Severe congestion stimulated research into its control. Raj Jain defined a notion of Max Min fairness [27], and designed a class of Additive Increase Multiplicative Decrease (AIMD) [28] algorithms which result in a Max Min fair allocation of resources. Van Jacobsen designed Slow Start and Congestion Avoidance algorithms, which were incorporated into TCP [29]. The combination of Congestion Avoidance and loss detection through duplicate packets is an AIMD algorithm, which achieves statistical fairness [30], that is, each flow has similar opportunity to obtain network resource. This macroscopic or steady state behaviour of TCP can be represented by the TCP Fair equation [31] below 1. [1]

$$X = \frac{S}{RTT\sqrt{p}} \quad (1)$$

For applications with real time constraints TCP is often not appropriate, consequently the question of how non-TCP

[1] TCP Friendly Rate Control [32] uses a more complex formula [33]



(a) SL Throttle Settings (b) TCP and SL Comparison (c) TCP and SL Throughput

Fig. 6. SL Adaptation to Loss

applications should regulate their behaviour is an ongoing one. The TCP Fair equations have been used as a reference point for evaluating their behaviour [34], [35].

If we plug the RTT, loss rate and average packet size, from our measurement study, into the TCP Fair equation and compare the resultant rate with the measured rate of SL traffic it will give us a ballpark figure of whether SL was acting more or less aggressively than we would expect long lived TCP flows to be. With packet size of 304 bytes, a loss rate of 0.02% and a RTT of 153 ms this would give a fair sending rate of 1455 Kbps per flow, which is over three times the bandwidth required by an SL client with default settings and a moving avatar. SL could use significantly more bandwidth without being overly aggressive vica-versa TCP traffic.

To determine how typical are the network conditions experienced by this study we look at Internet RTTs and loss. TCP uses window based flow control, consequently at smaller RTTs, the rate at which it allows data onto the network is larger. We utilised the overlay network PlanetLab [36] to measure the RTTs between hosts on the Internet. Inter-nodal connectivity between PlanetLab machines is generally very good with around 75% of node pairs reporting round trip times (RTTs) of approximately 200ms. Thus the RTTs used in this study are higher than most locations would experience, consequently, our estimates of TCP bandwidth utilisation are conservative.

In order to determine the effect of different loss regimes it is relevant to look at how SL controls its bandwidth usage. The downloading bandwidth to an SL client is controlled by a *throttle* system. The initial value defaults to 500 Kbps but may be set by the user to any value between 50 Kbps and 1500 Kbps. The server maintains a global throttle for each client, initially it is set to the smaller of 1500 Kbps and 1.5 times the user setting. This is used as a session maximum.

During the session the bandwidth cap may range between 0.1 and 1.5 times the initial user setting. The SL client tracks packet loss and adapts the bandwidth it requests from the server using the following algorithm.

- When the loss rate is less than 0.5% and the current cap is less than the starting value the rate is increased by 0.1 times the set rate.
- When the loss rate is greater than 3% the sending rate is reduced by 0.1 times the set rate.

In order to understand the working of the SL algorithm we compare it to TCP under the following assumptions; the data source is not application limited, loss is deterministic and the flows are long-lived. Under these assumptions for any given RTT and loss rate the TCP Fair equation can be used to estimate TCP bandwidth use. For SL if loss is greater than 3% the bandwidth used will be 0.1 times the user setting, and if loss is above 3% bandwidth will be 1.5 times the user setting (capped at 1.5K).

The maximum, minimum and default SL settings are compared with TCP for RTTs up to 500 ms and for loss regimes up to 5% in Figure 6(b). For each of the user settings to the left of the shaded area boundary the SL algorithm uses less bandwidth than TCP. To the right SL is more aggressive. At low levels of loss both the default and maximum settings are TCP fair. However, when loss reaches 1% for RTTs greater than 80ms SL is more aggressive than TCP.

Figure 6(a) shows box plots for the bandwidth used by SL for different initial throughput settings. The distributions are for ten minute sessions when the avatar is walking around a set course on an Island. It demonstrates, that for the same scenario, same hardware, same island, same number of Avatars present, SL makes use of different amounts of bandwidth. We found that more bandwidth results in less delay and more accurate avatar representation. A time series showing throttle values communicated from the SL client to the server and, the bandwidth used in communication from the server to the client are shown in Figure 6(c). The mean loss rate is 3%. This shows that the client throttle value may be used to dynamically adapt the bandwidth that SL uses.

From this we conclude that changing the algorithm which controls the throttle values so that SL can make use of the appropriate TCP Fair bandwidth will allow the correct balance, between the quality of user experience and fairness to competing traffic, to be achieved. We are currently experimenting with measurement based algorithms in a modified SL client.

V. Conclusion

For many years computer games have been adapted to support game based learning. In recent years the emergence of a new type of application, metaverse, has opened up new opportunities for GBL. Metaverses are designed to facilitate the creation of content by residents within the world. This has important consequences for educators. With the help of a growing community it is possible for educational environments to be built by the educators themselves for a much reduced investment in time and resources when compared to traditional computer games. In this paper we have evaluated the suitability of metaverses for game based learning, both from the perspective of user functionality and from the perspective of system resource requirements.

Firstly, an educational simulation, which incorporates methods from gaming, has been designed, built and evaluated. This simulation, of an excavation, makes use of the metaverse support for user generated content and the programmability of that content to provide a 3D reconstruction of the excavation site and to empower learners to create an exhibition from finds encountered in the virtual excavation. Our experience leads us to assert that metaverses allow us to create environments for game based learning, which are more flexible than previously, allow learners to exercise a greater level of control over their environment and at a reduced cost than previously.

Secondly, we have evaluated the properties of Metaverses from a systems perspective. A key difference between traditional computer games and metaverses lies in the area of communication. The dynamic downloading of content that metaverses require, has consequences both for the user experience and for the demands placed upon the network.

Our measurements of Second Life traffic confirm that the bandwidth requirements of SL traffic is many times that of computer games. However, for normal operational parameters, SL traffic remains within the bounds of TCP fair behaviour, requiring less bandwidth than an MPEG 1 stream. Our measurements suggest that dynamic bandwidth management would enable SL to both improve the user experience and widen the network contexts within which SL is usable.

In conclusion metaverses offer a flexible platform for game based learning, which facilitates the creation of new educational contexts. As baseline computer systems continue to advance and networks improve, the number of learners and educationalists that have access to this technology will continue to increase. How they make use of this new resource will be of considerable interest in the short to medium term.

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