Cloud gaming in Education: Evaluation of Multiple Game Streams in a Shared WLAN

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***Abstract*— This paper presents a platform for using digital games in an educational scenario – teaching in classrooms. The platform is based on the cloud gaming concept, whereby game content is delivered from a server to a client as a video stream, and game controls are sent from the client to the server. We shortly present the architecture of the solution and focus on the evaluation of the network performance inside schools. We study user perceived cloud gaming performance under the impact of multiple cloud gaming streams in a shared WLAN. An empirical user study was performed using the GamingAnywhere platform wherein participants were asked to report on perceived degradations of game play quality imposed by incrementally adding additional artificially generated cloud gaming streams to the same network. Results show that degradations are perceived (in the form of video jitter and higher latency) by most participants when four or more cloud gaming traffic flows share the same wireless access point.**

Keywords— Cloud gaming, education, teaching

I. Introduction

Using digital games as a tool in the process of teaching has been proven to improve learning outcomes. Students are better focused on the topic, better motivated and in general have better skills related to problem solving [1]. Nevertheless, many issues which hinder the use of digital games in teaching still remain. In a study reported by European Schoolnet [1] teachers identified the following major difficulties in using digital games in classrooms:

- Difficult to integrate in curriculum;
- Insufficient availability of computers;
- Lack of time;
- Lack of information and support;
- Inappropriate behaviour of children;
- Technical problems, and
- Cost and lack of resources.

These studies have been using traditional gaming methods such as gaming on consoles and PCs where the games are installed, stored and run on the local device, thus yielding great problems related to management, storing, and maintenance of required hardware and games. A possible solution to most of the listed issues is introduction of the cloud gaming paradigm. Cloud gaming is a service that allows on-demand streaming of game content from the server to the client, usually in the form of a video stream. In the streaming video approach, the server stores the game files, executes the game logic, renders the virtual 3D scene, encodes the video, and sends the video stream to the client in real time. The client is responsible for decoding the video and capturing player commands. This approach enables running of games with high graphics quality on end devices which do not have a significant amount of memory or processing power. Moreover, the end devices do not have constraints on operating systems for which the game has been developed, as only the video stream is decoded and the commands are sent to the server. This approach enables playing all types of games on tablets.

In our vision of the classroom of the future, all pupils will have tablets on which they will be able to write notes, store books, and play educational games. Even though cloud gaming offers many benefits, issues and challenges exist in this approach. As video streaming in cloud gaming requires continuous game content to be presented to end users without any interruption in content flow, this imposes a huge load on the network in terms of the bandwidth allocation for traffic generated by cloud gaming [2][3][4]. For example, network requirements for cloud gaming of the recently released NVIDIA GeForce Now services are minimally 10 Mbit/s (recommended 20 Mbit/s) and less then 60ms of round trip time between the server and the client. In a typical classroom scenario, around 30 pupils would be engaged in a gaming activity which implicates that for each one of them a separate cloud gaming flow needs to be created. This might cause bandwidth availability issues in the local wireless network. Hence, while the cloud gaming paradigm has significant benefits as compared to traditional online and local games, primarily in terms of alleviating the need for high-end end user devices and maintenance costs, meeting the corresponding network resource requirements remains a challenge. In this paper, we thus focus on the requirements and limitations when delivering multiple cloud gaming streams via a shared WLAN, as is envisioned in a typical classroom scenario.

Numerous studies have studied the impact of network impairments on cloud gaming performance, but only a few have addressed the issue of network congestion due to multiple simultaneous players in a shared WLAN. Chan [5] reports in his study the scalability of their video gaming on demand solution with a growing number of users in an 802.11g WLAN network. The study shows that when more than three users join (up to a maximum of 6 users), packet drops occur which results with increased latency. Early tests with video game streaming over a WLAN were also reported by Jurgelionis et al [6], who report on game experience in the presence of competing traffic, resulting with increased latency and video jitter.

In this paper, we report on a user study conducted to evaluate perceived cloud gaming performance under the impact of multiple cloud gaming streams in a shared WLAN. We aim to evaluate the most common currently deployed WLAN technology appropriate for this type of service. We analyzed game streaming traffic generated by the freely available open source GamingAnywhere (GA) platform [7] and modelled the traffic for the purpose of generating artificial game streaming flows. Participants took part in the study by playing a fast-paced racing game while artificial flows were incrementally added to the same WLAN. The goal was to identify the threshold in terms of number of feasible simultaneous flows at which most players quit playing. Results may thus be used for the purpose of identifying resource requirements and network planning when looking to deploy a cloud gaming-based architecture for multiple simultaneous users. While we discuss this in the context of a classroom scenario, the results are applicable in other use cases, such as an in-home streaming scenario involving multiple users sharing wireless network resources.

II. EDUCATIONAL PLATFORM FOR CLOUD GAMING

Our educational platform for cloud gaming is envisioned to consist of three major elements: cloud gaming clients, cloud gaming servers, and a management application. For our testing implementation, the GA server and GA Android client are used as cloud gaming server and client. Although there are other alternative cloud gaming platforms, such as Steam In-Home streaming, we chose GA because it is an open-source solution with many client and server side options which can be tweaked.

Fig. 1 UI of the management application (current version in Croatian)

We developed a Management application to enable teachers and administrators to choose and schedule which games to deploy in their classrooms. The application provides several functions: authorization of teachers, listing of games appropriate for specific lessons, reservation of time-slots for cloud gaming servers (run as virtualized servers), and assigning clients to reserved servers. The management application is still in development and currently enables choosing of grade, subject, topic and the game suitable for that topic/lesson (UI displayed in 1). The application controls the virtual servers on which the cloud gaming servers are run using Microsoft's Hyper-V technology.

The network segment can be divided into two main parts: the link between the school and the cloud gaming servers, and the wireless access network in the school, the latter of which is the focus of this work. The process which will enable a pupil to play a game is depicted in Fig. 2. The teacher using the web based interface first chooses a game from a list of games appropriate for a certain topic in the curriculum. After that the teacher indicates the time and date of the lecture and the students which will be playing the game. The management application handles the reservation of virtual servers and resources. At the scheduled time (e.g., *Mon, Feb. 1*st *from 10:00-11:00*), the students start the application and are

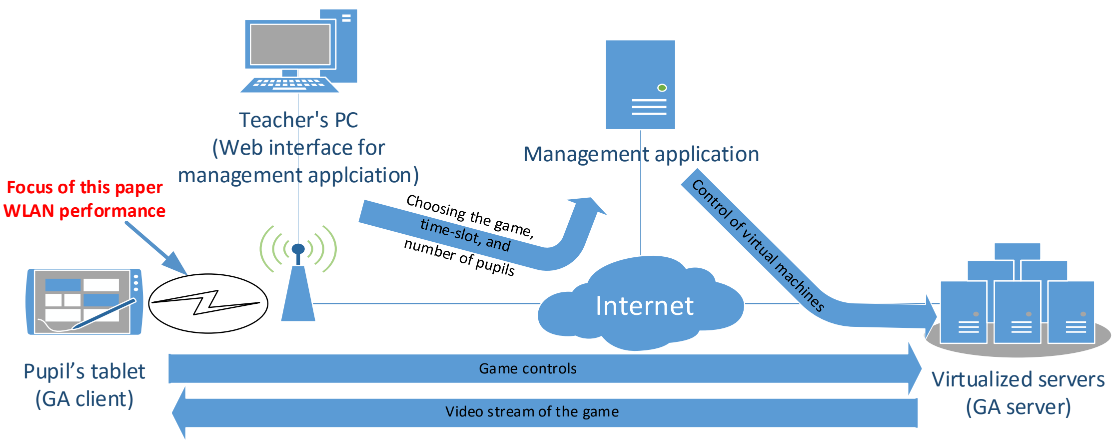

Fig. 2 Overview of educational platform for cloud gaming

automatically (based on their ID's) assigned to specific virtualized servers. The game is then streamed to the pupil over the Internet and local WLAN.

III. Methodology

A. *Cloud gaming traffic modelling*

To test the performance of the GamingAnywhere platform in a WLAN environment under heavy cloud gaming traffic load, our first aim was to find a fitting network traffic model to generate realistic network workload in our testbed. Several sets of measurements were performed to gather network traces of cloud gaming traffic using the GA platform with video traffic transmitted over RTP/TCP. Network traces were captured on the server side by using the Wireshark tool. Measurements were performed with the game Mario Kart 64, thus we note that the created network traffic model characterizes network traffic corresponding to the aforementioned game. Traffic is modelled based on the analysis of packet size distribution (uniform + constant value) and packet inter- arrival time distribution (uniform). We use these distributions as input for the D-ITG traffic generation tool [8] to accurately generate an artificial cloud gaming network.

B. *Laboratory set-up*

The GA testbed used in our study is shown in Fig. 3. The GA PC Server and a mobile GA client are connected via a wireless access point. Additionally, a D-ITG network workload generator and a D-ITG network workload sink are introduced in the testbed to generate realistic synthetic cloud gaming traffic in a wireless environment. The GA PC Server and D-ITG network workload generator have a wired connection to the wireless router, while the mobile GA client and D-ITG network workload sink connections are established via a wireless link. Both GA Server and D-ITG network workload generator were set up on Windows PCs (Windows 7 desktops, each with Intel 3.3 GHz i3 processor, 4GB RAM and GIGABYTE Radeon R7 250).

The D-ITG network workload sink was run on a notebook (operating system Ubuntu 14.04, Intel 2.7 GHz i5 processor, 4GB RAM). The GA client was installed on an Android tablet (operating system Android 4.4.2, 1.9 GHz Quad Core Processor, 3GB RAM and 12.2" TFT LCD display). The GA server (the GA platform version 0.8.0) was running in periodic (desktop capturing) mode, with default video encoding settings (H.264, resolution 1280x720, 30 fps) and with video bit rate set to 3 Mbit/s. The Wi-Fi router tested was Cisco Linksys model WRT54Gl which supports 802.11g standard with speeds up to 54 Mbit/s.

The game used in our experiments and installed on the GA Server was the 3D racing game Mario Kart 64. For testing purposes, we modified the existing implementation of the GA Android client in order to incorporate support for the construction of custom user interfaces. Our previous tests conducted using the GA platform showed that the user interfaces built-in at the time of testing had some minor issues (e.g. the combination of analog stick and acceleration button did not accurately respond to user input), and thus caused user interaction difficulties for the tested game. Thus prior to conducting this study we added support for a custom user interface that proved to be appropriate for the chosen game, allowing users to easily execute game commands [9].

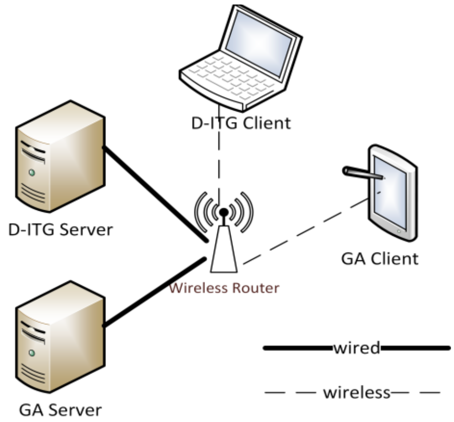

Fig. 3 Laboratory testbed

C. *Measurements*

The study consisted of approximately 5 minute long gaming sessions that were performed in the aforementioned laboratory environment. Overall, 10 participants took part in the experiments, 8 male and two female, with ages ranging from 19 to 25. Each gaming session consisted of one participant playing Mario Kart 64. At the beginning of each game session, the participants were given a small amount of time (one lap of a race) to familiarize themselves with game play mechanics. After this introductory phase, the participants started playing and racing with Artificial intelligence in the game. During game play, the test administrator used the D-ITG tool and incrementally generated a new cloud gaming traffic flow every 20 seconds to emulate an increase in the numbers of GA platform users sharing the same WLAN. Our goal was to identify the relationship between an increase in the number of GA traffic flows and the user gaming experience. The participants themselves are not aware of moments when new flows were introduced, and were only instructed to note if and when they notice any degradations or impairments in their gaming session. Also, they were instructed to inform the test administrator at which point in time degradations became too severe for them to continue playing.

IV. Results

Obtained measurement results are shown in Fig. 4. which shows how the number of parallel artificial cloud gaming traffic flows that are introduced in the WLAN affects users' game play quality, consequently forcing users to quit playing under present network conditions. Only a few of the participants reported minor degradations of game play quality with two or three parallel cloud gaming traffic flows in the network, whilst most users started experiencing significant degradations with four generated traffic flows. The first occurrence of a user giving up from playing was when five generated cloud gaming traffic flows were added.

Furthermore, all users were unwilling to continue playing by the time seven traffic flows were generated. It should be noted that the real GA video traffic flow achieves around 3 Mbit/s throughput and with every new cloud gaming traffic flow generated the amount of traffic is increased linearly until the maximum throughput supported by our tested wireless router is achieved. Although, nominal capacity of the 802.11g standard is 54 Mbit/s already at approximate speeds of 25 Mbit/s we encountered significant degradations in which the game was unplayable.

The degradations of game play quality during the tests resulted in additional latency introduced within the game, as well as jerkiness, which often results with video freezes. In the case of two and three cloud gaming traffic flows introduced in the network, the degradations of game play quality were visible in the form of video jitters and a higher response time to user input, but were still found to be tolerable for most of the players. However, with seven additionally generated cloud gaming traffic flows, the game video stream completely freezes and becomes unresponsive to the user commands, consequently resulting with players unwilling to continue playing. When examining the log produced by the D-ITG tool, it is noticeable that in the case of adding four or more parallel cloud gaming traffic flows, some percentage of packets are dropped due to network congestion. The percentage of dropped packets varies from 5% when four streams are added to 30% when seven new traffic flows are introduced in the network. This leads to the aforementioned degradations of game play quality: when dropped packets include user's input, the game becomes unresponsive from the user viewpoint. Also, when video payload packets are dropped, the video stream freezes and game play is suspended for a few moments. Furthermore, when the generated cloud gaming traffic flows are stopped, the GA client replays some of the recent user actions and the corresponding video is replayed, but in a noticeably increased pace.

The results clearly indicate that for application of cloud gaming in schools newer versions of the 802.11 standard needs to be supported by the Wi-Fi access points. 802.11n supports speeds up to 600 Mbit/s, but those still are not sufficient for 30 players with 30 Mbit/s, especially because theoretical maximum speeds are not achievable in practice like we showcased in our case of our 802.11g network. The conclusion is that standard 802.11ac should be used and for future work we aim to test our implementation with this standard.

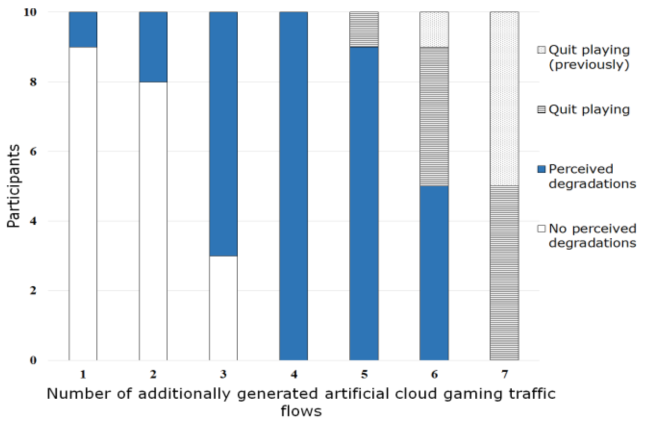

Fig. 4 Impact of the number of generated artificial cloud gaming traffic flows on game play quality

V. Conclusion

In this paper we presented a platform for using digital games in an educational scenario – teaching in classrooms. We have in detail investigated one section of the platform - the Wi-Fi access network in schools. For this goal we used user evaluation of cloud gaming performance in light of multiple game clients sharing a WLAN. We found out that networks based on 802.11g standard are not enough for this application, as at 7 concurrent flows no players wanted to continue playing. Also, we encountered significant degradations in which the game was unplayable at aggregate bandwidth usage of 25 Mbit/s (less than half of theoretical maximum of 802.11g). In future work we aim to conduct additional studies involving a larger test population and multiple real users playing simultaneously in a WLAN which supports the 802.11ac standard. Furthermore, we plan to investigate how and to what extent additional cloud gaming traffic flows in a local area network affect Quality of Experience by systematically collecting participant ratings.

Acknowledgment

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