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2006

## A conceptual study on perceptions of information seeking activity

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# Creation and Distribution of Real-time Content: A Case Study in Provisioning Immersive Voice Communications to Networked Games.

A thesis submitted in fulfilment of the  
requirements for the award of the degree

Doctor of Philosophy

from

THE UNIVERSITY OF WOLLONGONG

by

Cong Duc Nguyen  
Bachelor of Engineering (Honours Class I)

SCHOOL OF ELECTRICAL, COMPUTER  
AND TELECOMMUNICATIONS ENGINEERING  
2006

# Abstract

The rapid increases in network bandwidth and processing power have led to tremendous growth in Internet applications and changed the nature of delivering content. From earlier web application, which is only about retrieval of pre-computed static content, current content delivery architectures provide dynamic content and enable personalization of content. Recent interactive entertainment applications, such as multiplayer online games, require content to be created and distributed in real-time. In addition, the rapid increase in processor speed has led to various proposals to put real-time computation within or at the edge of the network that allow application specific processing on packet flow such as multimedia transcoding and content adaptation. In short, these emerging applications have a common characteristics that the contents of application flows are processed in real-time before being delivered to end users. We refer to these as applications that require *real-time content creation*.

This thesis aims to develop models for real-time content creation and distribution. We examine both network architectures for delivering content as well as server processing resource management for content creation. We concentrate on a case study when content creation is from a dynamic set of dispersed sources. In particular, we examine the provision of an immersive voice communication service to massively multiplayer online games, which requires real-time creation of audio scenes from dynamic sets of participants. We present various delivery architectures for this service, evaluate the performance of these architectures and provide recommendations based on the evaluation. In addition, this thesis designs a server resource management architecture for sharing processing resource among real-time content creation applications.

Our study begins with reviewing the evolution of content distribution over the Internet, ranging from simple caching proxies to content distribution networks and personalization of content. We then discuss current and future developments of content distribution which require real-time creation and distribution of content from dynamic sets of dispersed sources. These include *state information* processing and *communication information* processing in distributed virtual environments. While all networked games require state information processing, communication information processing has been recently seen as a key to enhance the reality and attractiveness of the virtual environment. In particular, this thesis reviews technologies and approaches for providing an immersive voice communication service to distributed virtual environments. Several delivery architectures are introduced for providing this service, namely peer-to-peer, central server, distributed locale server architecture, and distributed proxy architecture. Furthermore, we present a realistic simulation model that captures player distribution in the Internet and avatar distribution in the game virtual world and specify two key performance evaluation parameters: interactive delay and network bandwidth usage.

In the central server architecture, two optimization objectives are proposed for choosing an optimal central server from a set of potential servers. We also propose a dynamic relocation of a central server in response to changes in player distribution due to time zone differences. It is shown that relocation of the central server in response to these changes can significantly reduce the interactive delay by up to 40% and the network bandwidth usage by up to 50%. In addition, the optimal central server can significantly reduce the interactive delay compared to a randomly located central server.

In the distributed locale server architecture, the game virtual world is partitioned into smaller areas called locales and each locale is assigned to a server. We propose two server assignment algorithms for optimizing the latency performance of this architecture. The first algorithm is based on an Integer Linear Programming (ILP) model which provides an exact solution to the problem but is subject to high computation complexity. We then produce a new multi-layer graph representation of the problem and devise a greedy heuristic based on this graph. It is shown that the greedy heuris-

tics has low run time complexity and provides solutions close to the optimal (within 5% of the optimal in all cases). In addition, increasing the number of servers reduces the latency of the distributed locale server architecture significantly compared to the optimal central server when there is a physical/virtual world correlation. Specifically, with a reasonable number of servers, the distributed locale server architecture can reduce the delay of the central server by 20% to 60%.

In the distributed proxy architecture, players are assigned to a close proxy and each proxy manages the audio mixing operation on behalf of players and forwards audio streams from players to other interested proxies. This thesis develops an ILP model for an optimal proxy assignment and adapts the multi-layer graph approach used earlier to devise a greedy heuristics for solving the proxy assignment problem efficiently. While the ILP model is unscalable, the greedy heuristics is highly scalable and suitable for practical implementation. This thesis also investigates the efficiency of network multicast in different player and avatar distribution scenarios. The effect of varying the number of proxies is also investigated.

Extensive simulation experiments are carried out to evaluate the performance of all delivery architectures. In particular, since the distributed locale server architecture and the distributed proxy architecture are ‘dual’ of each other, we concentrate on comparing the performance of these. From the performance evaluation, we provide recommendations on choosing suitable delivery architectures based on the server resource availability, multicast, and game’s avatar aggregation behaviors. The quantitative study in this thesis will be of benefit to future immersive voice service providers in the design of a cost effective delivery architecture for this service.

Finally, the thesis presents a resource management architecture for sharing processing resources among various real-time content creation applications including the immersive audio mixing application. Due to the inability of determining processing times for scheduling, a processing resources scheduling algorithm called Start-time Weighted Fair Queueing (SWFQ) is proposed. From analysis and simulation, it is shown that SWFQ offers good fairness and delay properties compared to current schemes. In fact, the fairness of SWFQ was comparable to Weighted Fair Queueing (WFQ) and the delay behavior is better than Start-time Fair Queueing (SFQ).

# Statement of Originality

This is to certify that the work described in this thesis is entirely my own work, except where due reference is made in the text. I also acknowledge the guidance from my supervisors and ideas generated from discussions with them in this work.

No work in this thesis has been submitted for a degree to any other university or institution.

Signed

Cong Duc Nguyen

1 May, 2006



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# List of Abbreviations

ADPCM	Adaptive Differential Pulse Code Modulation
AS	Autonomous System
API	Application Program Interface
ASIC	Application-Specific Integrated Circuit
ATM	Asynchronous Transfer Mode
BGP	Border Gateway Protocol
CDN	Content Distribution Network
CPU	Central Processing Unit
CVE	Collaborative Virtual Environment
DiffServ	Differentiated Service
DNS	Domain Name Server
FEC	Forward Error Correction
FPS	First Person Shooter
FPGA	Field Programmable Gate Array
FIB	Forwarding Information Base
GPS	Generalized Processor Sharing
GT-ITM	Georgia Tech Internet Topology Model
HRTF	Head Related Transfer Function
HTTP	Hypertext Transfer Protocol
ICMP	Internet Control Message Protocol
IETF	Internet Engineering Task Force
ILP	Integer Linear Programming
IP	Internet Protocol
IPSec	IP Security Protocol
ISP POP	Internet Service Provider Point of Presence

---

LAN	Local Area Network
LPC	Linear Predictive Coding
LDD	Latency Driven Distribution
MMOG	Massively Multi-Player Online Games
MPLS	Multi-Protocol Label Switching
NP	Network Processor
NS-2	Network Simulator version 2
OSPF	Open Shortest Path First
PGPS	Packet Generalized Processor Sharing
PVN	Programmable Virtual Network
QoS	Quality of Service
RDD	Resource Driven Distribution
RFC	Request For Comment
RON	Resilient Overlay Network
RSVP	Resource Reservation Protocol
RTP	Real Time Transport Protocol
SFQ	Start-Time Fair Queueing
SON	Service Overlay Network
SPF	Shortest Path First
SIP	Session Initiation Protocol
SWFQ	Start-Time Weighted Fair Queueing
SWON	Switched Overlay Network
TCP	Transmission Control Protocol
UDP	User Datagram Protocol
VO	Virtual Organization
VPN	Virtual Private Network
WAN	Wide Area Network
WFQ	Weighted Fair Queueing