Abstract

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RESOURCE ALLOCATION AND PRICING FOR QOS MANAGEMENT IN COMPUTER NETWORKS.
(Under the direction of Douglas S. Reeves)

Computer networks must accommodate a wide variety of applications, ranging from simple file transfer programs to complex multimedia applications. Many of these applications require certain Quality of Service (QoS) guarantees for their proper operation. QoS guarantees include bounds on the packet delay, delay variation and loss rate. These guarantees can be provided through the allocation of network resources such as, processor time, buffer space and link bandwidth. Properly allocating network resources remains a challenging problem due to the number of users, diversity of network applications and the finite supply of resources. Furthermore, these resources are expected to have costs associated with their usage (amount and renegotiation). Given this environment, two important resource allocation issues are addressed in this thesis. First, methods are needed to reduce the amount of resources and renegotiations required to provide a desired QoS (thereby reducing the cost and increasing the utilization). Second, network administrators are interested in allocating and managing resources to all users in an efficient and fair manner.

Determining an efficient amount of network resources that will result in a desired QoS is difficult for certain sources, due to their unpredictable behavior and limited a priori source information. Such applications include the transmission of, MPEG-compressed video, live video and interactive multimedia. In this thesis, an allocation method called Dynamic Search Algorithm (DSA+) is introduced. DSA+ is an on-line algorithm that dynamically adjusts the resource allocation based upon the measured QoS. Advantages of DSA+ include efficient use of resources, few renegotiations, reasonable implementation cost, and stringent QoS control. The ability of DSA+ to allocate bandwidth to meet a desired cell loss probability is investigated and analyzed via simulation using generated (MMBP) and actual MPEG-compressed videos. Advantages of DSA+ over other allocation methods, the robustness to initial parameter selection and the ability to allocate for multiple hop connections are presented.

Network managers seek to allocate resources, to all users, in an efficient and fair manner. In this thesis, microeconomic-based allocation techniques are introduced that model the network as an economy, consisting of separate and independent competitive markets. In these markets, switches price their link bandwidth based on supply and demand, and users purchase bandwidth to maximize their individual QoS. Two different types of markets are used to allocate resources: the spot market and the reservation market. The reservation market provides users the advantage of bandwidth ownership over a period of time, while the bandwidth sold in the spot market has the advantage of immediate availability (no reservation overhead). These decentralized state-less allocation methods can provide efficient and fair allocations of bandwidth as well as guarantees of resource availability. Proofs of important microeconomic and standard computer network measures of fairness are presented, as well as price stability. The performance of these resource allocation methods are also investigated and analyzed using simulations with various network configurations and actual MPEG-compressed videos. Results indicate that these microeconomic-based resource allocation methods achieve high utilization, optimal allocations and provide better QoS than other allocation techniques.

RESOURCE ALLOCATION AND PRICING FOR QOS MANAGEMENT IN COMPUTER NETWORKS

by

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A thesis submitted to the Graduate Faculty of
North Carolina State University
in partial fulfillment of the requirements for the degree of
Doctor of Philosophy

COMPUTER ENGINEERING

Raleigh

1999

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To my wife, my parents and my brother

Biography

Errin W. Fulp earned his BS in Mechanical Engineering from North Carolina State University in 1991, followed by a MS in Computer Science in 1994. During this time he was employed by the Computer Science Department at North Carolina State University as a lecturer and course coordinator. He also authored a textbook and consulted for Prentice Hall Publishers. In 1994 he began work on a Ph.D. in Computer Engineering at North Carolina State University. At the end of his first year of study, he worked as a research assistant under the direction of Dr. Douglas S. Reeves. During his Ph.D. studies he also worked as a research assistant at the NEC C&C Research Laboratories in Princeton, NJ. This research has resulted in various publications and patents filed in the US and Japan. Errin W. Fulp is a member of the Phi Kappa Phi and Upsilon Phi Epsilon honor societies, and is a proud member of TUG.

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Chapter 3 Dynamic Search Algorithm, (DSA+)

t_n	Renegotiation instant n
A_n	Number of cell arrivals during interval n
I	DSA+ interrupt interval
K	DSA+ rate adjustment constant
L_n	Number of cell losses during interval n
$P_{0...n}$	Cumulative cell loss probability of intervals 0 through n
Q_l	Desired cell loss probability
U_n	Update interval n
μ_n	Server rate during interval n

Chapter 5 Competitive Market Model

b^j	Maximum desired resource amount for consumer j
h, i	Market indices
j, k	Consumer indices
p^i	Price of market i
p^i_*	Equilibrium price for market i
q^i_*	Utility for all consumers in market i
s^i	Resource supply of market i
$u^j(\cdot)$	Utility function for consumer j
$\bar{v}^i(\cdot)$	Aggregate inverse utility function for market i
w^j	Wealth of consumer j
A	Set of all consumers in the economic model
A^i	Set of consumers who participate in market i
C^i	Set of consumers who are completely satiated with market i
L	Set of all markets in the economic model
N^i	Set of consumers who are non-satiated with market i
R^j	Set of markets consumer j participates in

Chapters 6 and 7 Spot Market and Multi-Market Approaches to Multi-User Allocation

b^j	....	Maximum desired bandwidth amount for user j
d_n^i	....	The total demand for link i spot bandwidth at the end of interval n
e^j	....	Maximum amount of reserved bandwidth used by user j
$g_m^{i,l}$	......	The mth reservation market auction price for segment l at link i
$h_m^{i,l}$	......	The sum of the reservation bids for segment l at the end of the mth auction update interval of link i
i	....	Link index
j	....	User index
p_n^i	....	The spot market price for link i during interval n
p_*^i	....	Equilibrium spot market price for link i
s^i	....	Total bandwidth supply of link i
t_n^i	....	The nth spot market time instant at link i
$u^j(\cdot)$	.....	Utility function for user j
w^j	....	Wealth of user j
x^j	....	The bid for reserved bandwidth of user j
y^j	....	The amount of spot bandwidth to purchase for user j
G^i	....	Auction update interval for link i
P_n^i	....	The nth spot market price interval for link i
R^j	....	Set of links in the route of user j
T^i	....	The reservation segment length of link i
W^j	......	Total wealth of user j
α^i	....	Constant for the modified tâtonnement process (spot market) of link i
β^j	....	Percentage of link bandwidth sold in the reservation market of link i