

Annual Report for Period: 09/1999 - 05/2000

Submitted on: 06/01/2000

Principal Investigator: Elmagarmid, Ahmed K.

Award ID: 9972883

Organization: Purdue Research Foundation

CISE Research Infrastructure: MSI: A Research
Computing Environments

Infrastructure for Integrated Quality of Service Management in Multimedia

Project Participants

Senior Personnel

Name: Elmagarmid, Ahmed
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Korb, John
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Ghafoor, Arif
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Spafford, Eugene
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Park, Kihong
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Aref, Walid
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Fahmy, Sonia
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Prabhakar, Sunil
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Yau, David
Worked for more than 160 Hours: Yes
Contribution to Project:

Post-doc

Name: Lee, Heejo
Worked for more than 160 Hours: Yes
Contribution to Project:

Heejo Lee has begun preliminary work on ascertaining Cisco's network security framework for subsequent adaptation to the AdSec network

security architecture advanced in the project. Lee and Park (co-PI) have written a paper on probabilistic packet marking for distributed denial-of-service attack (DoS) prevention, which puts forth an effective technique for dealing with an important security and QoS threat.

Name: Hacid, M.

Worked for more than 160 Hours: Yes

Contribution to Project:

M. Hacid (Ph.D., Post-Doctorate) recently joined the MSI project. His main role will be to design and oversee the implementation of the QoP/QoS Interface.

Name: Fan, Jianping

Worked for more than 160 Hours: Yes

Contribution to Project:

Jianping Fan (Ph.D., Post-Doctorate) is pursuing his research in providing low-level support in video databases including, feature extraction, spatial and temporal segmentation, object detection and recognition, object motion tracking, and multimedia database indexing.

Graduate Student

Name: Hammad, Mustafa

Worked for more than 160 Hours: Yes

Contribution to Project:

Mustafa Hammad (Purdue Fellowship, Ph.D. student) is pursuing his research in developing access control mechanisms for video database systems both at the frame and object levels.

Name: Ilyas, Ihab

Worked for more than 160 Hours: Yes

Contribution to Project:

Ihab Ilyas (RA, Ph.D. student) is pursuing his research in developing multimedia indexing techniques to support fast content-based retrieval of multimedia objects in the context of video databases.

Name: Rezgui, Abdoulmounaam

Worked for more than 160 Hours: Yes

Contribution to Project:

Abdoulmounaam Rezgui (RA, Ph.D. student) is pursuing his research in developing scalable multimedia servers that support real-time streaming of video data, quality of service, and quality of presentation.

Name: Terzi, Evimaria

Worked for more than 160 Hours: No

Contribution to Project:

Evimaria Terzi (RA, Ph.D. student) will begin as an RA on the multimedia database project in August 2000.

Name: Fahmi, Husni

Worked for more than 160 Hours: Yes

Contribution to Project:

Husni Fahmi (RA, Ph.D. student) is pursuing his research in developing the overall framework for RTDMDS to allow searching and retrieval of distributed multimedia documents, using the extended Petri-net model. He is being trained in the area of resource scheduling in a distributed multimedia environment.

Name: Al-Khatib, Wasfi

Worked for more than 160 Hours: Yes

Contribution to Project:

Wasfi Al-Khatib (RA, Ph.D. student) is pursuing his research and is being trained in the area of multimedia databases. In particular, he has developed models for indexing and content-based retrieval of video data. He has published papers in several conferences and journals.

Name: Latif, Muddasar

Worked for more than 160 Hours: Yes

Contribution to Project:

Muddasar Latif (RA, M.S. student) is pursuing his MS thesis in multimedia document delivery over the Web. He is involved in the development of different modules of RTDMDS.

Name: Shafiq, Basit

Worked for more than 160 Hours: Yes

Contribution to Project:

Basit Shafiq (RA, M.S. student) is pursuing his MS thesis in multimedia document modeling and search mechanism. He has completed the development of several modules for RTDMDS. Currently, he is pursuing his work on the integration aspects of heterogeneous multimedia databases.

Name: Joshi, James

Worked for more than 160 Hours: Yes

Contribution to Project:

James Joshi (RA, Ph.D. student) is pursuing his research in the area of multimedia database security. Currently he is developing a framework that will allow integration of heterogeneous security and access control mechanisms in a distributed multimedia document environment. The framework will integrate both Role-Based Access Control (RBAC) models and Task-Based Access Control (TBAC) models.

Name: Chari, Rahul

Worked for more than 160 Hours: Yes

Contribution to Project:

Rahul Chari (RA, Ph.D. student) is developing a simulator for the storage management aspects of MSI, and developing and testing alternative schemes.

Name: Xia, Y.

Worked for more than 160 Hours: Yes

Contribution to Project:

Y. Xia is a graduate student working on an independent study project in the storage area.

Name: Li, Jiangtao

Worked for more than 160 Hours: Yes

Contribution to Project:

Jiangtao Li (RA, Ph.D. student) is implementing different storage management schemes for their testing and evaluation.

Name: Chen, Shaogang

Worked for more than 160 Hours: Yes

Contribution to Project:

Shaogang Chen (RA, Ph.D. student) has graduated May 2000, with his Ph.D. dissertation 'Stratified Best-effort QoS Provisioning in Noncooperative Networks' advancing the state-of-the-art in the area. Chen has joined CPlane, a start-up company that focuses on QoS and network management switching products.

Name: Cruz, John

Worked for more than 160 Hours: Yes

Contribution to Project:

John Cruz (RA, Ph.D. student) has performed end system scheduling work for end-to-end QoS using, in part, the Purdue Infobahn network QoS infrastructure.

Name: Ren, Huan

Worked for more than 160 Hours: Yes

Contribution to Project:

Huan Ren (RA, Ph.D. student) has published two recent papers on differentiated services QoS with a third paper presently in submission.

Name: Tuan, Tsunyi

Worked for more than 160 Hours: Yes

Contribution to Project:

Tsunyi Tuan (RA, Ph.D. student) has published one journal paper, one book chapter, and two conference papers based on traffic control work related to the project.

Undergraduate Student

Name: Stanton, Spencer

Worked for more than 160 Hours: Yes

Contribution to Project:

Spencer Stanton (senior) did an independent study with Park (co-PI) in the spring semester where he assisted graduate students with implementing the MPEG audio part of AFEC for Optibase real-time compression board under Windows NT.

Organizational Partners

Cisco Systems Inc

Clarian Health

Indiana University Medical School

Florida A&M University

Indiana Health Industry Forum

Med Institute

Methodist Hospital of Indiana Inc

Micro Data Base Systems Inc

Ohio State University

Siemens Corporate Research

Spelman College

University of Delaware

University of Notre Dame

Other Collaborators or Contacts

Fred Baker (Cisco)

E. Bertino (University of Milan)

Jennifer Hou (Ohio State University)

Andrea Lawrence (Spelman College)

Peiya Liu (Siemens Corporation)

Jon Reid (MDBS)

A. Vakali (University of Patras)

V. Verykios (Drexel University)

Deidre Williams (Florida A&M University)

Ashfaq Khokhar (University of Delaware)

Activities and Findings

Project Activities and Findings:

We are pleased to report great strides in several areas. We have ordered most of the equipment on schedule for the first year, we have been successful in getting the proper staffing, and we have started involving faculty and students from historically black colleges and universities in our research activities. We have also been successful in leveraging the NSF CISE RI funds in several significant and noticeable ways.

Equipment purchases to date, summarized by project area, include:

Networking		
Cisco routers (4) for QoS experiments		\$100,520
Intel workstations (9)		20,135
Sun workstation		3,829
Databases and Storage		
Sun E450/A1000 database server		53,197
Intel-based storage server engine	4,905	
Dell-based multimedia proxy servers (3)		20,858
Image Compression		
SGI high resolution display	2,335	
Applications		
Futuretel MPEG-2 encoder	5,520	
Sony camcorder		3,429
Laptop computers (3) for distance learning	10,146	
Workstation/printer accessories		1,062
Total		\$225,936

We have been extremely successful in obtaining research funds and grants from numerous sources. Noted among them is our recently awarded grant from the State of Indiana for supporting faculty and graduate students to conduct research and experimental development of a multimedia system for the telemedicine application. These funds are in direct support of this effort. The total funding from the State is over \$1.7 million for two years, starting February 1, 2000.

In addition, we have received the first year of cost sharing promised by Telcordia and we are in the process of obtaining the second year of funding. We have also established research collaboration in the area of multimedia document delivery with Siemens Corporation.

We have also received internal funding from the Center for Education and Research in Information Assurance and Security (CERIAS) to support one post doctoral fellow, a visiting scholar, and two graduate research assistants.

We are also pleased to report that our group has recently received two large grants, one from NCR/Wal-Mart and the other from Hewlett Packard (HP). The NCR grant is an unprecedented 1.6 terabyte parallel database engine valued at approximately \$7 million. This system will help augment the other storage and compute servers we are purchasing through the NSF grant. This state-of-the-art parallel server has 80 processors and 400 disk drives. The grant from HP allows us to have 20 workstations and one server to use as desktops for the researchers in this project. The NCR machine arrived on campus in late April and the HP machines are scheduled to arrive at the beginning of June.

The remainder of this section highlights specific activities in each of the three major areas of the project: multimedia databases and storage management systems, networking, and security.

Multimedia Databases and Storage Management Systems

À We have designed an architecture for a real-time distributed multimedia database system (RTDMDS) for managing multimedia documents with Quality of Service (QoS) guarantees. This system is one of the key components of MSI. The system allows distributed users to author, store, query, and retrieve multimedia documents over a broadband network. We have developed several modules of RTDMDS and continue the development of the whole system using the equipment acquired through the NSF grant.

À We are pursuing research issues related to the development of individual media databases. In particular, we are pursuing activities aimed at developing a video database to allow content-based retrieval and indexing of large-scale video data as a critical component of multimedia document management system.

À For physical storage management of multimedia documents, we have designed several novel data placement and scheduling schemes. These schemes are currently being implemented on a Sun E450 server and a Sun A1000 Raid array, acquired through the NSF grant. Also, for

video data, due to its unique temporal nature, we are analyzing several techniques for real-time disk scheduling.

À Currently, we are exploring different approaches that will allow mapping of the user-specified Quality of Presentation (QoP) parameters to Quality of Service (QoS) requirements for different system components of the overall MSI architecture, including storage, servers, networking and security subsystems. The implementation of the translation mechanisms will be an integral part of the QoS-based resource scheduling modules that will be implemented using several dynamic and static approaches.

Networking

À We have set forth a new unified theory of differentiated services that is implementable on IP networks. It improves on our earlier work on QoS scheduling, facilitating a theory of aggregate-flow QoS control.

À We have benchmarked the new architecture and theory using QSim, our ns-based WAN QoS simulator, confirming the theoretical predictions. Our work shows that differentiated services, following our architecture, can provide scalable and efficient user-specified services.

À We have installed Purdue Infobahn comprised of, presently, four Cisco 7206 VXR routers that form an IP-over-SONET QoS backbone. We have implemented initial signaling and end-to-end controls using both RSVP (Int-Serv) and AS (Diff-Serv) to ascertain the routers' operating capabilities.

Security

À We are focusing our efforts to build security-based access control mechanisms for video and multimedia databases. For video databases, we are currently developing an access control system on top of a video database system. At the higher levels, we are developing an access control model that specifies the users' credentials and qualifications as well as the content description of the underlying video. On the other hand, at the lower levels, we are building a toolbox for extracting desired features from the underlying video streams. For multimedia document system, we are developing a security framework to allow integration of heterogeneous access control policies in a distributed environment.

À We have advanced and analyzed a denial-of-service (DoS) attack prevention framework based on probabilistic packet marking (PPM), and shown its effectiveness in the presence of single-source DoS attacks. We have used an adversarial framework to derive solutions to optimal decision making in a 2-player environment comprised of the attacker and victim/target.

À We have investigated the distributed DoS attack problem under PPM and general network topologies where the attacker can pick the location and number of attack hosts. We have shown that uncertainty factor amplification --- a measure of the attacker's ability to hide his true location(s) --- is achievable by reducing the attack volume at each individual attack site.

À We have investigated the network security architecture of Cisco's router operating system IOS with the aim of incorporating the adaptive security architecture AdSec into its structure.

Project Training and Development:

The findings in this section are organized according to the three major areas of the project: multimedia databases and storage management systems, networking, and security.

Multimedia Databases and Storage Management Systems

À We have expanded our earlier proposed Petri-net based model for composing multimedia document to allow specification of user level QoP parameters and content information of individual media in a document. The enhanced model has several desired features that facilitate content based retrieval of documents, determination of system-wide resource requirements to guarantee QoS, and implementation of stream scheduling mechanisms for storage and server subsystems.

À For content-based retrieval and indexing of large-scale video databases, we have proposed an approach for automatically extracting video contents from the underlying video directly without relying on any annotations to be provided by the viewers of the video. We have also proposed and implemented several novel algorithms for low-level processing of video frames for their spatial segmentation. We have developed new indexing techniques beyond B-trees and R-trees that are more suitable for spatio-temporal and high-dimensional object indexing.

À For the storage management of multimedia documents, we have developed several novel data placement and scheduling schemes that exploit the timing relationship between the multimedia components that make up the documents, as well as the patterns of access. We are

currently analyzing schemes to determine the appropriate configuration for the storage hierarchy and data migration policies. For video storage management, we have developed techniques for progressively changing the spatial and temporal resolution of video to make best use of the available bandwidth and to get the best possible presentation quality.

Networking

À Advance foundations of effective differentiated services architecture. We have developed a framework for reasoning about the 'goodness' of various differentiated services architectures, which considers both the per-hop behavior (PHB) and edge control parts when provisioning user-specified QoS-sensitive network services. In the PHB part, we have formulated the problem of optimal aggregate-flow per-hop behavior and solved it by showing the optimal aggregate-flow classifier that dominates all other per-hop behaviors with respect to both efficiency and fairness. We have shown that the optimal aggregate-flow classifier--implementable over IPv4 and IPv6 in modern routers and performing stateless per-hop control scheduling in linear time--satisfies certain properties (called (A1), (A2), and (B)) which allows desired end-to-end QoS to be achieved using edge control, both open-loop and closed-loop. Our framework, analysis machinery, and tools allows pressing questions such as 'what is the loss of power due to flow aggregation?', 'what is the impact of a discrete, bounded label set (DSCP in the DS field) on QoS?', 'what edge control can achieve setting of end-to-end TOS label values to achieve system optimal QoS?' to be answered both qualitatively and quantitatively. We have benchmarked the architecture over QSim, an ns-based WAN QoS simulation environment, and shown that optimal aggregate-flow per-hop behavior can export efficient differentiated services commensurate with user requirements.

À Configure Purdue Infobahn QoS Testbed and perform initial tests and exploratory implementations. As a starting point to implementing a full-fledged version of our optimal aggregate-flow classifier inside Cisco 7206 VXR routers with system support from Cisco, we have implemented end-to-end signaling controls, both for current IETF Diff-Serv specifications (i.e., Assured Service) and IETF integrated services (Int-Serv) using RSVP. Our end-to-end signaling platform can be adapted, with modular changes, to the optimal aggregate-flow per-hop control architecture advanced in our theoretical and simulation work. We have tested the real-time scheduling and switching capabilities of a network of Cisco 7206 VXR routers connected as an IP-over-SONET internetwork with 100 Mbps network interfaces tapping end station PCs -- serving both as QoS end points and traffic generators -- and ascertained their operating dimensions and properties with respect to yielding predictable performance. The latter include saturation effects stemming from processor scheduling and software switching overhead at the router. We are in the process of implementing the first version of optimal aggregate-flow PHB inside Cisco 7206 VXR routers, which will then be tested with respect to its QoS provisioning properties when incorporating all software and processing overheads associated with routers and end stations.

À Advance end-to-end traffic control for QoS shaping. We have developed and implemented end-to-end QoS amplification techniques using adaptive packet-level forward error correction and multiple time scale traffic control. Adaptive FEC (AFEC) allows invariant end-to-end QoS to be exported over variable network conditions stemming from shared bottleneck routers and congestion effects. Since differentiated services-even in the presence of optimal aggregate-flow PHB-is subject to occasional variability due to imperfect QoS protection resulting from abstaining from per-flow reservation and admission control, AFEC can provide QoS amplification over varying degrees of imperfect QoS channels which can further improve the operating range and usefulness of differentiated services on top of scalability. We have advanced the multiple time scale (MTS) traffic control framework that exploits large time scale correlation structure present in bursty-in particular, self-similar-network traffic for traffic control purposes. An important consequence of MTS traffic control is the ability to mitigate the cost of feedback traffic controls in high delay-bandwidth product networks that which is especially pronounced in high-bandwidth wide area networks. By exploiting predictability structure resident at time scales exceeding the round-trip time (RTT) or feedback loop by an order of magnitude or more, timeliness of reactive can be achieved by bridging the 'uncertainty gap' inherent in reactive actions. Thus, MTS traffic control facilitates a much needed measure of proactivity, which, in turn, facilitates scalable end-to-end traffic and QoS control. MTS traffic control has been implemented both for QoS (a multiple time scale extension of AFEC called AFEC-MT), and throughput maximization for TCP (MTS extension called TCP-MT over Reno, Tahoe, and Vegas) and rate-based control for ATM. Multiple time scale redundancy control (i.e., AFEC-MT) has been benchmarked over UDP/IP internetworks that transport real-time MPEG I & II video and audio. The systems run both for UNIX and Windows NT. In the latter, the sender interfaces with a real-time MPEG compression board (Optibase I for MPEG I video/audio and Futuretel for MPEG II video/audio), which is fed by high-end digital and analog video cameras.

Security

À For video databases, we have developed an access control mechanism that can allow different users to view different contents based on their qualifications and credentials. The units of access control can either be a sequence of one or more frames, or parts of a frame, e.g., objects in a frame. For multimedia document system, we have developed a Petri-net based model for role-based access control mechanism that allows selective viewing of different parts of document by authorized users.

À We have advanced a framework for probabilistic packet marking for distributed denial-of-service attack (DoS) prevention which puts forth an effective technique for dealing with an important security and QoS threat. Instead of logging path information at routers which makes traceback of DoS attack overhead-prone and ineffective in high-speed networks where routers are expected to switch at Gbps or higher rates, the complexity is pushed to the edge following the end-to-end paradigm, and 'logging' is carried out by probabilistic sampling of path

information in an end-to-end manner. This method can be easily implemented in IP routers. Our work provides a comprehensive analysis of the power of probabilistic packet marking (PPM) with respect to DoS, both single-source and distributed. We use a 2-player adversarial framework to analyze the minimax and maximin optimal strategies of the attacker and victim, and show that PPM is effective at preventing DoS attacks. We show using numerical results the outcome of optimal strategies when using typical Internet based configurations including hop count, topology, spoofing, and marking probability.

Research Training:

The advanced multimedia course 'Multimedia Information Systems' taught by Ghafoor (co-PI) in Fall 1999 used the multimedia database servers (video data server) and exposed graduate students to state-of-the-art multimedia database and document management techniques.

The exploratory advanced networking course 'Multimedia and High-Speed Networks' taught by Park (co-PI) in Spring 2000 used the evolving Purdue Infobahn QoS Testbed, and exposed graduate students to state-of-the-art network QoS techniques and implementations.

Outreach Activities:

Our outreach efforts have been more successful than we anticipated in the proposal. We have been able to involve four HBCUs instead of only one originally. Our efforts have been in getting faculty and students from Fisk, Florida A&M, Spelman, and Morehouse to get involved in this research project. To this end, we have organized a workshop for department heads at these schools at Purdue on May 22, 2000. We have plans underway for a larger summer program to be held next May. The summer program has been finalized during our May 22nd meeting. It will be composed of four parts:

- À A two week workshop at Purdue to be held May 21 to June 1, 2001. This workshop will be attended by faculty representatives from each of the participating schools and up to five students from each institution. The two week program will consist of five two-day short courses: intensive review of programming languages and systems, database systems, computer networking, security, and multimedia computing. These courses will be taught by Professors Korb, Elmagarmid, Park, Spafford, and Ghafoor, respectively.
- À Summer internships will be arranged for students from the workshop with Telcordia Technologies for the entire summer.
- À Faculty from Purdue and faculty from the participating schools will visit periodically with the students during their internship.
- À We will encourage students to apply to the masters and Ph.D. programs at Purdue.

Three additional programs have also evolved out of our workshop on May 22, 2000:

- À Joint weekly seminar: Purdue will help the participating institutions to develop capabilities to attend a weekly seminar using video conferencing. The goal is to allow students and faculty at the participating institutions to attend the 'Advances in DBMS' weekly seminar. This will be first attempted in the fall semester to start in August 2000. Some institutions in close proximity will be encouraged to share the site such as Spelman and Morehouse.
- À Joint colloquia program: Purdue faculty will periodically visit participating institutions and faculty from those institutions will be encouraged to visit Purdue to give seminars on research topics related to the subject of this project.
- À Invite participating institutions to participate in our Web portal currently under development using state funding.

Kihong Park has interacted with members of the Santa Fe Institute in the capacity of Fellow-at-Large. Park is also organizing a workshop at the Santa Fe Institute (for February 2001) called 'The Internet as a Complex System', which looks at scaling, performance, and control issues related to the Next Generation Internet. It is a by-invitation only meeting, and selected contributions will be published by Oxford Press as part of the SFI book series.

Journal Publications

- J. Cruz and K. Park, "Towards performance-driven system support for distributed computing in clustered environments", *Journal of Parallel and Distributed Computing*, p. 132, vol. 59, (1999).) Published
- K. Park, M. Sitharam, and S. Chen, "Quality of service provision in noncooperative networks with diverse user requirements", *Decision Support Systems, Special Issue on Information and Computation Economics*, p. 101, vol. 28, (2000).) Published
- T. Tuan and K. Park, "Multiple time scale congestion control for self-similar network traffic", *Performance Evaluation*, p. 359, vol. 36, (1999).

) Published

- F. Kokkoras, H. Jiang, I. Vlahavas, A. K. Elmagarmid, E. N. Houstis, and W. Aref, "Smart Video Text: An Intelligent Video Database System", *Journal of ACM Multimedia Systems*, p. , vol. , ().) Accepted
- S. Dagtas, W. Al-Khatib, R. L. Kashyap, and A. Ghafoor, "Motion Modeling and Indexing of Video Data", *IEEE Transactions on Image Processing*, p. 1, vol. , (2000).) Published
- W. Aref, I. Kamel, and S. Ghandeharizadeh, "Disk Scheduling in Video Editing Systems", *IEEE Transactions on Knowledge and Data Engineering*, p. , vol. , (2000).) Accepted
- Jianping Fan, Walid G. Aref, and A. Rezgui, "Adaptive Motion-Compensated Video Coding Scheme Towards Content-Based Bit Rate Allocation", *Journal of Electronic Imaging*, p. , vol. , (2000).) Accepted

Books or Other One-time Publications

- P. Liu and A. Ghafoor, "Multimedia Document Systems: A Perspective", (1999). *Book*, Published
 Editor(s): P. Liu and A. Ghafoor
 Bibliography: Kluwer Academic Publishers
- S. Chen, "Stratified Best-effort QoS Provisioning in Noncooperative Networks", (2000). *Thesis*, Published
 Bibliography: Purdue University
- S. Chen and K. Park, "An architecture for noncooperative QoS provision in many-switch systems", (1999). *Proceedings*, Published
 Collection: INFOCOM '99
 Bibliography: IEEE
- K. Park, "Future directions and open problems in performance evaluation and control of self-similar network traffic", (2000). *Book Chapter*, Published
 Collection: Self-Similar Network Traffic and Performance Evaluation
 Bibliography: Wiley-Interscience
- K. Park and W. Wang, "QoS-sensitive transport of real-time MPEG video using adaptive forward error correction", (1999). *Proceedings*, Published
 Collection: Multimedia Systems '99
 Bibliography: IEEE
- K. Park and W. Willinger, "Self-Similar Network Traffic and Performance Evaluation", (2000). *Book*, Published
 Editor(s): K. Park and W. Willinger
 Bibliography: Wiley-Interscience
- K. Park and W. Willinger, "Self-similar network traffic: An overview", (2000). *Book Chapter*, Published
 Editor(s): Self-Similar Network Traffic and Performance Evaluation
 Bibliography: Wiley-Interscience,
- H. Ren and K. Park, "Toward a theory of differentiated services.", (2000). *Proceedings*, Accepted
 Collection: International Workshop on Quality of Service
 Bibliography: IEEE/IFIP
- H. Ren and K. Park, "Efficient shaping of user-specified QoS using aggregate-flow control", (2000). *Proceedings*, Accepted
 Collection: International Workshop on Quality of Future Internet Services
 Bibliography: Lecture Notes in Computer Science
- T. Tuan and K. Park, "Multiple time scale redundancy control for QoS-sensitive transport of real-time traffic", (2000). *Proceedings*, Published
 Collection: INFOCOM '00
 Bibliography: IEEE
- T. Tuan and K. Park, "Congestion Control for self-similar network traffic", (2000). *Book Chapter*, Published
 Collection: Self-Similar Network Traffic and Performance Evaluation
 Bibliography: Wiley-Interscience

Husni Fahmi, Walid G. Aref, Muddasar Latif, and Arif Ghafoor, "Distributed Framework for Real-Time Multimedia Object Communication", (2000). *Proceedings*, Published

Collection: Third International Symposium on Object-Oriented Real-Time Distributed Computing

Bibliography: IEEE

Jianping Fan, Walid G. Aref, and A. Rezgui, "Automatic Object-Oriented Segmentation and Conceptual Modeling Algorithm towards Content-Based Representation", (2000). *Proceedings*, Accepted

Collection: International Conference on Visual Communication and Image Processing

Bibliography: Unknown

Elisa Bertino, Mostafa Hammad, Walid G. Aref, and Ahmed Elmagarmid, "Access Control in Video Database Systems", (2000). *Proceedings*, Submitted

Bibliography: Unknown

W. Aref and I. Ilyas, "The SP-Tree: A generalized space-partitioning Indexing structure", (2000). *Proceedings*, Submitted

Bibliography: Unknown

W. Aref and William J. McIver, "Indexing Techniques for Video Database Systems", (2000). *Survey Article*, Submitted

Bibliography: Unknown

S. Dagtas and A. Ghafoor, "Indexing and Retrieval of Video Based Spatial Relation Sequences", (1999). *Proceedings*, Published

Collection: Multimedia '99

Bibliography: ACM

W. Al-Khatib and A. Ghafoor, "An Approach for Video Data Modeling and Query Processing", (1999). *Proceedings*, Published

Collection: Multimedia '99

Bibliography: ACM

Web/Internet Sites

URL(s):

<http://www.cs.purdue.edu/msi>

Description:

The MSI site, currently under construction, connects all the researchers and associated organizations working on this project. Additional URLs, linked from the MSI web page above, include...

Indiana Telemedicine Incubator

<http://www.cs.purdue.edu/icds/iti>

Indiana Center for Database Systems

<http://www.cs.purdue.edu/icds>

Distributed Multimedia Systems Lab

<http://shay.purdue.edu/~dmultlab>

Network Systems Lab

<http://www.cs.purdue.edu/nsl>

Other Specific Products

Contributions

Contributions within Discipline:

The RTDMDS architecture for the MSI framework is based on some of the most advanced techniques and models developed for multimedia document management and content-based retrieval of multimedia information. In particular, several novel techniques have been proposed by the PIs for the QoP-based specification of complex multimedia objects, video data modeling for efficient searching and querying of multimedia data and access control mechanisms for multimedia database systems. These techniques have the potentials of significantly advancing the Web-based multimedia information technology. In addition, the new techniques for multimedia storage management and access control will allow the development of high performance secure Web-based multimedia servers.

The network QoS architecture contains the some of the most advanced theory developed for differentiated services, with the potential to impact the design and implementation of the Next Generation Internet.

Contributions to Other Disciplines:

Several science and engineering disciplines can considerably reap the benefits from our research related to the MSI framework. In particular, the results and the products from the RTDMDS architecture can be directly extended to the GIS-based applications for the civil engineering discipline, to electronic publication and management of manuals and documents in industrial and mechanical engineering, and to telemedicine and digital library related science and engineering disciplines.

The optimal aggregate-flow switching theory in the networking area significantly advances the state-of-the-art in scheduling (electrical engineering, operations research, industrial engineering, applied mathematics), and the network QoS game theory advances the state-of-the-art in noncooperative game theory (economics, management science, applied mathematics).

Contributions to Human Resource Development:

Both our graduate students (Ph.D. and Master's) and undergraduate students get exposed to cutting edge material, encompassing both theory and implementation, related to the design and development of advanced multimedia database systems and broadband multimedia networking technologies. In the area of database the students learn the state-of-the-art techniques for storing, accessing, and delivery of multimedia documents in a distributed environment.

In the networking area, the leading edge research allows students to understand and experiment with the novel techniques needed for the design and development of the Next Generation Internet and its QoS provisioning architecture.

Contributions to Science and Technology Infrastructure:

Collaborative efforts, in particular, with industrial organizations foster technology transfer as well as collaborative research at the national and international scale. As a part of this project, we have been extremely successful in establishing collaboration with the several leading organizations that include Cisco, Sprint, Siemens, and many Indiana-based telemedicine and database companies. We also have close interaction with several academic organizations as listed at the beginning of the report.

Beyond Science and Engineering:

The success of the Next Generation Internet is one of the most pressing and important problems facing technological advancement of society today. The knowledge and experience gained from the network QoS project can have a significant impact on the development of the core international infrastructure critical to all other electronic infrastructures. The integration of secure multimedia document capabilities with this network infrastructure will have significant economic and social impact-and will help protect the environment by reducing our dependence on distribution media for videos, software, and data.

Special Requirements

Special reporting requirements: None

Change in Objectives or Scope: None

Unobligated funds: less than 20 percent of current funds

Animal, Human Subjects, Biohazards: None

Categories for which nothing is reported:

Any Product