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SCALABLE STREAM CODING FOR ADAPTIVE FOVEATION ENHANCED PERCEPT MULTIMEDIA INFORMATION COMMUNICATION FOR INTERACTIVE MEDICAL APPLICATIONS

Kent State University

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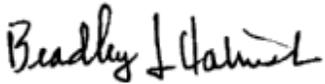
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13. ABSTRACT *(Maximum 200 Words)*
Project Perceptmedia is one of the few projects within the Active Network Initiative (ANI) to conduct a top down investigation into active networking from the point of view of realistically complex high performance applications. The project developed a suit of futuristic active applications based on the core idea of media transcoding. It then closely examined the issues if such complex active services were to run from network embedded router centric computing platforms contemplated in ANI. The demonstrated systems include interactive perceptual transcoding where real-time eye-tracker data fuses with a passing stream, the active subnet diffusion coding-- where multiple active nodes dynamically and adaptively aggregate to tackle intense tasks, and the active video content filtering and analysis. The research produced several novel algorithmic contributions to the field including the first algorithms for active computing mapping, jitter and delay reduction in active computing, and an IPV6 based novel mechanism for fast traffic interception. The project produced proof of concept implementations for almost all of these ideas.

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1. INTRODUCTION

The project PERCEPTRMEDIA is unique among all the ANI projects by not starting with any specific architecture for active networking. Rather, it begun the investigation from the point of view of a realistically complex and sufficiently sophisticated application and explored downward. It provided the valuable application driven perspective to understand the requirement at protocol, architectural and even at framework levels. The approach seems to be important because the marketplace of innovation in computing today is application driven. Architectures today are hardly defining applications-- but the reverse is becoming more common. A computing technology despite its intrinsic strength, tends to fail if it does not connect the 'last mile' to inspiring applications.

The approach brought several important contributions. The project has resulted not only one – but a suit of futuristic and exciting concept applications for active network[1]. All alone the project strived to produce visible proof of concept for all major ideas by direct implementation. Several of these are now available on the ABONE. The technical publications resulting from the project now document one of the most comprehensive application and system level performance analysis of active systems.

However, what is most important is the unique perspective offered by this top-down exploration helped to unearth a number of issues, which are central to the notion of active network framework, but which were not easy to see from other perspectives. A realistically complex service is seldom a simple system with one piece of code. Quite often there involve complex modules. There are dependencies between them each requiring various amount of computation and communication requirements. Not only is it complex because of its structure, also any network based complex service requires transactions and co-ordination between multiple parties-connected through multiple levels of provider subscriber relationship. The project demonstrated some pilot solutions to these formal issues for complex active services and applications. A series of publications and technical reports now documents the results. Below are some innovations that resulted from this project:

- **Self-Organizing Active Information Streaming:** Though the issue of *link adaptation* has been addressed before in various forms in networking research, this research for the first time investigates the issues, mechanics, and infrastructure support needed to *adapt with more general node resource* constraints with particular focus on computing. Indeed 'computation' is what is fundamentally novel in a flow in active networking. The impact of adding computing over the traditional solutions to problems such as optimum mapping of capsules to processing capable nodes, minimization of flow delay and jitter, redeployment and repositioning (over simple deployment), seamless capsule integration with minimum flow interruption, had not been addressed to this depth before. The project formalized, investigated and suggested potential solutions in each of the issues contributing to the general advancement of the field. The project was in the unique position to foresee and experiment with these issues because of the realistic complexity of the active system (including the application) it has been dealing with. A series of publications and technical reports document the technical detail of the idea and results [2,3,5,7,10,12].

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[1] In 1999, when the project began, transcoding was a novelty. In 2002, when project is finishing, at least some simple text transcoding has emerged as web based services. The media transcoding however, still remains a challenging frontier. However, its importance in the emerging web is beyond doubt.

- **Active Communication Harness:** An active generalization of SNMP, and a group communication ware for networked nodes. The approach first makes a clear separation between the "communication" from the "information" of the state exchange and propagation process. Both aspects are then individually programmable. It empowers any network layer algorithm or network aware applications. This has resulted from our need for resource mapping in the nomadic transcoding project. It is a potential permanent toolkit for the next generation of active net architecture at network layer. It will be useful for any network aware capsule and service. Publication [18] documents various technical details and the technical report [TR2003-01-02] shows its application in minimum spanning tree based power efficient communication.

- **Made-to-order Channels:** A Novel generalization of the classical socket API helps new type of applications to create custom channels with programmable communication services, including abilities for status polling, and event notification. Publications [4,5,6] document various technical details and sample MTO channel ideals.

- **TCP Interactive:** A new interactive version of TCP, which when there is a window resizing event, also can notify applications. The result is dramatic. Applications such as video coding schemes can adjust the original data volume and show no lost video even where TCP classic resulted in +50% frame loss. It provides a new dimension in current QoS research. Publications [1,9,11] document various technical details and the technical report [TR2003-02-02] shows its performance in worldwide video streaming on ABONE.

- **Active Intercept:** Any intelligent and dynamic processing of content requires stream intercept. However, if we look into the current protocol design, particularly the protocol packet structures we will see that it has little facility that enables efficient stream intercept. For example an H.261 video element may require access to 16 pre-dependent elements before the element of interest can be read. The problem has major implication on the CPU cycle, memory size, and overall performance of any intercepting appliance system's architecture. Essentially, the stream is the working data structure of a filtering system. In this research we investigated this new but important problem and demonstrated a novel content indexing scheme that can facilitate dynamic index based random access into streams and provide performance boost to intercepting filter like appliances. Publications [13, 14, 15, 16] and the technical reports [TR2002-08-02] document various technical details performance analysis on various active architectures.

- **Proactive Web Prefetching:** An active network experiment with web system. This is an interesting experiment to embed some intelligent proactivity inside the network between two communicating web entities. An actively embedded system intercepts HTTP request and response stream and selectively pre-fetches links. An active technology for realizing the surfers' dream (zero delay browsing on 14.4K line!). We demonstrated some very interesting results. Some ideas have been presented in the USENIX Internet Technologies, 2001 conference. See publications [21-24] for ideas presented on various active proxy based smart applications. See publication [14] where we discussed a generalized **content services network** (CSN) model that can support various network embedded transformation/filtering services.

Below are some additional details of the project's progress. While the project comes to an end, a number of initiatives have now emerged with different shades but continuing the core idea active networking pioneered, where the network is viewed as a federation of computing and communication resources. It includes Grid Computing, Automatic Computing, Applications Services Networking, etc. Many of the results are expected to find use in them transcending

beyond its original goal. Before we present the technical abstract of a few of the core innovations, we shortly present the project chronology.

2. TECHNICAL ABSTRACTS

2.1 THE BASE SYSTEM: ACTIVE PERCEPTUAL VIDEO RATE TRANSCODING

The project began with a proposition for a complex application, which was futuristic on its own right. The human vision offers a tremendous scope of data compression. Only about 2 degree in our about 140 degree vision span has sharp vision. The idea of eye-tracking integrated perceptual compression of image and video has fascinated many researchers for quite some time but any practical system was yet to emerge. As stated in the original proposal, one of the central objectives of this project was to first bring this idea into engineering realization with the help of active networking technology. Then apply it to build a self-organizing perceptual transcoder that can demonstrate network adaptation beyond any previously demonstrated system using the active network technology. The approach and computational complexity of the system also assured that if the above can be realized the transcoding system can also be used for arbitrary video transformation over active network. The project was successful. This DARPA funded project is to our knowledge is one of the first to implement the live perceptual video transcoding system and to pioneer the solutions to some hard technical challenges that came along the way.

A unique challenge in real time eye-gaze based perceptual video streaming is how to handle the fast nature of human eye-gaze interaction with compute intensive video transcoding scheme. Severe problems arises due to the control loop delay between sensing and coding associated with streaming in the network. It is important to note, that a network not only imposes control loop delay but also the delay is always dynamically varying. The effect cannot be ignored either. A typical network delay ranges from 20ms to few seconds. Saccades can move the eye position more than 10-100 degrees in that time potentially wiping out the entire advantage of designing an accurate acuity window within the 2 degrees of foveation. So it became apparent that this delay is much more dominant than degradation models around the point gaze that were so vigorously studied before.

The project took a novel approach to solve the problem with the help of active networking. Instead of relying on point gaze, this novel scheme dynamically tracks a vicinity of interest and integrates a dynamic prediction mechanism to compensate its interim movement between the sampling and actual coding. The solution provided the **Perceptual Media Transcoder** (PMT). The system has been demonstrated in DANCE'2002.

The developed **Percept Media Transcoder** (PMT) architecture has been designed so the concept is generalizable. The perceptual zone is not tied to the specific media. Multiple media types and media specific perceptual transcoding modules can be plugged into it without requiring the reorganization of the overall media distribution system's networking. This architecture enables one to use any standard-based media server and presentation system. For example, if remote rendered 3D graphics is passing through the PMT the graphics computation can be steered and optimize accordingly. The techniques we developed now show that more than 90% of the gazes can be dynamically contained within 20-25% window coverage area with active fusion offering tremendous scope of perceptual data optimization.

The implemented system incorporates a new full logic MPEG-2 high resolution region-based full-logic motion-vector inferencing (MVI) transcoder plugin into the PMT. This video transcoding system itself offers a number of novel improvements which in their own merit advance the state-of-the-art in video transcoding research. Some of these will be described shortly. The overall

transcoding mechanism then served as a building-block for a set of high performance active applications, which enabled the project to explore a number of active networking issues. These will also be evident in the following discussions.

As will be evident the investigation was designed to be compact and multifaceted. The eye-tracker also demonstrated another important advantage of active networking. The special high speed head mounted cameras used for eye-tracking are precision instruments. It observes the human eye at a speed of 240 frames per second (6 times the speed of regular camera) and determined the eye-movement with a precision on .5 degree. Instrument control over the Internet is still a very challenging task. The project is unique to work in the area of active instrument control and demonstrate the potential advantage of active networks to this branch of applications.

2.2 SONET: SELF-ORGANIZING ACTIVE TRANSCODING

Adaptation is a fundamental phenomenon in natural systems. The engineering of any large and complex system intrinsically requires inbuilt ability of its components to adapt. The Internet has already grown into a meganet with global reach. Interestingly, with its growth the capacity differential between various parts of the networks and the capabilities of egress devices has increased as well—though very few noticed. Historically the Internet architecture has been conceived to cope with the heterogeneity of network standards. It now appears that a second era is evolving. The next generation of large networked systems such as the evolving Internet will have to deal with more intrinsic heterogeneity— the asymmetry of hard resources such as bandwidth, switching, and egress device capability. Asymmetry can evolve from the fundamental physical limitations such as the power crunch in an intergalactic network element, or from something as close and insurmountable as socio-economical disparity- the digital divide. With the expansion and aging the relative size of the pool of older yet functional devices will also increase. The resource asymmetry can take the form of both bandwidth and computing capacity differential.

Without efficient and inbuilt adaptation ability systems tends to lose ubiquity in a large asymmetric environment. It is important to build protocols, applications and services which will operate seamlessly across networks and devices of widely varying capabilities and will not cease to operate at the splice points.

It is important to note growing asymmetry is not only a concern for egress-applications. It will increasingly become a concern in network protocol design as well. In the asymmetric situation the capability to execute a specific transport, routing, error correction algorithm may be constrained not only by the switch processor speed, but other factors such as power limitation (mobile devices, sensor network), or availability (periodic occlusion in line-of-sight communication, or in a vehicular network). Notably, concern about computational resource capability at intermediate nodes is increasing in all layers of networking. Power limited devices are requiring the design of power efficient low level protocols. In the upper layers, sophisticated computations are now being added in the data path of information flow in the form of various custom and adaptive information processing services.
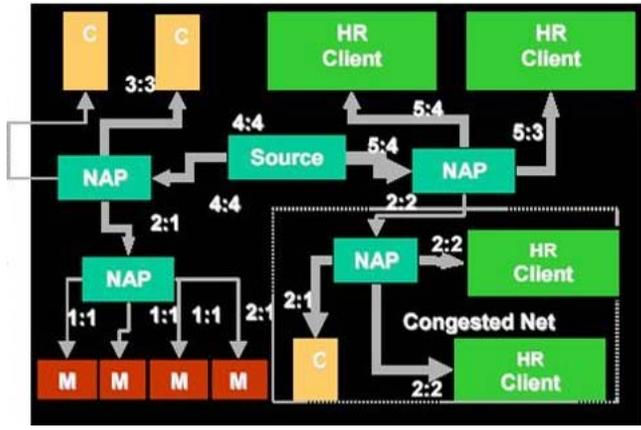
Figure 1 Video Distribution in a large network with heterogeneous links and clients. Labels show the capacity and flow. NAPs are the *constriction points.*

The emerging techniques such as programmable networks or the current active networking hypothesize that auto reactive protocols can potentially be built. As a test system, therefore, the project expanded the basic perceptual transcoder system to build and demonstrate one. The project has implemented an auto-morphing MPEG-2 ISO-13818-2 symbiotic video streaming system with automatic computation migration ability.

This concept stream is called **Self-Organizing Object-Based Network Embedded Transcoding** (SONET) stream. It is a futuristic prototype for an information flow network, which can serve video from a source to clients with heterogeneous capabilities via networks with unequal capabilities. Fig-1 illustrates the situation. It has regular (C), mobile (M) and high resolution (HR) clients. The link labels identify the varying link capacities and flow. Well placed network adaptation units (NAPS) can enable optimum data flow satisfying all clients at their desired rate. SONET represents an adaptive system with substantial software and systems engineering complexity, and involves high volume data communication with temporal quality constraints, reactivity with network state, and infusion of sophisticated domain specific processing. The general information flow distribution model of SONET is valid not only for live video multicast, but for any information distribution scheme from single source to multiple clients, whether simulcast or not. For example, for stored video distribution the NAP can be augmented with hybrid cache.
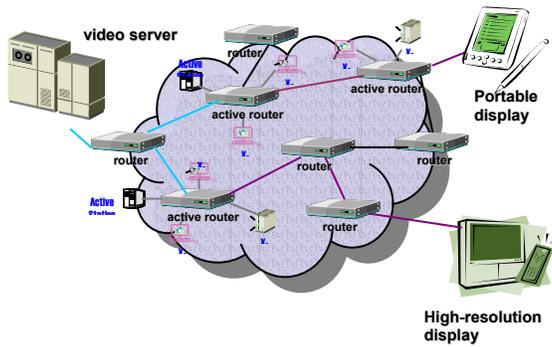
Figure 2 A self-organizing video stream adapts itself with network resources as the video packets diffuse and propagate via an *quasi-active* subnet

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The internal transcoding mechanism of SONET stream has been formulated with an information flow centric view rather than component centric view. The focus is on the flow of video information. The associated transformations (and the associated transcoding operations) take place in a distributed way on its flow path. The key to this design is the modular decomposition of the required transcoding operation—where instead of a single monolithic implementation we took an experimental approach of building them as dynamic hyper-linkable capsules with easily separable data flow optimized concurrent modules, and these active modules themselves can 'flow' with the video flow. The stream uses a quasi-active subnet for computation. In this model (Fig-2) a sparse set of active stations in a sea of regular routers cooperatively computes the transformations. As a result the SONET stream appears as a self-organizing stream, which automatically senses the network asymmetry and adapts itself as the packets diffuse via the active subnet.

As an experimental adaptive system in SONET we have carefully selected a set of adaptive attributes that are representatives of major class of adaptive behaviors. In the top level it shows (a) adaptation with respect to bandwidth asymmetry and (b) adaptation with respect to node computation capacity asymmetry. In each class, it has further selected sub-techniques. The transcoding operation itself acts as a means of *rate adaptation*. For the *compute power adaptation* SONET uses two mechanisms-- (ii) **modular self-organization** and (ii) **computation diffusion**. These two techniques represent different levels of reactivity with the network. To adapt to the available computation resource the first uses domain specific technique to cutback on the internal computation. However, when the capacity of a single node is insufficient to support the lowest transformation the second mechanism enables SONET to sweep computation power from other nodes and diffuse the computation onto multiple nodes in the network neighborhood. These two mechanisms help SONET streams to be uniquely ubiquitous, and to operate on networks with wide variety of computational and bandwidth constraints. Please see publications [5,7,12] for various aspects of the system.

2.3 THE AVIS TRANSPORT

As a test application the project has implemented the video version of SONET called Active VIdeo Streaming (AVIS) system that operates on the ABONE testbed. The AVIS system appears as a custom transport between a video server and a set of receiver end-points. The AVIS transport contains a full-logic pixel level transcoder with full picture decoding and re-encoding capability, and is capable of arbitrary transformation of an MPEG-2 ISO-13818 video stream. The transcoder operates using the compute power of a node (or multiple nodes) in the stream's logical pathway. For conventional end-to-end scenarios the transcoder can be placed at the media server end-point.

This rate adaptive AVIS system demonstrates adaptive behavior at both levels of SONET. In the first level, based on the local link bandwidth it provides on demand adaptation of video rate. Video transformation is a known computationally intensive task. To adapt with respect to the computing power, in the second level, the AVIS transcoder modules can sweep computing power from the neighboring nodes in the pathway. For flexible deployment, AVIS have been designed with modular processing components,, where components can be deployed on separate processing capable nodes. Also, the most computationally intensive tasks can be performed dividedly in multiple nodes.

The detailed architecture of AVIS provides a good glimpse into the class of capsules that will be needed to support complex active applications. AVIS required two types of modules. The transport modules of the AVIS transport has four capsules (i) X-DEC, (ii) X-ENC, (iii) X-MUX, and (iv) X-SPLITTER. Beside these transport modules, it also has control module AVIS-Manager. An X-DEC module decodes an input video stream to decoded frame images. An X-

ENC module receives decoded frame images and produces a GOP-ed encoding video stream slice. An AVIS may have several X-ENCs for maintaining proper transcoding rates. An X-MUX is used for guaranteeing the transcoded stream is in sequence. An X-SPLITTER is used for splitting the stream to get a proper branch location for multiple receiver end-point support. Given the end-points and a network map, with an AVIS transport, the modules X-DEC, X-ENC, and X-MUX are logically connected in a pipe. A particular deployment may have more than one X-ENC between X-DEC, and X-MUX. The X-SPLITTER modules can be located before X-DEC or after X-MUX. Because of the heterogeneous network environment, some X-ENCs are expected to run on high performance nodes, while the others on low powered ones. The variation in the (i) active processor speed, (ii) the CPU load in the processors from other active nodes, and (ii) the difference and variation on the network link bandwidth in each path from X-DEC to X-MUX via one of X-ENC cause the variance in delay.

2.4 Kent VSM/BEE EXECUION ENVIRONMENT

AVIS system runs on top of Kent VSM/VEE execution environment, which is loaded by ANETD. The Kent VSM/VEE is an execution environment supporting object oriented dynamic module management scheme. The Kent VSM/VEE supports dynamic loading and unloading of a service composed as a collection of modules, transfer of service configuration scripts, and log files via the module and file management service of ANETD. In addition Kent VSM/VEE also provides access to local SNMP MIBs for the application modules so that they can gather network resource information. For each service Kent VSM/VEE expects an Application Channel Manager (ACM) module. When an AVIS channel connection request is issued by the user it deploys this module. The ACM then initiates deployment of other modules via VSM/BEE. However, before launching the transport modules it can launch scout modules for gathering application specific resource information. Based on gathered network resource information, an AVIS channel manager makes a deployment map using a deployment algorithm. When the deployment map is decided, the AVIS channel manager requests deployment of each AVIS transport modules to a specific node by sending a request to Kent VSM/VEE for loading designated AVIS modules. The AVIS channel manager also sends service configuration information before running the AVIS channel module. After all the modules and configuration information are loaded in proper locations, the AVIS channel manager sends signal to each Kent VSM/VEE to start running the AVIS channel modules.

The Kent VSM/BEE represents significant difference from other previous major Execution Environments that evolved from any bottom up approach. Here are few of the differences. (i) It did not participate in module deployment decision making. Rather it appeared that in any sufficiently complex application, any module deployment has to be a very much application specific matter if any efficiency is desired. (ii) Also, the overall framework envisioned a separate management module for each instance of the active services—in this case the AVIS-manager. The Kent VSM provided plugin mechanisms to embed these managers- rather than performing those tasks itself. (iii) Also, Kent VSM/BEE emphasized the support for detailed monitoring and status reporting from components. This includes developing some formal methods such as adding formal visualization breakpoints into components. Interestingly, any other major EE is yet to emphasize it. Kent VSM/BEE provides an extremely visual and multi-view graphical interface for the overall control and application monitoring. We found it almost impossible to manage any complex application deployed over a complex network without them. The portability and security enforcement models found in other existing EEs seemed to be valuable, therefore the project choose not to reinvent them.

3. ALGORITHMIC CONTRIBUTIONS

The above applications provided us the opportunity to explore a number of central issues in active computing and communication. The Internet and particularly the Web are increasingly becoming 'active'. Beside active networking, while the Perceptmedia project is finishing, several initiatives are already underway which are looking for more efficient means for performing such embedded computations in the network. At one end of the spectrum, the Grid initiative is exploring technology so that distributed idle cycles of massive number of computers, including supercomputers, in the Internet can be used to perform advanced scientific tasks. Application Systems such as Gravitational wave detection, earthquake simulation with sensors embedded in buildings to various locations worldwide are the type of applications which can be handled. Active and Programmable Network initiatives looked into smarter router and switch architectures that can support packet processing. From yet another perspective, IETF Working Group has recently proposed the Open Pluggable Edge Services (OPES) and the Internet Content Adaptation Protocol (iCAP) defining the extended 'active' functions of future caching proxies. More recently automatic computing is looking at means for self-organizing networked computing resources. Below are some of the problems we investigated that are not only important for active network paradigm, but will find validity in many of the others.

3.1 COMPONET PLACEMENT FOR ACTIVE APPLICATIONS & SERVICES

Although, significant work has been reported in active module launching and deployment modes within the initiative, very little research existed on optimum mapping of active components in a network with a-priori unknown layout and computational characteristics.

The available classical algorithms for flow mapping have been designed for passive infrastructures and are based on maximum flow/shortest path evaluation. Unfortunately such algorithms can not be directly applied for the mapping of active computation, because an active computation may require assignments which are off from a straight path between the source and the sink. Also, the classical algorithms, mostly designed for parallel processing mapping, are not easily amenable to the hierarchical organization of the internet. On the other hand, researchers in active networks have investigated several mechanisms for capsule distribution over a flow path. However, none of them considered the capsules/network resource mapping. The closest set of work which has considered some form of optimized distribution of network embedded tasks can be found in Web caching research, which considered storage and delay optimization.

The SONET system allowed us to work with a novel mapping algorithm for active computation. An algorithm has been designed for component placement for flow based active computation. This algorithm takes specification of flow, specification of computation performed by a distributed application capsule set, and the bandwidth and compute power available in a given active sub network. Then it finds a constraint satisfying assignment for the nodes. The proposed mapping mechanism has two novel characteristics. Unlike other flow mapping algorithms, this addresses joint bandwidth and node computational capacity constraints. Secondly, this mapping technique can accommodate the hierarchical, irregular, and dynamic nature of the Internet. It is base on a novel hierarchical network factorization principle. This hierarchical algorithm can also be expanded as a building block toward designing a family of flow mapping algorithms each satisfying a different optimization goal. The technical detail of this algorithm has been presented in publication [8].

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3.2 COMPUTATIONAL JITTER REDUCTION FOR ACTIVE APPLICATIONS

The AVIS system gave the opportunity to study another interesting problem important to these paradigms. This is the temporal quality of transport issue, or in particular, delay and jitter management in active information streaming (AIS).

AIS considers how a passing stream can be arbitrarily processed while in transit. The AIS appears in active processing, grid computing as well as in the processing of web information services. In active information streaming additional design constraints appears pertaining to the temporal characteristics of the information flow and associated service. Unlike end-to-end streaming, active streaming enables the streamed information to be customized dynamically during its transit. Just like the current HTML based adaptation services, a wide range of active services can be potentially built for streamed information ranging from channel multiplexing/ demultiplexing, rate adaptation, watermarking, security scanning, to filtering etc.

The project investigated algorithms for dynamic delay and jitter optimization schemes for AIS computing. This problem is also quite different from its counterpart in classical networks. Delay-jitter management will be a central concern irrespective of the framework of networked computing-- whether it is Grid Computing, Active or Programmable Networks or Active proxy Services. This will be a major and central concern for conventional time sensitive application processing such as media streaming. Interestingly, many other application processing tasks, which are not normally known to be time sensitive, may become time sensitive. The new variability introduced by uncertain compute resources available over a loosely federated resource pool can seriously destabilize synchronization, load balancing, and utilization efficiency of known distributed solutions. We presented an application level framing (ALF) based scheme, which performs distributed measurement on AVIS and can reduce the delay and jitter by one point scheduling and one point buffering at the entry and exit point in a processing capable active subnet. This scheme has been a live experiment on ABONE. The technical details of this algorithm are presented in publication [2].

3.3 FILTER APPLICATIONS ON ACTIVE NETWORK

Though active network technology has begun with the premise of modifying the packets at intermediate network nodes, there can be another useful class of potential applications on active network which are by nature passive but require active technology These are filter applications. They are passive applications as they do not modify a stream, but they require active technology. They actively read and process a flow. The project studied the issues related to filter applications at both the architectural as well as the test application level.

3.3.1 HIGH PERFORMANCE ACTIVE INTERCEPT
The project also investigated a high performance active filtering-router architecture, which can facilitate active filtering. We observed a problem particularly unique to active networking is the optimum field packing in a protocol coding structure. Any intelligent and dynamic processing of content would require intercept. Stream interception is rapidly becoming a common task in Internet appliances. Beginning from cache, proxy, filters, firewalls and gateways, there are now host of new services including content adaptation, content personalization, location-aware data insertion, to security filters -- all are fundamentally stream interception machines requiring some form of intermediate access inside transiting traffic's content. A significant percentage of the delivered Internet traffic is now 'touched'. This is also the central task of an active module.

However, if we look into the current protocol design, particularly the protocol packet structures, we will see that it has little facility that enables efficient stream intercept. Most real-life content, particularly high performance networked multimedia transport data carried over a network

packet, are multi-level hierarchically encapsulated (that means bags within suitcases). For example an H.261 video element may require access to 16 pre-dependent elements before the element of interest can be read. The situation is also difficult for recent tag-delimited content protocol standards (such as XML, HTML), where this dependency is formally infinite. For example, in annotation based web content transcoding, the transcoder has to make considerable effort in searching a certain value in the annotations (basically tags/metadata expressed by XML) at the application level before it can decide how the content should be transcoded.

The problem has major implications on the CPU cycle, memory size, and overall performance of any intercepting appliance system's architecture. Essentially, the stream is the working data structure of a filtering system. It is perhaps as salient to appliance's overall architecture as the design of disk scheduling algorithm or multilevel memory/cache organization is to the conventional machine architecture. Simple end-to-end applications can do away with marginal treatment of this issue. However, the right placement of protocol elements inside data streams and some form of random access will be one of the most important factors for high performance stream data processing appliances.

In this research we investigated this new but important problem and demonstrated a novel content indexing scheme that can facilitate dynamic index based random access into streams and provide performance boost to intercepting filter like appliances. Though conceptually the mechanism can be implemented in layers above IP, we present an IPV6 [5] based protocol called Embedded Data Indexing Protocol (EDIP). It is an IPv6 extension header based content indexing mechanism, which defines the how a Content Provider (CP)'s serverlet can add special marks into the data stream, and how an intercepting Active Router (AR) can decode those marks from the data streams and gain pattern dependent random access into the elements of required data stream. The work presents a user space implementation of the proposed intercepting machine and a performance study of the scheme on this implementation. Even without any kernel level support, the implementation showed about 500-800% speedup over today's content servicing technique in normal conditions. The result suggests such random access can significantly speed up future intercepting applications of the Internet.

3.3.2 ACTIVE VIDEO ANALYZER
The project developed a very fast object based active video scene analyzer. This application can intercept a passing stream and perform high level scene analyses to detect and monitor scene objects. A user can specify expected scene and activity using a high level language on the filter. The filter then automatically detects the birth of conforming objects, can log it, track its progression in the scene, and if needed can trigger user defined events. The algorithm is one of the fastest scene analysis algorithms for video available to date. It categorizes the impacts of various types of complex scene movements on the motion vectors, and accordingly locks on to the objects. The system has been demonstrated in DANCE'2002. See publication [13] for technical details.

3.3.3 HYBRID PERCEPTUAL CODING
The project also developed a novel hybrid perceptual encoding technique that now optimizes the video quality not only with live eye-gaze but also with fast active video scene analysis. We are glad to report that this achievement exceeds our initial project target, where we set forth to demonstrate live eye-tracker based perceptual video coding, which itself has pushed the state-of-the-art.   The hybrid system first determines a perceptual visual window with eye-gaze information using techniques outlined earlier. The visual window is the scene area where most visual attention is distributed and is required to be encoded with high resolution. The new system now combines a compressed domain fast content analysis mechanism with it so that the focus area can be narrowed resulting in higher transcoding ratio without any penalty of perceptual video

quality. While, the eye-gaze helps in dynamic determination of human attention, the scene analysis helps in the prediction about the vicinity of focus. This scene analysis was possible using the active node's computation power. We are able to show that the hybrid scheme excels either of the base techniques, when applied alone. We have also added a second remote unit eye-tracker for binocular tracking and multi-instrument complex synchronization.

3.3.4   <u>PERCEPTUAL CODING FOR MULTIMODAL DATA</u>

However, it is important to note on the potential generality of the technique. Though we intended to further explore this very interesting development issue, due to time constraint we could not. First, though demonstrated for video, the overall visual window mechanism developed for video communication can be applied to any media type in future applications such as high speed 3D scientific visualization or environment teleporting. (This was one of the original goals). This semester we tested basic eye-gaze interaction with 3D dynamic models. Secondly, the developed video transcoding technique is applicable not only for rate adaptation, but the same model will be able to support arbitrary video stream processing over active network type architectures. The potential application ranges from video composition on the fly, to security screening, to real-time automatic video narration. Also, the same binocular eye-tracker can be rearranged to study interactive experiments for more than one user. To date almost no study has been performed on multiparty aspects of perceptual interactive encoding. This can result in the development of smart data optimization for many futuristic live multimedia applications such as the Digital World System for global Tele Concert organization and presentation, or the live management of a War Room, which will involve massive and very high fidelity multi-modal group communication (involving video, graphics, animations, audio) between multiple parties.

3.4 iTCP: ACTIVE TRANSPORT FOR REAL-TIME APPLICATIONS

The project investigated another class of programmability in protocols. These are the programmable transports- which require 'active' support only at the end points, and thus can be considered a special sub-class of active systems.

The project particularly investigated a transport extension idea of TCP Interactive. This is useful for applications which require high temporal quality on elastic data- such as audio, video. In this research a novel interactive extension to the transport protocol has been developed. The meta-protocol extension via active technology proposal does not change the dynamics or actual functionality of the transport protocols, but suggests providing local end transport level event feedback to the application layer. The idea is that the resulting feedback can then be used by the active nodes in various ingenious ways including the control of elasticity of the traffic and enables time-conformant communication. An experimental implementation of a FreeBSD TCP kernel based extension of the novel system has been implemented. The project then extended the base transcoder system with a rate symbiosis mechanism. The MEDIANET transcoder module then demonstrated real time-symbiosis on the basis of this TCP feedback. Dramatic improvement in time conformant video communication has been observed.

ABone node	Evt. num	Ref. Jitter	IAT per frame	SNR per frame	Bits per frame	Flight per frame	Time per video	Frames per Second
fokus	2	7.1494305	0.115616	21.942224	49737.387	0.34110329	115.615629	8.70646714
galileo (italy)	1.2	7.46529	0.107585	18.423304	36672.216	0.27807673	107.585495	9.34654553
columbia (usa)	1.6	1.0135707	0.101358	22.51238	50173.551	0.19717850	101.357553	9.90596598
princeton (usa)	1.2	3.5122045	0.110104	22.463844	50331.645	0.22855333	110.164151	9.22516667
isi (usa)	1	5.604205	0.107402	20.712062	47694.519	0.21521991	107.421659	9.37435276
AVERAGE	**1.4**	**4.9489401**	**0.108413**	**21.210763**	**46921.864**	**0.25202635**	**108.428897**	**9.31169962**

(A)

ABone node	Evt. num	Ref. Jitter	IAT per frame	SNR per frame	Bits per frame	Flight per frame	Time per video	Frames per Second
fokus	1	18.284166	0.14174	23.5559	54672.969	0.33439687	141.759976	7.90342341
galileo (italy)	2	36.890137	0.157235	23.5559	54672.969	0.35754888	157.254885	6.55484516
columbia (usa)	1.6	7.0201728	0.112287	23.5559	54672.969	0.17304129	112.286873	8.96444653
princeton (usa)	1.4	6.6170372	0.112419	23.5559	54672.969	0.23079274	112.419281	8.97858152
isi (usa)	2.2	10.950218	0.122707	23.5559	54672.969	0.30013761	122.706648	8.23842417
AVERAGE	**1.64**	**15.952346**	**0.129278**	**23.5559**	**54672.969**	**0.27918348**	**129.285533**	**8.12794416**

(B)

Table 1 Network and video parameters. Table (A) shows the results of the iTCP runs, while table (B) shows the results of the classic TCP runs.

This new Transport protocol has been tested in detail on active nodes around the globe over ABONE for video distribution. The table above shows a sample of results from real video streaming performed between a symbitic adaptation trasncoder at Kent and five other ABONE locations in Italy, Denmark, Princeton, Columbia and ISI. Technical reports [TR2003-02-02] contain the detailed performance. Publications [1, 9,11] contain further technical details of the research.

3.5 HARNESS: AN ACTIVE GROUP COMMUNICATIONWARE

Current known messaging primitives are leaf based (point-to-point or multicast). We developed an active inter-module group communication ware that includes intermediate junction nodes in the set, and is programmable.

Most of the current probing tools use a point-to-point mode of communication. But it often severely limits scalability in a large network. On the other hand, there are several specific probing kits that have been proposed which provide greater scalability. However, these hardly can be reused for other measurements. Nevertheless, the trend suggests that versatility of the information is becoming equally important. Exactly, what measurement is useful depends on the optimization objective. For example, in a video server scenario, whether the jitter or the hard delay is more important is dependent on the specific video repair algorithm. In some other scenario, the Emerging tele-interaction applications (such as tele-surgery, remote instrument control), require a handle on the delay incurred at the video frame level, which is not exactly the same as the packet delay. The trend suggests that as more advanced, and complex net centric applications are being envisioned, more versatile network state information would have to be exchanged. Can scalability and versatility both be retained simultaneously? Apparently, there may not be any efficient answer in an end-to-end paradigm. In this research using active technology the project has investigated a novel group communication ware for state information polling and propagation inside a network with similar embedded information synthesizers, which is both scalable and versatile. The approach first makes a clear separation between the "communication" from the "information" of the state exchange and propagation process. Communication is handled by the

component called "harness". Harness propagates all information via coordinated messaging. On the other hand the "information" component of the process is controlled by a set of soft programmable plug-ins. These plug-ins decide the content of the messages propagated by the harness. Publication [18] contains further technical detail about the active Harness. The technical report [TR2003-01-02] shows its novel application in automatic determination and communication mechanism for minimum spanning tree based power efficient communication.

4. RELATED ACTIVITIES & ISSUES

4.1 DEMONSTRATION

As originally planned, the project also actively participated in three active net demonstrations. The project was made part of the high performance active networking team. The high fidelity video processing in the target application was among the most sophisticated and computationally intensive applications attempted in the initiative.

In December 2000 DARPA PI Meeting demonstration, we tried to integrate the system with the Scout system and the Active router of WSU. We were able to port it in the user space of WSU router. We demonstrated active transcoding by showing a system where high performance broadcast quality DTV video was delivered from WSU router via vBNS into the meeting room. An active transcoder dynamically down-scaled the MPEG-2 video and broadcast it to a laptop via a 802.11 wireless LAN. We demonstrated three types of adaptation. In the first level we introduced (artificially) various amounts of congestion in the wireless link and let the transcoder automatically down-step the rate of the incoming vBNS video. Secondly, we introduced CPU contention at the active node running the transcoder. The transcoder, sensing the drop in processing frame rate, self-organized itself to the motion vector bypass configuration state for less computing intensive transcoding. In the third level, we demonstrated *region based encoding.* A Java interface was used to show that bulk perceptual quality in the video could be retained even when the rate was drastically down-scaled.

In October 2001 the project made a demonstration of the SONET system in ACM Multimedia 2001 held at Ottawa. In the demo we showed a live demonstration of the rate transcoding with automatic adaptive **computation diffusion** over multiple nodes.

Again in May 2002, in the DARPA Active Network Conference & Exposition, DANCE 2002 Exposition, the project presented three demonstrations. The first was the ABONE implementation of the AVIS system. The second was the active video scene filtering. Thirdly, the eye-gaze integrated live perceptual encoding was demonstrated. This was performed with pre-recorded eye-gaze data, as it was not logistically possible to take the eye-tracker.

4.2 HIGH-SPEED ACTIVE NET BACKBONE

The project in its first demonstration phase was identified as a high performance active application. A unique aspect of video transcoding is that transcoding logically incorporates both video coding and decoding. Also, the video data is substantially large. The Video transcoding by nature is computing intensive. On top of that, the base transcoding the project particularly focused on large format high fidelity MPEG-2 video. Also, the project focused on full logic video transcoding. Though several compressed domain methods have been proposed for specific transformation types, we adopted the full logic path so that arbitrary video transformation can be supported. Consequently, the video steam and the transcoder posed serious computational,

communication, as well as system level complexity. The developed video transcoding is most likely the most compute intensive active applications attempted to date.

Accordingly it was placed in the high performance team, along with complementary teams from Princeton University, Washington University, and University of Arizona, who were working on building performance active router and OS/EE architectures.

Since the demonstration we made several assessments of the requirements. During the assessment, the lab also conducted remote video experiments with Princeton university via Internet-2. It was determined that the test-bed would require high computing as well as communication performance nodes at least in clusters. Naturally, packet processing speed itself is not enough of an indicator of active router performance. Also after the development of the diffusion transcoder it became evident that the incoming video stream actually faces about 100-50 times volume explosion between the decoding and recoding phases. It became apparent that the volume explosion is also another normal phenomenon in active packets' life. Also we planned to acquire a good amount of storage for potential active caching. Consequently, it became evident a Gigabit connected ABONE cluster with a handsome amount of storage and computing power would be technically appropriate for the project. Correspondingly, the project aimed at building a high performance Active Network test-bed segment of ABONE at Kent. It was also decided that it will be a valuable asset to make it a part of "Thousand node ABONE" goal set forth by the initiative. (The budget was subsequently approved in the new work plan).

Our target was to contribute about 10+ high performance nodes. As the equipment cost goes down with time, we decided to upgrade then existing nodes and network only when the software system was ready for experimentation. Despite some difficulties in meeting the initial time estimate, we were indeed able to conduct several performance experiments on this high-performance test bed at the very last stage of the project. These latest results are in the Technical reports [TR2003-02-01] and [TR2003-02-02].

Kent MEDIANET lab now provides about 10-12 nodes in the network. KSU is now one of the three major node contributors in the entire backbone initiative. KSU expects to support these machines beyond the grant period from other funding. Sufficient reliable storage has been added. Also, a high speed connection has been provided. The cluster is internally connected via Giga-bit Ethernet. It is then connected to the campus fiber with giga-bit links including to the Internet2. Also a code server is running. This now enables, not only to us, but also to the researchers worldwide, to conduct high speed active application experiments with various sites in USA as well as in Europe. High performance experimental active applications such a high fidelity video transcoding can be executed and tested on the machines.

4.3 ACTIVE APPLICTIONS TO ABONE

Currently, three systems are available for experimentation and demonstration on ABONE. These are:

- The Perceptual Media Transcoder

- The Active Video Streaming System. Also the Kent VSM/Execution Environment and the SONET system on ABONE.

- The iTCP Symbiotic Transcoder.

The AVIS system employs multiple complex components on the active network to perform the joint task of video transcoding and is one of the most complex among the active applications to date.

4.4 SECURITY ISSUES: TRI-PARTITE TRUST MODEL IN ACTIVE SERVICES

As per the extension goal we have also investigated the problem of secured active transport. In the last quarter we have particularly investigated a generalized security architecture. During the initial investigation it became apparent that the few current active application deployment models (such as the one followed by ANTS/ABONE) now being considered by active network researchers are still mostly ad hoc. Indeed, an effective and practical active application deployment system is expected to support multiple active application deployment models. The emerging content data networking models already contain the signature of the varied model cases which may arise. Consequently, we began by first studying the range of various deployments models. The work formalized into a generalized **active services networking** (ASN) framework. This has been proposed to ensure secured deployment techniques that will encompass a range of the plausible deployment scenarios that will satisfy various active application architectures and models. We have investigated a X.509 certificate architecture that will ensure multi-perspective mutual trust model among the parties involved in ASN. At this point we are resolving a tri-partite system with content developer, user, and service provider. The objective is to build a X.509 system which will ensure mutual trust among the three. Though the project formally ended, an MS student continues on the topic and a publication will be forth coming.

5. GALLARY

In this section we present some photographs showing various experiments.

Figure 3 The subject is viewing a streaming video. The high fidelity video is perceptually optimized. The live eye-gaze information is fused with the stream data on an active node. The Kent team is one of the first to show integrated dynamic transcoding with eye-gaze based perceptual coding. The full logic active transcoder is capable of arbitrary video processing.

Figure 4 A part of the KSU Active Node cluster. The nodes can be easily connected in various network/subnet configurations by a re-configurable cross link box. The connections can be either 10/100 or GigE links, and the uplink is GigE ready. Experiments have been performed where multiple nodes were dynamically aggregated to perform active diffusion transcoding over various network connectivity configurations.
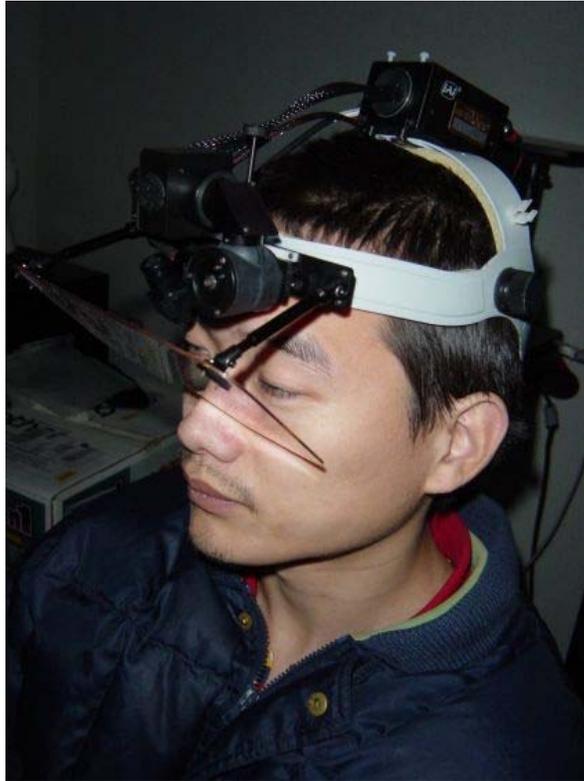
Figure 5 Active network technology has been used to reduce the control loop delay in instrument integration. A special high speed head mounted camera observes the human eye at a speed of 240 frames per second (6 times the speed of regular camera) and determines the eye-movement and fixations with a precision of 0.5 degree. The sample data stream has been integrated with the control loop of the transcoder via an active network. Instrument control over the Internet is very challenging and still rare. The project is unique to work in the area of active instrument control and to demonstrate the potential leverage of active networks to this branch of precision based performance applications.

Figure 6 Beside the head mounted eye-gaze tracker, this remote non-intrusive tracker can observe a viewer and can determine the eye-location on the screen. This is a potential pre-cursor to a future perceptual coder. A binocular system in the Kent Perceptmedia lab can track both eyes for point resolution in 3D space or track multiple users in interactive video applications leading to collaborative optimizations.

Figure 7 While eye-trackers determine the eye-position with respect to the human head, this remote magnetic head tracker additionally tracks the human head with respect to the scene plane. Thus it adds mobility to the KSU system.

Figure 8 The ABONE has been tested for active video streaming to worldwide destinations from Kent Server. The active router is intercepting an ongoing MPEG-2 video stream (shown on the monitor panel). The iTCP enabled kernal on the active node enables real-time symbiosis between the network events and immediate adjustment of video rate, resulting in a dramatic improvement in its temporal quality. The iTCP kernel has been developed at Kent and provides the programmable active modules access to low level network events. The symbiotic transcoder is running on the ABONE node.

Figure 9 The active media transcoder designed for the project is multifaceted. The concept of media transformation is generalizable. The Medianet lab also recently experimented with the active graphics. Interesting futuristic systems ranging from distributed collaboration to augmented reality graphics can benefit from active graphics with applications in live surgery, live war field media management, and performing arts production. Network embedded processing (such as in active networking) will be key in providing the underlying complex synchronization between human and instrument.

6. CONCLUDING REMARKS

The project PERCEPTRMEDIA is a unique top down exploration in active networking. The project provided a number of novel perspectives to the initiative. The project has resulted not only one – but a suit of futuristic concept applications which now are available on the ABONE. The technical publications resulting from the project now document one of the most comprehensive application and system level performance analysis of active systems. One of most lasting impacts is perhaps this top-down exploration helped to unearth a number of issues central to active systems, some of which were not easy to see from a bottom-up exploration. The project demonstrated some pilot solutions to these issues as well. A series of 30+ publications and technical reports now documents the results.

This project dynamically evolved through a continual learning and discovery process. In its very first year the project took up the challenge to join in the demonstration 2000. This was quite beneficial but unexpected. Being a new start among the continuing participants, (most already had at least a year of results to show) for us it meant an extremely hectic pace and major reorientation of the original work plan-- even at the very start. Notably, this was the first major project for the PI, who was in the very first years of the first faculty job. Not only the project itself had a high risk (and high pay-off) goal, but also there were challenges of setting up the whole research infrastructure at a new institution. Never the less, the project performed impressively in the demonstration. This process of collaborative demonstration turned out to be extremely valuable as it gave a clear view into the initiative. It enabled us to design the set of ambitious active applications, such as diffusion computing. It also helped us to identify some core problems, such as mapping, interception, etc., which yet needed to be addressed.

Another learning experience during the continuation of the project was personnel recruitment. As a system intensive project the need for additional personnel was soon realized. For example, in the middle it was realized that a full time programmer or post doctoral fellow can help the extremely system and implementation intensive refocusing of the project. However, the project failed to recruit one, and eventually we went back to the strengths of graduate students. Overall a pool of 6-8 graduate students contributed in various capacities in this project. The university and the department were supportive to offer a strong bridge as well as extra support (outside of the grant) for graduate students for the project.

Despite the hectic pace, the project continued eliciting exciting results. In October 2001 we demonstrated the SONET system in ACM Multimedia 2001. We brought attention to several interesting (yet previously unexplored) active network issues including that of harness group communication-ware, issues of fast stream intercept, programmability in protocol field organization, made-to-order channels, etc. In September 2001 we were granted additional funding to conduct investigation into a selected set of these problems. By this time the high performance nature of the project in relation to the other applications was also evident. Also, funding was granted for a set of advanced nodes that were to be used for the test applications and also to be integrated into the DARPA ABONE cluster for high performance applications. The opportunity to pursue these were exciting, however, the time frame was still the same. In the Spring of 2002 it was realized that while the core algorithms would be available. their performance analysis may not be realized. This was further constraining because our original plan was to do the major final performance analysis on the best possible ABONE platform with the best prepared software system possible. Accordingly we acquired mostly development equipment at pace with the research and planned to obtain the actual performance test equipment toward the end of the project once all the software systems would be ready.

Despite the feeling of a tight schedule, the project vigorously participated in the initiative-wide DANCE Exposition in May 2002. It presented three demonstrations and contributed two papers in its proceedings. However, in the exposition meeting of May of 2002 the project conveyed the severe concern to the program manager[2] and anticipated a six month extension. Based on the anticipated June 2003 deadline, the schedule of final equipment purchase and subsequent experimentations was determined. The software systems were as per plan ported on ABONE. Unfortunately in late October the project learned that this extension could not be granted. The software investment and intensive human investment by then was already made (a group of about 7 graduate students were seriously involved in the effort). So the project immediately went ahead to complete the experimentations including the completion of the test bed in the remaining months. We are glad to report, despite this acceleration in pace, that the project has been able to perform the objectives including substantial real system analyses. Technical report [TR2003-02-01] documents the experiment result from the AVIS on Gigabit ABONE. Technical report [TR2003-02-01] shows the extensive performance analyses of the adaptive video streaming over a worldwide ABONE experimentation.

However, this left some of the interesting issues that evolved from the natural course of the research unexplored. This includes some additional high speed network experiments, perceptual transcoding experiments with perceptual quality assessment, X.509 tripartite trust model building, active tuning of GigE network, and composition of active parallel transport. Also, if we had time we could have shown some pilot results from the bi-directional active transcoding of multi-user interactive video.

Despite the above few unexpected turns (particularly the ones at the project beginning and end) the overall progress was quite remarkable. The overall project turned out to be extremely productive. This productivity is well reflected in the width and breadth of the topics investigated. It is probably also reflected in the 20+ publications, 6 MS thesis (4 defended), and 4 PhD dissertations (final stage). 2-3 more graduate research students and one high school honor student also contributed to this project. The honor student over two consecutive summers built the system's player for small platform PDA.

The project formally ends now but we plan to continue investigating many of the issues identified. We plan to use the equipment that was granted to us and the shared infrastructure over ABONE at least in the coming 1-2 years. At the same time, we plan to maintain and make them available for ABONE experimenters from PI's start-up fund.

We observe that the idea of active and programmable systems has gained considerable foothold already-- though not exactly in the way the Initiative anticipated. A number of investigations have emerged which are conceptually based on various flavors of 'activeness'. It is further interesting to note that this growth is predominantly occurring in the complex and high performance end of applications, rather than the lower network layer optimizations. This trend of upper layer activity is reflected in the initiatives such as TeraGrid, Network Middleware, and the recent Automatic Computing. The area of active proxy is also attracting serious commercial interest. This project was one of the few with in the current initiative to target this high end. We expect many of the results contributed by this project will find lasting value also in these emerging paradigms.

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[2] In the DANCE'2002 PI Meeting with the DARPA Program Manager in May of 2002 the project conveyed the concern and requested a six month no cost extension and received assurance of extension until about June 2003. We were requested to initiate the extension process in September-October 2002. However, in October it was learned that the extension could not be granted for AFRL/ DARPA internal arrangement.

7. PUBLICATIONS

The following papers have been produced from this project. Several others are now under review. A complete list will be given in the final report.

1. [KhZG03] NET: Javed I. Khan, Raid Zaghal, and Qiong Gu, Symbiotic Streaming of Time Sensitive Elastic Traffic on an Interactive Transport, The 8th IEEE Symposium on Computers and Communications - ISCC'2003, Antalya, Turkey, June 2003 (to appear, accepted as full paper).

2. [YaKh03] NET: S. S. Yang & Javed I. Khan, Delay and Jitter Minimization in Active Diffusion Computing, The 3rd IEEE International Symposium on Applications and the Internet, Orlando, SAINT 2003, Florida, January 2003, pp.292-300.

3. [KhGu03] MMN: Javed I. Khan and Zhong Guo, Flock-of-Bird Algorithm for Fast Motion Based Object Tracking and Transcoding in Video Streaming, Proceedings of the 13th IEEE International Packet Video Workshop 2003, Nantes, France, April 2003, (accepted as full paper).

4. [KhYa02] NET: Javed I. Khan and Seung. S. Yang, Made-to-Order Channels: A Framework for Building Complex Netcentric Systems on Active Network, IEEE Proceedings of the Active Networks Conference and Exposition DANCE 2002, San Jose, CA May 21-24, 2002, pp.409-426.

5. [KhYa01] NET07: Javed I. Khan & S. S. Yang, Resource Adaptive Nomadic Transcoding on Active Network, International Conference of Applied Informatics, AI 2001, February 19-22, 2001, Insbruck, Austria, ISBN:0-88986-280-X (307), pp262-267.

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7. [KhPa03] MMN: Javed I. Khan & Darsan Patel, Extreme Rate transcoding for Dynamic Video Rate Adaptation, 3rd IASTED International Conference Circuits, Signals, and Systems, CSS 2003, May 2003, Cancun, Mexico (accepted as full paper).

8. [KhMY02] MMN: Javed I. Khan, Patrick Mail and Seung S. Yang, Flow Assignment in A Self-Organizing Video Stream that Auto Morphs Itself while in Transit via a Quasi-Active Network, 5th IEEE International Conf. on High Speed Networking and Multimedia Communications, HSNMC2002, Jeju, Korea, July 2002.

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12. [KYGP01] MMN10: Javed I. Khan, Seung Su Yang, Qiong Gu, Darsan Patel, Patrick Mail, Oleg Komogortsev, Wansik Oh, and Zhong Guo Resource Adaptive Netcentric Systems: A case Study with

SONET- a Self-Organizing Network Embedded Transcoder, Proceedings of the ACM Multimedia 2001, October 2001, Ottawa, Canada, pp617-620.

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14. [KhHe02] WW: Javed I. Khan and Yihua He, A Framework for Active Ubiquitous Application Services,, 6th IASTED International Conference on Internet Multimedia Systems and Applications, IMSA 2002, Kauai, August 2002, pp.145-151.

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17. [KhKo03] MM: Javed I. Khan and Oleg Komogortsev, Dynamic Object Window Prediction for Perceptual Coding of Wide Format Video with Eye-Gaze Tracking, 3rd IASTED International Conference Circuits, Signals, and Systems, CSS 2003, May 2003, Cancun, Mexico (accepted as full paper).

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20. [KhT01a] WW13: Javed I. Khan and Qingping Tao, Prefetch Scheduling for Composite Hypermedia, The IEEE International Conference on Communications, ICC'2001, Finland, June 2001.

21. [KhT01b]WW14: Javed I. Khan and Qingping Tao, Partial Prefetch for Faster Surfing in Composite Hypermedia, 3rd USENIX Symposium on Internet Technologies and Systems, USITS 2001, San Francisco, March 2001, pp13-24.

22. [Kha00a] WW15: Javed I. Khan, Dynamic Partial Prefetch Ranking in Hypermedia Neighborhood, Proc. of International Conference on Internet and Multimedia Systems and Applications, IMSA 2000, November 20-23, 2000 Las Vegas, USA, pp 280-285.

23. [Kha00b] WW16: Javed I. Khan, Active Streaming in Transport Delay Minimization, First International Workshop on Scalable Web Service, SWS 2000, in the 29th International Conference on Parallel Processing, ICPP 2000, August 2000, Toronto, Canada, pp95-104.

24. [KhZh00] WW17: Javed I. Khan and Lin Zhang, "Tree-Delta Communication for Serving Dynamic Resources in Asymmetric Internet", 1st Int. Conf. on Internet Computing, IC'2000, June 2000, Las Vegas, USA.

8. TECHNICAL REPORTS

The following technical reports are available from the project web site at:
http://bristi.facnet.mcs.kent.edu/~javed/medianet/technicalreports.html.

1. TR2003-02-02 Performance Analysis of TCP Interactive based World Wide Video Streaming over ABONE, February 2003, [Javed I. Khan and Raid Y. Zaghal]

2. TR2003-02-01 [Reaction Time Analysis of Self-organizing AVIS Channels on an Active Streaming Services Network (ASN) with Gigabit ANETD Node Cluster](#), February 2003, [Seung S. Yang & Javed I. Khan]

3. TR2003-01-02 [Computing Minimum Spanning Tree with the Active Programmable Harness: A Network Group Communicationware](#), January, 2003 [Javed I. Khan & Asrar]

4. TR2003-01-01 [Contour Approximation can Lead to Faster Object Based Transcoding with Higher Perceptual Quality](#), January 2003, [Javed I. Khan & Oleg Komogortsev]

5. TR2002-11-01 [Dynamic Gaze Span Window based Foveation for Perceptual Media Streaming](#), November 2002, [Javed I. Khan & Oleg Komogortsev]

6. TR2002-08-02 [Thesis: Impact of Webspace Organization and User Interaction Behavior on a Prefetching Proxy,](#) August 2002 [Qingping Tao]

7. TR2002-08-01 [Thesis: Fast Intercept of a Passing Stream for high Performance Filter Appliances,](#) August 2002 [Yihua He]

8. TR2002-06-01 [Perceptually Encoded Video Set from Dynamic Reflex Windowing](#) [Khan & Oleg]

9. TR2002-03-02 [Ubiquitous Internet Application Services on Sharable Infrastructure,](#) [Khan & He]

10. TR2002-03-01 [Fast Intercept of a Passing Stream for high Performance Filter Appliances,](#) March 2002 [Khan & Yihua He]

11. TR2002-01-01 [A Survey of Ideas in Programmable Networking,](#) January 2002 [Xubin Xu]

12. TR2001-11-04 [SYSTEMS OVERVIEW OF ACTIVE SUBNET DIFFUSION TRANSCODING SYSTEM FOR RATE ADAPTIVE VIDEO STREAMING](#) [Yang & Khan]

13. TR2001-06-01 [Presentation, "Active Trancoding with Escalated Logic- Network based, Content Protocol based and Content based Rate Adaptation", DARPA](#) [Active Net PI Meeting, Jackson Hole, Wyoming, June 2001](#)

14. TR2001-03-01 [A Polymorphic formalism for made-to-order custom channel building for large scale netcentric application](#), Panel in New Vision in Large Scale Networking Workshop, March 2001.

15. TR2001-01-01 [Architectural Overview of Motion Vector Reuse Mechanism in MPEG-2 Transcoding, January, 2001](#) [Khan, Patel, ALL]

16. [TR2000-12-01 Presentation, "Self-Organzing Active Video Transcoding", High Performance Team Demonstration, DARPA PI Meeting, Atlanta, December 2000.](#)

17. TR2000-10-01 [A Performance Profile of MPEG-2 Transcoding with Motion Vector Reuse, October, 2000](#) [Patel, Oh]

18. TR2000-08-01 [Architectural Overview of Medianet Multiprocessor Active Video Transcoder, August 2000.](#)

19. [TR1999-12-03 Ordering Prefetch in Trees, Sequences and Graphs, December, 1999](#)

20. [TR1999-11-01 Presentation, "Active Trancoding- Potential Payoff and Challenges", Active Net Workshop November, 1999](#)

21. [TR1999-04-01 Presentation, "Scalable Stream Coding for Adaptive Foveation Enhanced Percept Media Communication", Active Net Workshop April, 1999](#)

9. SOFTWARE DISTRIBUTIONS

Following software distributions are available from the project web site.

9.1 iTCP: TCP Interactive

- User Document
- Architecture Document
- iTCP Kernel Distribution v1.0 (4MB, tar)
- Symbiotic Abone MPEG-2 Media Transcoder (3MB, tar)
- Silent Abone MPEG-2 Media Player (0.3MB tar)

9.2 EDIP-IPV6 For Fast Steam Intercept

- o An IPV6 extension protocol for fast intercept of passing stream.
  - System Document [TR2002-03-01]
  - Installation Documents
  - Code Documents
  - EDIP-IPV6 Distribution [zip]

9.3 netAVT: Nomadic/Subnet Transcoder System

- o Abone System (AVIS)
  - AVIS System Document [TR2003-02-02]
  - Concurrency Architecture Document [TR2000-0801]
  - netAVT Transcoder v3.0 (zip) [Demonstrated at DANCE' 2002]
- o Subnet System (SONET)
  - SONET System Document[TR2001-11-04]
  - netAVT Transcoder v2.0 (Tar) [Demostrated at ACM Multimedia' 2001]
  - Past releases netAVT [v1.0]

9.4 mpAVT: Multiprossing Transcoder

- User Document

- Architecture Document (TR2000-0801)

- mpAVTS Transcoder v.1 (Tar)

9.5 objAVT: BOF Video Scene Filtering/Transcoding System

- System Document (TR2001-10-31)

- Architecture Document

- objAVT Transcoder v1.0 (Tar) [2xO Tracking]

9.6 AVTS: Resource Adaptive Active Video Transcoding System Distribution

- o Abone System

  -
  - abone AVT User Document
  - AVT Architecture Document (TR2001-0101)
  - aboneAVT Transcoder v.1.1 (Zip) [derived from v28]
  - aboneAVT MPEG-2 Media Player (zip)
  - aboneAVT MPEG-2 Media Server (zip)

- Subnet System

  - AVTS User Document
  - AVTS Control Center User Document
  - AVTS Architecture Document (TR2001-0101)
  - Distributions
    - Version 28 [S-mvX-Pv28, Demonstrated at Atlanta DARPA PI Meeting, December 01, 2000, Control Center Integrated]
    - Version 27 [S-mvX-Pv27 Oct 18, 2000, Unlimited Frame/ MB Breakup Bug Fixed]
    - Previous Versions [S-mvX-Pv26 Oct 15. 2000]
  - **Other Supporting Documents**
    - AVTS Architecture Document: Appendix V28 Code Log, December 31,2000
    - AVTS Control Center Design Document, January, 31, 2000

- Base System

  - [User Document](#)

  - [Architecture Document](#)

  - [AVT Transcoder v.1 (Zip)](#)

9.7 Kent MPEG2 Dragon:

- An MPEG-2 Player for Pocket PC platform developed at Kent Medianet as undergrad project.

- [Architecture Document](#)

- [MPEG-2 Dragon (exe file)](#)

9.8 Medianet Application Plug-in/ Composable Active Switch OS Distributions

- [User Document](#)

- [Architecture Document](#)

- [Medianet Composable Switch v.1 (Zip)](#)