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State University of New York Institute of Technology

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FOR THE DIRECTOR:

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/s/
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14. ABSTRACT

The Research Foundation, for and on behalf of SUNY Institute of Technology (SUNYIT), has contributed significant research capability and capacity to the in-house program at AFRL through the placement of highly motivated and accomplished faculty members and undergrad/graduate students pursuing advanced degrees in Engineering, Computer Science, Mathematics and other recognized technical disciplines critical to the advancement of Information Technologies. The program supported and enhanced the existing AFRL/Information Institute Summer Faculty Research Program and the AFOSR Summer Faculty Fellowship Program.

SUNYIT worked closely with AFRL to help build, foster and nurture in-house research teams. Under this effort SUNYIT recruited, placed and supported administrative requirements of 18 faculty members and 20 undergrad/graduate research analysts and coordinated 17 additional faculty extension efforts.

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1. SUMMARY

The Research Foundation, for and on behalf of SUNY Institute of Technology (SUNYIT), has contributed significant research capability and capacity to the in-house program at AFRL through the placement of highly motivated and accomplished faculty members and undergrad/graduate students pursuing advanced degrees in Engineering, Computer Science, Mathematics and other recognized technical disciplines critical to the advancement of Information Technologies. The program supported and enhanced the existing AFRL/Information Institute Summer Faculty Research Program and the AFOSR Summer Faculty Fellowship Program.

SUNYIT worked closely with AFRL to help build, foster and nurture in-house research teams. Under this effort SUNYIT recruited, placed and supported administrative requirements of 18 faculty members and 20 undergrad/graduate research analysts and coordinated 17 additional faculty extension efforts.

1. Faculty

The faculty and their research areas included:

2.1 2007 Summer Professors

2.1.1 **Madjid Tavana, LaSalle University** – "Network-Centric Decision Support Systems in Joint Air Operations" Joint Air Operations (JAO) are historically designed through centralized planning using static air tasking that assigns air assets to mission packages for the purpose of achieving campaign objectives. The current methodology cannot anticipate changes in the battlespace nor take advantage of real-time information. In this study, we develop a simulation model of the battlespace that utilizes a multi-criteria decision analysis (MCDA) model to assign vehicles to targets by considering four competing objectives (effort, effectiveness, efficiency, and connectivity). A Voronoi network is used to determine the paths of vehicles to their assigned targets and network optimization is used to validate the quality of the assignments. The results indicate that dynamic air tasking is considerably more effective and more efficient than static air tasking.

1.1.2 **Jorge Romeu, Syracuse University** – "Design of Experiments"
The objective of the NO'EM Project is to provide a decision maker and their staff with a strategic analysis/assessment tool that provides them with insight into the complex state space that is today's modern operational environment. To support this capability, the goal of the NO'EM tool is to provide the decision maker with a list of potential leverage (or pressure) points and their sensitivities associated with a number of responses that can be used to develop initial blue Courses of Actions (COAs). Based on the proposed set of leverage points, the decision maker can assess each option as to its ability and capability to alter the point in some manner, and to what degree. After choosing the set of actions, the decision maker can then play each proposed COA forward to view the forecasted short and long term ramifications. This work specifically supports the NO'EM tool in providing these leverage points and their sensitivities.

2.1.3 **Adam Bojanczyk, Cornell University** – "Singular Value Decomposition Analysis for Two Channel Signal Separation" Communicating and sensing in urban environments has become increasingly complex when multiple units operate in close proximity and use shared bandwidth. There is a need to improve strategies for band- width allocation in collaborative operations so as to achieve improved communication and sensing performance. One promising technique for dynamic bandwidth allocation comes from the theory of Partially Observable Markov Decision Processes (POMDPs). Most policies derived in the POMDP framework can be computed off-line but require substantial amount of computing resources. The main goal of this work is to investigate ways of speeding up POMDPs algorithms by mapping them onto parallel computers. The other goal is to investigate how approximate POMDP policies can updated on-line in a distributed environment when some of the parameters of the environment change over time.

2.1.4 **Tarek Taha, Clemson University** – "Architecture Design Space Parameters"
Several models of the neocortex has recently been proposed that are based on hierarchical Bayesian networks. The software implementation of biological scale models of these systems requires large amounts of computing resources. This report presents hardware implementations of hierarchical Bayesian network models of the neocortex. In particular it models an invariant pattern recognition model of the visual cortex presented recently. The system is based on a set of parallel computation nodes implemented on a distributed set of FPGAs within a Cray XD-1. The design was optimized for hardware by reducing the data storage requirements, and removing the need for multiplies and divides. The results indicate that the distributed set of 95Mhz FPGAs can provide a speedup of over 300 times compared to the 2.2GHz AMD Opteron processors in the Cray XD-1. The results of the model indicate the feasibility of specialized VLSI implementations of the model for high performance.

2.1.5 **Jian Ren, Michigan State University** – "Fault and Attack Tolerance for Cyber Security" Communication anonymity is becoming an increasingly important, or even indispensable security requirement for many applications. The existing research in anonymous communications can largely be divided into categories: mix-based systems, and secure multi-party computation-based systems, originating from mixnet and DC-net respectively. However, they either cannot provide provable anonymity, or suffer from transmission collusion problem. In this paper, we first propose a novel unconditionally secure source anonymous message authentication code (SA-MAC) that can be applied to any messages without relying on any trusted third parties. While ensuring message sender anonymity, SM-MAC can also provide message content authenticity. We then propose a novel communication protocol that can hide the senders and the recipients from each other, and thus can be used for secure file sharing. The security analysis demonstrates that the proposed protocol is secure against various attacks. Our analysis also shows it is efficient and practical.

2.1.6 **Krishnaprasad Thirunarayan, Wright State University** – "Investigation of Semantic Web Technologies for Resource Discovery and Collaboration" Embedded Networked Sensing involves untethered, networked devices tightly coupled to the physical world, to monitor and interact with it. Raw sensor observation can be annotated with semantic metadata to provide interpretation and context for it. In this paper, we discuss what, why and how of semantic sensor data and semantic sensor networks. Specifically, we explore (i) benefits of augmenting sensor data with semantics and potential areas of application, (ii) domain-specific and spatio-temporal problems to be addressed for realizing semantic sensor networks and processing data obtained from them, (iii) role of knowledge representation and reasoning (Semantic Web technology) in the organization and architecture of query and decision support system that can be built on top of semantic sensor networks foundation, and (iv) standardization efforts underway to make sensor-related data and sensor observations widely available and usable.

2.1.7 **Kannappan Palaniappan, University of Missouri** – "Architecture and Evaluation of VSIPL for Realtime Image Fusion" Architecture and Evaluation of VSIPL for Realtime Image Fusion Successful application of computational vision algorithms to accomplish a variety of tasks in complex environments requires the fusion of multiple sensor and information sources. However, collecting and fusing rich visual information creates a significant power and computational burden for realtime applications. The Vector Signal and Image Processing Library (VSIPL++) developed under the DARPA HPEC program offers a uniquely powerful API for developing computationally intensive image and video analysis algorithms using low power CPUs embedded within the camera sensor for operational applications. VSIPL++ additionally offers a platform and language independent environment for the development of "desktop" image analysis algorithms. The VSIPL++ API abstracts away to a large extent the need to tailor an algorithm to specific hardware architectures or embedded computing features, yet offers a fully optimized library customized for real-time application performance on a variety of hardware platforms by. Analyzing terabytes of image and video datasets for forensic analysis of Multi-INT persistent surveillance data can take months of processing time and man-years of analysts' time. Parallel architectures including (multicore) cluster

computing, symmetric multiprocessing, FPGAs, SoCs and other novel embedded parallel processing designs offer the potential to dramatically speed up the analysis of large data volumes that have strategic importance - to assist analysts in a timely fashion and ideally in real-time. VSIPL++ has the potential to reduce software development cycle times by offering hardware independence and high performance.

2.1.8 **Frank Moore And Brendan Babb University of Alaska** – "The Transform Revolution Continues: Genetic Algorithms for Improved Signal Compression and Reconstruction Under Quantization" State-of-the-art image compression and reconstruction techniques utilize wavelets. Beginning in 2004, however, a team of researchers at Wright-Patterson Air Force Base (WPAFB), the University of Alaska Anchorage (UAA), and the Air Force Institute of Technology (AFIT) has demonstrated that a genetic algorithm (GA) is capable of evolving non-wavelet transforms that consistently outperform wavelets when applied to a broad class of images under conditions subject to quantization error. Even with access to the Arctic Regional Supercomputer Center (ARSC), evolving a 9/7 wavelet with four multi-resolution levels (MRA 4) involves 128 real variables on one training image and optimization improvements were slowing down. The goal of this investigation was two-fold. The first was to see if improvements to Matlab code and supercomputer implementation could improve optimization experiments and results, and lay the ground work for further experiments with the size and shape of wavelet transforms. The second was, given our success with improved transforms for photographs and fingerprints, to determine whether transforms could be evolved that outperform wavelets on satellite images under quantization.

2.1.9 **Robert Penno, University of Dayton** – "Two D Wall." research The Prototype:

- Is a six-element, four-triad antenna array referred to as the Two-D Wall will assess and test multi-platform jammer applications;
- is being developed and constructed by the RCA Lab;
- Will provide for simulation of multiple targets with independently controlled flight paths for variable target ranges.

2.The Model:

- Written in Matlab;
- Inputs are two, arbitrary flight path(s);
- Outputs are divider switch configurations and triad dimensions coefficients.

3.Extensions to the M-target, N-element final version of the Two-D Wall will be discussed (e.g. M = 6, N = 210)

2.2 2008 Summer Professors

2.2.1 **Sanjay Madria, University of Missouri** – "Literature Survey and Review of Game Theory Models." Economic incentive models are becoming increasingly popular in Mobile Peer to Peer Networks (M-P2P). These models entice node participation to combat free riding and to effectively manage constraint resources in the network. Due to the dynamic topology of the M-P2P network, the connections between the peers become unpredictable and therefore, reliable routing becomes important. Many routing protocols proposed earlier (such as DSR, AODV) are based on best effort data traffic policy, such as the shortest route selection (hop minimization). Using economic models to find a cost effective optimal route from the source to the destination, while considering Quality of Service (QoS) aspects such as bandwidth and Service Capacity constraints for data delivery, remains a challenging task due to the presence of multiple paths and service providers. In this paper, we propose a Game theory based economic approach for routing with QoS support in M-P2P networks to forward data. Modeling the network as a directed weighted graph and using the cost acquired from the price function as an incentive to pay the intermediate nodes, we develop a Game theoretic approach based on stochastic games to find an optimal route. We formulate a capacity function, which provides the available bandwidth to support the QoS aspect. The performance of our routing protocol is also evaluated and compared with some existing routing protocols and the result shows that our protocol proves to be efficient compared to shortest-path DSR and multiple paths SMR in terms of average response time, energy utilization and bandwidth availability in the network.

2.2.2 **Hoda Abdel Aty Zohdy, Oakland University** - "BioInsired BioChip Architecture for Embedded Processing." Novel information technology required for insertion and usage in future CyberCraft requires more than just mimicking intelligent biological systems. Artificial Intelligent Information Processing's (AIIP) third generation is currently referred to as "Neuromorphic Systems".
An effective neuromorphic system is very much application dependant. Similar to the classical customized Application Specific Integrated Circuits (ASICS) - versus- off-the-shelf components, PLDs or FPGAs. As the system complexity increases and the number of required parts increase the optimum solution is a customized ASIC. Similarly, as the required effective functionality from a biological/bio-inspired system increases along with the environmental complexity a neuromorphic machine presents a solution rather than combinations of Van Neumann machines.
Bio-inspired spiking neural networks (SNN) and adaptive recurrent dynamic NNs (ARDNN) have been developed and implemented for biochemical detection (E-Nose) and for integrated information processing and reliability improvement in telecommunication systems.

The Summer Faculty Fellowship, 2008, significantly contributed to:
1. EIGHT CONFERENCE PUBLICATIONS, in collaboration with graduate research students at the Microelectronics Systems Design Lab/Oakland University, Student interns at WPAFB, the VFRP Advisor, and other significant collaborators.

2. TWO CMOS 0.5 um AMI Chips designed for processing on tiny chips for realizing real-time identification of volatile chemicals in dynamic environments, on site, and on real-time.

2.2.3 **Leszek Lilien, Western Michigan University** – "Applying Oppnets for Opportunistic Resource Utilization in the Joint Battlespace Infosphere Program." This report is bipartite, describing two projects that we embarked upon during the 2008 VFRP program. The two research problems are: (i) Using Oppnets for Emergency Response Operations; and (ii) Providing Feedback and Quality-of-information Mechanisms in Shared Information Space Environments via Oppnets.

In Part I, we consider use of the oppnet technology for emergency response operations following a chemical spill or attack. Oppnets represent the category of opportunistic resource utilization networks, which are specialized ad hoc networks. An oppnet is initially deployed as a seed oppnet. When it needs more capabilities (e.g., resources, services, and skills), it starts discovering foreign nodes that happen to be within its range and have such capabilities. The oppnet can invite them to join its efforts as helpers. (Some are "reservists" that have pre-agreed to join when needed and can be ordered to join.) The oppnet takes control over joining helpers, incorporating their capabilities. These additional capabilities facilitate or even enable realizing the goals of an oppnet-based application (such as optimizing rescue operations).

We present basic operations and characteristics of oppnets, and provide a brief summary of capabilities of chemical sensors that must be used when dealing with a chemical spill or attack. Then, we present a scenario of a chemical spill or attack, and show how an oppnet can be used in rescue operations. The scenario illustrates how a wide variety of oppnet helpers, including chemical sensors and imaging devices, can be utilized in a rescue operation.

The scenario is the basis for identification of research problems related to oppnet-based rescue operations. Four problems are described in some detail. A methodology for solving the problems is discussed next. It will involve an analytical model, and a more comprehensive simulation model. The main role for the analytical model will be validation of the simulation model and simulation experiments. The simulation model will include as its components an oppnet model for emergency response operations, a victim model, a victim recognition model, and the chemical spill model. Some details of the simulation model follow.

In Part II, we discuss the issue of providing feedback and quality-of-information mechanisms in shared information space environments (SISE). The Joint Battlespace Inphospere system (JBI), which is a prominent example of a SISE, will be our main test case for the proposed solutions. Quality of information (QoI) can be viewed as the "subset" of quality of service (QoS) "specialized" for information services. We consider only QoI (i.e., information-related portion of application-level QoS) rather than QoS (that in addition includes host- and network-level QoS.

The JBI design is based upon specific architectural paradigms and principles. The foremost ones are the publish/subscribe model of communication, enhanced with a queriable information repository. They result in a challenging setting for providing feedback and QoI management. As a consequence, a number of challenges w.r.t. feedback and QoS (and QoI) have been identified in the current JBI by other researchers,

and are summarized here. Earlier results also include identification of requirements for QoI management in the JBI. Since oppnet satisfy these requirements, we propose using them to deal with the feedback and QoI issues in SISE.
We identify architectural principles to be followed in order to integrate oppnets into JBI (and, in general, into SISE), and provide the on-demand fragment of the proposed architecture providing feedback and QoI mechanisms to JBI. Deliverables will include a complete architectural design of the system and its components. The design will be verified via simulation experiments

2.2.4 **James Stine Jr., Oklahoma State University** – "Exploration of Nanometer Cognitive Reasoning VLSI Computer Architectures." The research objectives of this work are to design, develop, and evaluate low-power hardware support for computer architectures at the VLSI level. Many of these architectures are currently or will be employed in advanced architectures that may have cognitive capabilities within the Air Force Research Laboratory in Rome, NY. This will be accomplished by designing complete design flow integration with commercial and open-source EDA tools. The design flow will take as inputs a high-level system-level architecture description, along with area, critical path delay, and power dissipation constraints. Based on the System on Chip architecture description and design constraints, the tools will automatically generate synthesizable Hardware Descriptive Language (HDL) models, embedded memories, and custom components to implement the specified VLSI architecture. Results show significant improvement over previous approaches with respect to power dissipation and leakage reduction.

2.2.5 **David Schwartz, Rochester Institute of Technology** – "Modernizing Wargames." This report attempts to organize, document, and advocate AFRL/RISB's wargame research efforts. Upon starting the summer 2008 visiting faculty research program, the branch's wargame research efforts had been wrestling with furthering new RISB research directives:

- Commanders' Predictive Environment
- Course of Action Analysis
- Cyberspace Warfare
- Space Warfare

Previous work had focused on wargame modeling and tool development. Although still worthy efforts, they did not tie into the updated branch mission. Thus, I embarked on a less defined, riskier project: explore cutting edge wargame research areas to advise AFRL/RISB on new directions to support their mission statement.
This report encapsulates the results of the summer research, which involved a broad search for anything related to wargame research with respect to computational science. The "experimental methodology" was essentially a vast literature search and synthesis, including numerous conversations with the branch researchers. Unfortunately, many aspects of the burgeoning area of "serious game development" do not necessarily fit within the branch mission. However, as this report shows, a number of areas/questions do show promise, though they will require significant development:

- Clarify/Unify the disparate communities that study "wargames."
- Can a wargame achieve fidelity and speed of a simulation?
- Learn how to engage information operations in conjunction with conventional warfare.
- Test if/how a conventional warfare system can handle non-kinetic effects.
- Design a computational environment in which players can alter game rules.
- Use/study MMOs as environments for testing and assessment.
- Does Linguistic Geometry (LG) "work"?
- Learn how to generate and abstract narrative for wargames.

This report will explain these ideas in addition to the others I explored. Because of the tremendous scope of the project, the results show breadth instead of depth in any particular area. Hopefully this exploration will help to focus AFRL's efforts.
Due to the "dynamic" nature of this work, this report exists in the form of a Wiki provided to AFRL—consequently, this report resembles a vast collection of links to papers and resources. When possible, the report gives the most recent website to facilitate access to papers and reports to encourage quick review of each idea. I deliberately provided a "live" version (the Wiki) that could continue to grow, especially to encourage collaboration with AFRL researchers. And so, I further recommend referring to the Wiki, as it should continue to reflect the most updated state of the various ideas.

2.2.6 **Sandeep Shukla, Virginia Polytechnic University** – "Multi-Threaded Code Generation for Multi-Core Processors." This Paper details the design of a new environment CodeSyn: for the multi-rate data flow based (visual) specification of embedded applications for code synthesis, execution, and visual debugging. The environment transforms the visual specification into a specific XML format that we have defined for such multi-rate data flow specifications. This XMLized model is passed to a backend code generator for code-synthesis. Compilation, and simulation of the generated code is then controlled through the visual interface, and various feedback paths enables visual debugging. This environment is the initial result of our attempt to create a formal semantics based visual framework for declaratively specifying safety critical applications such as automotive control, avionics fly-by-wire control, etc. In contrast with SIMULINK/Stateflow, LabVIEW and other visual tools, our specification formalism is based on a synchronous programming paradigm akin to the polychromous language SIGNAL.

The formalism, on which this work is based, is called MRICDF (Multi-rate Instantaneous Channel Connected Data Flow Network). The specification formalism has relational semantics, which enables static rate-analysis for scheduling the computation in the code generation stage. Hierarchical data flow specification with a minimal amount of control specification makes it easier for designers to compose MRICDF models to create larger ones. Optimizations of the C-code generated by CodeSyn and implementation of the other target languages will be the immediate future extensions of this specification driven design environment.

2.2.7 **Adam Bojanczyk, Cornell University** – Studies of Algorithms for Wireless Distributed Parallel Computers." Please see extension report

2.2.8 **Henry Zmuda, University of Florida** - "A Wavelength Diversity Array Architecture for High-Speed Optical Interconnects." It is well-known that the metal interconnect poses a significant bottleneck for improving the performance of integrated circuits. Power, speed (bandwidth), and size all affect the computational performance and capabilities of future systems. High-speed optical processing has long been looked to as a means for eliminating the interconnect bottleneck. Proposed here is a preliminary study for a novel optical (integrated photonic) processor which would allow for a high-speed, secure means for arbitrarily addressing a multiprocessor system. This study will model, simulate, and optimize the performance of the proposed system and present a preliminary design of a proof-of-concept level system to be constructed in a later phase of this effort.

2. Students

Students supported under this effort were enrolled in undergraduate or graduate education programs, demonstrating excellent academic accomplishment; they included:

3.1 2007 Students

Justin Fiore
Lei Zhao
Christopher Dziak
Leanne Hirshfield
Steven Mazur
Aaron Moscho
Corey Waxman
Marcus Calhoun Lopez
Larry Harris
Fan Ng
Brian Sharpe
Veronica Smith
Michelle Sadallah
David Murrell

3.2 2008 Students

Jacob D'Agostino
Benjamin Heiner
Cristian Popescu
John Mountney
Clarence White
Fuad Alnajjar

3. Continuing Research Projects

This initiative was intended to allow AFRL scientist and engineers to identify and support the continuation of outstanding faculty research projects begun during the summer. Due to limited funding, the continuation efforts proved to be very competitive and sought after. Following the summer of 2007 and 2008 continuation projects were supported, they included efforts by:

4.1 2007 Extension Grants

4.1.1 **John Kieffer, University of Minnesota** – "Network Traffic Data Compression." An Intrusion Detection System (IDS) is used to detect attacks on computer systems. An IDS employs an anomaly detection model to judge when observed activities deviate significantly from normal activities. To derive an effective anomaly detection model, raining algorithms are utilized which operate on huge data files consisting of network traffic data, which we call intrusion detection data files. These files entail a cost both monetarily and in data processing time; there is also the maintenance problem of dealing with such large files. To alleviate these problems, a special-purpose compression algorithm is sought via which (a) intrusion detection data files are quickly compressed for storage using much less memory space and (b) the stored data can be quickly decompressed with no loss of the original data.

Intrusion detection data files consist of data of differing types. In order to take advantage of this fact, the desired compression algorithm must decompose the data file into sub files of the same data type; these sub files are then individually compressed via good algorithms for that type of data. In other words, the compression algorithm should have a local structure. If instead one were to employ a compression algorithm which operates globally without regard for sub file data types (such as the Lempel-Ziv algorithm), one would not expect to achieve as good a level of compression as with a local algorithm.

4.1.2 **Jian Ren, Michigan State University** – "Towards Trustworthy Anonymous Communications." Communication anonymity is becoming an increasingly important or even indispensable security requirement for many applications. The existing research in anonymous communications can largely be divided into categories: mix-based systems, and secure multi-party computation-based systems, originating from mixnet and DC-net respectively. However, they either cannot provide provable anonymity, or suffer from transmission collusion problem. In this paper, we first propose a novel unconditionally secure source anonymous message authentication code (SA-MAC) that can be applied to any messages without relying on any trusted third parties. While ensuring message sender anonymity, SM-MAC can also provide message content authenticity. We then propose a novel communication protocol that can hide the senders and the recipients from each other, and thus can be used for secure file sharing. The security analysis demonstrates that the proposed protocol is secure against various attacks. Our analysis also shows it is efficient and practical.

4.1.3 **Sandeep Shukla, Virginia Polytechnic University** – "Model Driven Distributed Real Time Embedded Software Generation for Avionics Applications." Writing multi-threaded C programs requires programmers to segment the computation into several tasks, analyze dependencies between tasks, discover concurrent tasks and the synchronization points, and finally apply all these to produce a correct multi-threaded program. This could be a tedious and error-prone process, especially when the computation in the program is specified in a sequential form. Synchronous programming languages capture concurrency between various computational operations on data maximally. Moreover, *multi-clock synchronous* or *polychromous* specifications can capture even more independence of dataflow operations by allowing multi-rate processing of data. Various dependency and scheduling relations are analyzed and exploited by synchronous programming compilers such as SIGNAL compiler. While sequential code generation is efficient with these compilers, one cannot compile such specifications into multi-threaded implementations without enhancing the compiler for multi-threaded code generation. We therefore took a *noninvasive* approach. Instead of changing the compiler, we use the existing sequential code generator and synthesize some programming glue to generate multi-threaded code. This paper describes the problem of multi-threaded code generation in general, and then how SIGNAL compiler for sequential code generation, can be used in without any change to accomplish multi-threaded code generation.

4.1.4 **Sunil Kumar, San Diego State University** – "Design of Intelligent Cross-Layer Routing Protocols for Airborne Networks." Our objective is to design a novel cross-layer routing protocol using multi-path intermittent links with predefined link priorities to address the issues faced in 'Airborne Networks'. This protocol will be benchmarked against AODV as an improvement in parameters like end-to-end delay, routing overhead, throughput, packet delivery ratios, and so on. The AODV scheme combines the DSDV and DSR approaches and is most suitable for unstable / intermittent link scenario. Several improved versions of AODV have been reported in the literature which can guide us to design a novel protocol for our scenario.
Video streaming over wireless networks is becoming increasingly popular. These applications also play a very important role in airborne networks and other military applications like reconnaissance operations for providing intelligence to mobile ground cavalry units, generating topographical layouts to pinpoint enemy hideout locations to fast moving jets and so on. Wireless ad-hoc networks do not require a fixed infrastructure and also support fast and flexible deployment. These advantages however add to the woes of streaming high bit rate, low latency videos over unfavorable channel conditions and through unreliable limited bit rate links with dynamic networking issues. This report analyzes the performance of streaming scalable H.264 video over such unreliable networks and discusses the need to design cross layered (MAC, routing and transport) protocols.

4.1.5 **Adam Bojanczyk, Cornell University** – "Multi Channel Signal Separation via Singular Vectors of the System Matrix." This note addresses the problem of separating a source signal from its multipath when the signal is unknown. This problem was recently addressed by Bojanczyk and LaRue in [2] for the case of two channels. It was found that by looking at the singular vectors of the system matrix one can simultaneously estimate the multipath length as well as the coefficients of the multipath vectors. That method worked particularly well when the sample system matrix had low null subspace dimension and outperformed methods based on singular values only when the signal to noise ratio was low. In this note we generalize the technique developed in [2] to the case of three and more channels. We illustrate the performance of the method when there are three channels. Our experiments suggest that the performance of the method improves only slightly when compared to the case of two channels.

4.1.6 **Tarek Taha, Clemson University** – "Accelerating Hierarchical Temporal Models of the Neocortex on the IBM Cell Processor." Several models of the neocortex have been proposed recently that are based on hierarchical Bayesian networks. The biological scale implementations of these models have the potential to evaluate complex information processing problems in real time that are beyond the capabilities of current algorithms. The software implementation of such biological scale models requires large amounts of computing resources. Specialized computing platforms can be utilized to accelerate these models.
This report examines the software implementation of a hierarchical Bayesian network model of the neocortex on the IBM Cell processor. The model implements invariant pattern recognition as seen in the visual cortex. It is the basis of the Hierarchical Temporal Memory (HTM) model being developed by Numenta. The software implementation optimizes the data structures seen in the model and utilizes several techniques to avoid costly branch instructions. A vectorization factor of four is achieved by processing four images simultaneously. The model is evaluated over the multiple processing elements in the Cell processor. It was tested on Cell processors in a Sony Playstation 3 and on an IBM QS20 blade. The latter system allowed a preliminary investigation of the scaling of the model on multiple Cell processors. The results indicate that with the six synergistic processing elements (SPE) available in the Cell processor on a Playstation 3, throughput increases of up to 49.08 times can be seen over optimized C implementations on a 3 GHz Intel Pentium 4 processor. With the 16 SPEs available on two cell processors on an IBM QS20 blade, throughput increases of up to 65.57 times are seen. This indicates that a cluster of Cell processors can provide high performance for these algorithms.

4.1.7 **Huan Liu, Arizona State University** – "Deep Search for Modeling Group Interaction Using Open Data Sources." National Operational Environment Model (NO'EM) is a strategic analysis/assessment tool that provides insight into the complex state space that is today's modern operational environment, and supports stability operations, forecasting of failing or failed states, quantifiable and systematic analysis of possible leverage points, sensitivities, and indicators important to critical decision making. Developing public opinion of the US in a foreign country through open data sources is one of the key challenges of NO'EM. In particular, we are faced two research

issues: (1) adaptive group representation, and (2) finding representatives in a group. The summer AFRL faculty project has provided an excellent opportunity for this PI and the advisor's earlier research works on topic trees, dynamic group profiling, and identifying the influential bloggers on the blogosphere to be applied to and integrated in to achieving NO'EM. We have been investigating *a focused research topic* on public opinion of Iraq's major communities: Shi'a, Sunnis, and Kurds via online sources.
Similarly, following the summer program of 2008, these projects were continued:

4.2 2008 Extension Grants

4.2.1 **Kannappan Palaniappan, University of Missouri** – "High Performance Computing for Video Stream Processing in Net-centric Exploitation and Tracking." I helped to define the video analysis component of the NCET project through interaction with Mark Linderman, James Metzler and Duane Gilmour. NCET is a new effort in RI to enhance intelligent exploitation by cross cueing sensors, fusing multisensory information flows using on-board processing, and distributed access to these synthesized sensor products in a net-centric manner for tactical environments. Cooperative organic sensing, synergistic computing and exploiting opportunities of target acquisition through rapid communication of processing sensor information under constraints of scarce resources (bandwidth, computing, storage, security, etc) are the hallmarks of high performance computing within the NCET framework. The summer extension grant was to continue performance benchmarking of the vision modules, evaluate the progress in parallelization of the video stream processing algorithms for the IBM Cell processor, to provide input for NCET 2009 demo, and to complete a peer-review quality paper suitable for publication.

4.2.2 **Chin Tser Huang, University of South Carolina** – "Early Detection and Filtering of Peer to Peer Botnet Traffic." Botnets have become the top threat to Internet security. When receiving the order from the attacker, the bots can simultaneously generate and transmit huge amounts of traffic toward the victim. The botmasters continue to improve the command and control (C&C) mechanisms of their botnets in order to avoid the single point of failure problem and evade from botnet detection schemes. As an Air Force Summer Faculty Fellow, the PI has designed the Early Botnet Traffic Detection and Filtering System which aims to mitigate the problem of botnets by coordinating routers to block botnet traffic early. In the extension project from September to December 2008, we implement our algorithms by modifying the Quagga routing software, and conduct experiments on the DETER testbed. In the present extension project, we conduct more experiments to evaluate and optimize our algorithms, and enhance the routing software with functionality to forward the malicious traffic to the nearest security center.

4.2.3 **James Stine Jr, Oklahoma State University** – "VLSI Architecture Design Environment for 65 NM and its Application Towards Power Management Techniques." The research objectives of this work are to design, develop, and evaluate low-power hardware support for computer architectures at the VLSI level. Many of these architectures are currently or will be employed in advanced architectures that may have cognitive capabilities within the Air Force Research Laboratory in Rome, NY. This will be accomplished by designing complete design flow integration with commercial and open-source EDA tools. The design flow will take as inputs a high-level system-level architecture description, along with area, critical path delay, and power dissipation constraints. Based on the System on Chip architecture description and design constraints, the tools will automatically generate synthesizable Hardware Descriptive Language (HDL) models, embedded memories, and custom components to implement the specified VLSI architecture. Results show several orders of magnitude improvement over previous approaches with respect to power dissipation and leakage reduction.

4.2.4 **Sanjay Madria, University of Missouri** – "Performance Evaluation of the Routing Protocol Based on Economics Incentive Model Inc QoS Constraints using Game Theory." Economic incentive models are becoming increasingly popular in Mobile Peer to Peer Networks (M-P2P). These models entice node participation to combat free riding and to effectively manage constraint resources in the network. Due to the dynamic topology of the M-P2P network, the connections between the peers become unpredictable and therefore, reliable routing becomes important. Many routing protocols proposed earlier (such as DSR, AODV) are based on best effort data traffic policy, such as the shortest route selection (hop minimization). Using economic models to find a cost effective optimal route from the source to the destination, while considering Quality of Service (QoS) aspects such as bandwidth and Service Capacity constraints for data delivery, remains a challenging task due to the presence of multiple paths and service providers. In this paper, we propose a Game theory based economic approach for routing with QoS support in M-P2P networks to forward data. Modeling the network as a directed weighted graph and using the cost acquired from the price function as an incentive to pay the intermediate nodes, we develop a Game theoretic approach based on stochastic games to find an optimal route. We formulate a capacity function, which provides the available bandwidth to support the QoS aspect. The performance of our routing protocol is also evaluated and compared with some existing routing protocols and the result shows that our protocol proves to be efficient compared to shortest-path DSR and multiple paths SMR in terms of average response time, energy utilization and bandwidth availability in the network.

4.2.5 **Annamalai Annamalai Jr, Prairie View A & M University** – "Cross Layer Design of Embedded Modulation and Retransmission Diversity for Multimedia Airborne Radio Networks." The current and future wireless systems need to support a multitude of services with a wide range of data rates and reliability requirements. The limited battery resource at the mobile terminals coupled with the hostile multipath fading channel makes the problem of providing reliable multimedia services challenging. In this report, we develop a novel method to mechanize a prioritized unicast transmission at the physical layer in response to the disparate quality of service requirements for multimedia traffic

(imposed by upper layers) and investigate how the unequal bit error protection offered by multiresolution modulation is capitalized at the data link layer to yield a substantial throughput gain and minimize the packet loss probability of the "more important" packets in an integrated voice/data and delay-sensitive applications (especially in poor and moderate channel conditions). However, there exists a slight throughput penalty in the high signal-to-noise ratio regime due to competitive nature of the "optimal reliable signaling rate" in an unknown time-varying channel.

4.2.6 **David Schwartz, Rochester Institute of Technology** – "Wargame Strategy Prediction with Linguistic Geometry." Summer 2008 VFRP work involved trying to identify relevant and fruitful areas of wargame research that tie into the AFRL/RI missions of prediction, course of action, space, and cyber goals. Not only do the areas have "cutting-edge" game concepts, but they must involve computational science. As indicated in my final summer report, there are indeed a variety of fields/areas that show promise. The in-house wiki I provided had links and explanations to most recent material/concepts up to the moment at that time.
One area in particular stood out as seeming to address the entire mission statement. From the Silman Strategies brochure (Section A.2, www.stilman-strategies.com/movies/LG-PACKAGE.pdf): STILMAN's premier technology is based on *Linguistic Geometry* (LG) [48], a new type of game theory *revolutionizing* the paradigms of battle management and mission planning. In essence, LG-based tools automatically generate winning strategies, tactics, and courses of action (COA) and permit the warfighter to take advantage thereof for mission planning and execution. LG looks far into the future – it is "predictive". With unmatched scalability, LG provides a faithful model of an intelligent enemy and a unified conceptual model of joint military operations.
So, LG seems handle the commander's predictive environment and course of action analysis. However, given that AFLR/RISB was not exploring LG due to difficulty in understanding the technique, it seemed worthwhile to try to see if a team could help understand the technique.

4.2.7 **Sandeep Shukla, Virginia Polytechnic Institute and State University** – "Development of Specification and Synthesis Framework for Embedded Software." Synchronous programming languages such as Esterel [1], SIGNAL [2], LUSTRE [3] etc., have been successful in embedded reactive software specification and generation of sequential software code from them. With rigorous formal semantics, a stepwise correctness preserving refinement strategy from specification to implementation, works quite well for them. At the heart of these languages is the *synchrony hypothesis* that abstracts away the computation and communication time and hence the term synchronous languages. Even though broadly classified as synchronous languages due to the underlying synchrony assumption, these languages often have very different underlying model of computation (MoC).

In this project, we provide an alternative for multi-rate specification model, with analysis and synthesis techniques that are very simple to understand for designers. This alleviates the bane of complicated semantic theory of SIGNAL based on clock equations, without compromising the rigor. The relative popularity of Esterel and LUSTRE is due to the simplicity of its globally synchronized execution model. We believe that it makes our specification formalism more useful by ordinary engineers. After all, synchronous languages are specification languages, not implementation languages. Specifications must be as abstract as possible, leaving more choice to implementers for optimization. This is the philosophy with which we have developed **MRICDF** as a more user friendly polychromous modeling formalism, a theory of implement ability, and a visual environment **EmCodeSyn** to support such modeling and synthesis.
This technical report is organized as follows. The second section will introduce the basic concepts of MRICDF formalism. We limit this section as an introduction to understand the concept and usage of MRICDF which forms the basis for EmCodeSyn explained in Section 3. The environment, design flow and intermediate and final file structures are explained in this section. Section 4 will provide two MRICDF models which will guide the reader through the design flow for EmCodeSyn from anMRICDF model to synthesized C code. Section 5 and 6 deal with real-time and multi-rate extensions respectively which enables EmCodeSyn to generate more faithful implementations fromMRICDF models. Section 7 concludes the report with the summary and current status of the project and the possible directions from here. To keep this document brief, we have referred to several publications which contain more detailed information on the proofs, theorems, modeling examples etc.

4.3 Spring 2009 Extension Grants

4.3.1 **Chin Tser Huang, University of South Carolina** – "Early Filtering of Botnet Traffic Using Routers." Botnets have become the top threat to Internet security. When receiving the order from the attacker, the bots can simultaneously generate and transmit huge amounts of traffic toward the victim. The botmasters continue to improve the command and control (C&C) mechanisms of their botnets in order to avoid the single point of failure problem and evade from botnet detection schemes. As an Air Force Summer Faculty Fellow, the PI has designed the Early Botnet Traffic Detection and Filtering System which aims to mitigate the problem of botnets by coordinating routers to block botnet traffic early. In the extension project from September to December 2008, we implement our algorithms by modifying the Quagga routing software, conduct experiments on the DETER testbed, and prepare a research paper that we plan to publish. We request for the extension grant to conduct more experiments to optimize our algorithms, and enhancing the routing software with a functionality to forward the malicious traffic to the nearest security center.

4.3.2 **Sandeep Shukla, Virginia Polytechnic Institute and State University** – "Codesyn: A Visual Framework for Specification of Safety Critical Embedded Software and Code Syntheses." Synchronous programming languages such as Esterel [1], SIGNAL [2], LUSTRE [3] etc., have been successful in embedded reactive software specification and generation of sequential software code from them. With rigorous formal semantics, a stepwise correctness preserving refinement strategy from specification to implementation, works quite well for them. At the heart of these languages is the *synchrony hypothesis* that abstracts away the computation and communication time and hence the term synchronous languages. Even though broadly classified as synchronous languages due to the underlying synchrony assumption, these languages often have very different underlying model of computation (MoC).
In this project, we provide an alternative for multi-rate specification model, with analysis and synthesis techniques that are very simple to understand for designers. This alleviates the bane of complicated semantic theory of SIGNAL based on clock equations, without compromising the rigor. The relative popularity of Esterel and LUSTRE is due to the simplicity of its globally synchronized execution model. We believe that it makes our specification formalism more useful by ordinary engineers. After all, synchronous languages are specification languages, not implementation languages. Specifications must be as abstract as possible, leaving more choice to implementers for optimization. This is the philosophy with which we have developed **MRICDF** as a more user friendly polychromous modeling formalism, a theory of implement ability, and a visual environment **EmCodeSyn** to support such modeling and synthesis.
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4.3.3 **Sanjay Madria, Missouri University of Science and Technology** – "Workshop on Research Directions in Situational-Aware Self-Managed Proactive Computing in Wireless Ad hoc Networks." Economic incentive models are becoming increasingly popular in Mobile Peer to Peer Networks (M P2P). These models entice node participation to combat free riding and to effectively manage constraint resources in the network. These types of networks may be large and some of the peers in these networks may be critical from the point of view of survivability. For example, in a military application soldiers get the data from the commander's laptop for the distribution later in the field. In other words, the failure of commander's computer can cause temporary disruptions in the network either due to its strategic location in the topology or the service it provides. Also, in order to increase the network life time, such nodes with scare resources such as battery power will demand a high cost to route so that they can provide service to others for the longer period of time. Due to the dynamic topology of the MP2P network, the

connections between the peers become unpredictable and therefore, the reliable routing becomes important. Many routing protocols proposed earlier (such as DSR, AODV) are based on best effort data traffic policy, such as the shortest route selection. Using economic models to find a cost effective optimal route from the source to the destination, while considering the cost and the quality of service (QoS) aspects such as bandwidth and latency constraints for data delivery, remains a challenging task due to the presence of multiple paths and different service providers. To analyze the problem, we considered a scenario of a military application where a soldier would like to send a message to his commander or vice-versa. Any delay in the delivery of the information may result in abandoning the mission. The successful delivery of the information lies in sending it in the best possible route which has a low cost and faster turnaround time. Here, we consider each soldier in the battle field as a peer and the commander as the peer who perform services to the requesting peers (customers) by serving the requests. *In this work, we have designed* a Game theory based economic approach for routing with QoS support in M P2P networks to forward data. By modeling the network as a Directed weighted graph and using the cost acquired from the price function as an incentive to pay the intermediate nodes, we have designed a Game theoretic approach based on stochastic games to find an optimal route. We formulated a capacity function, which provides the available bandwidth to support the QoS aspect.

4. Expenditures

The expenses under this effort were broken down on a faculty/week and student/week basis. The rates for the professors were established by the National Research Council for summer research fellows. These rates were:

5.1 Faculty Labor

Assistant Professor	$1,250/week
Associate Professor	$1,450/week
Full Professor	$1,650/week

5.1.1 Faculty Per Diem

Those faculty members whose home residence/university is more than 50 miles from AFRL/IF were entitled to: $250/week

1.2 Students

Were compensated based on a sliding scale according to published government rates. Entry positions were based on GS-09 scale, which was commensurate with "lab-demo" hourly rates for new hire employees at RRS. Doctoral students with unique qualifications were addressed individually. Students were also given a meal allowance of $100/week and the award paid SUNYIT for their dorm rooms at $160/week.

Under terms of placement agreements, the candidates were only paid for actual days worked. Absences were not to be paid; this includes non-lab sponsored meetings or symposiums. Federal holidays were also not to be paid.

Faculty and students were paid for their travel to Rome Lab from their home at the beginning of their participation in the Visiting Faculty Summer Program. They were also reimbursed for their expenses incurred to travel home from the Lab at the end of their assignment.

5.3 Other Costs Associated with Program

Occasionally expenditures for supplies were required for the program. Other expenditures made on this award included:

- Sponsorship of 4th Annual Cyber Security Awareness Conference at NYU's Polytechnic University
- Registration fees for 2008 Challenges conference for some faculty/students
- Sponsorship of 5th Annual Cyber Security Awareness Conference at NYU's Polytechnic University
- DSS Labs Incorporated (Eric Thomsen) –AFRL Seminar on "A Logical Framework For Solving Information Problems in Mission Planning and Battlefield Awareness"
- Administrative Assistant salary and fringe from October 1, 2008 to March 27, 2009