PAPER COVER SHEET

High Productivity Computer Systems: delivering information superiority with specific applications for Software Define Radios and Cognitive Computing

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Abstract

Reports from DoD entities and DARPA call attention to a nationally recognized gap between current high performance computing technology and the need for quantum computing power in order to handle important national security applications. Current trends, e.g., the availability of high-end computing power via commodity manufacturers who are focused on the business needs of mass-market consumers, are an ineffective and unmanageable solution source for DoD. The mission of DARPA's Information Processing Techniques Office (IPTO) - conduct a focused research and development program that creates a new generation of high productivity computing systems – emphasizes high productivity as opposed to simply high performance. Additionally, of interest to the SDR Forum, is IPTO's articulated vision for the uses of a High Performance Computing System (HPCS) accentuates information superiority with specific applications that include Cognitive Computing and Software Define Radios! In today's complex data sharing environment, specifically complex simulations, the imbalance between computer power and software complexity can result in applications software with poor scalability (utilizing less than a dozen processors for optimized codes) and poor single processor performance (as low as 1% of peak processor performance). Additionally, industry is just starting to acknowledge that Moore's Law - the doubling of microprocessor performance every 18 months - will not continue through this decade; thus, new and innovative ideas in computer architecture will be required to maintain the current pace of CPU performance improvement. Fortunately, recent research indicates that significant gains can be achieved by increasing the "effective" productivity of current high-end solutions. This paper highlights the intent, foci and progress of an ongoing design and development project at Diversified Technology Incorporated (DTI). The intent and focus section will highlight DTI's high productivity computing system solution that is economically viable and attributes that include; a) dramatic improvement in computational efficiency and reduced execution time; b) reduced cost and time of development for HPCS applications; c) insulation between application software and system specifics; and d) robustness, measured in improved reliability and reduced vulnerability to intentional attacks. The primary goal of DTI's effort is an increased understanding of cognitive processes, through the use of high end processing computers, resulting in the ability to handle large amounts of associated data while addressing the cost associated with current HPC systems. What sets DTI's

HPCS apart from other approaches is its focus on developing and applying a tactical package with computationally intensive techniques, data mining, and machine learning algorithms. Major research efforts in the field include biometrics, process improvement, sequence alignment, gene finding, genome assembly, protein structure alignment, protein structure prediction, prediction of gene expression and protein-protein interactions, and the modeling of data evolution. The progress section discusses how far DTI’s R&D effort has come in resolving issues discovered in technical areas, e.g., a) high, effective bandwidth, b) a balanced system architecture, c) robustness that considers system brittleness and susceptibility and d) the relationships between the hardware and software for enhanced performance.

1. Introduction

The primary goal of DTI’s effort is an increased understanding of cognitive processes through the development of highly productive computers that results in the ability to handle large amounts of associated data while addressing the cost associated with current high performance systems.

What sets DTI’s design apart from other approaches to developing a platform of the stated capabilities is its focus on developing and applying a tactical package with computationally intensive techniques. Major research efforts in the field include biometrics, improvements in computing processing, integrated FPGA technology, Clustering, multifunction threading, structure alignment, on board climate control, and the modeling of data evolution.

This paper highlights DTI’s High Productivity Computing System (HPCS) as a viable solution with attributes such as a) dramatic improvement in computational efficiency and reduced task execution time; b) reduced cost and time of development for HPCS platforms; c) insulation between application software and system specifics processes; and d) robustness, measured in improved reliability over blade configurations. How far DTI’s R&D effort has come in resolving technical issues in technical areas is evident by- high, effective bandwidth, balanced system architecture, robustness that considers system brittleness and susceptibility and the relationships between the hardware and software for enhanced performance. Also, germane and salient architectural notes on the HPCS’ configuration are proffered.

2. Project Initiatives and Intent

Cognitive technology is a new and evolving field, which combines the interactive qualities of modern high performance computers with the knowledge acquired by cognitive psychology to create tools that can preserve and improve our cognitive abilities. The standards of neural networks to date have not been as successful as first believed they would become. However, after some 8 years of research and development, DTI’s cognitive s/w team has developed, in mathematical terms, a number of logic circuits that combine the human related predicate and modal logics subdivided into sub-levels of logic under each of these overarching logic categories. Our logic circuits and neural networks have been consolidated into a unique, adaptive technology that enables our software to learn the users abilities. Based on the resulting data we have created a personalized cognitive training program for a computer that trains the computer to learn the environment it exist in and provide an accelerated cognitive processing structure.

With this R&D effort underway Diversified Technology Incorporated (DTI) recognizes, along with a nationally supported recognition, that there is a huge gap between "late 80's" high performance computing technology and quantum computing. Recent agorithm development efforts by DTI engineers to demonstrate the ability for a computer to learn and make decisions have been successful, relative to the algorithm working. A desk top computer was given 100+ characteristics of the color red, then the color pink characteristics were given to the computer and the computer was asked to evaluate those characteristics. On its own, gave the answer, "It's not red." The algorithm worked; however, it took the desktop 40+ hours to come up with that determination via the algorithm's analysis functions. Efforts such as this along with reports from DoD entities and DARPA call attention to that gap:

- high performance computing is at a critical juncture.
- current trends in commercial HPC and emerging threats are creating technology gaps that
  threaten continued U.S. superiority in important national security applications.
- high-end computing will be available only through commodity manufacturers focused on mass-
  market consumer and business needs; an ineffective and unmanageable solution for important
  national security applications.

The mission of DARPA's Information Processing Techniques Office (IPTO) - conduct a focused research and development program that creates a new generation of high productivity computing systems – emphasizes high productivity as opposed to simply high performance. This undertaking focuses on the development of economically viable, high productivity computing systems for the national security and industrial user communities. Attributes for these systems include:

- Performance: Improved computational efficiency and reduced execution time of critical national security applications.
- Programmability: Reduced cost and time of development for HPCS applications.
- Portability: HPCS application software insulated from system specifics.
- Robustness: Improved reliability and reduced vulnerability to intentional attacks.

The IPTO's vision for HPCS applications accentuates information superiority in critical applications areas such as: operational weather and ocean forecasting; planning exercises related to analysis of the dispersion of airborne contaminants; cryptanalysis; military platform analysis; survivability/stealth design; ***Cognitive Computing and software defined RF communi***cations; intelligence/surveillance/reconnaissance systems; virtual manufacturing/failure analysis of large aircraft, ships, and structures; and emerging biotechnology for both public safety and military applications.

3.Project Foci and Challenges

Cognitive computing, an area of immense interest to the Software Defined Radio community, is one of the focus areas for DTI as it develops its HPCS that will require adaptations of existing artificial intelligence applications in concert with multi-layered pattern recognition software.

Characteristics of the cognitive

software/algorithms (See Figure 1 for a model of these characteristics) include:
- Data sets (a finite amount)
- Topology (a roadmap to define the data's nodes, edges, and faces in a topology)

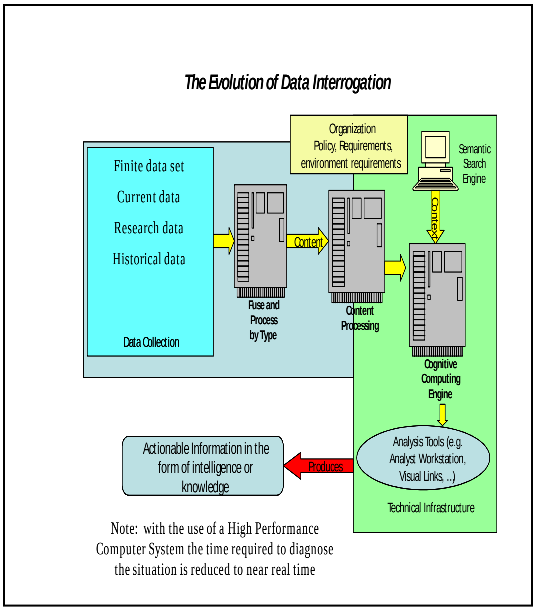


Figure 1

- Ontology (the *specification of a conceptualization*)
- Semantic Dictionary
- Defined training set
- Unique logic circuits (DTI's software will be different from existing models)
- Predicate, first order logic; propositional logic is not powerful enough to represent all types of assertions that are used in computer science and mathematics or to express certain types of relationship between propositions, e.g., equivalence.
- Modal operators; distinguishing two sorts of truth - *necessary* truth and mere *contingent* truth by applying Lambda Calculus.
- Neural networks; an information processing paradigm that is inspired by the way biological nervous systems, such as the brain, process information; learning, in biological systems, involves adjustments to the synaptic connections that exist between the neurons.

The paradigm is the novel structure of the information processing system that is composed of a large number of highly interconnected processing elements (neurons) working in unison to solve specific problems. Like people, computers can learn by example if they are configured for a specific application, such as pattern recognition or data classification, through a learning process.

The design of DTI's HPCS is not limited to a single 'cognition application.' Another area that DTI has focused this High Power Computing Capability for is Information, Surveillance and Recognizance (ISR) analysis where cognitive computer functions, truly, can accelerate the tactical user's situational awareness. However, for a balanced technology and system development effort that "works" for both of these challenging applications, those four attributes championed by the IPTO - productivity <u>performance</u>, <u>programmability</u>, <u>portability</u> and <u>robustness</u> - will drive all solutions.

<u>Performance characterization</u>, metric development, technology go no/go criteria, and prediction activities, along with end user and industry involvement will provide DTI with the active feedback required to answer this challenging R&D program goals as well as meet Mil Stds 1553, 810 and 461E. With the HPCS' <u>performance baseline set to a Cray XT5</u>™ DTI's design approach <u>addresses</u> current technical challenges confronting the development and use of current high-end systems and applications, e.g., <u>programming productivity</u>, <u>performance</u>, <u>portability</u>, scalability, reliability, and tamper resistance.

The HPCS core technical challenges are:

1. **High, effective bandwidth:** Expanded bus speeds to 8GHz or above with the capacity to run multiple operating system simultaneously.
2. **Balanced system architecture:** balancing the performance of processors, memory systems, interconnects, system software, and programming environments.
3. **Robustness:** balanced system hardware; software reliability and fault tolerance capabilities; active application software tolerance; intrusion identification and resistance techniques.
4. **Improved reliability and reduced risk of malicious activities by ensuring:** A processor sustaining 128 simultaneous threads and connected with up to 8 GB of memory.
5. **High power computing capability for ISR analysis:** A scalable, multithreaded platform with shared memory architecture for large-scale data analysis and data mining; multi-threaded technology is suited ideally for tasks such as pattern matching, scenario development, behavioral prediction, anomaly identification and graph analysis.
6. **Enhanced performance:** The system couples industry-leading scalar processing capability with high-bandwidth vector processing and reconfigurable FPGA acceleration to establish a new paradigm in high productivity and performance.

4. Progress

Electrical Design

The prototype HPCS will be composed of modular Cluster Nodes (CN). Each CN will be comprised of nine (9) subsystem processing boards and one subsystem network switch board. The HPCS itself is created when one or more of these Clustered Nodes are connected together, creating a high performance Aggregate Clus**te**red System (ACS) that's housed in a Mil-Spec 810E complaint chassis.

Computational Subsystem

To show that the COTS model alleviates dependencies on any on computer architecture the prototype HPCS will use two differing architectures. The first CPU node used will be composed of DTI's MPBCL0030 ATCA nodes that allows up to 16GB of ECC DDR2 RAM on each subsystem processing node.

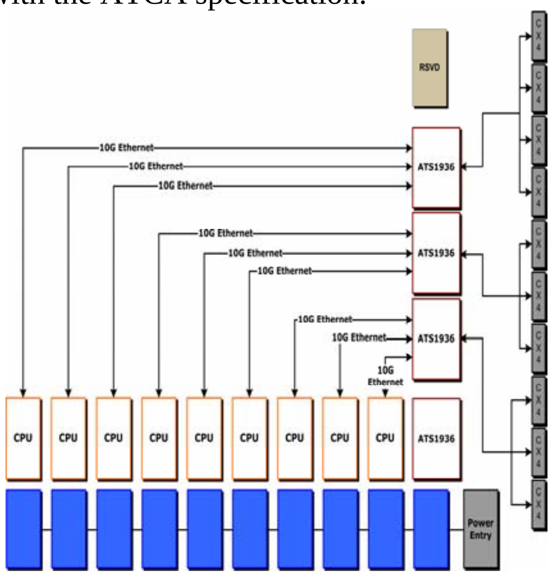
The second CPU subsystem blade will use DTI's ATC6239 ATCA compute node; a processing node powered by Dual 64-bit Quad-Core AMD Opteron processors, up to 16GB RAM, and features 10GbE intra- and inter-chassis connectivity.

Communication Subsystem

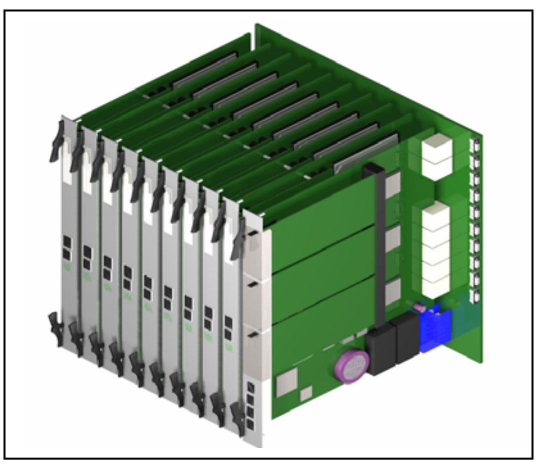
Intra- and Inter-Clustered Node communication will be handled by DTI's ATS1936 10G Switch. Utilizing a 10G switch as the common communications subsystem allows for easily upgrading the node subsystem, perhaps to DTI's upcoming ATC6239 10G node, to take advantage of the 10G networking capabilities at a future date. A block diagram of the ATS1936 follows:

Cluster Nodes

To facilitate modularity a Cluster Node will consist of nine processing subsystem blades (either ATC6239 or MPBCL0030), one switch, will be linked together by a passive backplane, which will be partially compliant with the ATCA specification:

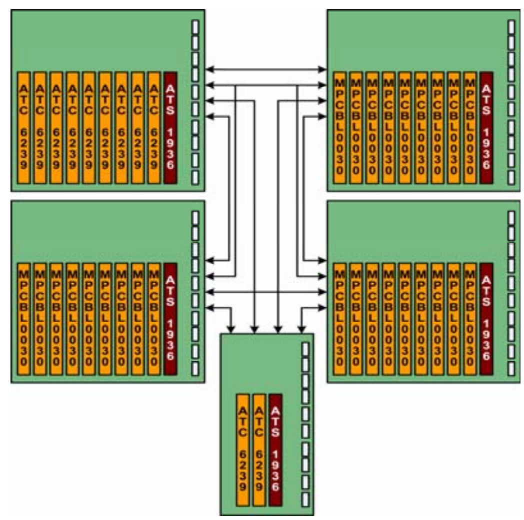


With this backplane, nine MPCBL0030 or ATC6239 compute subsystem blades and one ATS1936 communication subsystem blade will be inserted to form the following Cluster Node arrangement.



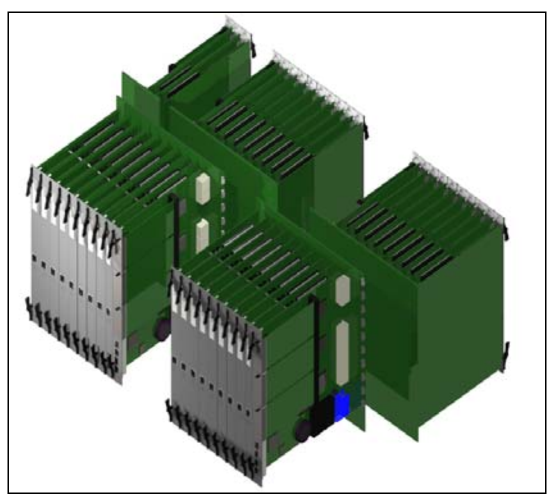
Aggregate Cluster System

An Aggregate Clustered System is created whenever more than one (1) Clustered Node exists within the set; referred to as a Site-based Aggregate Clustered System (SACS)all CN subsystems exist “under one roof” and share a main external link. In DTI’s proposed prototype four Cluster Nodes and one Primary Control Node (a modified CN) will form the (Site-based) Aggregate Cluster System:



Prototype HPSACS Connectivity Concept

The following diagram shows a more ‘real world’ connectivity example:



HPSACS system with backplane mounting

The four Cluster Node subsystems are arranged in a 'butterfly' pattern. This allows the processing and communication subsystems of each CN to be incorporated into a double sided, split-backplane setup, allowing for easier chassis mounting and subsystem servicing.

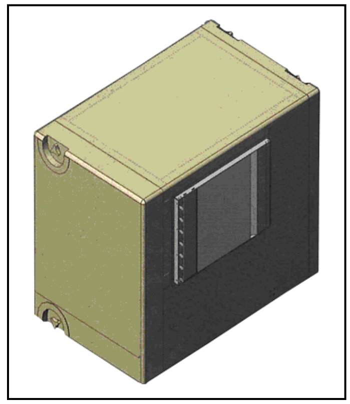
Software

The HPC nodes will operate at the OS level via Linux, specifically CentOS 5.2. CentOS is essentially a RHEL rebuild project, and as such contains the same base functionality as the latest RHEL releases. CentOS 5.2 integrates load balanced clustering, storage clustering, HA clustering, and virtualization into the base kernel package. CentOS incorporates many network servers into its base installation which allows for the setup of clustering techniques without the need of obtaining many additional packages. This will allow for easier expansion into new avenues of application for DTI's basic HPC build beyond a Beowulf-style computational cluster.

Software developed for the DTI HPC system must be compiled to communicate over MPI, thus distributing processing tasks among nodes in the system. DTI does not plan to do this development for any application and it will be up to the end user to ensure that system software is capable of taking advantage of the Beowulf-style computational cluster DTI will supply.

Chassis

Since all of the fundamental electronics exist today in the form of ATCA CPU nodes and ATCA switches, most of the prototyping work centers around the Site-based Aggregate Clustered System chassis design. The chassis houses the Cluster Nodes, comprised of compute and communication subsystem nodes, that make up the parallel clusters. Estimates place the chassis dimensions around 48 inches by 48 inches by 37 inches, which is small enough for the cluster chassis to sit on the back of a two-seat HMMMV. The prototype chassis contains the air conditioning necessary to air-cool the cluster boards, and AC-DC power supplies required to power the cluster nodes. As with all computer devices, thermals, size and power are the driving factors; for this application thermal is the chief driver. The ATCA computer can dissipate up to 400W of power, therefore a large AC unit will be required to cool the boards in high temperature environments.   The A/C unit isolates the box from external ambient temperatures and the electronics from dust and potentially corrosive gasses. Computational Fluid Dynamic (CFD) simulation will ensure that the cool air is adequately distributed throughout the chassis and help DTI design any purposeful re-circulation needed to account for differing mass flow rates over the electronics. Since the cooling is self-contained the only external connection to the cluster chassis will be power and six 10G optical Ethernet connections.   Power is estimated at 15kW with peaks to 19kW during A/C startup, however this number will largely be driven by software on the cluster. In extremely cold environments cluster start up may present an issue but can be solved by pre-heating the cluster; to limit the scope of the prototype and meet the chief goal of benchmarking the cluster this pre-



heating design will not be included in the prototype. Once the cluster is started in cold environments it will self-heat and likely still need the A/C unit to operate. The prototype is designed to meet Mil-spec 810E but actual testing and design changes resulting from the testing will not be accomplished in this first run funding. Final exterior package is illustrated in the photo to the left.

5. Summary

Developing the cognition piece of a cognitive radio - e.g., the learning and reasoning controls for a software defined radio and the algorithms required - is a monumental undertaking. High productivity versus high performance is recognized by those technologically influencing entities such as DARPA and DoD, who recognizes the value of marrying cognitive computing with Software Defined Radios, as a valid approach to solving this problem.

High productivity, the end goal of DTI's HPCS R&D effort, will be realized when its HPCS is rolled out in the latter part of 2009. This system will offer an attractive platform for further research into the understanding of how to develop and running those algorithms that will offer cognitive processing capabilities - learning and reasoning through the handling of large amounts of data, data mining and bayesian inference techniques. The platform is scalable and physically small enough to be considered "portable." It offers a solution to an existing computational gap that, currently, is thwarting R&D efforts aimed at achieving information superiority - an area of key interest to wireless networks, communications and the Software Defined Radio community.