High Density Digital Signal Processing with ATCA

Rob Persons, Senior Field Applications Engineer
Embedded Computing
Emerson Network Power
Emerson.com/EmbeddedComputing

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Data in the modern battlefield has become as essential as munitions. Detection, target tracking, and the decisions that must be made based on data acquired from sensors and cameras mounted to UAVs or a myriad of radar and sonar devices on a cruiser, all require sophisticated algorithms executing on powerful computing equipment. Traditional methods of digital signal processing (DSP) have used specialized FPGA equipment, multiprocessor VME and OpenVPX solutions, but a new class of computing has the potential to replace some of those expensive highly specialized processing elements.

Advanced Telecom Computing Architecture (AdvancedTCA® or ATCA®) is an open computing standard that has a significant amount of value to military applications requiring a huge amount of processing. Advances in microprocessor technology and accompanying software will make ATCA a very powerful signal processing technology for future complex signal processing applications.

The paper assumes a basic understanding of AdvancedTCA. An introduction to the technology is provided in the Emerson Network Power white paper, *"What is ATCA?"* More information is also available in the white paper, "*ATCA for Military, Aerospace and Other High Performance Embedded Computing Users.*"

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Digital signal processing (DSP) includes subfields such as audio/speech signal processing, sonar and radar signal processing, sensor array processing, spectral estimation, statistical signal processing, digital image processing, signal processing for communications, control of systems, biomedical signal processing and seismic data processing.

New technologies are emerging that will enable Advanced Telecom Computing Architecture (AdvancedTCA® or ATCA®) to address DSP applications, especially those in defense and aerospace.

These include:

- High performance multicore processors
- Updated vector processing units in cores
- High speed fabrics in the ATCA backplane
- Advanced flow control software on ATCA switches and blades
- Repurposing packet processing software to target DSP applications

The trends driving the opportunity for defense contractors include the cadence of Intel® Xeon® processor performance and functionality, and underlying fabric interfaces moving from 10G to 40G with the release of PICMG3.1R2.

The inherent ruggedness of ATCA, having been designed for the telecom industry's NEBS standards, lends itself to semi-rugged deployments such as shipboard manned, airborne and transit case applications.

There is a now an opportunity for defense contractors to leverage packet processing blades and software originally developed for telecom networks for very dense computing and signal processing.

This new category of ATCA blades - based on general purpose processors but applied to digital signal processing applications - can be termed *algorithm processing blades*.

Digital Signal Processing

The frame of reference for this paper is digital signal processing, which we will define as the mathematical manipulation of an information signal to modify or improve it in some way. The basic concept in a defense application can be characterized that:

1. Some kind of sensor device detects objects
2. A high speed interface transfers this data to a rack with computing equipment
3. Analog data is either
   - Converted to digital at the sensor
   - Or converted to digital at the signal processing unit

Traditionally, digital signal processing subsystems have been based on VME technology and there is drive for high speed serial interfaces to replace the VME parallel bus, which is an ideal opportunity to evaluate technologies such as OpenVPX and ATCA.

These computing architectures offer multi-processor boards that support high level DSP libraries and a host processor to manage data flows, as well as a range of ruggedization levels depending on the requirements of the application.

AdvancedTCA Refresher

- An open standard (COTS) developed over 10 years ago and deployed in all major telecom networks
- An ideal basis for a common platform, on which many applications can be built
- The standard covers shelves, boards, mezzanines, and management
- Systems are 19" wide and are designed to fit in 600mm deep racks
- Current ATCA chassis can support 350W+ per slot, but can be limited to 200W
- High speed 10G and 40G internal data fabrics now deploying
- Blades are 8U (14") high and have no fans

High Performance Processing Core

The latest generation Intel Xeon processors, such as the Intel Xeon E5-E2600 processor family (formerly code named '*Sandy Bridge*') feature many high speed interfaces into the processors.

Beyond the eight multi-threaded cores running at 1.8GHz per core, these processors also offer a large 20MB Level 3 (L3) cache. Many memory interfaces thanks to four integrated memory controllers provide a very fast method for moving data that is sent to the blade into the processor itself.

A dual processor ATCA blade offers very high speed dual Intel QuickPath Interconnect (Intel® QPI) connections between the processors should the application need to move data between processors.

These new processors feature 40 lanes per socket of third-generation PCI Express connectivity directly to the processors, where previous generation devices offered PCI Express connectivity in a host bridge. This connectivity can be leveraged for high speed fabric interfaces in ATCA.

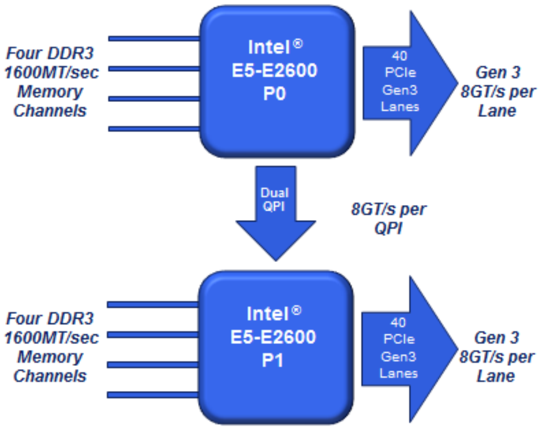

Figure 1: The latest Intel Xeon processors provide a high performance processing core for signal processing applications

ATCA blade designs, such as Emerson Network Power's ATCA-7470 packet processing blade, are designed to be ready for the next generation Intel Xeon processor family which will offer more cores and additional functionality (code named '*Ivy Bridge*') such that customers can take advantage of the newer processor with minimum disruption.

Along with the processors, Intel is developing hardware acceleration functionality that might traditionally be seen in a dedicated packet processor.

Intel® Advanced Vector Extensions (AVX)

Introduced in the 2nd generation Intel Xeon family processors, Intel® Advanced Vector Extensions (AVX) is a set of instructions for doing Single Instruction Multiple Data (SIMD) operations on Intel® architecture CPUs. The 128-bit SIMD registers of Intel® Streaming SIMD Extensions (Intel® SSE) have been expanded to 256 bits.

This potentially doubles floating point operation performance when using single precision floating point numbers.

Intel AVX also offers specific instructions that support signal processing applications and Intel supplies optimized libraries for AVX. Optimized VSIPL libraries are also available from third parties.

For applications such as radar detection, signal processing frequently requires multiple processors, often distributed across multiple blades.

The performance boost provided by Intel AVX implemented in an ATCA system helps developers reduce processor and blade counts, lowering BOM and design complexity. The reduced processor count and inherent efficiency of the ATCA bladed architecture can significantly lower power consumption.

40G ATCA Fabric

Figure 2 shows two options for achieving 40G Ethernet bandwidth in an ATCA backplane.

The first is a 4x 10GBASE-KR Fabric configuration defined in the ATCA specification as PICMG 3.1R2 “Option 3-KR” and has 10G Ethernet links through separate MACs and data running over four individual Fabric lanes.

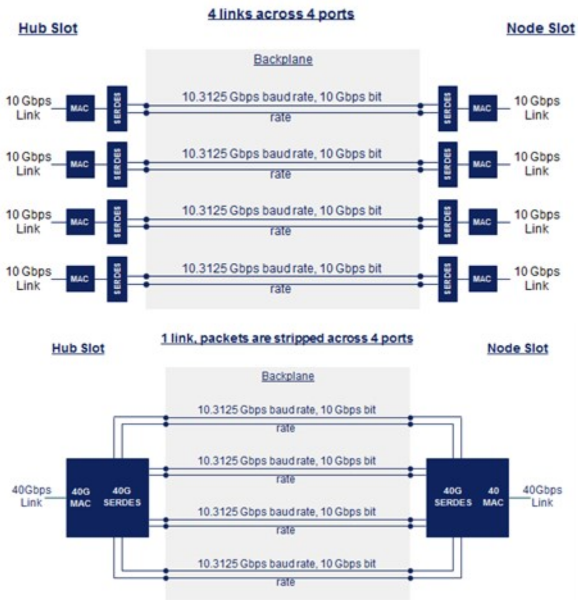

Figure 2: Two options for achieving 40G Ethernet bandwidth in an ATCA backplane

The second option is a single 40GBASE-KR4 Fabric configuration defined in the ATCA specification as PICMG 3.1R2 “Option 9-KR” and has a single 40Gbps link to a single 40G MAC.

Both options provide total bandwidth at 41.25 Gbps baud rate of 40 Gbps bit rate.

40G ATCA Switch Blade

Figure 3 shows the architecture of a 40G ATCA switch blade, such as Emerson’s ATCA-F140. The new 40G interfaces allow for inbound and outbound traffic at 40G while still supporting the older 1G and 10G standards.

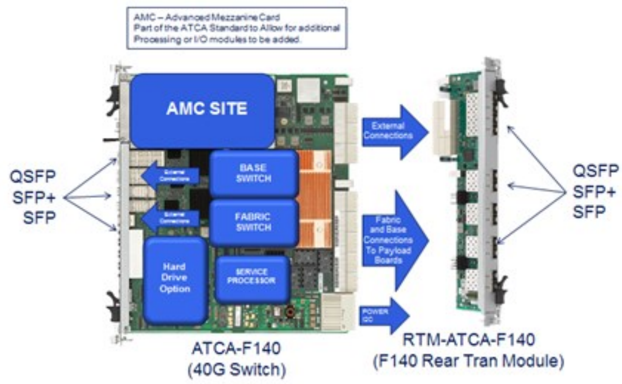

Figure 3: 40G ATCA switch blade architecture (Emerson ATCA-F140)

The primary goal for the purposes of this paper is to understand how to effectively get the data coming into the system to the right processor payload blades.

This has resulted in the development of advanced flow management software to take individual IP streams, classify them and then direct them to specific boards in the system. Furthermore, the software will optimize the return flow of the data as it exits the system.

Flow Management

Emerson’s FlowPilot™ add-on package enables this functionality, using software and hardware capabilities of the 40G switch on the ATCA-F140.

This ensures fast packet handling inside the system, with multiple configuration options to tailor the function of FlowPilot to the feature set actually required.

More importantly, FlowPilot will distribute flows across a number of configured blades according to configured parameters, ensuring they remain constant over time and the same inspection device receives the entire flow.

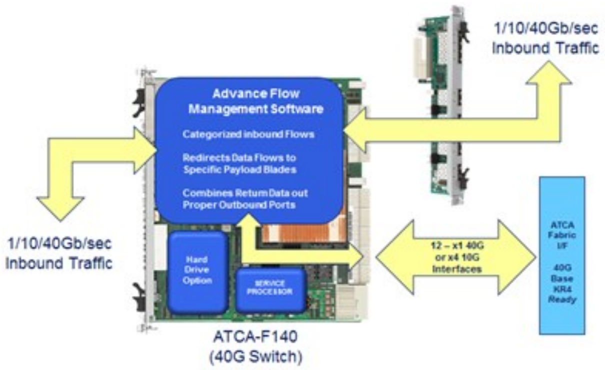

Figure 4: Flow management software such as Emerson's FlowPilot™ can help optimize packet handling inside and ATCA system

Additional functions include health check on an application level and link transparency, connecting left side and right side cables to a virtual connection.

40G ATCA Payload Blade

Figure 5 shows the architecture of Emerson's ATCA-7470 as an example 40G ATCA packet processing blade based on dual 8-core Intel Xeon E5-2600 family processors.

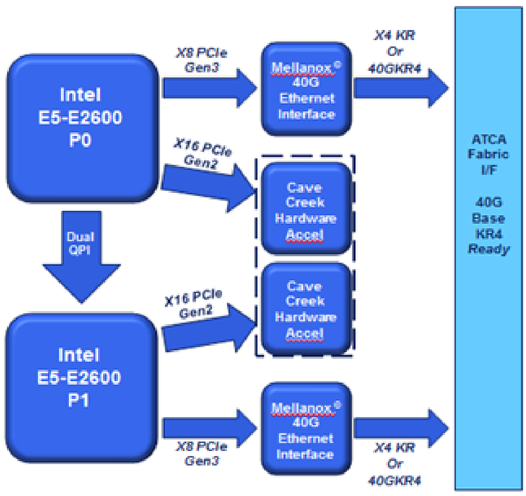

Figure 5: Example of a 40G ATCA packet processing blade based on dual 8-core Intel Xeon E5-2600 family processors (Emerson ATCA-7470)

Each CPU is connected to one 40G Mellanox ConnectX3 Ethernet controller using third-generation PCI Express, allowing maximum throughput between controller and memory, and direct connection to a processing unit. Additional 10G ports to the external world to add pre-processing capabilities can be added using a rear transition module (RTM, a plug-in card that is connected to the rear of a blade inside the chassis to add interfaces and features) with 4-6 10G ports.

The blade is designed to take advantage of the packet processing capabilities of the Intel® Communications Chipset 89x0. This device provides offloaded hardware acceleration to improve the cryptographic and compression performance of the processors. The ATCA-7470 also allows the mounting of a mezzanine module featuring two more Intel Communications Chipset 8920 devices to take further advantage of the offload capabilities.

Intel® Data Plane Development Kit (Intel® DPDK)

Intel has made available a lightweight run-time environment for Intel architecture processors, offering low overhead and run-to-completion mode to maximize packet processing performance: the Intel® Data Plane Development Kit (Intel DPDK).

The Intel DPDK focuses on how the individual processor cores can be more tightly managed outside of any encumbrance of the operating system activity and allows those cores to act in quite a deterministic fashion. Additional libraries around memory, queue and buffer management help manage the flow of how the data moves to individual cores, between cores or to another core outside the system.

It provides a selection of optimized and efficient libraries, also known as the Environment Abstraction Layer (EAL), which are responsible for initializing and allocating low-level resources, hiding the environment specifics from the applications and libraries, and gaining access to the low-level resources, such as memory space, PCI devices, timers and consoles.

The EAL provides an optimized Poll Mode Driver (PMD); memory & buffer management; and timer, debug and packet handling APIs, some of which may also be provided by the Linux OS.

To facilitate interaction with application layers, the EAL, together with standard the GNU C Library (GLIBC), provide full APIs for integration with higher level applications.

Algorithm Processing Blade

Figure 6 shows an architectural example of a 40G ATCA blade based on dual Intel Xeon E5-E2600 processors, such as Emerson Network Power's ATCA-7470 packet processing blade, tailored for digital signal processing to create an *algorithm processing blade*.

One physical core on each device is dedicated to control plane applications based on Linux.

This core works in tandem with the 40G network interface controller to move the data in and out of the other processor cores at optimal speed.

The rest of the cores are available to run individual DSP algorithms. A section of data would be distributed to each core and processed to completion without interruption.

The combination of high performance processors with Intel AVX and 40G blade interfaces creates a set of DSP engines from general purpose processors that can run at a very high speed.

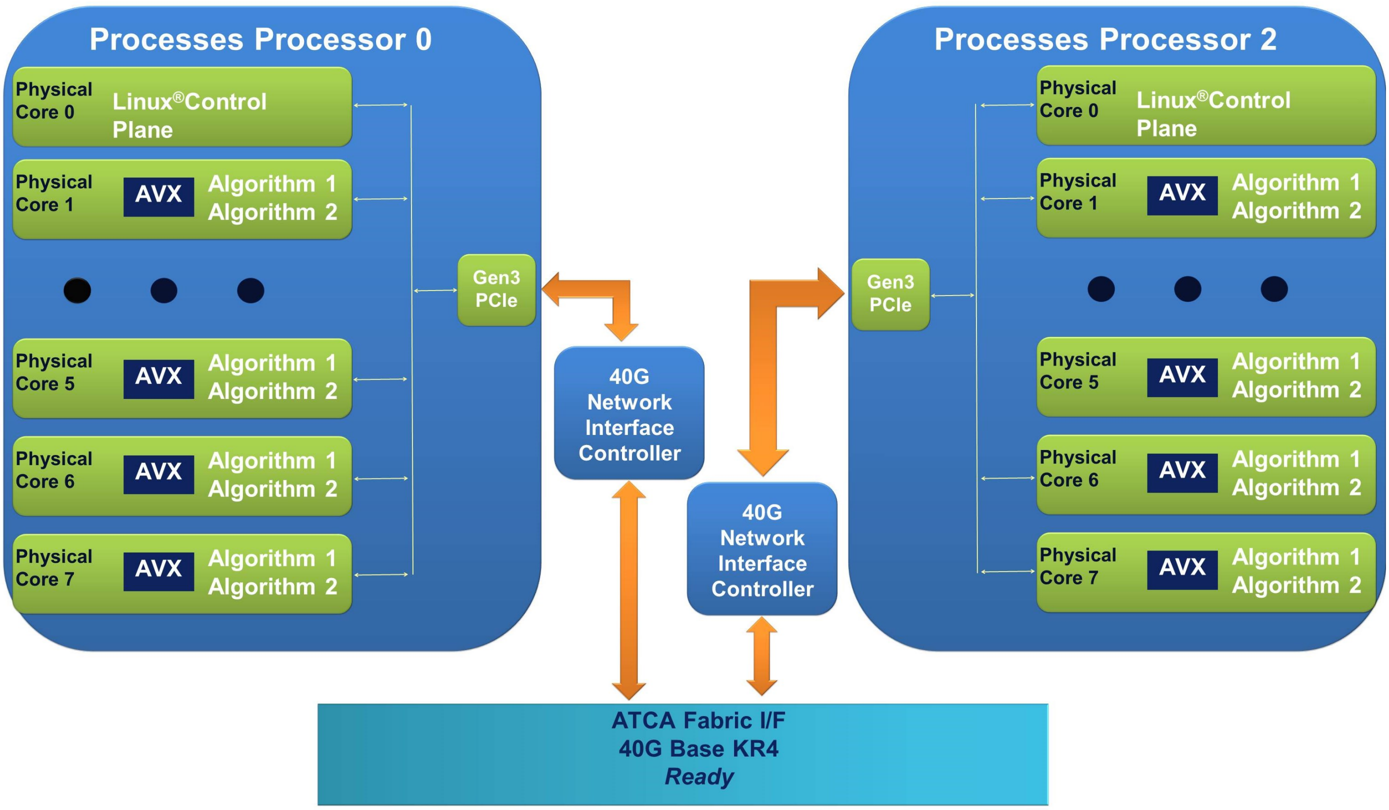

Figure 6: Architectural example of an ATCA processing blade tailored for digital signal processing to create an algorithm processing blade.

System Architecture

1. Packetized sensor data enters into the ATCA switch as 10G or 40G data
2. Flow control software on the switch load balances and distributes the data to the appropriate processor board
3. Flow control software on the blade then load balances and distributes the data to the specific algorithm running in a specific thread of a specific core
4. With the assistance of the AVX coprocessor, the DSP algorithm is completed without Interruption
5. Flow control on the board and the switch then directs the results to another payload board for further processing or out the system

Conclusion

The technologies outlined in this paper support the argument that ATCA is an ideal computing platform to address digital signal processing applications, especially those in defense and aerospace.

The other benefits of ATCA for defense and aerospace contractors – such as being a truly open architecture, with inherent ruggedness and power efficiency – mean that the time is right for to leverage packet processing blades and software originally developed for telecom networks for very dense computing and future complex signal processing applications.

For more information on Emerson's ATCA solutions, please contact your local Embedded Computing sales office.

Worldwide HQ
Tempe, AZ U.S.A.
1 800 759 1107 or +1 602 438 5720

Global Offices

EMEA	+44 1509 236490
Munich, Germany	+49 89 9608 2564
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Tel Aviv, Israel	+972 9 956 0361
Hong Kong	+852 2176 3540
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