Dense Wavelength Division Multiplexed Interconnects for High Performance Embedded Computing Architectures

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Introduction

The telecommunications industry makes heavy use of Dense Wavelength Division Multiplexing (DWDM) fiber optic infrastructure for their high capacity data links in metropolitan and long-haul networks (Figure 1). There are numerous advantages of DWDM optical networks relative to electrical networks including:

- Extremely high data capacity (100's of Gbps to 10's of Tbps per fiber).
- Improved signal integrity leading to increased link distances.
- EMI immunity.
- The ability to increase data rates and add communications channels without changing the cabling infrastructure.
- Lower-weight cabling.

However, insertions of DWDM networks in rugged High Performance Embedded Computing (HPEC) systems have been rare due to environmental and packaging concerns. The transmitters and receivers needed as end-points to these networks have traditionally been bulky and limited in temperature range. Lockheed Martin has been increasing the Technology Readiness Level (TRL) of DWDM networks through Research and Development (R&D) investments to the point that DWDM can be seriously considered for insertion in military and aircraft environments. This paper will consider the architectural implications of DWDM for high performance signal processing applications and propose a passive solution to the traditional switched-fabric interconnect.

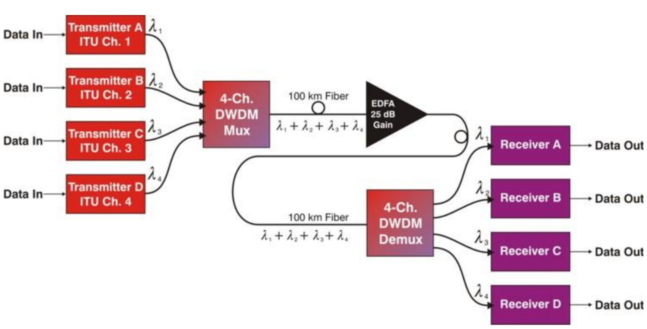

Figure 1: DWDM Optical Network

Passive DWDM Network Benefits

DWDM networks are able to achieve extremely high throughput by multiplexing many optical wavelengths onto a single fiber. The group of wavelengths are generally centered around the 1550nm (C-band) or 1595nm (L-band) optical bands where losses through the fiber optic cabling are low. Channels are spaced at 50 or 100 GHz to conform to the International Telecommunication Union (ITU) standards. Standard data rates for each channel are 10 Gbps to 40 Gbps, and the telecommunications industry is starting to deploy systems transmitting 100 Gbps per channel.

The use of passive combiners and splitters within the fiber optic network permits the deployment of systems with full connectivity between endpoints, while isolating the active components to the transmitters and receivers that provide the interface to the network. An example device is a passive optical star coupler which receives data from multiple input fibers, mixes the data, and then outputs the data on multiple output fibers. Each output fiber now carries all the data from the input fibers (Figure 2).

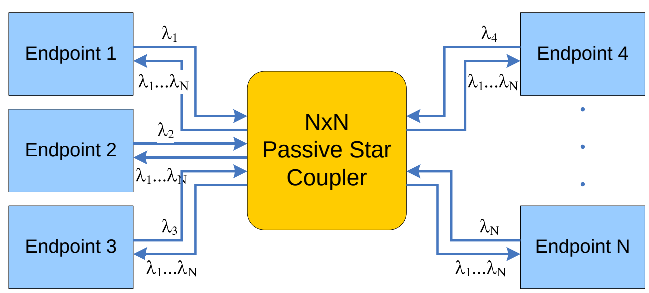

Figure 2: Passive broadcast fiber optic interconnect.

Application to HPEC Systems

HPEC systems can see numerous benefits from the application of this passive broadcast architecture. It allows designers to build a highly scalable, flexible system where additional endpoints can be added to the network with no impact on previously installed hardware. The infrastructure can carry multiple protocols on a single fiber, each of which could be carrying data at a different signaling rate. The architecture eliminates contention and blocking within the network since all data is assigned a unique optical wavelength for transmission. Finally, the architecture allows new levels of data sharing because data is inherently broadcast to any endpoint with no extra overhead.

These features translate to new capabilities and improved performance in HPEC systems. Data sources, such as sensors, can more easily be shared among multiple processing systems. The passive broadcast infrastructure eliminates the need for switching hardware, which reduces size, weight, and power (SWaP) requirements. In the final paper, an example HPEC architecture will be detailed which highlights the benefit of the DWDM network.

Challenges of the DWDM Network in HPEC Systems

Lockheed Martin has been investing significant effort to increase the TRL of DWDM networks for the unique requirements of rugged HPEC systems found in Mil-Aero platforms. Focus areas include:

- Reduction of the SWaP envelope of the DWDM transmit and receive endpoints so that they can be designed into standard HPEC form factors such as PMC, XMC, and VPX.
- Hardening the active components against the temperature, shock, vibration, and other environmental requirements encountered in military aircraft systems.
- Addressing Information Assurance (IA) and Multi-Level Security (MLS) requirements by developing a secure passive infrastructure for systems where data separation must be provided.
- Developing endpoint firmware that leverages standard high-speed point-to-point protocols, such as Serial RapidIO or 10 Gigabit Ethernet, while updating them to support the DWDM broadcast interconnect.

Details of these TRL advancements will be provided in the final paper.

Conclusion

HPEC systems deployed in military and aircraft platforms can benefit greatly from the use of a passive DWDM optical interconnect. The flexibility and scalability permits low-cost technology insertions when endpoints are upgraded. The passive network infrastructure eliminates contention and blocking and removes the need for switching hardware.

These HPEC system benefits utilizing DWDM technology are not limited to military and aircraft applications. These benefits can be applied to many HPEC applications where interconnect bandwidth limitations are becoming an issue. The use of a larger numbers of multicore processors do not provide any real computational improvement if the associated memory and I/O bandwidth don't increase proportionally. DWDM technology, implemented on a processor-to-processor basis, has the potential to enable the full realization of the computing potential of multicore processors for many applications.