MIT Communications Technology Roadmap

Technology Working Group:
Open Architecture System Optimization

TWG Chair:

Participants for Planning TWG meetings:
judyp@cisco.com
lckim@mit.edu
bob.pfahl@inemi.org
bill_bottoms@3mts.com
rgrzybowski@photoniccontrols.com
nilyadis@broadcom.com
kwada@material.t.u-tokyo.ac.jp
h.j.s.dorren@tue.nl

Technical Working Group Meetings:

Kick-off Meeting: MIT Micro photonics Center Fall Meeting, October 15-16, 2013
Working Meetings:

Document Last Updated: September 1, 2013
Proposed Charter: Open Architecture System Optimization

Background:

Photonic technologies are now ubiquitous components in data-communication, computing networks, and telecommunication. These markets for high-end data centers, high performance computation and telecommunication networks have grown, and customized solutions are available with premium pricing. The performance demand in commodity-sized markets for these applications are now sufficient to support a robust components industry, particularly if research and development required to realize the full potential of photonic technologies can be coordinated across the industry.

Emerging applications hold the promise to provide a sustainable total-addressable-market, but in most cases, these applications are highly cost sensitive. A key barrier to realizing necessary cost targets is poor capital utilization across the industry. This condition was addressed in the microelectronics industry through the decoupling of design and manufacture. Within the optoelectronics industry, process variety impedes the adoption of this approach. One promising approach would be to adopt widely available and proven technologies from Si microelectronics. The focus of this TWG will be identifying the technology challenges and opportunities for utilization of an integrated Si microphotonic platform for optoelectronic applications.

Target:

The OASO TWG will develop a strategic roadmap that i) identifies critical technical requirements for next-generation system integration and packaging, ii) details potential solutions to meet those requirements economically, and iii) identifies the technology supply chain limitations for commercial deployment of the required component performance in the 2014-2035 time frame.

Scope:

- The OASO TWG will initially identify the key functionality of photonics in high performance, high margin segments.
- The TWG will identify necessary changes in the technology supply chain required to deliver microphotonic components at high unit volume and high system reliability.
- The TWG will identify potential technology solutions for system cost, power, bandwidth density and performance constraints to meet market demands for large scale production within the next 3, 6, 15 year time windows.
Process:

1) **Identify future system requirements**: Rely on expert testimony to identify technology challenges for emerging applications. Specify a reasonable set of requirements for emerging markets over a 3, 6, and 15 year horizon.
   a. Specific metrics to be tracked include i) supply chain (vendor) ecosystem; ii) assembly and packaging; iii) electronic-photonic integration; iv) availability of a full suite of optoelectronic IP; v) system-level reliability, testability, and failure analysis; vi) standardized optical connectors; vii) converged communication protocols.

2) **Characterize opportunities for platform convergence**: Develop a matrix of specifications for each of the system requirements, and identify opportunities where converged *Si process platforms* can simultaneously address the most challenging requirements.
   a. The technical barriers and potential solutions uncovered by this group will be distributed to the collaborating technical working groups during the study.

3) **Develop a Roadblock Analysis**: With industry-wide cooperation, identify the Roadblocks that could preclude the adoption of the converged Si platform technology.

4) **Develop an Action Plan**: Develop a strategic roadmap, with multiple layers of risk, to proactively address each roadblock and potential solution. Communicate this plan broadly to the photonics industry.

Output:

Source material shall be generated and submitted for publication in the CTR Roadmap Document. Key elements to be included are:

1) Position paper to identify technology challenges, future technology requirements and converged Si platform processing strategies for emerging markets, covering a 3, 6, and 15-year time horizons.

2) A strategic roadmap, which
   a. lists market-based and technical challenges which must be addressed in order to realize the long-term requirements and opportunities for a ubiquitous Si Platform.
   b. identifies opportunities and barriers to implement a converged system design and manufacture.
   c. identifies technical barriers for achieving the recommended convergence.
d. provides a timeline by which the challenges must be proactively addressed.
e. identifies industry-based impacts if the industry cannot meet the roadmaps or convergence opportunities.

**TWG Exit Criteria:**

- No fixed end-point is defined.
- Following an initial issue of a TWG Roadmap Report in Fall 2013, this group will establish data and analyses for initial release at the Spring 2014 Microphotonics Center Industry Consortium Meeting (April 1,2); and revisit the Roadmap on a timeline consistent with the publication of Communication Technology Roadmap Documents.
- This group will disband itself when it is no longer relevant to a sufficient number of TWG members, when the Communication Technology Roadmap program ends, or if the group’s function is recognized to be duplicated by an organization that is viewed as better suited to address the function.
Exemplary analysis:

Network and Access Systems

Performance/cost, not energy, is the current issue.

In 2012, NTT energy consumption was 57 TWhr. Access accounted for 97% of the communication energy consumption in Japan, while the network consumed only 3%. The largest data center firms allocate >50% of energy consumption to data mining and feel no immediate economic squeeze from energy cost. For both the network and client sides, performance in terms of bandwidth availability is the target market issue, while energy consumption is a subject of long term research.

Routers provide the Network interface with Access. On the network side, premium priced linecards drive long haul (100 Gb/s per channel) communications with (bandwidth x distance) as the performance metric. On the access side, the router interfaces with a switch matrix that feeds information to clients (10-40 Gb/s per channel, 100m-120 km). Network service providers have a significant problem of interoperability between new photonic technology and legacy equipment. Large client side firms (Google, Facebook) and HPC installations can prescribe interoperable component standards and architectures for their ‘greenfield’ systems. The driver for commodity volume, cost effective photonic integration is the large and diverse ‘rest-of-the-market’.

Photonic performance is required to meet bandwidth demand, but expensive linecards conflict with the diverse client side market. The variety of client side distances and data rates have created a virtual ‘zoo of photonic technology’ that drives establishment of a standard integrated platform. The market is now optical cables with pluggable transceivers for mating routers to serve the client side or to backplanes to serve linecards and switches. The points of premium to commodity convergence will be integrated functionality in the router and the server.

Open architecture system optimization is essential to the determination of what should be economically integrated and when. For example, data transport protocols at interfaces reflect directly on the switch IC design and enter the selection criteria for Infiniband, Ethernet and Fiber Channel. The network side seeks increased data rate and reach, while the client side reduces latency and increases density. Integrated server and switch functionalities will be key to scalable architectures.