Photonic Routers Supporting Application-Driven Bandwidth Reservations at Sub-Wavelength Granularity

D. Simeonidou, G. Zervas, R. Nejabati
Photonic Networks Laboratory
Electronic Systems Engineering Dept
University of Essex, UK
Colchester CO4 5UT
Networks are expected to support an increasingly diverse set of applications

- Telecommunications, Grid, eScience, eHealth, eStorage, eContent, emerging broadband services (infotainment, interactivity, mobility, 3-D imaging...)
- Demands triggered by applications are having direct impact on the network data and control plane technologies

Advances in networking technologies

- Support the evolution of existing applications
- Enable the emergence of new applications

Optical networks already play an important role in supporting new applications and services

Optical networks research had/has to fit into the new overall network scenario
Convergence of applications & networking research: drives a revolution in networking creating new network models and architectures:

- Optical network architectures for new service delivery models
  - Dynamic, multi-service, user/application controlled networks, application aware optical networks, etc

- New concepts for network and service management
  - Network information and control exposed to the service layer
  - Higher layer intelligence migrating in the network layer

- Service oriented networks or service aware networks
  - Intelligent networking providing advanced application driven services (collaborative services)
What are collaborative network services?

- A collection of network resources deployed by shared and geographically distributed facilities (user terminals, instrumentation, computing, storage, digital repositories, archives...)

Why collaborative network services?

- Science, research, education, medicine, business have no bound and are based on collaboration of international expertises
- Creation of distributed virtual facilities for sharing resources
Today's optical network infrastructure for collaborative services

- Data intensive users (mainly scientific)
- Optical network provides dedicated end-to-end high-bandwidth (λ) connections
  - Well known virtual organisations
  - Static or semi-static point-to-point connections
    - long-lived wavelength paths between client and resources
  - Centralized service management strategies

Emerging collaborative services:

- Need infrastructures that makes vast amount of storage and computation resources potentially available to a large number of users.
  - Distributed virtual laboratories
  - Digital libraries and data repositories
  - Remote medicine
  - Consumer services: immersive interactive learning environments and gaming
e-science: global, large scale scientific collaborations enabled through distributed computational and communication infrastructure

radio astronomy

- Electronic Very Long Baseline Interferometry (eVLBI)
  - 2005 ~= 512mbs -> 1 Gbs
  - 2006 up to 20 Gbs
  - 2008 up to 40+ Gbs
Application Driver: Radio Astronomy Experiments

- Jodrell Bank, UK
- Onsala, Sweden
- Cambridge, UK
- MERLIN
- Chalmers University of Technology, Gothenburg, Sweden
- Torun, Poland
- Westerbork, Netherlands
- Dwingeloo
- Medicina, Italy

Gbit link:
- Dedicated
- DWDM link

Application Driver: Radio Astronomy Experiments
Example: Neptune Project

- Joint US-Canadian project to build large undersea fiber network (British Columbia, Washington, Oregon)
- Interconnect instrumentation devices, robotic submarines, sensors, cameras
  - Oceanography, seismology, deep sea ecology
- Distributed computing and data storage devices on CA*net 4 and Internet 2 will be used to analyze and store data
- All devices available to researchers connected to CA*net 4 and Internet 2 networks
- Distributed, shared resources interconnected by plentiful bandwidth (DWDM)

- Wavelength switching
  - Data intensive applications can ask the optical network for any point-to-point connectivity
  - High bandwidth dedicated links, dynamically allocated on-demand or by scheduled reservation
The Optical Network Backbone for High Performance-Data Intensive Applications

User

Data Intensive Application

Application middleware

Resource Broker

Lightpath provisioning API

Resource Information

Computational Resource

Data Intensive Application

IP Network

Data/Query

Data/Query

Data/Query

Data/Query

Data/Query

Lightpath provisioning API

GMPLS Control Plane (traditional)

OUNI (standardised)

OXC 1

OXC 2

Physical layer adaptation

Physical layer adaptation

Optical Transport Network
Increasingly organisations, societies or individuals want to communicate, access information or collaborate using networks.

Need infrastructures that makes vast resources potentially available to a large number of users.

Service oriented network concept must be extended to wider group of users.

**CHALLENGE**
- Define *generic* network architecture that can adapt to *any* user and service requirements.
OBS can provide transport for highly demanding collaborative applications

- Offers sub-wavelength granularity and high spectral efficiency
- Accommodates medium and large size jobs
- Short lived & long lived relationships
- From packet level to circuit (wavelength) level
- Burst terminal can communicate directly with multiple destinations across a network
- Native mapping between bursts and jobs
Focus is to:
- Enable network to directly offer resources (network and data) as service
- To migrate service layer functionality close to the optical layer

Network elements are able to recognise and process application demands/request
- To offer resources as a service
  - To facilitate intelligent discovery of distributed resources across the network
  - To cope with random changes user patterns, demands for resources (storage/processing) as well as availability of resources
- To provide network with self-organisation ability
  - Topology set-up
Job Construction Scheme: User/Application Side

Complete User Job

Second stage

1. Data Burst
   - Actual Job
   - Non-Active
   - Job Header
   - Non-Active
   - Actual Job
   - Active
   - Offset time

First stage

1. Data Burst
   - Resource Request
   - Active
   - Active Burst
   - Job Spec.
   - Offset time

2. Data Burst
   - Actual Job
   - Non-Active
   - Burst Control Packet
   - Offset time

Job Specification

- job ID
- Payload Type
- OBS parameter
- Payload length
- Offset time
- source node
- job requirements
- BW
- Processor
- Memory
- Deadline

Actual job data

- job ID
- Payload Type
- OBS parameter
- Payload length
- Offset time
Centre to the programmable OBS network is **ACTIVE OBS ROUTER**

- Normally routers perform forward functionality
- The Active OBS router performs compute-forward functionality (i.e. compute on Job requests)
- Routing engine: optical switch
- Processing engine: high performance NP

**User controlled networking functionalities:**

- Quality of service (Data and Network)
- Reliable multicast
- CBR
**Principle of networking concept**

- Some OBS router in network topology are active nodes
- Active OBS routers must perform resource discovery algorithm on user requests
- Other OBS routers simply route and forwards the Burst
The application submits a service request (BW + Resource) to the middleware, which processes it and forwards it to the network ingress node.

- The edge device will formulate the client request into an active burst.
- The active burst will be multicasted to active routers in the network for resource discovery.
- The result of resource discovery will be sent back to the application/user by the active routers.
- The application/user chooses one of the possible optical path+resources.
- The application data is encapsulated into a passive data burst and routed to the selected resource.
Hybrid Optical Burst/Circuit Switching (OBCS) for future applications

- Optical networking should optimally serve users/applications with diverse network requirements (BW, latency, setup time etc.) without compromising the network utilisation.

- Application-aware optical-burst/circuit switched (OBCS) network is a promising solution.

  - Optical circuit switching (OCS) addressing bandwidth requirements for data intensive services (particle physics, radio-astronomy) involving well-known scientific user communities through long lived wavelength paths.

  - Optical burst switching (OBS) addressing bandwidth and network requirements for increasing emerging and evolving applications (e-health) Short lived bandwidth reservations.

- Solution: Hybrid OCS/OBS networks.
Hybrid Optical Burst/Circuit Switched Ingress Edge Router

- **Input line card**
  - Forwarding engine

- **Output line card**
  - CoS provisioning - Assembly (Burst or Circuit) - Resource allocation (E/O)
Hybrid OBCS Ingress Router architecture incorporates:

- High-speed packet classification
- Optical circuit generation
- Optical Burst aggregation and generation
- Wavelength allocation
Optical circuit and bursts over 4 different wavelengths

Asynchronous Optical Burst Ethernet Switched (OBES) control plane (continuous data)

Asynchronous aggregation and transmission of variable length bursts with variable offset times (Burst mode)

Burst Control Header (BCH) over OBES control plane at 2.5 Gbps

BCH @ 2.5 Gbps

BCH @ 2.5 Gbps

BCH @ 2.5 Gbps

BCH @ 2.5 Gbps

BCH @ 2.5 Gbps

BCH @ 2.5 Gbps

BCH @ 2.5 Gbps

BCH @ 2.5 Gbps

BCH @ 2.5 Gbps

BCH @ 2.5 Gbps

BCH @ 2.5 Gbps
Traditionally OBS switches are based on slow switching technology (e.g. MEMs)

- Suitable for long bursts with large offset time
- Not suitable for networks with large number of users transmitting small data bursts
  - Not efficient for short bursts with short offset time

Combination of fast and slow optical switching technology is emerging for future OBS networks

- SOA based switch technology for fast switching
- MEM based switch technology for slow switching
Fast SOA-Based Switch

Slow Mem-based Switch

Burst Generator + Tuneable laser

FPGA

GCSR Tunable Laser
Technology trends for application driven (service-oriented) optical network infrastructure.

- Existing wavelength switched network infrastructure
- Novel programmable network architecture based on active optical burst switching
  - Transport format has been tailored to provide network level application awareness
  - Architecture utilizes advanced hardware solutions and new protocols
Thank you

dsimeo@essex.ac.uk