Constraint Based Anycasting in Optical Burst Switched Networks.

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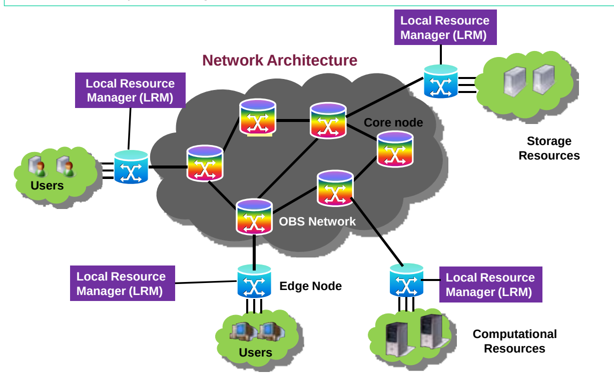
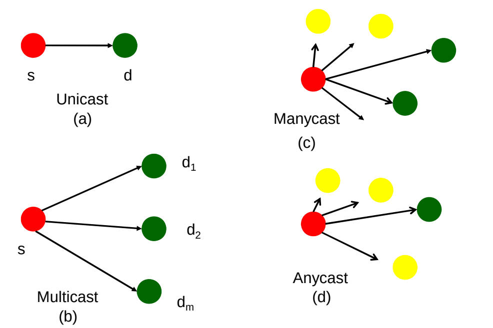
Introduction

- Emergence of recent interactive applications, has led to development of on-demand provisioning of wavelengths channels with service differentiation.
- As Quality of Service (QoS) policies implemented in IP network does not work in optical network, there is need to develop an intelligent optical control plane.
- With advent of many new switching techniques, researchers were able to tap huge bandwidth capacity of the fiber.
- Control plane plays an important role in especially in switched optical networks.
- Control and management mechanisms include
  - Access signaling, and
  - Bandwidth provisioning.



Different Communication Paradigms

- Unicast deals with one-to-one association between ***source (s)*** and ***destination (d).***
- In Multicasting source communicates to a fixed set of destinations in the network.
- Manycasting is a variation of multicasting with the destination set not fixed. In Manycasting any subset of given destination set can be selected.
- An anycast communication is similar to unicast, but with the destination not know a-priori. Anycasting is similar to deflection routing, except the fact that different destination can selected instead of routing the signal along the alternative path to the same destination.
- Mathematical notation for each communication paradigm is given by,
  - (s,d) for unicast
  - (s,D) for multicast, where D is the destination set.
  - (s,D,k) for manycast, where k is number of destinations that can be chosen from D.
  - (s,D,1), for anycast. Anycast is a generalization of manycast with k=1.



QoS Aware Anycasting Algorithm (Q3A)

Service Parameters

- We consider the following service parameters,
  - Residual wavelengths (w_i),
  - Noise factor (η_i),
  - Reliability factor (γ_i) , and
  - End-to-end propagation delay (τ_i) for link *i*.
- We denote the network element vector for a link *i* as,

$$NEV_i = [w_i, \eta_i, \gamma_i, \tau_i]^T$$

- Let NEV_i and NEV_j be the two network element information vectors of the link *i* and *j* respectively, then we define a comparison,

$$[w_i, \eta_i, \gamma_i, \tau_i]^T \prec [w_j, \eta_j, \gamma_j, \tau_j]^T$$
$$\Rightarrow (w_i \geq w_j) \wedge (\eta_i \leq \eta_j) \wedge (\gamma_i \geq \gamma_j) \wedge (\tau_i \leq \tau_j)$$

- The overall *NEV* of a destination $d_n \in D$, $1 \leq n \leq m$ along the shortest path route $R(d_n)$ is given by,

$$\Rightarrow NEV_{R(d_n)} = \left[\left| \bigcap_{\forall i \in R(d_n)} W_i \right|, \prod_{\forall i \in R(d_n)} \eta_i, \prod_{\forall i \in R(d_n)} \gamma_i, \sum_{\forall i \in R(d_n)} \tau_i \right]^T$$

- A destination d_n is said to be feasible for a given service requirement if, $NEV_{R(d_n)} \prec T^{(S_i)}$

Algorithm and Flow Chart

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Input: T^(S_i), NEV[n-1,n], (n, D_n)
Output: Updated Anycast request and NEV
Initialization NEV_init = [w_max, 1, 1, 0]^T
if n ∈ D_n then
   exit;
else
   ∀ d ∈ D_n, h_min = SHORTEST_PATH[n, d]
   D'_n ← SORT{D_n}
   d' ∈ D'_n {where d' is the destination that is at a minimum-hop distance from n }
   NEXT_HOP_NODE[n, d'] = n_k {n_k is calculated from the shortest path }
   NEV[n-1, n_k] ← NEV[n-1, n] ∘ NEV[n, n_k]
   if NEV[n-1, n_k] ≺ T^(S_i) then
      The path [n-1, n_k] is a feasible path and destination d' can be reached
      New NEV ← NEV[n-1, n_k] and anycast request (n_k, D_{n_k})
   else
      Update the destination set D' ← D' \ {d'}
      {      Since route to d' does not satisfy the QoS requirement of the service S_i }
   end if
   If |D'| = ∅, then anycast request is blocked or lost
end if
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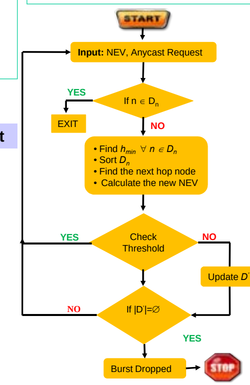


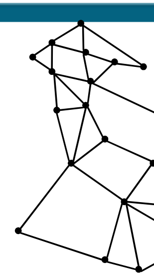
Simulation Results

Control Plane Signalling

- Service-differentiated scheduling is considered for analysis, i.e., threshold parameters of the particular service are known a-priori.
- Burst Control Packet (BCP) or Burst Header Packet (BHP) can be used to maintain the NEVs and update them as they traverse each NE.

Burst ID	Source Node (n)	Destination Set (D_n)	Threshold Vector for service S_i $T^{(S_i)}$	NEV[n-1,n]

Fig: Burst Header Packet used in simulation

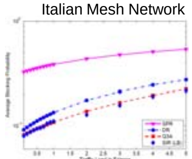


Italian Mesh Network

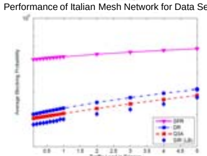
Simulation Framework

- Our proposed algorithm is compared with the performance of,
  1. Shortest Path Routing (SPR),
  2. Deflection Routing (DR), and
  3. Source Initiated Routing (SIR).
- Two service classes used for modeling are,
  - Data Service with the threshold NEV $T^{(DS)} = [1, 5.7, 0.7, 20]^T$
  - Real time service with threshold requirement, $T^{(RTS)} = [1, 4, 0.8, 10]^T$
- 10^8 bursts were used in the discrete event simulation model.
- Average blocking probability is evaluated as,

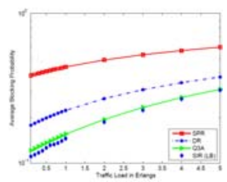
$$P_{avg} = \frac{\text{\# bursts dropped due to in-sufficient QoS}}{\text{\# bursts used in the simulation}}$$



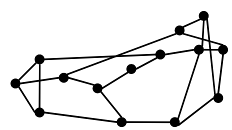
Performance of Italian Mesh Network for Data Services



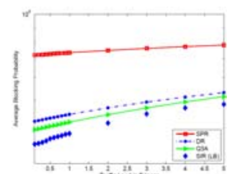
Performance of Italian Mesh Network for Real Time Services



Performance of NSF Network for Data Services



NSF Network



Performance of NSF Network for Real Time Services

Summary

- QoS provisioning for anycasting over optical burst switched networks.
- Using the information vectors available at each NE, QoS parameters were computed in a distributed manner.
- Anycasting communication allows the application to choose the candidate destination according to its service requirement.
- Results are compared with our baseline algorithm (Q3A) against the most commonly used routing algorithms such as shortest-path routing, deflection routing and source-initiated routing.
- From the simulation results we observe that, our proposed algorithm has 33% reduction in the burst loss compared to the shortest path routing.

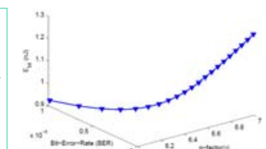
Publications

- Journal
  1. B.G.Bathula, J.M.H. Elmirghani, *"Constraint Based Anycasting Over Optical Burst Switched Networks"*, to appear in OSA Journal of Optical Networking, A Special Issue on Optical Networks to the Future Internet (ONFI), Vol.8. No.3 (2009).
  2. B.G.Bathula, R.R.C.Bikram, V.M.Vokkarane, S.Talabattula, *"Impairment-Aware Optical Manycasting"* submitted to IEEE/OSA Journal of Lightwave Technology.
- Conference
  - B. G. Bathula, J. M.H. Elmirghani, *"Providing QoS for Anycasting over Optical Burst Switched Grid Networks"*, Proc.LNICST, GridNets-2008, Beijing, China, October 2008.

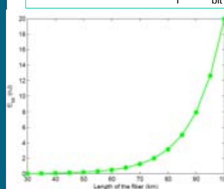
Green Networks: Energy Efficient Optical Networks

- Anycasting can also be used as the path selection mechanism for energy conversation.
- Using clustered architecture for nodes in optical networks (CANON) via *sleep cycles*, energy efficiency is obtained.
- Total energy consumed to transmit a bit through an OXC situated at a distance *l* km is given by,

$$E_T = E_{bit} + E_{OXC}$$



Energy versus Bit error rate (BER) and q-factor for OOK.



Energy versus Fiber length for OOK

- The average time to transmit 1 (optical) bit over a channel (fiber) is the inverse of the average bit rate (B).
- The energy associated with the transmission of 1 bit can be expressed as,

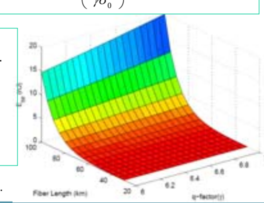
$$E_{bit} = P_T \times T_{bit}$$

where E_{bit} is given by,

$$E_{bit} = \frac{\left(\frac{2RL_r B}{\gamma\sigma_0}\right) + \left(\frac{2qR_r BB_e}{\sigma_0^2}\right)}{\left(\frac{RL_r B}{\gamma\sigma_0}\right)^2}$$

Future Work

Using anycasting communication on a new clustered-node architecture, we have minimized the energy consumption. This energy saving is obtained without scarifying the QoS. We will consider dynamic sleep-cycles for the clusters based on the traffic conditions in our future work.



Energy versus q-factor and Fiber Length for OOK.