FIND

January 17, 2006

We propose a novel backbone architecture for the future Internet. The proposed architecture consists of two essential components: fine granularity dynamic switching in optical domain, and simple yet robust routing at IP layer. Those two components work seamlessly to provide an efficient and resilient backbone network. More specifically, we design the architecture to satisfy the following requirements:

- **reliable/resilient:** it will provide connectivity between PoPs under link/node failures; it will survive traffic anomaly, either due to flash crowd or malicious attacks; it will contain the propagation of network configuration errors.
- **efficient:** it should efficiently utilize physical resource, such as fiber bandwidth and switch capacity, to support high speed and low latency traffic between access networks.
- **adaptive:** it should quickly adapt to traffic demand change; it can be dynamically reconfigured to provide *Bandwith on Demand*.
- **manageable:** it should be easy to manage such a network; network diagnosis can be done quickly and accurately.
- **security?**
- **...**

To achieve those design goals, we propose the following architecture

- **two-layer structure:** At the first layer, we employ fine grain (such as ...) optical switching to provide a circuit between any two PoPs. Therefore, on top of the optical layer, we have a full mesh network at IP layer.
- **circuit dimensioning:** The circuit bandwidth C_{ij} between PoP i and PoP j is dimensioned such that it can accomodate the normal traffic demand between PoP i and j, $D_{ij}(0)$, which can be obtained from measurement and history data, i.e., we will have $C_{ij} \geq D_{ij}(0)$.
- **IP routing design:** At PoP i, denote by $D_{ij}(t)$ its current demand to PoP j, if $D_{ij}(t) \leq C_{ij}$, send all traffic directly through logical link (i, j). If $D_{ij}(t) > C_{ij}$, PoP i will forward residual traffic $D_{ij}(t) - C_{ij}$ to several PoPs, which will relay those traffic to PoP j. The relay PoPs can be chosen to either minimize e2e delay on relay path, or minimize congestion on relay nodes/links.
- **dynamic reconfiguration** Optical switches can be reconfigured in real time to dynamcially change bandwidth matrix $[C_{ij}]$. Time scale issue, details $\cdots$

Advantages compared with other proposed schemes, such as Nick Mckeon's

- minimize packet processing in the backbone network, thus reducing cost associated with each packet processing, such as route lookup, packet classification, traffic management, buffer, packet schedulers, and packet switch fabrics
- minimize number of hops, thus reducing end to end delay
- minimize bandwidth fluctuation required between any two core routers by aggregating the traffic at the core router level
- maximize bandwidth granularity by using optical cell switching approach or just-in-time multiple-layer reconfiguration over the DWDM network (wavelength, wavelength, and fiber)
- achieve bandwidth demand between the core routers through provisioning and dynamic control through IP-layer routing
- support more traffic than dynamic routing on top of fixed topology.

  Conjecture 1 *The feasible Traffic Matrix set of our approach is a* **superset** *of that of dynamic routing on top of any fixed topology.*

- higher efficiency in resource utilization: under normal situation, one packet only consume resource on one logical link. *should we argue for physical link usage instead?*
- ....

Possible counter arguments

- **why put routing/switching complexity into optical domain, which is known to be more difficult to do routing than electronic?** To address this, we need to clarify how complex optical switching need to be, and argue that it is doable, at least in future...
- **it is more difficult to manage optical switching than IP routing**
- **when there is a fiber cut, should one reconfigure the switch or just resort to IP routing? where to draw the line?**
- **single path IP routing is not reliable enough**
- **...**

Research issues:

- *fine grain optical switching:* details...
- *dynamic topology reconfiguration:* time scale, transient behavior, details ...
- *optical level reliability:* multiple lightpaths for one logical path, details ...
- *IP routing:* how to choose relay PoPs? how to allocate traffic on relay paths? May have to convert to multihop relay if there are major failures?
- *Interaction between IP routing and Optical switching:* exchange traffic (IP to Optical) and topology (Optical to IP) information; coordination when there is major failure or big traffic surge; avoid bad interaction lead to lose-lose situation.
- *.....*