“Lambda Networking”

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This paper provides a working definition for “lambda networking” as it is currently being used in the research and education data networking community. Lambda networking, as it is properly defined by the telecommunications industry, is the technology and set of services directly surrounding the use of multiple optical wavelengths to provide independent communications channels along a strand of fiber optic cable.

Fiber optic communications changed fundamentally in the early 1990s as the result of two technology breakthroughs which dramatically lowered the cost of circuits: erbium-doped fiber amplifiers (EDFAs), which have the ability to amplify the communications being carried on a fiber optic cable independently of the speed or method of signaling; and wave division multiplexing (WDM), which allows for multiple communications channels over a single fiber by using different frequencies for each channel.

EDFAs are solid state devices that amplify the number of photons carried in a signal within a particular wavelength band, regardless of their signaling rate or modulation. Be cause EDFAs are analog devices and they need not be replace as faster and more sophisticated signaling techniques are developed. Spans of fiber amplified only by EDFAs, such as transoceanic cables, may be upgraded to higher capacity as newer signaling techniques are adopted, without the need to visit the submerged cable.

WDM translates a combination of optical inputs, such as Gigabit Ethernet 1000baseLX or OC48c SONET, into separate optical channels (i.e. wavelengths) which are then combined onto a single fiber optic cable.

WDM uses optical transponders to detect the input signal, turn that signal into an electrical format, and use the electrical signal to modulate a laser tuned to a specific wavelength. As many as 160 wavelengths on current systems are combined by waveguides and routed to a single fiber optic cable. The receiving end of a WDM system separates the many wavelengths contained in a fiber with an optical prism or Brigg’s grating. Once separated, each wavelength is routed to a transponder that converts the optical signal into an electrical signal. The electrical signal is used to modulate a laser turned to the standard wavelength for that particular signal type (e.g. 1000baseLX or OC48c SONET).

EDFAs and WDM are analogous to the broadband amplifiers and the multiple television channels on the cable TV networks of the last 30 years. As with cable TV channels, WDM separates various signals by allocating each its own frequency band. The broadband amplifiers used in cable system are able to amplify a relatively large range of frequencies. The flexibility of using a combination of analog broadband amplification and frequency division multiplexing (the equivalent of WDM in the radio frequency domain) is demonstrated by the ability to offer new digital services, such as hundreds of digitally compressed TV channels and cable modems, over existing cable TV facilities.

EDFAs and WDM have allowed the telecommunications industry to develop more advanced and cost-effective services. The services resulting from this technology include ultra-long-haul and submarine cable systems that carry many gigabits a second, some reaching terabits a second.

The research and education network community has expanded on the telecommunications-based connotation of "lambda networking" to include technologies and services that have one or more of the following attributes in common with this new optical technology:

1) Transmission capacities of 2.4 and 10 gigabits per second. These capacities represent the typical provisioned capacity of a wavelength in a DWM system.
2) The circuit nature of individual wavelength provisioned capacity. These individual wavelengths are provisioned as constant bit rate circuits. The term "light paths" has been coined to describe end-to-end circuits.
3) The lower cost of high capacity circuits in both long-haul and metro systems.
4) The ability to more directly interface high-speed local area network technologies (e.g. gigabit and 10 gigabit Ethernet) to telecommunications services.
5) The ability to provision new services in a more automated fashion.

Examples of "lambda networking" in this context include:

- The Chicago Starlight facility. This facility is designed to provide inter-connection services and co-location space for high-speed national and inter-national research and education networks. Interconnection will initially use one and ten gigabit Ethernet technology over layer-two switching. Starlight's mantra, "bring us your lambdas", implies connecting to Starlight with sufficient capacity and appropriate equipment to interconnect at gigabit speeds.

- SurfNET's transoceanic 2.4Gb/s experimental lambda. – This connection is interfaced at both ends as an unprotected transparent OC48c, but Cisco time division multiplexing (TDM) equipment is being installed at each end so that engineers may experment with customer-provisioned circuits to support traffic engineering and quality of service. CA*net4's current design document also describes a similar approach of using TDM based equipment as a functional model for future customer-provisioned lambda networking.

- The Distributed Tera Scale Backbone. This network will consist of unprotected transparent OC192 SONET circuits terminating in Juniper M160 routers. One of its goals is to allow for a "virtual machine room", where over provisioning of bandwidth in the wide area network allows for transparent placement of devices across the multi-location machine room.

In each of the above examples institutions are deploying and investigating various attributes of lambda network services, but there are no concrete plans to access the analog lambdas themselves. Given the various overloaded meanings of "lambda networking", this author recommends the following extended nomenclature to more precisely identify particular networking techniques:

High Speed Lambda Service (HSLS)
Constant bit rate communication channel services, typically not resilient to infrastructure disruptions (e.g. fiber cuts), which are provisioned over systems using optical technologies (i.e. WDM and optical amplification). Examples include unprotected OC48 and OC192 services as well as gigabit Ethernet services.

On-Demand Communications Circuit (OCC)
Non-shared, payload transparent, constant bit rate communications channels that are dynamically provisioned. These may be implemented with a range of techniques from traditional TDM services (e.g. provisioning an OCx service between two end points) to direct provisioning of lightwaves.

Optically Extended LAN (OEL)
Wide-area application of traditional LAN technologies (e.g. Ethernet).