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Towards the Telecosmic Grid[1]

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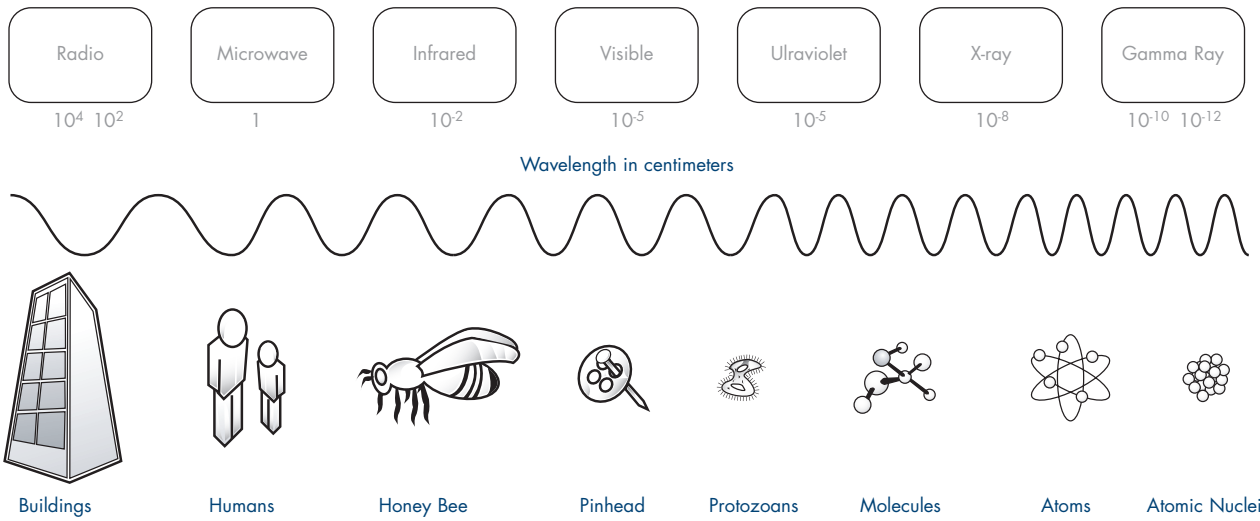
Grid Computing has a real knack for creating convergence. Currently in the limelight is the feverish activity aimed at fusing The Grid with Web Services. While software dominance is poised for pay dirt with the Open Grid Services Architecture (OGSA), it's prudent to reflect on past and potential hardware-driven convergence that punctuates the evolution of Grid Computing.

Dubbed The Microcosm by hi-tech visionary George Gilder, the highlights of this awakening *in silicon* were breakthroughs in the physics of the very small (a.k.a. quantum theory) that led to the development of solid-state devices. By leveraging vast numbers of network-accessible commodity microprocessors, each one not even close to breaking a sweat most of the time, SETI@Home exemplifies the procession of philanthropic possibilities. A few stalwart survivors have succeeded in establishing for-profit ventures, thus paying homage to this intersection of The Microcosm and The Grid.

Using Gilder as our muse again, the post-microcosmic momentum shift is to The Telecosm. Here domains of technology - e.g. fiber optics, cellular telephony, satellite communications, etc. - are unleashed by exploiting the electromagnetic (EM) spectrum (Figure 1). Distinguished purely on the basis of wavelength (the spacing between the successive crests of a wave) this spectrum is a smorgasbord of radiation - spanning from long-wavelength radio waves through visible light to short-wavelength gamma radiation. Following an age-old tradition, whose purpose is perhaps only to further obscure, physicists often use the Greek alphabet in mathematical expressions. In the case of wavelength, it's the Greek letter λ (lambda) for lower-case "l". Now just to be sure that we're still on the same wavelength, it's all about λ in the emerging *in silica* convergence between The Grid and The Telecosm.

Figure 1. The electromagnetic spectrum (Source: Educational resources from NASA, http://imagers.gsfc.nasa.gov/ems/waves3.html



Viewed at this exciting new juncture with Grid Computing, at least two of Gilder's original Laws of The Telecosm beg to be revisited:

- Law # 2: Gilder's Law
  This second law states that "Bandwidth grows at least three times faster than computer power". With Gilder's Law besting Moore's Law by a factor of three, it's difficult *not* to get giddy with possibilities for revolutionizing the world through infinite bandwidth.

- Law #3: The Black Box Law
  This third law states that "Networks will become black boxes: dumb pipes, with intelligence spread to the machines at their peripheries".

In striking contrast, intersecting The Telecosm with The Grid results in the twofold rebuff:

- Infinite bandwidth is overrated - with struggling service providers and the ongoing decline in bandwidth price as solemn indicators; and
- Smart pipes rule.

Why?

Compelling possibilities arise from being able to isolate and manipulate discrete wavelengths of the EM spectrum across intelligent networks.

Recent examples of this convergence presage the emergence of a Telecosmic Grid. This hybrid doesn't discount Gilder's original Laws of the Telecosm, it simply suggests that they need to be re-contextualized when taken together with Grid Computing.

λ Grid

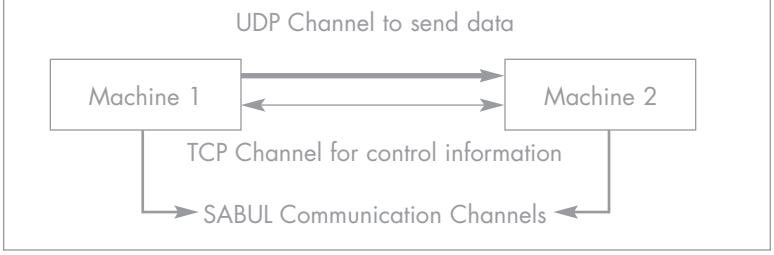
Isolating and manipulating discrete wavelengths of visible light across intelligent optical transport media results in the λ Grid - a specific instance of The Telecosmic Grid. Several examples serve as beacons of possibility.

Project DataSpace together with American (National Center for Data Mining at the University of Illinois at Chicago), Canadian (CANARIE) and Dutch (SARA) researchers recently collaborated in an award-winning demonstration at SC 2002 of data mining over an isolated-wavelength optical network. This team showcased a λ -join - the ability of databases to join two tables in a database by a common key in real time. Use of the optical network was further enhanced by leveraging:

- Efficient protocols to move data over long distances. Developed by the National Center for Data Mining/Laboratory for Advanced Computing at the University of Illinois at Chicago, a new protocol called SABUL (Simple Available Bandwidth Utilization Library) uses two existing channels from the standard TCP/IP stack in *tandem* (Figure 2) - Transmission Control Protocol (TCP) for control information, and User Datagram Protocol (UDP) to transmit the data. Separating management (control information) from activity (data transfer) via channels is a strategy that is used successfully in many computing contexts; and

- Efficient algorithms to merge two data streams. Also developed by National Center for Data Mining at the University of Illinois at Chicago.

Figure 2 . Overview of SABUL architecture
(Source: http://www.dataspaceweb.net/sabul.html



This λ -join demonstration is not an isolated example in the use of optical transport technology in a Grid Computing context. The California Institute for Telecommunications and Information Technology (Cal-(IT)^2) is developing a regional LambdaGrid that will interface with the national-level TeraGrid.

On March 10, 1876, Alexander Graham Bell uttered the words "Mr. Watson - come here - I want to see you." With Thomas A. Watson in an adjacent room, the proof-of-concept demonstration of what was to become the telecommunications industry was a tremendous success. Such has been the nature of invention - initial demonstrations need to be highly staged. Well-choreographed automation systematically replaces roles played initially by people - e.g., human telephone operators are replaced by electronic switches. The complexities of the technology disappear in the shift from the eureka of discovery to market adoption. To take proof-of-concept demonstrations like the λ join to the next level, there are two required elements:

- First, the network must be regarded as a bona fide resource; and
- Second, the network must be managed as a bona fide resource.

Isolated-wavelength optical networks permit this two-stage leap. Another Canadian research group is on the forefront of innovation in this area. SHARCNET (Shared Hierarchical Academic Research Computing Network), a multi-university consortium with industry partners in Southern Ontario, has established a regional grid to investigate isolated-wavelength optical networks. DWDM (Dense Wavelength Division Multiplexing) optical networking technology from Nortel Networks connects several clustered SMPs from HP. With Grid middleware from Platform Computing, identification and management of this optical network as a real resource is possible. Using several Grid-level scheduling policies - e.g., advance reservation, resource leasing, etc. - SHARCNET principal investigator Dr. Michael Bauer and colleagues are investigating the intersection of isolated-wavelength optical networking technology and Grid middleware.

Future Prospects

The Telecosmic Grid has already spawned its first offspring:

> The λ Grid is a wavelength-centric exploitation of EM radiation (e.g., visible light) on smart pipes (e.g., optical transport technology).

Though few examples exist today, the λ Grid is bursting with possibilities for next-generation applications.

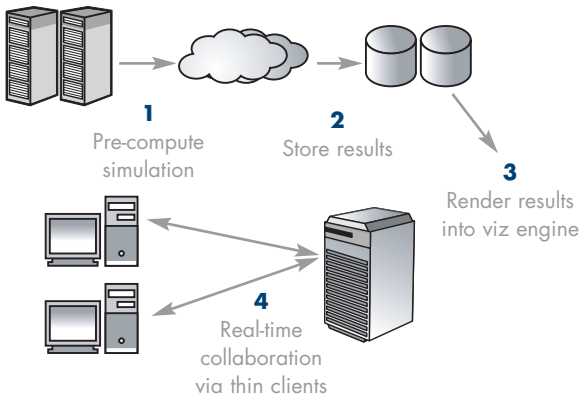
It's clear that non-interactive data processing and computation via a λ Grid is a no-brainer. What about highly interactive use? Scientific visualization offers an illustration. Since its inception two decades ago, SGI has become synonymous with the visual element of computing for artists, scientists and engineers. Originally demonstrated for brain-imaging research spanning a physical distance of almost 2,000 miles, SGI's Visual Area Networking (VAN) delivers visualization in a Grid Computing context. A joint demonstration at SC 2002 by SGI and Platform illustrated (Figure 3) this enabling technology:

1. Hurricane formation is simulated on supercomputers using a mesoscale atmospheric model;
2. Results, for a variety of atmospheric fields (e.g. pressure, temperature, relative humidity, velocity, etc.), are stored at regularly spaced increments in time;
3. An OpenGL program running on an SGI® Onyx® server, renders the results for visualization; and
4. Scientists and engineers interact with the results via thin clients connected to the Onyx server.

What makes VAN compelling? Many things:

- Multiple scientists and engineers collaborate in real time;
- Geography is not binding - scientists don't need to relocate to the site of the compute, data or visualization services;
- Required bandwidth is minimal - the thin client churns pixels, not data files; and
- Security is simplified - after authentication and authorization, wire-level encryption (e.g. via SSL/TLS) suffices.

Figure 3. Schematic for Visual Area Networking demonstration at SC2002.



Other next-generation possibilities might include:

- Online gaming - where pioneers like Butterfly.Net have already embraced Grid Computing;
- Homeland Security - where digitally signed λ Grids could be used to facilitate inter-agency collaboration;
- Virtual touch - where haptic (touch) technology and λ Grids take Virtual Reality (VR) to a new level (e.g. distance education in surgical operations);
- Virtual persistent storage - where data literally bears no fixed address;
- IPv6 - where Quality of Service (QoS) has been designed from the outset into the IETF's next-generation protocol to replace the current-version Internet Protocol; and
- Beyond the visible spectrum - where other EM spectrum constituents can be isolated and manipulated across transport technology.

Even though the Telecosmic Grid is in its embryonic stage, it's exciting to view the spectrum of possibilities that are already well within reach.

Resources

- Cal-(IT)^2 – http://www.calit2.net/index.html
- Lambda Join demonstration wins award at Supercomputing 02 Conference – http://www.canarie.ca/press/releases/02_11_27.html
- Laws of the Telecosm – http://www.kurzweilai.net/meme/frame.html?main=/articles/art0004.html
- Nortel Networks – http://www.nortel.com
- Platform Computing – http://www.platform.com
- SABUL – http://www.dataspaceweb.net/sabul.html
- SHARCNET – http://www.sharcnet.ca
- TeraGrid – http://www.teragrid.org
- The Open Grid Services Architecture (OGSA) – http://www.globus.org/ogsa
- Visual Area Networking – http://www.sgi.com/visualization/van

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