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ALLWAVE DIVIDES AND CONQUERS

Companies using Lucent's AllWave have the opportunity to transform the topology of communications.

My first optical guru was Will Hicks, the co-inventor of single mode fiber, who ten years ago read *Microcosm* and told me that I had it all wrong. In a little over a decade, Moore's Law might assure a doubling of computer power every 18 months, for a total factor of 128. But over the next ten years, he declared, the laws of fiber optics would increase communications power a millionfold. In the face of the coming tidal waves of network bandwidth, betting your future on Moore's Law would be like betting on the Bay of Fundy for a beach hotel.

Exit Microcosm, enter Telecosm. Hicks offered his millionfold prophecy in 1990, when a fiber backbone ran at around 45 megabits a second. So a million fold increase by the end of the year 2000, would put fiber backbones at 45 terabits per second. Meanwhile, a total bandwidth estimate must account for at least a 100 fold increase in the number of fiber miles. Thus, the increase in total available bandwidth will be far above a million. You don't believe it? You think Hicks, and yours truly, are indulging in hyperbole? You should have been at SuperComm in Atlanta last month, where Wavelength Division Multiplexing (WDM) broke out in a coruscating cascade of new colors and capacities.

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Cover Story: Lucent's AllWave, NEON Lights, Chorum's Light Switch, Huber's Corvis Comeback, Avanex's Optical Nirvana, The QoS Illusion

Before the event, GTR Technology Analyst Jeff Dahlberg and I drove out US85 17 miles to the northeast edge of the city to attend the opening of a monster new factory that **Lucent** (LU) is adding to its existing 1.7 million square feet of manufacturing space at their Norcross, Georgia site. There we wanted to investigate AllWave fiber, a Lucent revolution that expands by some 60 percent the total bandwidth of single mode silica strands.

Discussing a revolutionary invention at an establishment redoubt like Lucent is always somewhat anticlimactic, of course, because company executives always want to pry the new blockbuster neatly into their current product line without busting any legacy blocks. In its Western Electric incarnation, Lucent, after all, is the company that pretty much invented WDM way back in the late 1980s at Bell Labs, and then cancelled the project because it would always be more efficient to multiply phone call time slots in their synchronous optical network (SONET). In Norcross, the Lucent execs seemed to realize that AllWave could be useful to fend off uppity SuperComm rivals in the cable TV and metropolitan fiber markets. But Lucent focused attention on its new version of TrueWave, their prevailing non-zero dispersion long haul fiber (don't ask).

AllWave, though, will soon render TrueWave a trivial product. Fiber optics does not work just anywhere in the electromagnetic spectrum; it requires special conditions such as the absence of water molecules and the availability of lasers and amplifiers at the wanted frequencies. Every textbook on WDM optics contains an attenuation chart signifying which wavelengths can be transmitted down a fiber without unacceptable losses. It is a bifurcated chart, showing a low attenuation window between 1310 nanometers and

Bisceglia's pioneering decision to deploy this technology puts NEON on our Telecosm list.

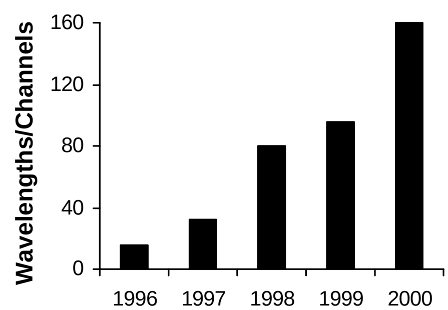
1380 nanometers and a still lower attenuation window between 1520 and 1625. In between, presented as an eternal fact of nature, is an attenuation mountain centered around 1400 nanometers, where infrared light is blocked off by microscopic water molecules in the fiber itself.

In late 1998, David Kalish, Mike Pearsall, Tom Miller, and Kai Chang, working at various Lucent fabs and laboratories, sought a patent for a new method of fiber manufacture that flattens this water spike mountain. By extinguishing the residual water, they opened up the spectrum space between 1310 and 1625. Although Lucent implies this fiber is a specialized niche product, the new band around 1400 is lower in loss than the 1300 band and lower in dispersion than the 1500, and both lasers and amplifiers are increasingly available to use it. I knew it was a genuine breakthrough when, at January's Optical Fiber Conference in San Diego, **Corning** (GLW) experts told me they could do it too, if they wanted, and besides it wasn't important, and anyway their customers were more interested in large effective area fiber (LEAF) than in multiplying WDM wavelengths, or "lambdas", as they are called in this context.

With conservative spacing of wavelengths, separated by the 100 gigahertz of the ITU (International Telecommunications Union) standard, AllWave could hold some 375 lambdas. At the 50 gigahertz spacing widely adopted for new systems, it could hold 750 lambdas. At the 12.5 gigahertz spacing increasingly demonstrated in laboratories, AllWave fiber could hold more than 2000 lambdas. Assuming a conservative 500 wavelengths of 10 gigabits per second apiece on one fiber thread, that's five terabits a second, about the average traffic on all the communications networks in the world put together two years ago or the total capacity of US phone networks today. Lucent now can put 864 of these fibers in one cable sheath (**Metromedia Fiber Network** [MFNX] recently ran two such sheaths through the Holland Tunnel to Manhattan). But the average is a little over 140 fibers, which multiplied by five terabits per second yields 700 terabits per second in a single cable. Hicks was an appalling pessimist. Forget terabits per second, and begin to get used to petabits (ten to the 15th).

Chart 1

With 2000 Wavelength WDM Possible, Nortel Promises 160 Channels by 2000



Source: Nortel, Lucent, Ciena Announcements

NEON Lights

First to deploy AllWave is an optical innovator called **NorthEast Optic Network** (NOPT) which beginning in 1994 raised some $20 million in private placements and quietly assembled rights of way from electrical utilities in New England and New York. It went public in August 1998, issuing 4.5 million shares at $12, and floated $180 million of junk bonds through Credit Suisse First Boston and Warburg Dillon Reed.

Known as NEON, the company now commands 1000 concentrated route miles (75 thousand fiber miles) that exploit the utilities' inter city and intra city towers, poles, and conduits to deliver a network reaching some 540 cities and towns, from New York to Portland, Maine. NEON has learned how to encase its fibers indestructibly in the powerline ground wires, themselves on the tops of trestles or in subterranean ducts.

Aggressively deploying AllWave in both backbone and distribution, trunk and branch, it is creating a state-of-the-art optical network throughout the Boston area and down a dense Connecticut corridor to New York City. A carriers' carrier that earlier sold out its retail network in Springfield to Brooks Fiber, NEON's strategy is "to sell lambdas, not bits per second." That is exactly how AllWave should be used, enabling a true all optical network with thousands of wavelength lambdas. As CEO Vincent Bisceglia puts it, NEON's plan is to "run AllWave over utility rights of way that reach everywhere there is a lightbulb."

A tiny company with $500 thousand revenues in 1998, NEON is on track to reach at least $5.5 million in 1999 and plans to replicate the model around the country in 2000 and beyond. With scores of new customers in the queue, NEON has already contracted to supply links in New England to **Level 3** (LVLT), and to Hyperion Telecommunications, recently renamed **Adelphia Business Solutions** (HYPT), the second largest winner in the Local Multipoint Distribution Service (LMDS) broadband wireless auctions. AllWave and powerlines are so fundamental to the paradigm that Bisceglia's pioneering decision to deploy this technology puts NEON on our Telecosm list.

Who knows what will happen next in WDM. Like the semiconductors of the Microcosm, optics is an anti-Murphy's arena, where what can go right usually does. Selling lambdas rather than bitstream slots, NEON and other companies using AllWave have the opportunity to transform the topology of communications, moving the network–from core to capillaries–beyond both packet data channels and voice circuits. Now emerging is a new regime of wavelength circuit switching altogether transparent to the coding of the bitstreams. Only on the network's periphery will anyone read a packet header. The recent SuperComm demonstrated that this new regime is closer to fulfillment than any of the experts previously predicted, with the exception of Will Hicks.

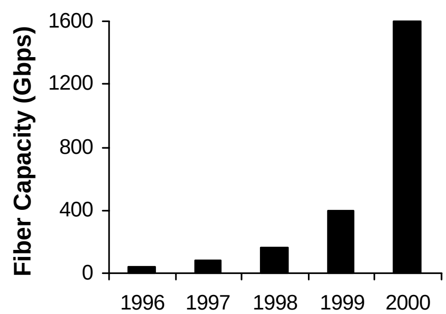
Proceeding on to the SuperComm floor, almost everywhere we looked we found amazing WDM breakthroughs on display. Angels were thronging the points of pins all across the arena.

Chorum's Light Switch

Let us begin slowly, with a company from the telecom corridor in Richardson, Texas, outside of Dallas, called **Chorum**. Started by two Taiwanese named J.Y. Liu and Kuang Yi Wu, the team has since attracted the Sevin Rosen venture firm, raised $24 million in two rounds of financing, and hired as CEO the estimable Scott Grout, formerly a technical VP of Lucent. Chorum's business is to produce key components that can enable the new era of 12.5 gigahertz spacing and all optical add-drop mutiplexers and cross connects.

Chorum follows in the train of the popular Internet joke: "That's not a bug, that's a feature." Turning bugs into features is a common way of advancing a technology. Camels slipped on slicks of oil amid the sands of the Middle East for centuries before industrial uses were found for this treacherous gunk. Electricity began as a nasty shock.

Chart 2
WDM up to 2000 Gbps in 2000 Say Nortel, Lucent, and Ciena



Source: Nortel, Lucent, Ciena Announcements

Radio originated with the use of electromagnetic amplitudes alone (AM) for bearing information, with frequency shifts an annoying "drift" of the connection. Soon it became possible to encode the message by manipulating frequency as well, as in FM. Alterations in waveform timing or phase were treated as unwanted jitter or delay. Today, in such ubiquitous modulation schemes as PSK (phase shift key), phase changes are controlled as the chief way to transmit more than one bit of information per hertz of bandwidth. **Silk Road** wants to put jitter variations to work as well.

In most contemporary fiber links, however, polarization (the vertical or horizontal orientation of the light) is still a bug: mischievous polarization-dependent loss or nasty polarization mode dispersion.

To turn this bug into a feature, Chorum uses the same liquid-crystal technology used in the screen of your notebook computer. Because the speed of passage through the crystal is dependent on polarization and frequency, liquid crystals can separate wavelengths with high precision. Describing the function as "optical signal processing," Chorum calls its filter a light slicer. Chorum then uses polarization changes as a directional signal that indicates along which of two paths to send the wavelength bitstream or lambda. As the technology is perfected, these binary gateways can be cascaded into an arbitrarily large passive optical switch.

Adding no power in the optical path, the passive switch directs information streams simply by shifting the course of their wavelength carriers, rather than by actively reading and processing the immense gigabit and soon terabit streams themselves. That process of poring through hundreds of thousands of SONET time slots every second or reading as many as 10 million packet addresses requires converting photons to electrons and channeling them through vastly expensive optoelectronic switches, terabit routers, add-drop muxes, or cross connects from Lucent, **Nortel** (NT), and **Tellabs** (TLAB), among others, that can weigh tons, occupy thousands of square feet, and cost tens of millions of dollars apiece. Even **Cisco** (CSCO) 12000 routers can cost some $4 million.

The key reason current fiber networks use so much costly electronic gear is the photonic paradox: while photons are the fastest moving entities in the Universe, they are devilishly slow in a switch. A liquid crystal optical switch, for example, works in milliseconds while an electronic switch operates in nanoseconds, a million times faster. The very features that make photons supreme in communications–lack of mass or impact on other photons–render them nearly impossible to store or manipulate. That is why the attempt to ape electronic switching with active optical switching (the "optical computer") is a dead end. No one will succeed in making a practical optical packet router or forwarding engine that can read packet headers at wirespeed and dispatch packets to their destined addresses. Route calculation and control has to be performed electronically, then applied to optical switch elements such as liquid crystals from Chorum or micromirrors from **Astarte Fiber Networks** that can send wavelengths on their way.

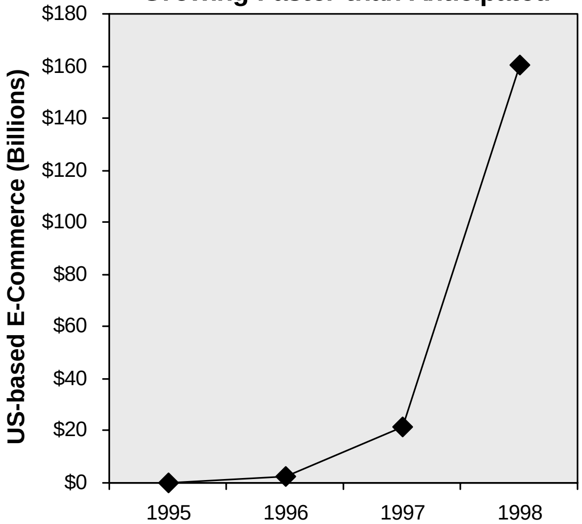
Much of the cost of prevailing optoelectronic systems comes from the transponders that convert signals flying through a fiber at the speed of light into electronic packets sitting in silicon buffers ready to be processed by silicon chips in routers and switches. Every wavelength carrier requires a separate transponder and each transponder costs some $10 thousand to $20 thousand.

Back to Circuit Switching

The tantalizing promise of WDM is to leave all these costs behind–indeed, banish packet switching from the network, or at least marginalize it. The all optical network will go back to the future, back to circuit switching. It will ply entire wavelength links from end to end, in a system as simple as the old

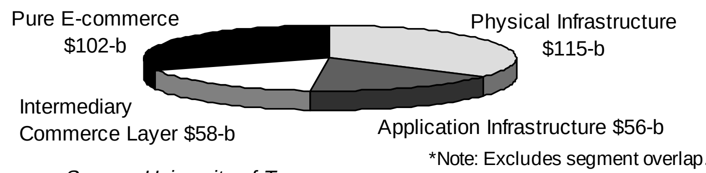
The all optical network will go back to the future, in a system as simple as the old electro-mechanical shuffling of copper wires.

Chart 3
Internet Commerce Revenues Growing Faster than Anticipated



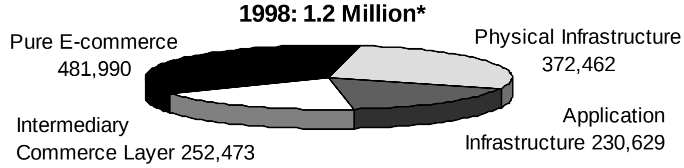
Source: ActivMedia, University of Texas

Chart 4
US-based Internet Economy Revenues
1998: $301 Billion*



Source: University of Texas

Chart 5
US-based Internet Economy Jobs
1998: 1.2 Million*



Source: University of Texas *Note: Excludes segment overlap.

Internet Transactions Generated $160 Billion in Revenues in 1998

*Three recent studies claim global e-commerce will top $1 trillion by 2002, 2003 or 2005. But telecosmic growth has always been faster than predicted, one reason we avoid forecasts. IBM, Intel, Cisco, and Dell are generating annualized e-commerce revenues of $20, $15, $10 and $5 billion, respectively. Yet the University of Texas concludes that the top 80 players accounted for only a third of the $102 billion in goods and services sold over the Net in 1998. Revenues of portal sites, online advertising, and commissions of online travel agents, brokerages, and other intermediaries added $58 billion for an e-commerce total of $160 billion. That was more than 7 times ActivMedia's 1997 figure, which was 8 times 1996's total (***Chart 3***). A similar increase would put us over $1 trillion* this *year.*

The $301 Billion Internet Economy would Rank 18th Among Nations,

*behind Switzerland and ahead of Argentina. That's an economic sector larger than energy or telecommunications and just smaller than automobiles. To the $160 billion figure for Internet commerce and intermediaries' revenues, the University of Texas study adds 1998 revenues from Internet infrastructure—including Internet backbone providers, Internet Service Providers (ISPs), Internet-related fiber optics, network hardware, PCs and servers; and revenues from Internet applications—including Internet consultants and software (***Chart 4***).*

Over 1.2 Million Internet Related Jobs, and an Impact on All Careers

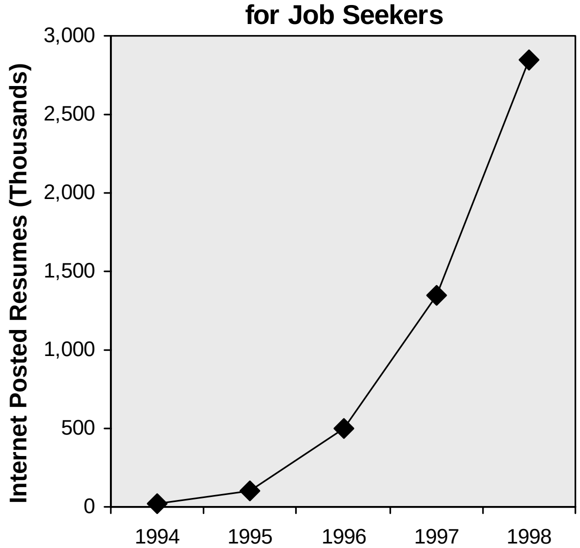
*An estimated 20% of America's high-tech-industry work force is already working within the Internet economy (***Chart 5***). Career strategies in all industries are changing with three million resumes posted online (***Chart 6***). 82% of college graduates will search for careers and employment information online.*

Music is Just One Example of Entire Industries Changed by the Internet

*Music is one of the rare goods which can be completely digitized and downloaded directly to consumers. The International Federation of Phonographic Industries estimates 3 million music tracks are downloaded from the Internet daily. The explosion in downloadable music, retail availability of hard-drive juke boxes and portable players, and new schemes to reduce piracy of commercial albums will transform the industry even faster than the rise in online CD sales (***Chart 7***).*

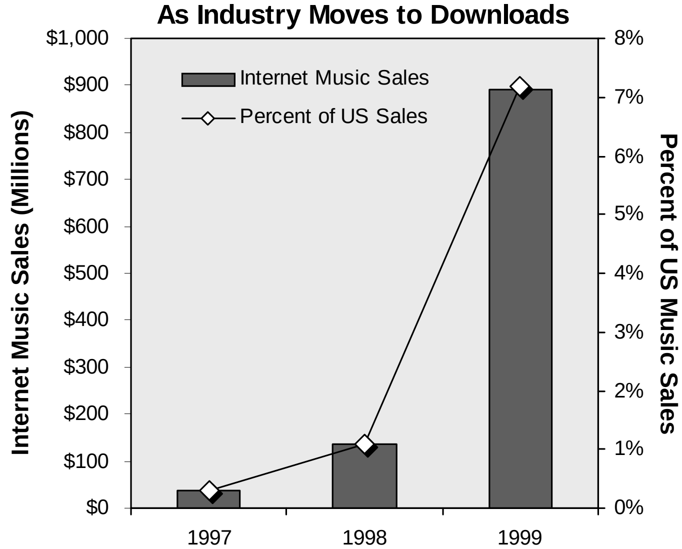
-Ken Ehrhart

Chart 6
The Internet becomes a Mecca for Job Seekers



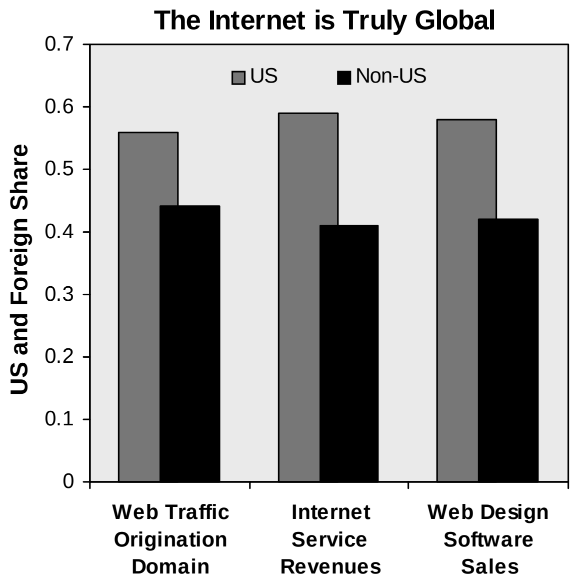
Source: Computer Economics

Chart 7
Internet Music Sales Explode As Industry Moves to Downloads



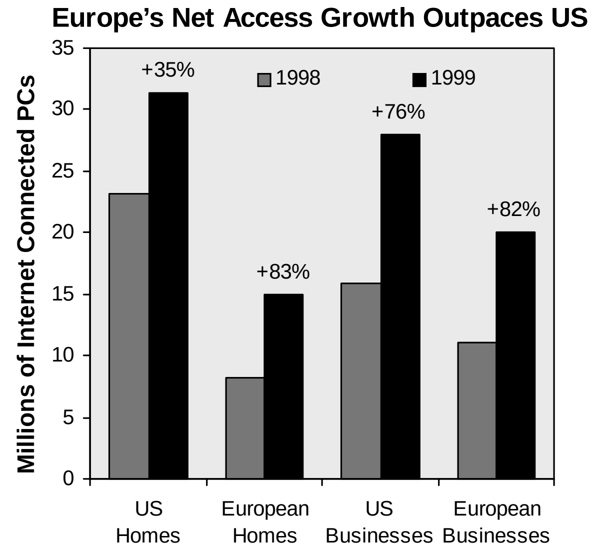
Sources: Recording Industry Assoc., Forrester

Chart 8



Sources: WebSideStory, IDC

Chart 9



Sources: Ziff-Davis, Dataquest

The Net is Truly International with US Share Less Than 60 Percent

*Web traffic from foreign domains has increased to 44%, according to WebSideStory's measurement of over 28 million unique daily visitors to more than 86 thousand websites. Accounting for foreign visitors within the non-country-specific .com and .net domains would raise the total even higher. The US, according to IDC, represented $4.6 billion or 59% of the $7.8 billion spent globally in 1998 on Internet services and accounted for less than 58% of 1998's $243 million web authoring and design software market. (***Chart 8***)*

Internet Access Growth in Europe is Outpacing the US

*The number of homes and businesses accessing the Net in Europe is increasing at a faster rate than in the US (***Chart 9***). MCI Worldcom, Global Crossing, Level3 and other pan-European providers such as the just announced Interoute, which contracted for $1.5 billion in Corning fiber, will benefit. One factor driving Europe's Net growth is a rise in "free" Internet services in which ISPs receive a portion of toll charges in lieu of monthly subscription fees.*

Competition Creates Telecom Opportunity in Europe

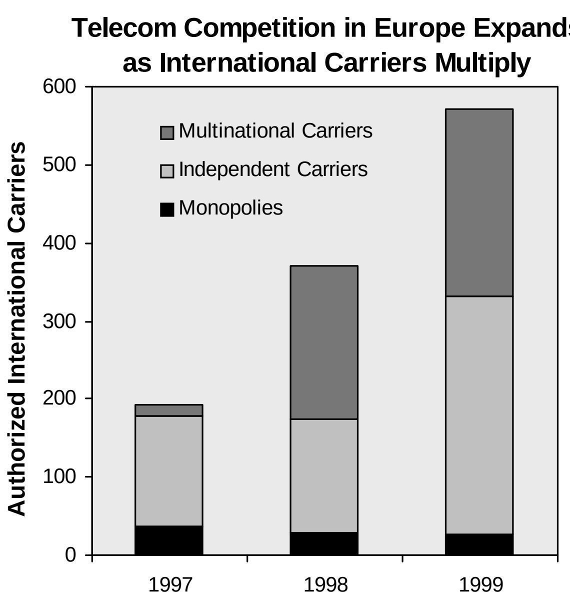
*The number of telecom carriers authorized to provide or resell international service in Europe has increased 200% in two years (***Chart 10***). The move toward liberalization and privatization dramatically speeds the promise of lower prices, increased usage, and greater profits.*

Foreshadowing the Rise of Data Over Voice, Europe's 3000 ISPs Dwarf its Telecom Carriers

*Whether viewed as catalyst or consequence of telecom reform, the explosion of ISPs in Europe dramatically outpaces the number of international telecom carriers there (***Chart 11***). The promise of WDM (wave division multiplexing) and IP (Internet Protocol) to dramatically reduce the price of voice services and enable huge data bandwidth, will further alter the competitive landscape in favor of providers with a Net-centric data focus.*

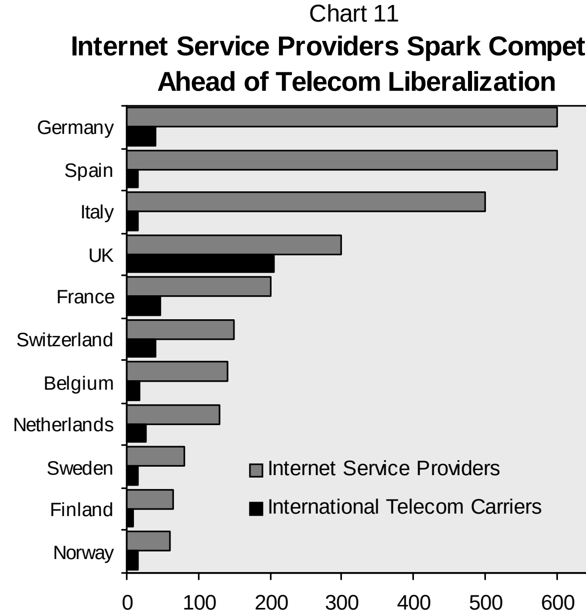
-Ken Ehrhart

Chart 10



Source: TeleGeography

Chart 11



Sources: Analysys, TeleGeography

Corvis's startling claims have enlisted a chorus of flattering imitation.

electro-mechanical shuffling of copper wires, in which the circuit was also switched with no need to read its contents. The new wavelength circuits, of course, will command a capacity millions of times greater.

To achieve this all optical goal, however, requires surmounting a long insuperable roadblock. It has long been regarded as a law of nature that optical signals must be converted to electronic form to be reshaped and regenerated every 400 to 600 kilometers. This is about the distance between American or even European cities, logical switching points. Since the signals had to be expensively converted to electronics for regeneration anyway, it made sense to switch them in convenient packets by fast electronics rather than in seemingly cumbersome wavelengths by slow optics. Therefore electronic switches and routers have ruled the industry and companies such as **Nexabit**, **Juniper Networks** (JNPR), **Avici Systems**, **Pluris**, **Alteon WebSystems**, and others continue to prance and posture as the next Cisco, go public meteorically (Juniper), or be bought, lucratively (Avici 20% by Nortel), or lucently (Nexabit).

Launching a market for Chorum's slow optical switches and add drop multiplexers therefore depends on overthrowing the 600 kilometer distance limit between regenerators. If you don't have to convert the photons anyway to electrons for regeneration, you can save the huge costs of optoelectronic transponders by using passive optical "switches." You convert to electronics and read packet headers only on the edge of the network in a router on your LAN, or perhaps even in the back of your PC (remember the **SoftCom Microsystems** Gigablade, GTR May 1999).

Huber's Corvis Comeback

Here is where **Corvis Corporation** entered the fray on the floor of SuperComm. Rumored to be a purchaser of Chorum devices, Corvis was founded by former **Ciena** (CIEN) founder David Huber to create the first all optical network systems. Key to the promise of Corvis is its claim that its dispersion management tools and modulation schemes enable optical signals to travel not six hundred kilometers or a thousand kilometers, but 3,200 kilometers. Suddenly optical switches and add drops become not a luxury but a necessity and Chorum and Corvis become hot companies.

Corvis's claims are startling. But they have enlisted a chorus of flattering imitation. The key obstacle to long distance transmission is the tendency of signals to mush out unreadably through various forms of dispersion and nonlinearity. **LaserComm** of Israel and Richardson declares that it can radically reduce dispersion anywhere in an optical link by temporarily transforming the signal to a higher mode or harmonic of the basic frequency. This process alone can lengthen the path to 1000 kilometers or more. But perhaps most stunning were the claims of **Avanex Corporation** of Freemont, California, unveiled for the first time at SuperComm.

Avanex's Optical Nirvana

Avanex announced optical nirvana: a regime of virtually "any wavelength, any bitrate, any channel count, any distance." At the heart of these claims is the contribution of Simon Cao, formerly of **E-Tek Dynamics** (ETEK), who has achieved 38 patents, passed or pending, in his 36 years. The key patents apply to an ingenious new dynamic optical filtering technique that he contentiously calls a spectrum "slicer" (Hey, sorry, but Chorum got there first). Using another nonlinear fiber bug, he creates a feature rich PowerMux that can adapt to different bitrates on different lambdas on the fly. Enhancing still further the potential of AllWave, this Avanex device would allow NEON, for example, to allocate 10 gigabits per second to one wavelength and shrink a contiguous channel snuggly to hold a few megabits, and price accordingly.

The other miracle product of Avanex is its dynamic dispersion compensator, called the Power Shaper, which can adjust the dispersion maps on any fiber link to adapt to new pulse formats, such as solitons or video and send each down a different channel. Like LaserComm's transformer, this device can extend the distance between optoelectronic regenerators from 600 kilometers to a thousand or more. With solitons–which balance off dispersion against nonlinearities to achieve an undulatory version of eternal life–the Power Shaper might even allow Avanex to reach the Corvis distance of 3,200 kilometers or more.

Among scores of advances exhibited at this scintillating SuperComm, these inventions mostly complement those of Corvis and Chorum in bringing ever closer the all optical dream. John Fee, formerly of **MCI** (WCOM), now CTO of Avanex with some 20 patents of his own, sums up the impact of the new wave of optics as increasing the spectral efficiency from the current 15 percent to 80 percent. Between 1285 nanometers and 1625 nanometers are 42.5 terahertz of bandwidth. Today on 160 wavelengths, the current state of the art, Nortel can send 1.6 terabits per second down a single fiber. Before SuperComm, that seemed pretty awesome, but it is only 15 percent of the real capacity of the AllWave band. By using Simon Cao's super filters, and adaptive PowerMuxes, and dispersion compensators, it will be possible to fit more than two thousand flexible lambda channels in an expanded frequency space.

When the contents of the pipe is divided into thousands of wavelengths–each of which can be switched independently with passive optics–messages will be able to ride from origin to destination entirely on wings of light. Shaping these wings will be an increasing array of companies, led by Avanex, Chorum, Corvis, and others already familiar to GTR readers, such as

JDS Uniphase (JDSU), Nortel, Ciena, and **Bookham**, and of course, Lucent with AllWave.

The QoS Illusion

The new network enabled by the SuperComm miracles, however, requires the industry to abandon its perennial goal of guaranteeing various "qualities of service"–the QoS acronym that buzzed across the SuperComm floor like an infestation of flies at a field of dreams. The old players want to guarantee low latency, low jitter, and assured rates of committed bandwidth–through "policy based networking," constraint based routing, time division muxing, rate shaping, flow control, flow based queuing, weighted fare queuing, reservation protocol, Multi-Protocol Label Switching (MPLS), and summing it up in one intricate archaic package, Asynchronous Transfer Mode (ATM), along with other fashionable buzzes which are even more complex than they sound. In effect, these companies are supplying a different network for each kind of traffic. Their algorithms (no political pun intended) theoretically enable you to provide guaranteed channels for full motion video, CD quality voice, superbursty data, real-time transactions, secure financial flows, and palpable guaranteed jitter and bug-free, low-latency, holographic, osculatory, burst-mode petabytes of Laetitia Casta over the net, and charge differently for each feature.

It won't happen. Everyone wants to charge different customers differentially for different services. Everyone wants guarantees. Everyone wants to escape simple and flat pricing. Forget it.

As my Gilder Group colleague Clayton Christensen would say, the telcos and their younger imitators find themselves in the classic predicament of a traditional or "sustaining" technology, facing–or, actually, trying to ignore–a "disruptive" technology boring up from below. The sustaining technology here is an ever improved, ever more expensive version of the intelligent network, using fiber like copper on steroids, and packed with ever more sophisticated electronics and brilliant programming. As always the disruptive technology is in many ways inferior to the sustaining technology it will replace. The truly optical network is dumb by definition. Photons, useless for computation, cannot be stored, buffered, processed, or read with any of the facility of electronic systems. The summit of optical switching is to turn this bug into a feature, to switch bit streams without knowing what is in them, to shed as a costly inconvenience the very intelligence that was the proudest achievement of the telco networks and one of the greatest achievements of the computer era.

They bet the farm that you will want their service guarantees badly enough to bear the costs of the fantastically costly electronics that sustain them. All sustainers follow the same strategy: raise margins by adding quality and features valued by your best and most lucrative customers. It usually works. But the collapse comes suddenly when your customers discover you are selling them more quality than they need, compared to a far cheaper technology that becomes good enough.

Big dumb bandwidth doesn't guarantee Quality of Service or anything else because it doesn't know what it contains. But it is advancing its cost effectiveness at least 40 times faster than is the big software that drives intelligent networks. With a pace of advance 40 times faster, you can make up for a lot of latency and jitter, misalignments and misfits.

Most Quality of Service software is an optical illusion contrived by companies trying to prop up the past in the name of progress. It adds complexity, actually consumes the bandwidth it allegedly saves, and increases delay while promising to reduce latency. While extending new guarantees and assurances of quality and reliability, it actually multiplies the number of potential points of breakdown and failure. It brings you into a maw of big software, proprietary systems, and smart networks.

Explaining why **America Online** (AOL) had thrown away its smart ATM switches with their elaborate QoS, AOL architect Victor Parente told an audience at the Las Vegas InterOp in late 1998: "I don't understand where this demand for Quality of Service is coming from. We don't want it. Does anyone here want to pay less in order to have packets dropped? That's the same as paying more to have all packets delivered. The only answer if you are dropping or delaying packets is to add more bandwidth."

AOL architect Parante asks, 'Does anyone want to pay less to have packets dropped?'

Tortured Photons

Listen to the technology. Optics is for communicating; electronics is for computing and switching. Throughout the domains of both communications and computing, engineers resist this clear duality. In at least fifty laboratories today, from Lucent in Parsippany, New Jersey, to **NTT** (NTT) in Yokosuka, Japan, researchers are torturing photons in an effort to create an active optical switch that can compete with the terabit per second electronic machines wrought by companies such as Nexabit and Juniper, Avici and **GTE** (GTE).

ASCENDANT TECHNOLOGY	COMPANY (SYMBOL)	Reference Date	Reference Price	6/99: Month End
Cable Modem Service	@Home (ATHM)	7/31/97	9 3/4	53 15/16
Silicon Germanium (SiGe)	Applied Micro Circuits (AMCC)	7/31/98	22 11/16	82 1/4
Analog to Digital Converters (ADC), Digital Signal Processors (DSP)	Analog Devices (ADI)	7/31/97	22 3/8	50 3/16
Dynamically Programmable Logic, SiGe, Single-Chip Systems	Atmel (ATML)	4/3/98	17 11/16	26 3/16
Single-Chip Broadband Data Transmission	Broadcom Corporation (BRCM)	4/17/98	12 *	144 9/16
Digital Video Codecs	C-Cube (CUBE)	4/25/97	23	31 11/16
Erbium Doped Fiber Amplifiers, Wave Division Multiplexing (WDM)	Ciena (CIEN)	10/9/98	8 9/16	30 3/16
Linear Power Amplifiers, Cable Modems	Conexant (CNXT)	3/31/99	27 11/16	58 1/16
Fiber Optic Cable, Components, Wave Division Multiplexing (WDM)	Corning (GLW)	5/1/98	40 15/16	70 1/8
Submarine Fiber Optic Networks	Global Crossing (GBLX)	10/30/98	14 13/16	42 5/8
Low Earth Orbit Satellites (LEOS)	Globalstar (GSTRF)	8/29/96	11 7/8	23 3/16
Business Management Software	Intentia (Stockholm Exchange)	4/3/98	29	24 7/16
Wave Division Multiplexing (WDM), Fiber Optic Equipment	JDS Fitel (Toronto Exchange) [See Below]	5/1/98	19 1/4	81 1/2
Broadband Fiber Network	Level 3 (LVLT)	4/3/98	31 1/4	60 1/16
Single Chip ASIC Systems, CDMA Chip Sets	LSI Logic (LSI)	7/31/97	31 1/2	46 1/8
Telecommunications Equipment, WDM, CDMA, SiGe	Lucent Technologies (LU)	11/7/96	11 25/32	67 7/16
Telecommunications, Fiber, Internet Access	MCI WorldCom (WCOM)	8/29/97	29 15/16	86 1/16
Single-Chip Systems, Silicon Germanium (SiGe)	National Semiconductor (NSM)	7/31/97	31 1/2	25 5/16
Nationwide Fiber and Broadband Wireless Networks	Nextlink (NXLK)	2/11/99	40 7/8	74 3/8
Telecommunications Equipment, WDM, CDMA, SiGe, Cable Modems	Nortel Networks (NT)	11/3/97	46	86 13/16
Carriers Carrier and AllWave Pioneer, Using Utility Rights of Way Strategy	NorthEast Optic Network (NOPT)	6/30/99	15 1/16	15 1/16
Point to Multipoint (7-50 Ghz), Spread Spectrum Broadband Radios	P-COM (PCMS)	11/3/97	22 3/8	5 15/64
Code Division Multiple Access (CDMA)	Qualcomm (QCOM)	9/24/96	19 3/8	143 1/2
Nationwide CDMA (Code Division Multiple Access) Wireless Network	Sprint PCS (PCS)	12/3/98	15 3/8	57
Java Programming Language, Internet Servers	Sun Microsystems (SUNW)	8/13/96	13 3/4	68 7/8
Broadband Wireless Services	Teligent (TGNT)	11/21/97	21 1/2 *	59 13/16
CDMA Cable Modems	Terayon (TERN)	12/3/98	31 5/8	55 7/8
Digital Signal Processors (DSPs)	Texas Instruments (TXN)	11/7/96	23 3/4	144
High-Speed Copper Networking	Tut Systems (TUTS)	1/29/99	18 *	48 15/16
Wave Division Multiplexing (WDM) Modulators	Uniphase (UNPH) [See Below]	6/27/97	29 3/8	166
Field Programmable Gate Arrays (FPGAs)	Xilinx (XLNX)	10/25/96	16 7/16	57 1/4

Added to the Table: NorthEast Optic Network

*** Initial Public Offering**

Note: As of 7/6/99, JDS Uniphase Corporation, the result of the merger of Uniphase and JDS Fitel, trades as JDSU on the NASDAQ and JDS Uniphase Canada Ltd. trades as JDU on the Toronto exchange.

Note: This table lists technologies in the Gilder Paradigm, and representative companies that possess the ascendant technologies. But by no means are the technologies exclusive to these companies. In keeping with our objective of providing a technology strategy report, companies appear on this list only for these core competencies, without any judgement of market price or timing.

At the same time, electronics engineers are torturing copper conduits to carry multi-megabit and even gigabit loads. Rather than succumb to the obvious superiority of fiber, they contrive ever more baroque algorithms to convolve and compress, buffer and shuffle frequencies in digital subscriber lines, power cables, and coax. "Copper optics," they lamely call it. Meanwhile, vendors of optical equipment attempt to create transmitters and receivers that perpetuate the old telco SONET architectures and topologies by loading innocent wavelengths with up to 40 gigabits per second worth of time slots.

Listening to the technology, one can hear a resoundingly contrary message. The all optical network will not switch packets; it will shuffle wavelengths. This means a contrarian return to circuit switching based on lambdas. With thousands of lambdas on every fiber and hundreds of fibers in every sheath, wavelengths will be the currency of communications. Adding them, dropping them, cross connecting them and routing them, splitting them and coupling them are all possible by mostly passive optical devices. These devices will be the network. On the edge of the network, where packets of bits and bytes are stored and processed, sorted and searched, decoded and displayed, electronics will hold sway. Connections between these computers on the edge and the fiber core will increasingly be wireless. The all optical fibersphere in the center finds its complement in the wireless ethersphere on the edge.

In the transition to this goal, many compromise solutions will work for a time. Even NEON is adopting some SONET. But in the end, the nations, companies and individuals who listen to the technology, and pursue its abundances, will steadily and surely prevail over those who try to make a reluctant technology listen to them.

George Gilder, July 8, 1999

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Editor: George Gilder; Publisher: Richard Vigilante;
Director of Research: Kenneth Ehrhart; Technology Analyst: Jeff Dahlberg
Monument Mills P.O. Box 660 Housatonic, MA 01236 USA
Tel: (413) 274-0211 Toll Free: (888) 484-2727 Fax: (413) 274-0213
Email: gtg@gildertech.com