The Internet: A Preliminary Analysis of Its Evolving Economic Geography[1]

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Abstract

The Internet is arguably the defining technology of the emerging twenty-first century. This paper examines the infrastructure that comprise the "network of networks" and the imbalances that have emerged in the Internet's short existence. Two sets of imbalances are documented empirically, using global data for Internet backbones and metropolitan data on telephone switch capabilities for several US and Canadian cities: (1) a global bias of fiber-optic backbone networks toward world cities, and (2) a bias within cities toward high-density central-city locations. Implications for both theory and policy are presented.

Introduction

The Internet is arguably the most significant technology of the intermillennial era, the leading technology of the fifth Kondratiev wave (Hall 1998). It fills this role in part because it is a *general purpose technology* (GPT) – one of a small number of drastic innovations that creates innovational complementarities that increase the productivity in a downstream sector (Helpman (1998). The Internet clearly qualifies as a "key" technology, characterized by the potential for pervasive use in a wide range of sectors and by its technological dynamism, and as an "enabling technology," opening up new opportunities rather than final solutions (Bresnahan and Trajtenberg 1995). GPTs have wide impact because of their scope for improvement, wide variety of users, wide range of uses, and strong technological complementarities. Historically, writing, printing, and electricity were GPTs; recent examples, in addition to the Internet, include lasers, the factory system, mass production, and flexible manufacturing (Lipsey, Bekar and Carlaw 1998).

The newness of the Internet has hidden some of its not-so-new characteristics (see the review in Malecki *in press*). Four of these are most important for the present paper. First, large firms – and particularly banks – also greatly influenced the telegraph and the evolution of all subsequent communications technologies. This is, in part, a result of a second feature common to all telecommunications technologies since the telegraph: that moving intangible, invisible information is not the same as the transportation of goods (Hillis 1998). Financial tallies that represent money have been among the easiest items to send across the ether, and all of the largest categories on-line or e-commerce to date are intangibles: travel and ticketing services, software, entertainment (including gambling, music, online games and pornography), and financial services (Wyckoff and Colecchia 1999). A third feature common to all telecommunications technologies is that telecommunications is at "the extreme end of the systemness spectrum" because of its primary distinctive feature: to function as a network with simultaneous utilization by many users (Rosenberg 1994, 208).

The fourth and final element of stability of the Internet is the importance of "private roads." Private telecommunications networks are hardly a new phenomenon. The use of leased fiber-optic lines by global firms for their internal networks merely continued a trend that began in the 1870s, when US banking firms assembled coast-to-coast private telephone networks and, with European bankers, were among the backers of the transatlantic cables (Gabel 1996; Hugill 1999). The early private networks were created to establish more reliable service, not only for banks but also for newspapers to transmit telephotographs and facsimiles. Private networks of leased lines remain the core of the Internet, and collectively are "far larger" than the public Internet (Coffman and Odlyzko 1998; Paltridge 1999). The result is that the Internet is a largely unregulated system into which corporate networks have hooked (Schiller 1999). A deregulation and privatization diminish the significance of national telecommunications monopolies, "it is possible that eventually the only communication infrastructure will be a set of interfaces among myriad private networks" (Crandall 1997, 168).

The remainder of the paper proceeds, first, by setting research on the Internet into the context of conventions within economic geography. The market or industrial structure of the Internet is an outcome of the firms that have invested in “backbone” networks and smaller networks that comprise it. The paper then focuses on interfirm linkages as they are manifested through interconnection of the many networks of the Internet. The spatial agglomeration of linkages and linkage sites is set in the context of the urban hierarchy of world cities. Taken together, the nodes and links of the network of networks define the geography, although not the content, of the space of flows

Economic Geography of the Internet

A great deal of the research on the Internet stems from research paths outside mainstream economic geography. What is the “mainstream”? Scott (2000) suggests that “flows and interactions through space” were among the preoccupations of spatial analysts – both economic geographers and regional scientists – until perhaps the early 1970s, when interest waned and shifted to political economy and toward local and regional economies. Other topics, such as localized production systems, institutions and local labor markets, and dynamic learning and innovation processes, were among the lines of investigation, and the term “networks” began to take on a meaning rather distinct from that of transportation and communication. To some degree, a parallel focus on globalization, including transnational corporations and the international division of labor, has always involved global flows at least implicitly. Indeed, communications technologies enabled the creation of global corporations. Likewise, any probing of the geography of money and finance necessarily runs into the telecommunication networks on which the global financial system depends (e.g. Leyshon 1996).

As a phenomenon of the 1990s, then, the Internet as a topic of research has grown largely outside of economic geography. Instead, the bulk of research on the Internet has sprung from those concerned with social phenomena for whom *cyberspace* represents a separate space in which people live and operate. Cyberspace, the interactivity between remote computers (and from nodes to nets) for real communication, not just data transfer, is not necessarily imagined. Cyberspace is, however, only one of the spaces of *virtual geography* created by computers and communications (Batty 1997). The four are: (1) place/space, (2) cspace or computer space (i.e. inside computers and their networks), (3) cyberspace, and (4) cyberplace, or the impact of the infrastructure of cyberspace on the infrastructure of traditional place. It is this last space, *cyberplace*, which is most easily subsumed within economic geography. It consists of all the wires that comprise the networks that are embedded into man-made structures; these are only partially charted and indeed are difficult to chart. All networks have a built infrastructure, including wireless networks, which rely on antennas and connection with conventional telephone switches. In effect, cyberspace depends on the “real world spatial fixity” found in cyberplaces (Kitchin 1998). The many geographies of cyberspace are only beginning to be studied (Dodge and Kitchin 2000; Donert 2000).

A multidimensional framework, therefore, is necessary in order to comprehend the effects of not only the Internet but of related economic and technological developments. Ohmae (2000) also sees various spaces or dimensions what he describes as a new *invisible continent* in which the global economy takes place:

$ a *visible dimension*, which contains economic dimensions of the old world, such as net present value (NPV), local commerce for delivery, and bakeries baking cakes – the mortar dimension of the clicks-and-mortar world

$ a *borderless dimension*, illustrated by electronic communication that transcends national borders, and perhaps most by cross-border migration of capital

$ a *cyber dimension*, represented by the computer and communications technologies that have changed the consumer, producer, and civic environments in irrevocable ways. The cyber dimension includes the Internet but also call centers and mobile phones.

- $ a *dimension of high multiples*, or mathematics based on a set of imaginative assumptions – whether in the form of speculators' leverage or the P/E ratios of equity markets.

Ohmae's inclusion of the fourth dimension takes into account how perceptions are significant. The rapidly-changing fortunes of dot.com firms reflect both the power of perceptions and their instability.

The combination of technological and economic trends also merge within e-commerce. In this context, several *layers* of infrastructure can be identified (Center for Research in Electronic Commerce 2000):

Layer 1: Internet Infrastructure - telecommunications companies, Internet service providers (ISPs), Internet backbone carriers, "last mile" access companies and manufacturers of end-user networking equipment

Layer 2: Internet Applications Infrastructure - software necessary to facilitate Web transactions and transaction intermediaries; consultants and service companies that design, build and maintain Web sites, from portals to full E-commerce sites.

Layer 3: Internet Intermediaries - Web-based businesses that generate revenues through advertising, membership subscription fees, and commissions. Some layer three companies are purely Web content providers; others are market makers or market intermediaries.

Layer 4: Internet Commerce - companies that are conducting web-based commerce transactions

A somewhat different organization by Zwass (1999) sees seven levels of e-commerce organized into three meta-levels: infrastructure, enabling services, and the products and services themselves.

Infrastructure and the Space of Flows

What is evident from these various perspectives of the Internet as a multidimensional phenomenon is the persistent significance of infrastructure, whether measured as networks, facilities, equipment or other fixed investments that facilitate electronic interaction. While some of the infrastructure has been in place for decades in the public switched telephone network (PSTN), it was the emergence of data traffic (including faxes and other non-voice communication) that prompted investment in fiber-optics, which facilitate faster transmission not meaningful for voice communication. The advent of the Internet, corporate intranets, e-commerce, and consumer Web sites have compelled networks to respond to the significance of data communication, which is growing far faster than voice traffic (Hulfactor and Klessig 2000; Wellenius et al. 2000). Data traffic demands high-speed (high bandwidth) links to transmit video (especially) at normal speeds.[2] Indeed, it is the digitization of several intangibles, such as music and video, that accounts for much of the growth of data traffic. Exactly how much traffic is not known; Coffman and Odlyzko (2001) suggest that we simply do not have comprehensive data on flows, yet best estimates confirm that traffic is probably doubling each year.

Castells' (1989, 2000) term, *the space of flows*, best captures the new spatial form, "the material organization of time-sharing social practices that work through flows." The space of flows consists of three dimensions or layers:

- The first layer, the material support for the space of flows, is constituted by a circuit of electronic exchanges. It is largely the technological infrastructure of telecommunications networks.
- The second layer of the space of flows is constituted by its nodes and hubs, which are hierarchically organized.
- The third layer in the space of flows refers to the spatial organization of the dominant, managerial elites (Castells 2000, 442-445).

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[2] Bandwidth is the term commonly used to designate transmission speed, measured in bits per second. A simple "rule of thumb is that good video requires about a thousand times as much bandwidth as speech. A picture is truly worth a thousand words" (Mitchell 1995, 180, note 28). *Broadband* generally refers to transmission speeds

The third of Castells' layers is a long-standing focus of study by economic geographers. Multinational firms have been prominent exploiters of telecommunications networks as enablers of their global reach (Dicken 1998). Multinationals rely on a "double network" that comprises both an *internal network* and a set of *external networks* (Zanfei 2000). Both types of network utilize communication links as well as face-to-face contact. Early work of Goddard and Pye (1977) on communication within large firms, extended to the dual-locational ABB by Lorentzon (1995), shows clearly that electronic communication complements and reinforces face-to-face contacts (Gaspar and Glaeser 1998; Moss 1998). Indeed, business travel shows no sign of decline despite massive growth of data traffic. At the same time, it is not the case that the fiber-optic "pipes" are full all the time; in fact, utilization of corporate networks is not particularly high. Odlyzko (2000) suggests that average utilization of corporate networks over a full week is around 20%, with occasional spikes of demand, a figure that matches the usage of three redundant networks by one firm reported by Roberts-Witt (2000).

A second body of theory is particularly useful to understanding the economic geography of the Internet at the global scale is the concept of world or global cities (Friedmann and Wolff 1980; Knox and Taylor 1995). The Globalization and World Cities (GaWC) Study Group at Loughborough University has operationalized Castells' (1989) concept of a "space of flows" to the global city system, defining a new meta-geography based on relational links (Beaverstock et al. 2000; Taylor 1999). Demarcating *alpha*, *beta*, and *gamma* world cities as three meaningful tiers, the *alpha* tier includes the usual urban triumvirate (London, New York, and Tokyo) but also Paris. At a slightly lower level of 'world city-ness' are Chicago, Frankfurt, Hong Kong, Los Angeles, Milan, and Singapore. It remains the case that we have precious few data on actual *flows* themselves – not only data transfer volumes but also time spent in data or voice communication, whether face-to-face, by telephone, e-mail, "instant messenger," or teleconferences, or person-days (in specific locations) away from the office.

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above 64kbps, the base normal speed of a voice call (Huston 1999a, 160-171). Higher bandwidths generally are

Although these telecommunications flows are the objects of interest, it is difficult to reconcile such flows with the conventional topic of linkages. The reason is both a lack of data on the transactions that take place via the Internet and the evolving system of interconnection within the Internet industry. Easier to grapple with is the geography of the backbone networks that together form the Internet.

The Geography of Internet Backbones

The original Internet network was little more than a back-of-the-envelope sketch of connections among four university nodes: (University of California in Santa Barbara, UCLA, the Stanford Research Institute, and the University of Utah in Salt Lake City (Abbate 1999). As computing and communications technology converged, private networks grew to serve corporate clients (Langdale 1989). It is the new telecommunications carriers, as well as the old telecom monopolies – many of which have become global players through acquisitions, mergers, consortia, and other arrangements – whose individual networks make up the present Internet. However, deregulation or liberalization are perhaps as significant as technology in forming the structure of the Internet (Finnie 1998; Graham 1999). Paltridge (2000) has made the case that access prices – lower in competitive markets – largely determine Internet use. The OECD, for example, has instituted a regularly update Local Internet Price Comparison (http://www.oecd.org/dsti/sti/it/index.htm).

The competitive environment means that universal service, a mantra of the regulated era of voice communications, has been replaced by "cherry-picking" and opportunistic behavior by the various backbone networks as they attempt to tap the demand in the world's largest cities. Within those cities, it is the central business districts and their potential clients – office tower-dwelling producer service firms – that attract most investment, reversing decades of unrelenting suburbanization (Graham 1999). WorldCom (and its many subsidiaries) represents the new telecom strategy: to be a global fiber provider

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made possible by multiplexing the base line.

in an archipelago of wired cities, offering “route diversity” and largely by-passing the public switched telephone networks (PSTNs) and participating in consortia for investment in new underseas cables (Graham 1999). Although there is no single map of the Internet, Dodge (2000a) provides what we know about it, including several of the backbone networks and the local mesh of fiber-optic networks in several cities.

Where deregulation of telecommunications has been more thorough, a larger number of new firms have emerged to compete with former monopolies. These new carriers must interconnect with both existing carriers and with each other to provide global service to their corporate customers. To quote Castells (2000, 440): “The Internet cannot bypass mega-cities: it depends on the telecommunications and on the ‘telecommunicators’ located in those centers.” Table 1 shows the connectivity of European cities on 20 networks that serve the continent. Amsterdam, merely a gamma world city in the GaWC metageography, is second behind London, and ahead of Paris, Frankfurt, and Hamburg. London is the only cities conected by all 20 European networks. Press (2000, Figure 7) illustrates the central position of the USA, Europe and, to a lesser degree, Australia on the network comprised of 48 of these backbone networks.

A large number of firms provide long-haul transmission, dominated by WorldCom, Sprint, and Cable & Wireless, which together account for perhaps 55% of the Internet market (TeleGeography 2000d, 57). These firms and their competitors have invested heavily to install new fiber optic cables and in new technologies that provide greater bandwidth capacity. A great deal of new fiber-optic capacity is being installed throughout the world, much of it “dark” fiber in anticipation of future demand. Over 20 networks are being built in Europe by telecom providers whose customers demand seamless communications. Dark fiber is fiber-optic cable which has not yet been “lit” by the optoelectronic equipment that facilitates transmission of data. Indeed, several firms in the electricity, pipeline, and railroad sectors install such fiber along their rights-of-way. Technological change also has permitted massive increases in bandwidth, the speed at which data can be transmitted through the cable.

Growth in backbone capacity is among the most prominent trends in Internet development (NRC 2001). Table 2 illustrates the massive investment in Internet backbone capacity that has occurred between 1998 and 2000 in the USA. In early 1998, all 38 backbone networks claimed bandwidth of DS-3, or 45 Mbps, on their backbones, and only 13 of those offered any higher bandwidth, such as OC-3 (155 Mbps), OC-12 (622 Mbps), and OC-48 (2488 Mbps or 2.488 Gbps). Higher bandwidth was implemented rapidly over the next two years. In mid-2000, only 59% of US backbones were at the slowest (DS-3) bandwidth, and fully 63% (26 networks) had installed capacity of 622 Mpbs (OC-12) or faster, and 41% (17 networks) had bandwidths of 2488 Mbps or faster. Such bandwidths easily overwhelm networks of the slower capacity: a single OC-48 cable has the same bandwidth as 55 of the older DS-3 capacity.

International routes have concentrated on the *alpha* world cities to some degree, but it is clear from Table 3 that the set of best-connected cities is mainly in Europe, and excludes the Asian cities Tokyo (rank 15), Hong Kong (28) and Singapore (33). Chicago (14), Milan (16) and Los Angeles (25) also fall well short of their standing in the GaWC metageography, which focuses on office location of producer service firms and implicitly incorporates travel and market factors as well as Internet traffic. However, Europe does appear to form a coherent *panregion* (Taylor 2000) , and a growing counterweight to the “bandwidth colonialism” by the USA that appeared to prevail only two years ago (Cukier 1999).

Several recent analyses of Internet backbones have all ranked US cities or metropolitan areas according to measures of their Internet connectivity (Malecki and Gorman 2001; Moss and Townsend 1998; Wheeler and O’Kelly 1999). Several different measures are used, with slightly different results, but San Francisco, Washington, and Dallas generally outrank the much larger areas of New York and Los Angeles, suggesting that Internet accessibility is responding to demand beyond that measured by population alone. This finding is especially strong when bandwidth-weighted links are analyzed (Malecki and Gorman 2001; Moss and Townsend 1998).

Comparisons and analyses over time are rare in the context of the Internet's recent and sudden growth. Gorman and Malecki (2000) compare several Internet backbones in the USA, and focus in on the change for Cable & Wireless after it acquired the MCI backbone network from WorldCom as a required divestiture for WorldCom's acquisition of MCI. That analysis showed that what appears to be a single network was in fact dramatically different: Cable & Wireless was able to serve new cities, and much more efficiently. Now, after over a year, the Cable & Wireless network in the USA is one of the best connected networks, despite serving only 17 metropolitan areas (http://www.cwusa.net/internet_backbone.htm).

Moss and Townsend (2000) provide one of the few analyses of Internet *growth*, comparing the intermetropolitan Internet backbone capacity in the USA in 1997 and 1999. The 1997 data included 29 networks, and there were 39 by the Spring of1999. They found that a "core group of seven metropolitan areas (San Francisco/San Jose, Washington DC, Chicago, New York, Dallas, Los Angeles, and Atlanta) had maintained their dominance as the central nodes of the Internet in the United States" (Moss and Townsend 2000, 41). They also found that a group of metro areas in the central part of the country had become "hubs for new, large network links" (ibid.). Third, they found that the USA's global cities – New York, Chicago, and Los Angeles – were relatively weak in backbone links. Similarly, Boston and Seattle, well-known for their technology-based firms, ranked below Atlanta and Dallas – largely because of the geographically central locations of the latter.

Table 4 builds upon the data compiled both by Moss and Townsend (2000) and Malecki and Gorman (2001). The 1998 data in the latter came from the compilation of links on 33 networks compiled by the Cooperative Association for Internet Data Analysis (CAIDA). These were based largely on the data from the annual *Boardwatch Directory of Internet Service Providers* and included the network for MCI which, at that time, refused to provide enough data to be included in the *Boardwatch* directory. This paper adds a compilation of data for the links of 41 networks in mid-2000. The group of seven from Moss and Townsend's work remains, but might be seen to have collapsed in 2000 to a group of five – such is the gap between Dallas and Atlanta. No other obvious breaks occur in the numbers for 2000.

Table 5 compares the top ten urban regions in bandwidth for each of the four years. What is most striking about Table 5 is that New York and Chicago have risen to the top of the list in bandwidth in 2000. New York, the most populous metropolitan region in the USA, had ranked no higher than fourth in any of the three preceding years, and indeed had fallen to sixth in 1999 in Moss and Townsend's analysis. What also is significant is that the "core group of seven" urban regions remains in effect. In general, "the new information and communication technologies *per se* do not make local and regional milieux dynamic but, rather, … more dynamic milieux are better able to use new technologies to their advantage than are less dynamic ones" (Gilbert and Villeneuve 1999, 115).

To what degree does population account for the installation of backbone bandwidth? Table 6 illustrates the role of urban area population alone on the data in Table 4. Notwithstanding the small number of cities analyzed, particularly for 1997 and 1999, urban area population explains from one-third to three-fifths of the variance across the four years (in log-log specifications). The best fit was for 1998 when, as Table 4 indicates, a large number of small to midsize urban areas, such as Portland, Orlando, Indianapolis, Las Vegas and Charlotte, had relatively small amounts of bandwidth. By 2000, these cities were intermediate hubs on broadband networks connecting larger cities, and massive investments in bandwidth on them exceeds what could be accounted for by population alone.

The rise of New York and Chicago in absolute bandwidth connectivity masks the relative standing of these cities. Table 7 illustrates the fact that it is the urban areas located in the central region of the USA that are serving as intermediate hubs in the transcontinental routes, much as they served as break-of-bulk points in earlier transportation networks. Four cities have more than double the bandwidth their population would suggest, based only on the 32 cities in Table 4. Expanding the list to the top 100 metropolitan areas shows that the phenomenon of central and intermediate hubs having high amounts of bandwidth continues: the average bandwidth per 1000 population for the top 100 cities is 19.60 Mpbs, scarcely lower than the 19.83 Mbps for the top 32 cities alone. Well below-average bandwidth/population ratios are seen in the largest eastern cities: Boston, Philadelphia and New York; in the western cities of Phoenix and San Diego; and in the manufacturing belt cities of Detroit and Pittsburgh. In Florida, Orlando, as the hub connecting both Tampa and Miami, is far better connected with bandwidth. Charlotte serves as a similar midpoint between Atlanta and Washington.

Network bandwidth, as a form of infrastructure, is supplied in response to demand – actual or anticipated – for data transmission. However, demand for Internet bandwidth is a difficult concept to define, let alone to measure. There are perhaps three dimensions: a combination of network economies and agglomeration economies, and the density of users (business and residential). A network (and any node on a network) is more valuable the greater the number of users (or other nodes) on the network. Some locations are more productive or advantageous because they are also the locations of other networks. Through interconnection, a network is able to reach or serve locations on other networks. This translates into a larger number of alternative locations that can be reached expeditiously via other networks (in addition to one’s own).

Bandwidth is not the only indicator of the emergence of the Internet in the spatial economy. Domain names are an equally common measure (Moss and Townsend 1997; Zook 2000a, b). As Zook (2000b) points out, the use of domain names is especially problematic at the national level, where generic top-level domain names such as .com, .net, and .org are not specific to any country. However, Zook (2000a) provides perhaps the most complete analysis of the geography of domain names in the USA, and concluded that, over time, there has emerged a stronger connection between Internet content and information-intensive industries than between Internet content and computer and telecommunications technology industries, although the latter was not measured by backbone connections or bandwidth.

While the largest concentrations of domain names were in the New York, Los Angeles and San Francisco urban areas, the highest specialization ratios (similar to locations quotients) were found in San Francisco, Provo (Utah), Denver, San Diego, Washington, Austin, Boston, Santa Barbara, Las Vegas, Portland (Zook, 2000a, 416). Kolko (1999) also analyzes domain density in US cities from 1994-1998, and includes several variables that, in addition to population, account for the location of domain names, such as income and education. He finds that domain density is higher in larger cities, even after controlling for other variables, and this relationship grew stronger over the five years. Moreover, domain density is higher in more isolated cities, those distant from cities of similar size, such as Denver, Miami and Seattle.

The tremendous growth of bandwidth linking the major cities of the Europe and the United States presents a second overriding issue surrounding the Internet: that of interconnection of the various backbones. The interconnection points are another key aspect of geography that is of growing significance. Once again, agglomeration and network externalities favor large cities. However, a twist is added to the attraction of large cities, related both to demand and to supply factors.

Interconnection

The counterpart to what we call interfirm linkages are the transactions that connect the various individual networks into the Internet. The original Internet had no hierarchy of hubs; interconnection was complete. The popular view of these transactions, reflecting the situation as it was about a decade ago (i.e. ages ago in Internet time), is of relatively few networks agreeing upon a mutual access point, installing the necessary equipment and then monitoring traffic to manage load levels. This process was called *peering* because it was connection between two equal, or peer, networks. Billing mechanisms for data traffic flows of the sort common to voice traffic still do not exist, a fact that has kept the cost of Internet access low. The evolution of Internet interconnection, to maintain end-to-end service through multiple providers, is perhaps the greatest pressure point caused by the commercialization of the Internet (NRC

2001; Thomas and Wyatt 1999). The trend toward oligopoly and unequal power relationships has had three principal effects. The first is a billing mechanism, such as the item on my monthly DSL account with BellSouth for Internet connection to WorldCom (UUNET) for access to the Internet. The second effect is the growing implementation of transit charges, or hierarchical peering – charging for interconnection. The third effect is the emergence of an industry to facilitate peering and interconnection.

Peering and financial settlements are the core of interconnection. An ISP must pay for knowledge of the routes that can take data onward or upstream in the Internet. "Routing information is not uniformly available" (Huston 1999a, 561). *Peer-to-peer bilateral* interconnections are private peering points established between large firms that see themselves as equals (thus the term peers) (Bailey 1997). Private peering has become so common that many backbone providers have left the public NAPs and refuse to peer with smaller network providers. In order for small companies to get their data to a non-peering provider, they must pay transit fees to stay connected. The two-party contracts define a *hierarchical bilateral* interconnection, the most pervasive interconnection model in today's Internet. In general, however, the large networks do not make public their peering criteria under non-disclosure agreements – nor are they required to – keeping smaller ISP's at a disadvantage (Bailey 1997; Kende 2000). The technical aspect of interconnection is that ISPs that are able to interconnect exchange routing entries that enable traffic. Upstream routes are learned from upstream ISPs, such as backbone providers, only as part of a transit service contract executed between the ISP and the upstream provider (Huston 1999a, 555-556).

Interconnection originally took place at public interexchange points, or network access points (NAPs). In the USA, four NAPs were established by the National Science Foundation as it turned over operation of the Internet to the commercial sector in 1995. These NAPs were located in Chicago, New York (actually in New Jersey nearer to Philadelphia than to New York), and San Francisco. Predating the NSF-established NAPs, the Commercial Internet Exchange (CIX) was established in 1991 for interconnection of the growing number of commercial networks that served business clients; a similar exchange in the UK, LINX (the London Internet Exchange), was established in 1994.

Table 8 shows that the degree of interconnection at the NAPs has not been complete in recent years. Only MAE-East, in the Washington area, has been an interconnection point for all major backbone networks; the same has been nearly true (and is presently) of MAE-West in San Jose, California. All 38 backbone networks (3 of the 41 in 2000 do not list any public interconnection points in the USA) presently interconnect at both MAE-East and MAE-West. The other two original NAPs, in Chicago and in the New York area, are noticeably less utilized – the Chicago NAP by 31 networks and the New York NAP by 24. Indeed, it is a set of private IX points that have become increasingly important in recent years. Table 8 illustrates this in the case of the Palo Alto Internet Exchange (PAIX), which has become increasingly utilized by the backbone networks as a private peering point. Both PAIX and LINX claim over 100 members in November 2000.

A particularly important set of hubs in the Internet is the Internet exchange (IX) point, where individual networks interconnect. TeleGeography's directory of Internet Exchange Points (http://www.telegeography.com/ix/index.html) illustrates the uneven global geography of IXs (Table 9). IX points might be a response to extant or future demand, or they might be an example of attempts to reap first-mover advantage within a region. In fact, network externalities accrue to both networks when interconnection takes place (Varian 2000). Nearly all of the *alpha* world cities are in the top tier of IX point locations. Compared to its *gamma* (third-tier) status in producer-service networks, Amsterdam is among the most wired cities in Europe; Stockholm also is relatively stronger in Internet connections than in producer-service firms.

Private peering has changed the Internet from a universal good to one controlled by commercial interests (Angel 2000; Huston 1999b; Wyatt and Thomas 1999). Private peering is particularly prevalent among the largest and oldest backbone providers, including Cable & Wireless, GTE Internetworking (now Genuity), PSInet, Sprint, and UUNet (part of WorldCom) These firms are the members of an “old boys’ network” that peer equally with each other, splitting the cost evenly, because they have similar networks and traffic patterns. Smaller players can connect to their backbones via high-speed access lines, paying for a transit link to make the connection (Gareis 1999; Kende 2000). These payments, called “settlements,” are perhaps the greatest “pressure point” in the ongoing evolution of the Internet (Kahin and Keller 1998; Thomas and Wyatt 1999). Although data are extremely difficult to come by, a Digex source cites $30,000 per site per month as the access fee charged by Sprint (Gareiss 1999). “The only thing that’s certain is that the large players don’t pay one another for peering – and that they’re very well connected to one another. There are 60 private peering connections among members of the club. Nearly half of Cable & Wireless’ private links are to members, as are more than half of Sprint’s” (Gareiss 1999). Interconnection and settlement agreements make the Internet a hierarchical infrastructure more akin to telecommunications than to the Internet’s image of a flat democratic network of networks (Frieden 1999, 17). It is not only the “old boys” that peer privately, however. In 13 of 31 networks in Gareis’ (1999) “peering snapshot,” private peering accounts for 50% or more of all interconnections, based on traceroutes to 1.2 million destinations in mid-1999, and private peering represents 33% or more of all interconnections on 19 networks. The levels of traffic passing through private peering points are much higher: Gareis (1999) reports that Qwest and Savvis send 90 % of their traffic through their private peering points.

Traceroutes can identify most, if not quite all, aspects of interconnection, and it is the best option at present (Carl 2000; Dodge 2000b). “Traceroute reveals the hidden complexity of data’s path to a given destination — sometimes across 10 or 20 nodes or more, perhaps owned and operated by competing companies” (Dodge 2000b). Tracerouting identifies – with some gaps – the customer interrelationships based on transit arrangements, in which one backbone pays another for interconnection. These arrangements change over time, as networks create new arrangements – new linkages with new suppliers and customers. A case in point is the Gainesville-Tampa traceroute. Two years ago, Gorman (1999) performed a traceroute from the University of Florida (UF) to the principal newspaper in Tampa, a city about 100 miles (160 km) south. At that time, the 18-hop route traveled from UF to Jacksonville via BellSouth, the local telephone carrier, interconnecting with UUNET's Alternet network, traveling through UUNET's major hub in Atlanta to Chicago, where the packets changed to AT&T's backbone to travel to Washington (actually to a node labeled ar2-a3120s1.wswdc.ip.att.net, probably in Arlington, Virginia). There is no evidence that the Web site is anywhere but Washington. In November 2000, the same traceroute (using NeoWorx's NeoTrace) again took 18 hops, but the route had changed dramatically. UF now connects to the Internet via the Internet provider, GRU.net, a division of the local city-owned electric utility. All of UF's Internet traffic destined for commercial sites, such as www.tampa-tribune.com, travels via GRU.net to an interconnection west of Gainesville with the Qwest backbone. The Qwest link actually goes to Tampa, and then via a OC-12 (622 Mbps) link to Atlanta, where Qwest peers with AT&T, to travel to Washington, DC (actually to ar10-p310.wswdc.ip.att.net, again probably in Arlington, Virginia).

All traffic to other major universities in the USA and Europe travels a different path, one that avoids the issue of private peering. Internet2 utilizes a network called Abilene, which "is an advanced backbone network that supports the development and deployment of the new applications being developed within the Internet2 community. Abilene connects regional network aggregation points, called gigaPoPs" (http://www.ucaid.edu/abilene/). Peer networks of Abilene include a host of academic networks around the world, including APAN/Transpac (the Asia-Pacific Advanced Network Consortium), CA*net-3 (CANARIE's advanced Internet development organization), CERNET (the China Education and Research Network), DANTE (the Delivery of Advanced Network Technology to Europe), JANET (the UK Academic and Research Network), NORDUnet, and SingAREN (Singapore Advanced Research and Education Network), among others (http://www.ucaid.edu/abilene/html/peernetworks.html).

Therefore, traceroutes to UCL and to NUS travel on the Abilene backbone to New York and Indianapolis, where JANET and SingAREN, respectively, peer with Abilene. (Abilene's Network Operations Center is in Indianapolis.)

Connections to private universities often do not use Abilene. Traceroutes to Clark University travel from Gainesville via Sprint's backbone to Sprint's New York NAP in Pennsauken, where Clark's New hampshire-based Internet service provider, Vitts, pays for interconnection, taking packets to Framingham, and then to Worcester. Likewise, traceroutes to INSEAD, the international business school located outside of Paris, travel via Qwest to New York, where they connect with Opentransit, a France Telecom subsidiary, to Bagnolet, where a France Telecom link connects to INSEAD at Aubervilliers. Traceroutes to INSEAD's new Singapore campus stay on the Qwest backbone from near Gainesville to PAIX in California, where SingTel interconnects with Qwest in what might be a true peer relationship (at serial1-1-0.paix-peer1.ix. singtel.com).

Other than by tracerouting, to determine whether – not to mention where – private peering takes place is difficult at best. The hyper-competitive nature of the telecom industry has meant that few details are available on the relationships – the linkages – between the various companies involved. Gareiss (1999) includes data matrices of the number of private peering connections among 30 firms. Three firms account for 35% of all private peering among the 30 firms: UUnet accounts for 86 of the total of 534 connections, Sprint 58, and Cable & Wireless 41, or a total of 187 private peering connections, some of which are with ISPs outside the US, such as Ebone, EUnet, Telia, and Telstra. What such data do not indicate are the interconnections between non-peers, or the interconnections based on settlement agreements or transit charges. It also is evident from LINX peering details (www.linx.net/memberinfo/peer.html) that the "old boys" do not peer with a large number of other members of the exchange. In particular, Cable & Wireless is only peering with 3 of the 104 networks, with uncertain peering with two additional networks. This extremely small number suggests either that

C&W prefers not to disclose peering partners, or that the interconnection is taking place elsewhere – probably next door in the TeleCity facility.

Colocation: An Industry to Facilitate Linkages

A large number of firms have been established to offer similar services, including co-location and private peering. For-profit IX points, such as PAIX, have long provided an alternative to the NAPs, although not necessarily with less congestion. Increasingly, private IXs have been established for private interconnection, such as Telehouse's NYIIX and SIX in Seattle, both of which appear among the largest IXs in the world (TeleGeography 2000a). Telehouse, established in London in 1990, now operates Telehouse facilities in Frankfurt, Geneva, two in London (one the original facility at the Docklands), and two Paris, in addition to NYIIX in New York and LAIIX in Los Angeles.

The growth of this industry to facilitate interconnection – alternatives to both public access points and local telecommunication networks – has been remarkable. At the upper tier of this industry are privately developed IXs and MAEs, all of which facilitate private interconnections. The success of the Palo Alto Internet Exchange (PAIX) has led the IX's new owner, Metromedia Fiber Network, to build PAIX-East in Tyson's Corner, VA, as well as facilities in Seattle, Dallas, Atlanta, and New York. Below the IX tier is the booming colocation business: telecom hotels, colocation, real estate firms, and carrier-neutral colocation facilities. The extent of the business is seen in Table 10, which lists the cities chosen for the facilities of 18 colocation firms; several other firms offer facilities at a single site or multiple sites in a single city. The table shows that the urban hierarchy is reinforced by these facilities, which respond to both demand and supply factors. Demand is indicated by the larger number of competitive local exchange providers (CLECs) in large metro areas (Malecki 2000) and from the larger number of local Internet-based businesses (Moss and Townsend 1997; Zook 2000a). Supply in the form of bandwidth and multiple fiber-optic connections also is present in these areas, as seen in Tables 3 and 4. A second indication of local demand within US cities is seen in the concentration of Web design firms in a survey by *Internet World* (2000). Just four metropolitan areas (CMSAs) – New York, San Francisco, Los Angeles, and Washington – are the homes of 51% of 167 Web design firms. The same four metro areas stand above and apart from the others in Table 10.

Private interconnection has proliferated, and new services and industries have emerged to serve the phenomenon. Below the colocation tier is an amalgam of facilities, including data centers and Web hosting facilities, operated by backbone providers as well as by small ISPs. Greenstein's (1999) research suggests that 20.7% of all US ISPs provide some Web site hosting. Among national ISPs and especially among Internet backbone firms, *Web hosting* appears to be less concerned about peering than about keeping clients plugged into the hoster's network and to provide services that firms find better to outsource. *Data centers*, likewise, are less about peering than with providing services, whether that is management of operations 24/7 which most firms cannot do in-house as cheaply or network connectivity. For example, Intel has no network to trap clients onto, so it offers managed services plus colocation (Bernier 2000). AT&T, on the other hand, is primarily concerned with keeping customers on its network. Thus, there are a growing number of shades of gray as classic telco hotels seen the addition of carrier-owned data centers inside such hotels and to a new crop of "concierge floors" inside those hotels, operated by colocation firms (Branson 2000).

The high-speed fiber-optic network is concentrated on high-volume routes and at high-demand locations. These "choice cyber-locations" are where data centers, server farms, and other facilities that depend on Internet-related infrastructure tend to the agglomerate or cluster. Strom (2000) identifies three distinguishing characteristics of cyber-buildings: (1) multiple fiber connections to several different backbone providers, and priority for space inside to cables and gear; (2) ideal cyber-buildings make it easy for multiple ISPs to connect to each other inside, reducing the number of network hops; and (3) an aggregation of expensive equipment to facilitate fast switching and peering. In addition, Strom alludes to a fourth characteristic: Many of the buildings are far from being prime real estate; most are aging and in declining neighborhoods in the center or edge of downtown. Although a few new, custom-built buildings are being built, many are “recycling” old factories, office buildings, and department stores.

The complex arrangements and coalescence of demand for several technologies has a geographical effect: to locate key infrastructure (routers, switches and long-distance hubs) at common locations. These common locations typically are at (some of) the central offices of telephone carriers or at “carrier-neutral facilities.” These locations are hubs of fiber-optic networks, are often the location of points of presence (POPs), and therefore and serve as private peering points where ISPs interconnect. They also provide access points for local demand, especially by mid-size businesses and high-tech small firms that were never part of leased-line networks. “The collective behavior of dozens of backbone network companies has created a highly organized system. Although the Network Access Points established at the end of the NSFNet era were important in providing seed points for private networks to converge, we have seen commercial backbone providers establish private connections in these same regions as well” (Moss and Townsend 2000, 45). In only 11 cities in the USA, the POPs of four interexchange carriers (all of which also are Internet backbone providers) are located within a single central office or wire center. These four (AT&T, MCI, Sprint, and Cable & Wireless) are colocated – facilitating private peering – in Anaheim, Austin, Atlanta, Cleveland, Hartford, Indianapolis, Kansas City, Minneapolis, Orlando, Pittsburgh, and San Antonio – all mid-size cities well-provided by backbone bandwidth (Table 4). The agglomeration of bandwidth, POPs and other telecom infratsucture in these cities has made them attractive for the colocation industry (Table 10). Of the 11, only Atlanta and Anaheim (part of the Los Angeles conurbation) are among the top ten metro areas in bandwidth.

Conclusion

The evolving network of networks and its network of interconnection and data center facilities has once again reinforced the urban hierarchy. Although a steady stream of optimists see ubiquitous communications as the salvation of rural and remote areas, the growth of new technologies “does not automatically result in the decentralization of economic activity” (Richardson and Gillespie 2000, 201). Urban agglomerations remain better-connected to markets and to competitive product and service innovations.

The unregulated situation in the USA – the triumph of neoliberalism in the Internet age – has crossed the Atlantic (Kende 2000; Oxman 1999; Schiller 1999). Worldwide, but particularly in Europe and North America, investments in cyberplaces are being made by several firms simultaneously. The attraction to these firms of accumulated infrastructure suggests inertia, but mainly represents rational market-oriented decisions. To a large degree, the evolving infrastructure of the Internet is reinforcing old patterns of agglomeration: the world cities are alive and well. At the same time, new technologies cause new “disturbances” that can result in the emergence of new clusters – perhaps particularly evident in the weightless context of an Internet world in which transport cost does not matter (Quah 2000). The prominence of Amsterdam and Stockholm in Europe, and of Salt Lake City and Atlanta in the US suggest that new clusters can emerge. London and New York remain important, if only because of the agglomerations of cumulative investment that they represent. Whether Tokyo will rise to its world-city status in Internet measures remains to be seen; Hong Kong and Singapore are credible competitors.

Policy is needed more, perhaps, within cities, where an array of “premium networked spaces” is emerging: new or retrofitted telecommunications infrastructures, “customized precisely to the needs of the powerful users and spaces, whilst bypassing less powerful users and spaces” (Graham 2000, 185). He attributes this emergence to four distinct processes: (1) the unbundling of infrastructure networks via privatization, with cherry-picking of business clusters such as financial districts and foreign firms, (2) the erosion of comprehensive urban planning and the construction of new consumption spaces developed, organized and managed by property-led development bodies, (3) in residential areas, the construction of "infrastructural consumerism" (with geodemographic targeting to pinpoint concentrations of potentially high spending customers; infrastructural choice tends to be limited to certain social and spatial groups within the city, and (4) urban decentralization and the polynucleated urban region (with highways as the dominant form of transport). These somewhat distinct processes coalesce to create privileged spaces.

The fact that central-city buildings and districts are among the prominent IX points in many cities reflects the accumulated investment in prior networks that have served producer-service firms in central-city locations. In other areas, such as the Northern Virginia suburbs west of Washington, DC and the Silicon Valley area south of San Francisco, more recent investment has concentrated a large amount of Internet-related infrastructure in the form of data centers and IX points. The prominence of established telephone network hubs (wire centers), largely originating in an earlier era, with their concentrations of switches and other equipment for interconnection, is one element in this inertia. For example, five sites in Manhattan and seven in Dallas have clusters of ten or more switches in conventional telephone wire centers, well-served with fiber-optic cables. Ongoing research will be needed to determine the importance of these and other locations within several US cities in the context of Internet interconnection.

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Table 1

Connectivity of Cities in Europe on 20 Networks

City	Number of networks
London	20
Amsterdam	19
Frankfurt, Hamburg, Paris	18
Berlin, Brussels, Düsseldorf, Milan, Munich, Zürich	17
Geneva, Madrid, Stockholm	15
Marseille, Oslo	14
Barcelona, Copenhagen, Lyon, Strasbourg, Stuttgart	13
Vienna	12
Bordeaux, Cologne	11
Bilbao, Dublin	10
Rotterdam, Valencia	9
Antwerp, Dresden, Gothenburg, Hannover, Leipzig, Nuremberg, Toulouse, Turin	8
Basel, Helsinki, Prague	7

Manchester, Rome	6
Birmingham, Bremen, Budapest, Edinburgh, Lille, Warsaw	5
Bristol, Leeds, Malmö, Moscow	4
Belfast, Bern, Bonn, Bratislava, Lisbon, Porto, Tallinn	3

Source: Calculated from the City Connectivity Matrix in TeleGeography (2000a: 132-134).

Table 2

Bandwidth on Backbone Networks of US Backbone Providers

Bandwidth on Network Links	1998 (38 networks)	2000 (41 networks)
DS-3 (45 Mbps)	38 (100%)	24 (59%)
OC-3 (155 Mbps)	10 (26%)	26 (63%)
OC-12 (622 Mbps)	5 (13%)	15 (37%)
OC-48 (2488 Mbps)	2 (5%)	12 (29%)
OC-96 (4976 Mbps)	0	1 (2%)
OC-192 (10,000 Mbps or 1 Gbps)	0	4 (10%)
Number of networks with bandwidth 622 Mbps (OC-12) or higher	7 (18%)	26 (63%)
Number of networks with bandwidth 2488 Mbps (OC-12) or higher	2 (5%)	17 (41%)

Compiled from data in Boardwatch (1998 and 2000).

Table 3

Top International Internet Hub Cities, 2000

Rank	City	International Internet bandwidth (omits internal country routes)
1	London	86,590 Mbps
2	Amsterdam	68,302
3	Paris	62,197
4	New York	61,071
5	Frankfurt	52,332
6	Stockholm	18,652
7	Brussels	18,631
8	Geneva	17,849
9	Toronto	16,399
10	Düsseldorf	15,863

Source: Adapted from TeleGeography (2001: 107).

Table 4

Total Internet Bandwidth Connecting US Metropolitan Areas, 1997-2000

Rank	Metro Area	Population 1999	Total bandwidth on Internet backbones (to or from metropolitan area), in million bits per second (Mbps)			
			1997	1998	1999	2000
1	New York	20,196,649	6,766	9,543	22,232	234,258
2	Chicago	8,885,919	7,663	14,809	23,340	221,738
3	Washington	7,359,044	7,826	14,174	28,370	208,159
4	San Francisco	6,873,645	7,506	14,924	25,297	201,772
5	Dallas	4,909,523	5,646	10,985	25,343	183,571
6	Atlanta	3,857,097	5,196	5,426	23,861	149,200
7	Los Angeles	16,036,587	5,056	9,397	14,868	140,649
8	Seattle	3,465,760	1,972	5,409	7,288	109,510
9	Denver	2,417,908	2,901	5,942	8,674	97,545
10	Kansas City	1,755,899	1,080	2,715	13,525	89,292
11	Salt Lake City	1,275,076		495	9,867	87,624
12	Houston	4,493,741	1,890	3,061	11,522	80,483
13	Boston	5,667,225	1,325	2,785	8,001	75,044
14	Philadelphia	5,999,034	1,610	5,045		74,167
15	St Louis	2,569,029	1,350	1,800	10,342	69,031
16	Portland	2,180,996		765		68,174
17	Cleveland	2,910,616	1,080	3,461	6,201	61,671
18	Detroit	5,469,312	900	1,309		53,262
19	Phoenix	3,013,696	1,890	2,565	6,701	45,868
20	Orlando	1,535,004		990		45,528
21	Las Vegas	1,381,086		585	4,791	42,414
22	Miami	3,711,102	1,567	1,575		42,138
23	San Diego	2,820,844	870	1,495		42,062
24	Sacramento	1,741,002		675		40,702
25	Indianapolis	1,536,665		315	9,307	39,484
26	Charlotte	1,417,217		360	5,191	35,441
27	Tulsa	786,117				34,906
28	Austin	1,146,050		1,522		32,884
				29	New Orleans	1,305,479
30	Tampa	2,278,169		810		30,310
31	Minneapolis	2,872,109		1,570		29,734
32	Pittsburgh	2,331,336		2,565		25,178

Source: 1997 and 1999: Moss and Townsend (2000); 1998: data compiled by Sean Gorman from CAIDA (Winter 1998); 2000: data compiled from *Boardwatch Directory of Internet Service Providers* 12th edition (2000) and firm Web sites. Urban areas are MSAs or CMSAs.

Table 5

Top Ten Metropolitan Areas in Total Bandwidth on Internet Backbones Serving Them

1997	1998	1999	2000
Washington	San Francisco	Washington	New York
Chicago	Chicago	Dallas	Chicago
San Francisco	Washington	San Francisco	Washington
New York	Dallas	Atlanta	San Francisco
Dallas	New York	Chicago	Dallas
Atlanta	Los Angeles	New York	Atlanta
Los Angeles	Denver	Los Angeles	Los Angeles
Denver	Atlanta	Kansas City	Seattle
Seattle	Seattle	Houston	Denver
Phoenix	Philadelphia	St Louis	Kansas City

Source: 1997 and 1999: Moss and Townsend (2000); 1998: data compiled by Sean Gorman from CAIDA (Winter 1998); 2000: data compiled from *Boardwatch Directory of Internet Service Providers* 12th edition (2000) and firm Web sites.

Table 6

Population as a Predictor of Bandwidth in US Urban Areas, 1997-2000

	1997	1998	1999	2000
Constant	0.40	-0.78	2.28	2.60
Population (t-value)	0.815 (3.47)	1.185 (7.28)	0.500 (3.98)	0.641 (5.83)
F	12.06	52.97	15.84	33.94
Adjusted R^2	.381	.619	.438	.515
Number of urban areas	19	33	20	32

Note: Analyses were of log bandwidth for each year on log 1999 population.

Table 7

Bandwidth Connecting US Urban Areas on 41 Backbone Networks, 2000, per 1000 population

1	Salt Lake City	68.72
2	Kansas City	50.85
3	Tulsa	44.40
4	Denver	40.34
5	Atlanta	38.68
6	Dallas	37.39
7	Seattle	31.60
8	Portland	31.26
9	Las Vegas	30.71
10	Orlando	29.66
11	San Francisco	29.35
12	Austin	28.69
13	Washington	28.29
14	Cleveland	27.76
15	St. Louis	26.87
16	Indianapolis	25.69
17	Sacramento	25.67
18	New Orleans	25.11
19	Charlotte	25.01
20	Chicago	24.95
Average of 32 urban areas	19.83	
21	Houston	17.91
22	Phoenix	15.22
23	San Diego	14.91
24	Tampa	13.30
25	Boston	13.24
26	Philadelphia	12.36
27	New York	11.60
28	Miami	11.35
29	Pittsburgh	10.80
30	Minneapolis	10.35
31	Detroit	9.74
32	Los Angeles	8.77

Table 8

Number of Backbone Networks Connecting at Public Network Access Points (NAPs)

Network Access Point	1998 (of 36 networks)	1999 (of 41 networks)	2000 (of 38 networks)
MAE-West (San Jose)	35	39	38
MAE-East (Vienna VA)	36	40	38
Ameritech Chicago NAP	21	30	31
Sprint NAP- New York (Pennsauken NJ)	20	27	24
Number of networks at all 4 original NAPs	13	20	19
PacBell San Francisco NAP	21	27	24
PAIX-Palo Alto	13	20	21
MAE-Dallas	0	5	12
CIX-Santa Clara	16	11	6
MAE-LA	5	6	4
PacBell Los Angeles NAP	1	0	2

Source: Compiled from data in the *Boardwatch Directory of Internet Service Providers*, vol. 3, no. 2, Winter 1998, 11th edition, 1999 and 12th edition, 2000.

Table 9

Internet Exchange (IX) Points by Region

Continent	Number of IXs	Internet Exchange (Location) and number of Internet service providers connected
Africa	2	Capetown Internet Exchange - 11
Asia and Middle East	40	HKIX (Hong Kong) - 49 JPIX (Tokyo) - 36 iIX-JKIX (Jakarta) - 35 L2IX (Seoul) - 32 THIX (Bangkok) - 27
Europe	78	LINX (London) - 82 AMS-IX (Amsterdam) - 71 M9-IX (Moscow) - 54 DeCIX (Frankfurt) - 51 SFINX (Paris) - 47 VIX (Vienna) - 43 BNIX (Brussels) - 30
Latin America	5	Internet NAP (Bogota) - 12 Chile NAP (Santiago) - 9

North America		
Canada	5	TorIX (Toronto) - 11
United States	94	MAE-East (Washington) - 116 Chicago NAP - 93 MAE West (San Jose) - 83 PAIX (Palo Alto) - 80 New York NAP (Pennsauken) - 32

Source: Based on TeleGeography (2000c) and TeleGeography (2000d: 120-121)

Table 10

Urban Areas of Colocation Facilities of 18 Firms

Urban Area (MSA/CMSA)*	Current	Planned	Total
Los Angeles	12	4	16
New York	10	5	15
London	12	1	13
San Francisco	7	5	12
Washington-Baltimore	6	6	12
Boston	6	3	9
Chicago	6	3	9
Atlanta	6	2	8
Dallas-Fort Worth	8		8
Seattle	5	3	8
Paris*	4	2	6
Tokyo	5		5
Miami	2	3	5
Orlando	2	3	5
Philadelphia	2	3	5
Portland OR	3	2	5
Amsterdam*	2	2	4
Frankfurt*	2	2	4
Sydney*	1	3	4
Cleveland	1	3	4
Houston		4	4
Phoenix	1	3	4
Pittsburgh	1	3	4
San Antonio	1	3	4

Note: Only cities with 4 or more total colocation facilities are shown. Amsterdam, Frankfurt, Paris, and Sydney were allocated planned centers identified only for Netherlands, Germany, France, and Australia, respectively.