Network Competition and Industry Structure

Padmanabhan Srinagesh
Senior Economist
Bellcore

Jiong Gong
Member of Technical Staff
Bellcore

March 4, 1996

Note: This is a draft paper, not a Bellcore public release. Please do not quote, cite or put on a Web page.

The recent development of the US telecommunications industry can be characterized by the trend towards industry convergence and market competition. This powerful trend is driven by technological advances and changes in the political and regulatory environments. The passage of the Telecommunications Act of 1996 epitomized this trend. The Congressional conference report begins with a section that addresses local loop competition. Sections 271 and 302 contains articles regarding the Regional Bell Operating Companies' (RBOCs) entry into interLata and cable services.

Technological advances are rapidly blurring industry boundaries and enabling competition between firms which did not previously compete with one another. For example, numerous telephone companies are currently testing the delivery of cable services or interactive video on-demand services to households over their telephone networks.[1] Cable TV providers are testing local telephone access service and data service (Internet access) over their hybrid fiber coax networks.[2] They have also ventured into wireless PCS service.[3] In addition, new firms have recently entered new markets that were not subject to major inroads in the past. Competitive access providers (CAPs) have begun to offer end-to-end data and voice services to businesses customers in downtown business districts of large cities, in competition with both local exchange carriers (LECs) and interexchange carriers (IXCs). Direct broadcast satellite services have achieved initial success since introduction, competing with the cable industry.[4] In sum, new entrants are applying

1. Among the companies that have conducted trials are Bell Atlantic in Dover Township, New Jersey, US West in Omaha, Nebraska, Bell South in Chamblee, Georgia, Southern New England Bell in W. Hartford, Connecticut, and Ameritech and Pacific Telesis in various cities in their own business territory.
2. Time Warner is conducting trials or building up systems in Orlando of Florida, Rochester of New York, Memphis of Tennessee and other areas. In the United Kingdom, TeleWest Communications Group PLC, a joint venture between TCI and US West, has CATV/Telephony operation. Time Warner is conducting cable modem trial in Elmira, New York. TCI @ Home has a cable modem trial in Sunnydale, California. Comcast is testing Internet access service in Lower Merion, Pennyslvania. Cox has trials in Phoenix, Arizona and San Diego, California. Continental Cablevision has trials in Boston and Chestnut, California.
3. STV, an alliance between Sprint and several cable operators, is deploying a national PCS network using CDMA technology.

new technologies to compete with incumbents, and incumbents in previously separate industries are beginning to compete with one another.

Network services are not like stand-alone goods that different companies produce to compete with each other. Competing networks may decide that interconnection allows their customers to take advantage of fundamental network externalities. The terms and conditions of network interconnection affect the competitive dynamics in complex ways, and market forces are different from those at work with stand-alone goods. The commercialization of the Internet is a good example of the forces at work. Companies with varying degree of vertical integration operating at different layers of the network architecture interoperate with each other. Such a network of competing and cooperating networks will be the norm in the future. What is the architectural framework and market structure under which service providers and carriers will compete? Will they compete effectively in a stable equilibrium? This paper provides a framework to analyze these issues.

Layered Network Architecture

The telecommunications market can be characterized by a stack of hierarchical service layers.[1] Each layer provides the essential services that support the services in the layer above. The bottom layer is the physical infrastructure, which usually consists of fiber, copper or wireless lines and electronics equipment like amplifiers and switches. The top layer usually consists of various applications, which generate ultimate value to end users. Several architectural designs have been proposed to link physical resources of the network infrastructure. The well-known OSI model is

---

4. One report estimates that direct satellite dishes are in more than 5.4% of all U.S. households. *Communications Daily*, Feb. 26, 96.

1. Some of the issues discussed here were first looked at by E. Noam, "Telecommunications Regulation Today and Tomorrow," 1983, Law & Business, Inc., New York, NY 10017.

one such framework focusing on the technical aspects of layered communications services. More recently, an effort has been made to develop layered economic models that describe the market structure that can support the evolving needs of end users and suppliers.

On such economic model is the Open Data Network (ODN) proposed by the influential Computer Science and Telecommunications Board of the National Research Council (NRC).[1] At the lowest level of the ODN is an abstract bit-level transport service called the bearer service. It sits on top of the network substrate that includes the communications links (copper, microwave, fiber, wireless) and the communications switches (packet and circuit switches of various types). On top of the bearer service layer is the transport layer with services feature like reliable, sequenced delivery, flow control, and end-point connection establishment. The third layer, middleware, is composed of functions like directory services, file system support, privacy protection, authentication and other security functions. The uppermost layer consists of applications.

Telephone service is offered in a much simpler framework. The 3 khz voice channel is provided directly on top of the physical infrastructure layer by the same companies that manage the physical layer, the LECs and IXCs. On top of this infrastructure, new applications have been constantly introduced, like facsimile, voice mail, 1-800 service and other advanced intelligent services. Many of the voice services on this infrastructure have been offered by vertically integrated telecommunications companies (the LECs and the IXCs).

The Internet provides another paradigm for layered networking. The Internet is a virtual network that is built on top of facilities and services provided by telephone carriers. Until recently, Internet Service Providers (ISPs) located routers at their network nodes, and interconnected these nodes (redundantly) with point-to-point private lines leased from telecommunications companies.

1. "*Realizing the Information Future*," National Research Council. National Academy Press, Washington, D.C. 1994.

More recently, some ISPs have been moving from a private line infrastructure to fast packet services such as Frame Relay, Switched Multimegabit Data Service (SMDS) and Asynchronous Mode Transfer (ATM) service. Specifically, among the providers with national backbones:

- PSI runs its IP services over its Frame Relay network, which is run over its ATM network, which in turn is run over point-to-point circuits leased from five carriers;
- AlterNet runs part of its IP network over an ATM backbone leased from MFS and Wiltel
- ANS's backbone consists of DS3 links leased from MCI SprintLink's backbone consists of its own DS3 facilities.
- CERFnet, a regional network based in San Diego, uses SMDS service obtained from Pacific Bell to connect its backbone nodes together.

These examples reveal different degrees of vertical integration, with Sprint the most integrated and AlterNet the least integrated ISP in the group listed above. In the future as companies are allowed to enter each other's business, how will they respond to the changing market and regulatory environments and how the competitive equilibrium will unfold becomes an important question. Can companies with varying degrees of integration coexist in an industry equilibrium? Under the layered network architectural framework, the answer hinges on the competitive strategies of companies operating at different layers. These strategies are obviously determined by the cost structure of the services at each layer.

In the case of the Internet, the costs of integrated firms depend on the costs of producing the underlying transport fabric on which IP transport rides. The cost structures of unintegrated firms are determined in large part by the prices they pay for transport services (such as ATM and DS3 services) obtained from telecommunications carriers. These prices, in turn, are determined by market forces. More generally, the layered structure of telecommunications services leads to a

recursive relationship in which the cost structure of services provided in any layer are determined by prices charged by providers one layer below.

Cost Structure of Network Layers

The cost structure of the bottom layer in the hierachical network architecture -- the cost of the physical infrastructure - is distinctively different from the cost structure of the layers above. Typically the sunk cost of network construction (estimated by some to be $13,000 - $18,000 per mile for cable systems) is huge.[1] The major cost of constructing fiber optic links is in the trenching and labor cost of installation. The cost of the fiber is a relatively small proportion of the total cost of construction and installation. It is therefore common practice to install "excess" fiber to accommodate future growth and for greater reliability through redundancy. According to the FCC between 40 and 50% of the fiber installed by the typical interexchange carriers is "dark"; the lasers and electronics required for transmission are not in place.[2] The comparable number for the major Local Operating Companies is between 50 and 80%.

Such a cost structure with features of huge sunk cost and excess capacity displays what is called cost subadditivity in the economics literature. Subadditivity means that the cost of constructing several units of capacity separately (including the capacity for future use) strictly exceeds the cost of constructing the whole system that allows for future demand growth. Typically, the average (or unit) cost of an industry displaying cost subadditivity decreases over the range of output demanded by the market. The only stable equilibrium in this case is for one regulated producer (natural monopoly) serving the entire market.[3] In other words, it would be socially

1. Cable TV moves into Telecom Markets. Larry I Yokell, *Business Communication Review*, November 1994, pp. 43-48
2. *Fiber Deployment Update*, May 1994.

wasteful to have several service providers competing against each other. The provision of raw transport (point-to-point transmission links) is likely to display cost subadditivity, and if a market in raw transport were to evolve, theory suggests that a natural monopoly may emerge.

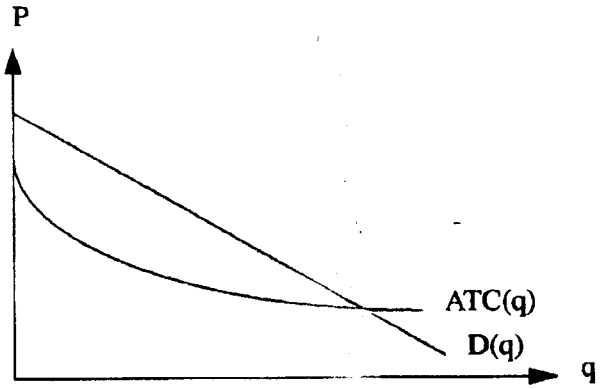

Figure 1

The cost structure for service providers at higher layers, especially providers who cater to the need of end users, is quite different from the cost structures of facilities-based providers who supply raw transport alone. The costs of service providers typically consists of several parts. An important cost component is the price paid to facilities-based carriers for leased lines or fast packet data connection services like Frame Relay, SMDS or ATM services. Service providers may also incur additional expenses for software and hardware to ensure a quality of service. Internet service providers for example, typically need routers, and network management and control equipment. However, since capacity expansion can be accommodated in small increments that keep pace with demand growth, and in particular, since adding capacity does not require trenching

3. The theory of contestable market is pioneered by W. Baumol, J. Panzar and R. Willig. See "*Contestable Markets and the Theory of Industry Structure*," 1982, Harcourt Brace Jovanovich, Inc., New York, NY.

for laying cables, this part of cost may not display strong cost subadditivity. Another important item in the cost structure is customer support costs. Customer support costs are incurred when a customer is acquired, on an ongoing basis during the business relationship, and when the business relationship is terminated. The cost of customer support is by no means trivial. Although the level and cost varies widely across individual customers, the overall portion in the total cost of a service provider can be significant. Service establishment may require a credit check, customer interaction, and network configuration to recognize the customer. Sometimes adding a customer may require that hardware and software at both ends of the connection interoperate. During the business relationship, customers may call in to report problems or dispute the billing. Costs at service termination include a final settling of accounts, and reconfiguration of the network. In summary, for companies operating at higher layers, the total cost may contain a relatively small fixed cost. Thus the average cost curve may be U-shaped, with the demand function intersecting the average cost curve to the right of its minimum point. Such a cost structure is compatible with a stable and sustainable equilibrium where several service providers compete against each other.

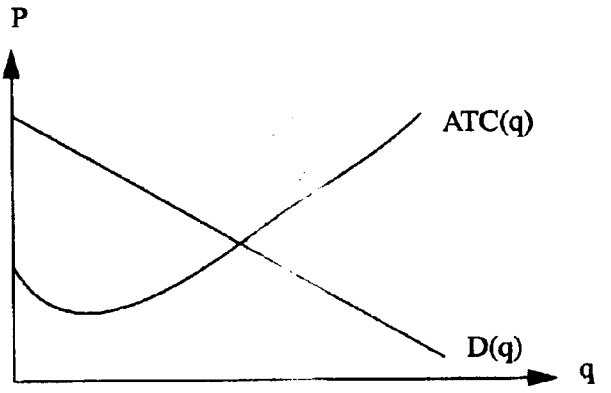

Figure 2

Vertical Integration

The presence of excess capacity at the bottom layer coupled with a competitive marketplace for companies at the higher layer is a complicating factor affecting equilibrium prices and industry structure. Since a significant part of the costs for companies at the higher layer is the prices they pay for the services at the lower layer, the industry structure is ultimately determined in large part by the market forces driving the competition at the bottom layer -- the physical infrastructure. Will facility-based carriers produce an undifferentiated point-to-point raw transport service and compete solely on price? Although the recent history of leased line prices has a strong downward trend, economic theory predicts that price competition would soon drive companies out of business. According of economic theory, the only Nash equilibrium with equally efficient firms, constant marginal costs, and homogeneous products is for each firm to price at marginal cost (Bertrand equilibrium). If this is true, facility-based companies would not be able to recover their sunk costs and would go out of business.[1] Therefore there will be no stable and sustainable equilibrium for healthy market growth.

A more likely scenario is the vertical integration where facility-based companies and higher layer service providers seek strategic alliances or mergers and acquisitions. As facility-based companies go up the layer stack, variable costs could rise significantly, resulting in a U-shaped average cost curve with a minimum efficient size that is well to the left of the average cost curve for physical infrastructure. In addition, the demand curve for end to end service may be far to the right of the demand for raw transport. In other words, we can think of the resulting industry structure as coming from combining figure 1 and figure 2. The combined average cost curve becomes

1. See J. Gong and P. Srinagesh, "Economics of Layered Network," paper presented at the NII 2000 conference, Washington D.C., April, 1995.

U-shaped while the demand curve shifts to the right. As a result, more firms are supportable in equilibrium.

In fact, recent developments in the industry may support the theoretical prediction of vertical integration/alliances. Time Warner, the second largest cable operator, has been actively pursuing the acquisition of Turner Broadcasting, a major cable network programmer. US West, a local telephone service provider just announced purchase of Continental Cablevision, another large cable operator. AT&T announced several acquisitions to get into cellular, the Internet service and direct satellite TV business. All these new industry developments reveal the underlying fundamental incentives for companies to seek vertical integration as an effective competitive strategy.

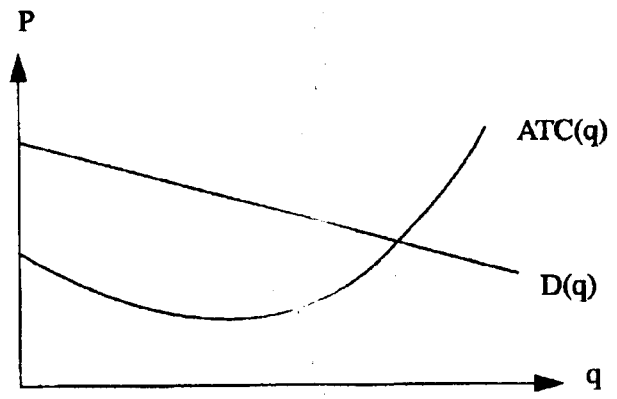

Figure 3

Horizontal Integration

Horizontal integration can lower customer support costs through sharing of resources and

facilities. Service providers at higher layers may benefit from economies of scale and scope in operation and greater bargaining power in negotiating the purchase of lower layer services provided by others. Network providers offering applications and services directly to end users may see greater consumer demand if they offer application interoperation, because more users can communicate with each other using different but interoperable applications that previously did not work with each other. This follows from the fundamental principle of network externality, which implies that the value of communications increases as the network grows larger.

One effective strategy of horizontal integration is service packaging and bundling. Unified customer support and billing brings convenience to customers and adds value. It can also serve as an effective means of differentiating among customers with different willingness to pay, leading to greater market share and higher profit.[1] Sprint and its cable allies may be implementing this kind of strategy. They have announced that the alliance's goal is to market a package of services under the Sprint brand name in one bill that meets a wide range of communications and entertainment needs of residential customers.

There are several underlying forces that are driving increased customer demand for service packages.[2] New products and applications are constantly being introduced as a result of the rapid technological advancement. Convergence of data, voice and video communications, computer-telephone integration (CTI) and mobile wireless needs provide ample opportunities for system integrators. As computers get more powerful and increasingly involved in communication functions, there is an emerging tendency in the industry to move intelligence to the periphery of the

1. Flexible pricing options tend to capture a wider customer base whose willingness to pay for each service in the package can vary substantially. See Schmalensee, R., 1984, "Gaussian Demand and Commodity Bundling," *Journal of Business* 57: S211-S230. Lewbel, A. 1985, "Bundling of Substitutes and Complements," *International Journal of Industrial Organization* 3: 101-108.
2. See also E. Noam, "Beyond Liberalization II: The Impending Doom of Common Carriage," *Telecommunications Policy* 18.

network. For example, adoption of LANs and PBX all create a complex environment for system management. In-house integration soon gets complicated as the number of carriers, prices and services multiplies. Today many companies are outsourcing these functionalities to carriers or system integrators that can provide one-stop turnkey service. Finally, deregulation of the access and carrier market brings a complex and diversified multi-vendor/multi-carrier environment. Complexity in turn translates into demand for an integrated package of various types of services. Therefore, besides the geographic market expansion, top telecommunications companies are trying to extend their reach into the enterprise by offering complete systems integration services.

When service integration is at service and billing level and bundling and packaging is a major form of competitive strategy, carriers with physical networks are effectively competing with system integrators who are mostly from backgrounds in resale, value-added services, and data and computer systems services. System integrators' strength is flexibility in service and pricing. Customized service operation requires close attention to and contact with customers, and this factor is a competitive advantage for system integrators. They can get favorable quantity discounts by buying bulk from common carriers. They then package communications services with other services to meet the needs of large business customers in a cost effective manner. For large common carriers such as LECs and IXCs, service integration may require expansion into nontraditional service areas such as video programming, data communications, Internet access, content provision and publishing.

Integration at the customer support and billing level speed the proliferation of new communications applications and services. Once they gain wider acceptance among closed user groups, the market may demand greater interoperability and connectivity. The fundamental principle of network externality implies that the value of communications increases as the network grows larger.

Interoperability of different applications permits greater internalization of the network externality.

Interoperation is driven by the economies of scale and scope in providing communications services. Application interoperation may stimulate increased usage of the network, and increased usage may alleviate the problem of excess capacity particularly during off peak periods. Therefore, facility-based providers may see revenue increases to recover the sunk cost. Interoperation also adds value to customers and may serve an effective strategy for product differentiation. Whether customers are willing to pay for enhanced features enabled by interoperation is largely an unanswered marketing question. But even in the absence of customers' willingness to pay, competitive pressure may drive companies to provide interoperation features without adding cost to customers.

Interoperation of applications may require complex technological solutions. This complexity is further compounded by the fact that different network service providers may support on their networks different or similar applications that compete with each other. Interoperation within the network is largely a technological issue. Several companies have studied or launched services that supports interoperability across several applications.[1] AT&T's Easylink currently offers text-speech conversion of e-mail over a telephone dialup 800 number. AT&T also formed a strategic alliance with Lotus to integrate its Intuity Audix voice messaging system with both cc:Mail and Lotus Notes. Fax and e-mail gateway services have been introduced recently, including InterFax and FAXiNet. CompuServe has introduced CallingAll Card, which enables subscribers to access, through a 1-800 number, fax mail, voice mail, conference calling, news and other calling features. International Discount Telecommunications (IDT), is planning to start marketing an Internet telephony service that would let computer users ring up anyone with a telephone at substantially

1. Also see Bridger Mitchell and P. Srinagesh (1995) Chapter 5, "*Universal Access to E-mail*," Rand, Santa Monica, CA.

lower cost than current rates for international calls.

Interoperation across networks raises technological and economic issues, because technical problems of the gateway interconnection point needs to be worked out, and financial terms of interconnection between competing networks need to be arranged.

Conclusions

This article examines the possible scenarios for the developments of the telecommunications market as a result of further industry convergence and changes in the political and regulatory environments towards competition. The passage of the Telecommunications Act of 1996 has added to the competitive momentum. We look at the cost structures of the industry under a hierarchical layered network architecture framework, and raise some difficult economic problems that may need to be addressed. We argue that vertical and horizontal integration may be a possible means to healthy market growth.

There is an urgent need for a clearer economic analysis of the future market structure in the telecommunications industry. Empirical studies that quantifies the underlying changes in consumers' purchasing behavior and providers's cost structure will also provide insight to public policy makers.