Technological Transformation and Innovation: The Development of the New Communications Order

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INTRODUCTION

This paper first traces the dynamics of change in the traditional telecommunications systems — diversity, centrifugalism, interconnection, modularization, and systems integration. It then moves beyond the United States and looks at the spread of these trends across borders, first in a theoretical and then in a more specific fashion. The changes observed and anticipated add up to radically different telecommunications environments than in the past, a system based on personalized packages of service modules offered across borders and subject to very different regulatory regimes.

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DIVERSITY AND CENTRIFUGALISM

Two basic forces shape today's telecommunications: the integrative forces of technology that push towards integrated narrow and broadband networks, and the economic forces of centrifugalism which move the network toward a decentralized and segmented federation of subnetworks (Noam, 1991, p. 4).

The trends toward technical integration and toward institutional and business diversity are, to some extent, substitutes for each other. To advance technologically, one can upgrade a telecommunications system by more powerful integration, such as fiber networks, and benefit from their economies of scale and scope. Or one can choose diversity and benefit from its dynamism and cost consciousness.

Generally speaking, traditional telecommunication monopolies around the world stressed integration. In contrast, the United States mostly followed the path of diversity, a comparative advantage of its society. Such diversity can lead to innovation, but it can also retard technical progress where there are many independent parts of a system that must interact.

The network environment evolved through several phases. At first, telecommunications were synonymous with the monopoly telephone provider. This is true in most of the world today. In the United States, however, cable television emerged in the 1960s as a low cost and high capacity communication wire that today passes around 90 percent of American homes, leading to a *dual system* of two parallel and separate networks (NCTA, 1992, p. 1A).

In the 1970s, alternative narrowband networks began to interconnect into the telephone network. At first, new long distance private line providers emerged, then switched carriers, mobile carriers, and rival local companies.

This *multi-tel* stage is the present state of evolution in the United States. But near at hand is the *multi-cable* stage where various networks will interconnect into the cable infrastructure, by both contract and partial leased access rights, offering alternative access to the end user, first for mobile and private line and later for more general service.

In the 1990s, the narrow telephone pipe also broadened as fiber migrated upstream towards the end-user. There were still two largely separate systems, only sporadically interconnected, and requiring dual wiring by each user. Quite conceivably, the inside wire could migrate to a "tele-mailbox" near the user's premises, thus avoiding the need for duplicate wiring, and permitting the interconnection of others communication streams, such as radio-based mobile carriers, second cable companies, second telcos, satellite based transmission systems, and others (Noam, 1992b, pp. 7-8).

As this system evolves, there will be numerous subnetworks creating a total communications matrix. These network elements become linked with each other through various interconnection and access arrangements and form a *network of networks.*

INTERCONNECTION AND MODULARIZATION AS PREREQUISITE TO AN INTEGRATION OF THE NETWORK OF NETWORKS

In such a diverse environment, it is necessary to provide the system with tools of integration where they are not self-generating by market forces. To do so requires a conceptual picture of networks and interconnection. It is helpful to think of a network as consisting of hardware and software functions. In software the tendency is toward modularity. An example for modular software hierarchy is Open Systems Interconnection (OSI), which was adopted in 1986 by the International Standards Organization. OSI is based on a hierarchy of seven layers, each of which has defined functional responsibilities. An upper level layer is reliant on the lower layers. But they are, in principle, independent modules, and in theory one can rewrite the software protocol for any layer, and replace it without having to change any of the other layers.

The other dimension is hardware. Here it is helpful to think of a network architecture as a sequence of physical segments: for example, the subscriber terminal itself, or the inside wiring from the terminal to the network termination point, or the trunk between the local office and the tandem office higher up in the switching hierarchy.

One can combine the software and the hardware presentations into a system of coordinates. On the horizontal axis of Figure 1 we have the physical segments, from the periphery of the end user up through the network hierarchy. On the vertical side, one has a software hierarchy.

The upper box of Figure 1 thus graphs the network schematically. Each part of the network is defined by a set of coordinates for its software and hardware location, and each service element can be graphed into this map. Element α, for example, could be an interoffice transmission trunk. Element β, similarly, is an applications module, located in the top layer and physically in the central office port. Element γ is terminal equipment, such as a fax machine.

Almost all this territory was once occupied by telecommunications monopolies such as AT&T or the PTTs. But one of the developments of the last two decades has been for other suppliers to emerge. The alternatives are schematically graphed in the lower box of Figure 1. In this case, there are α_2 and β_2 elements that are offered by alternative vendors, in competition with the α_1 and β_1 of the traditional monopoly carrier. However, the alternative service blocks usually lack the connecting physical and software elements necessary for an end-to-end connection with users. If the alternative service elements are to exist and survive, one must therefore provide a framework of interconnection with the other elements of the network, in a way shown schematically by the winding path in the graph, so that one could use the alternative α_2 and β_2 and still not be left cut off from the rest of network functionalities. Eventually, the islands will grow larger and fill the entire map.

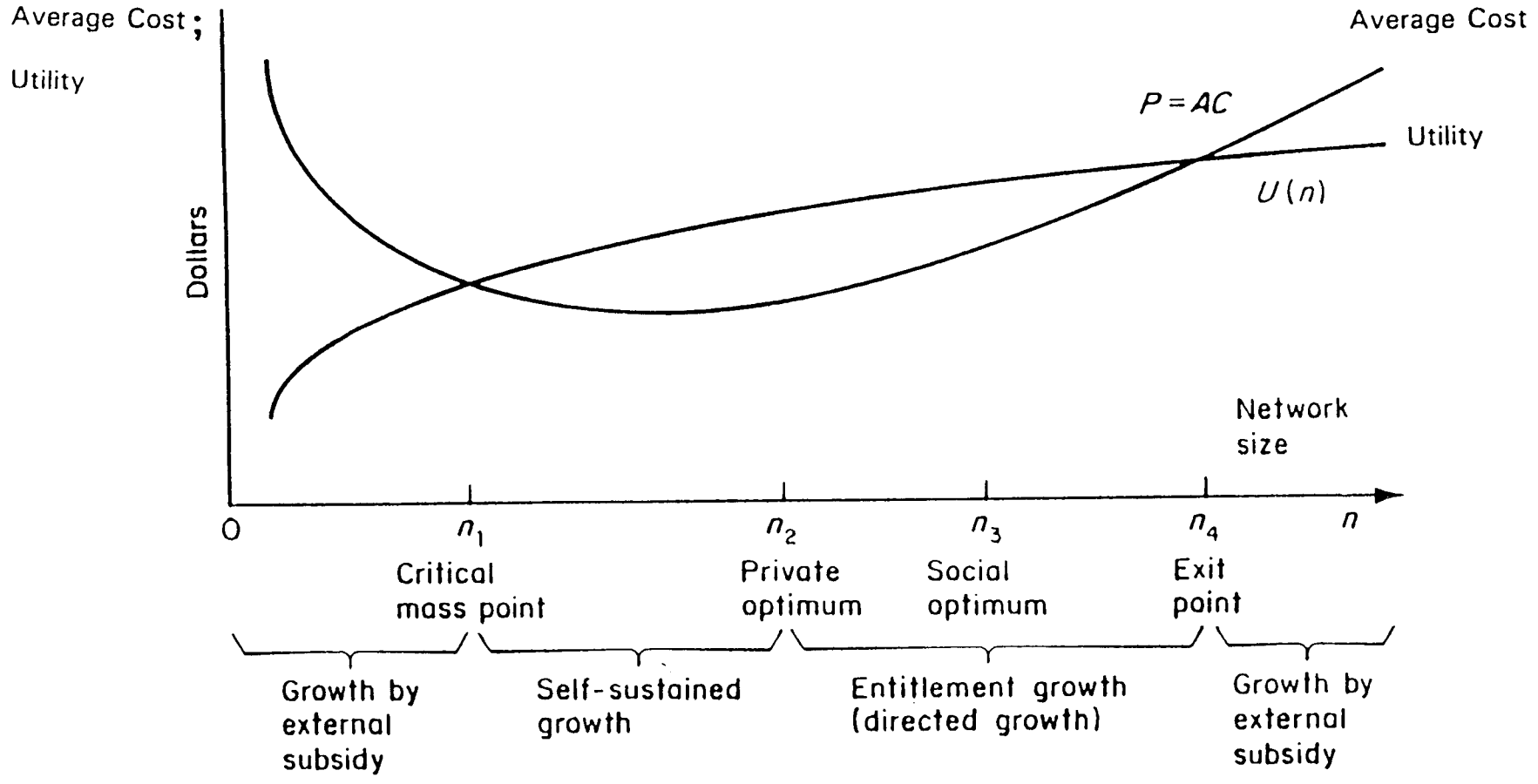
Average Cost;
Utility
Average Cost
P = AC
Utility
U(n)
Dollars
Network
size
0
n1
n2
n3
n4
n
Critical
mass point
Private
optimum
Social
optimum
Exit
point
Growth by
external
subsidy
Self-sustained
growth
Entitlement growth
(directed growth)
Growth by
external
subsidy

Figure 1

In the meantime, however, one can establish islands of competition only if one assures the ferry service to them (Noam, 1992b, p. 415).

One can think conceptually about network interoperability and interconnectivity in terms of a network grid of defined vertical and horizontal coordinates, with technical standards of interconnection and interface between them. In this fashion one would set out a system of *modularity* that would make possible an interconnecting network system of various telecommunication carriers, new rivals, and other forms of media such as cable systems or satellite operators. Within the modules, providers could do more or less whatever they wanted. And they could connect modules together. But one could replace one module with another, and still interact with the rest of the network.

This does not mean modules and interface points exist everywhere, since this would be burdensome in many respects. Nor will the transfer from one module to the next be free. The charges can be structured to support the viability of network functions or segments one wishes to support as a matter of public policy. Examples might be universal service at affordable rates, or technology development.

Market niches for small hardware suppliers would open. The carriers could encourage the development of software applications by outside suppliers, just as IBM did by opening software applications for its personal computers. This would enhance the telephone carriers' flexibility. Right now, changing network capability and services is a very onerous process.

It would be similarly possible for the VAN service providers to offer new applications by placing them among the central office software functions themselves, as collocated software. This could open up a scenario of new applications.

METHODS OF INTEGRATION

The network modules, provided by numerous participants, provide the elements for the matrix of the "network of networks" that will envelop us electronically. But they must still be put together. This can be done in a variety of ways.

User's Do-It-Yourself Integration

This is basically today's system for American residential users. They arrange for their own long distance company, and for their own terminal equipment. Large users, too, often put together networks on their own by leasing lines and buying and operating equipment. Self-integration gets complicated very quickly as the number of modules (carriers, services, prices, and equipment options) multiplies.

Terminal-Based Integration

Under such a system, a user's terminal equipment incorporates some built-in intelligence which can make the right choices among modules on a real-time basis. On the whole, customer-premises integration, even if done through intelligent devices, still suffers from the associated transaction cost.

Expansion Into End-To-End Carriers

This could be done by carriers entering horizontally into new geographic markets, or vertically into new services—by expansion, merger, or acquisition. Realistically, it is hard to imagine today any company that is big and varied enough to offer all types of facilities and services, and to do it well—locally, domestically, internationally, and across services—in telecommunications, enhanced services, computers, and other equipment.

Joint Ventures Among Carriers

Companies specializing in different market segments could link up with each other through joint ventures or institutionalized cooperation, such as under the traditional international regime of a cartel of national monopolies. This is a very likely scenario, and one which is emerging.

Integration By Systems Integrators

Perhaps the most promising scenario for the integration of the bits and pieces of network modules is systems integration. A new class of systems integrators is emerging. Their role is to provide the end user (corporate, governmental, affinity groups) with access to a variety of services, in a one-stop fashion.

Systems integrators might typically put together local, long distance, mobile services, VANs, equipment, and so forth. The characteristic of "pure" systems integration—for there will obviously be hybrids—is that they do not own or operate the various modules but rather select the best elements in terms of price and performance, package them together, manage the bundles, and offer it to the customer on an integrated basis. They relieve customers from the responsibility of integration for which expertise is required, and yet are not captive to recover major investments as carriers are.

Today, systems integrators exist for large customers and groups. Tomorrow things may be different. The additional step would be for systems integrators to emerge that put together individualized networks for personal use—or *personal* networks. This means an individually tailored network arrangement that fits an individual's communications needs. It will not be a separate physical system but, mostly, a "virtual" system with a variety of functionalities such as communications, information, entertainment, processing, and storage.

As these personal, group, and inter-organizational networks develop, they access and interconnect into each other, and form a complex interconnected whole, sprawling across carriers, service providers, and national frontiers. The telecommunications environment evolves from the "*network of networks*," in which modules interconnect, to the "*system of systems*," in which systems integrators link up with each other (Noam, 1992a, p. 12).

THE ROLES OF REGULATION IN THE SYSTEM OF SYSTEMS

Where does such a system leave government regulation? Regulation by government existed partly to right the imbalance of power between huge monopoly suppliers and small, atomized, and technically ignorant users. In a system of systems, on the other hand, systems integrators act as the users' representative, or agent vis-à-vis the carriers. They can protect users against carriers under-performance in quality, privacy, and price. This assumes that users have a choice among systems integrators, and that systems integrators have a choice among non-colluding suppliers of underlying services.

Of the various policy goals underlying regulation, the availability of user choice of integrators and integrator expertise would largely resolve traditional problems of *price, quality, market power, security*, even *privacy*. *Technological innovation* is likely to be accelerated by knowledgeable buyers and marketers of services.

On the other hand, traditional policy goals that are left unresolved by competing systems integrators are *universal service/affordable rates, free flow of information among the modules and systems, and interconnection among the modules.*

Furthermore, a key policy question is the role of traditional carriers, formerly monopolies, in systems integration. Competitive systems integration requires competitiveness in each important stage. If such competitiveness exists, there should be no problem of carriers participating. In competition, it is more likely that independent integrators will have a competitive advantage over established companies who promote their own services over lower-priced independent offerors. To be truly competitive as a systems integrator, a traditional carrier's systems integration operation would have to be willing to compete against its own carrier and in effect become independent. While this scenario is conceivable, it might require significant rethinking. And where monopoly power persists in any transmission segment, end-to-end competitiveness would have to be assured by the imposition of non-discriminatory access to these segments.

INTERNATIONAL DIMENSIONS

The system of systems works as long as it is competitive in each of its stages, or as long as regulation establishes non-discrimination. However, in an international setting neither one of these conditions is likely to be met. Most

countries lag the United States in the evolution of a diversified network of networks and are only now entering network diversity. The traditional monopoly carrier is almost always firmly entrenched, operating in all stages of communications. As a consequence, systems integrators cannot truly compete against the semi-official network operator in systems integration, except in market niches. This might be considered to be an internal problem of these countries, except that it has a global anti-competitive impact. This is the case since some international monopolies are also pursuing international systems integration, while at the same time holding gate-keeper powers over entry into their own home markets. Thus, a telephone provider in an important European country could restrict the effectiveness of an American or Japanese systems integrator looking to offer global services, and at the same time enter more liberalized environments themselves.

Of course, all countries can play the same game, and as a result, a new trend of international carrier collaboration has emerged in which major telecommunications providers enter into joint ventures of systems integration. Potentially, at least, these alliances of dominant national carriers could create international cartels and barriers to competitive entry to other systems integrators, whether in their home countries or abroad. To prevent this, it is essential to establish international non-discriminatory access, lease, and interconnection arrangements that are neutral as to the nature or the nationality of the systems integrator.

DOES NETWORK EVOLUTION CONVERGE INTERNATIONALLY?

Thus, the evolution of networks into a system of systems depends on developments in other countries, too. At the beginning of this discussion, I described the forces shaping network evolution—technical integration and institutional diversification. The question is whether these developments are unique to the United States, or whether they are common to other developed countries, beyond the politics of the moment.

Obviously, technology is widely shared and dispersed. Fiber, digital switching, satellites, and so forth, are available to each country's system. On the other hand, institutional diversity is much more country-specific. Can widely different models coexist in a stable equilibrium?

Interaction creates instability. The more interrelated countries and economic activities are, the less likely are there stable solutions to separate policies. And where instabilities exist, they ripple throughout the entire system. It becomes increasingly difficult to control all the elements in a complex matrix of interrelations. Ultimately, overarching control over many countries and many economic activities would be necessary to restore

stability. And since this power does not exist, or is usually not deemed desirable, extreme solutions unravel.

We can think of two "reaction functions," f_1 and f_2, that track the response of one regulation to the other's given level. An example is lower telephone rates, if one wants to attract business from the other jurisdiction.

A point such as **R'** would denote the two independently set regulatory policies. But once we postulate reactions to each other, there would be a shift to **R***:

$$R^*_1 = (R^1_1, R_2)\, C_1 \exp(1/1 - C_1C_2) \qquad (1)$$

where $\mathbf{R}_i$ is a country's regulatory strictness, and $\mathbf{C}_i$ are the cross-elasticities of regulatory strictness across countries.

Under moderately sized and positive cross-elasticities, there will be an equilibrium point such that regulation will be lower for desirable activities, and higher for undesirable ones. There is no need for *coordination* between one and two; an equilibrium can be reached by unilateral actions and reactions. However, an equilibrium requires that one reaction is steeper than the inverse of the other at the point of intersection.

If the reverse is true, there is no equilibrium and the regulatory strictness either moves successively higher or lower to corner solutions. One example is a telecommunications haven. In telecommunications, communications "havens" are possible and likely to emerge. The example of telex service is instructive. In the 1980s, London-based telex bureaus started to retransmit traffic between North America and continental Europe in defiance of CCITT cartel "recommendations" against such retransmission. It was profitable for United Kingdom (U.K.) firms to break these rules, since this generated more traffic and made the United Kingdom more attractive as a business location. In time, the cartel rules were held to be illegal (Noam, 1992b, p. 121).

Thus, corner solutions may emerge. For other parameters of the reaction functions, cyclical change is possible.

Instability raises questions of how to prevent it, and therefore leads to the issue of policy coordination. Such policy coordination can take place by *supraregulation*. Supraregulation is encompassing regulation across jurisdictions or across functions. This expands regulation to a ***higher*** level of institutions (e.g., to the European Commission) or to a *wider* institution, such as the Interstate Commerce Commission in the United States which regulates all modes of surface transportation.

Supraregulation is not invariably stricter than particularist regulation, for the reasons discussed. In telecommunications, for example, the regulatory principles of the European Commission are less strict than those of most of the member states. In the United States, the same holds true for the Federal

Communications Commission (FCC) vis-à-vis the state Public Utility Commissions. But the reverse is also often the case (e.g., in the regulation of securities).

Generally, the changes lead to unstable situations which affect the entire system. A single inconsistency has multiple secondary effects, which in turn lead to further inconsistencies. At the same time, collaborative regulatory adjustments become more difficult, because they cannot be confined to subsectors.

Applied to telecommunications, one should therefore expect an overall trend toward greater openness, though accompanied by efforts to stabilize its collaborative aspects. As the matrix of interrelations becomes steadily more cross-elastic, one could have some oscillations. But the overall tendency should lead to reduced regulatory strictness internationally. In that sense, unravelling of monopoly is an expansionary process. This is not so much an ideological choice as a response to an internal inability to structure a stable equilibrium that serves the multiple domestic interests and goals.

THE NATURE OF POLICY CHANGE

After this more abstract discussion of domestic and international instability of traditional arrangements, let us now be more concrete in describing these policy changes. In the 1980s, after a century of institutional stability, the traditional telecommunications monopolies—known as the PTTs—underwent in many countries in the 1980s a metamorphosis. The main new policies follow.

Liberalization

Liberalization means the introduction of competition into monopolized equipment and service markets. On the services side, liberalization may involve licensing entrants to provide a particular service, such as cellular telephone or long-distance. Liberalization policies often require government scrutiny to prevent anti-competitive behavior by the former monopoly.

Devolution

Devolution is a policy of dismantling a single monolithic structure into several units. On one level, this has occurred wherever the postal and the telecommunications authorities were split. Another more important level is the devolution within telecommunications organizations, along lines of functional operations or geography. The prime example of devolution is the divestiture of AT&T in the United States into local and long distance operations. So far, no other country has pursued devolution, but it is under consideration in Japan and Britain.

Consolidation

Consolidation has occurred where a country's telecommunications were divided for various historical reasons along geographic or functional lines. The rationale for consolidation is to capture the economies of scale and scope of a single monopolist, which are important to competition in global markets.

In Denmark, the country's four regional service providers were merged with the national PTT that provided long-distance service to create a single operator, TeleDenmark. Similar plans to create national integrated "super-carriers" were advanced in Italy and Portugal.

Deregulation

Deregulation is an imprecise concept and is often used as a synonym for liberalization, that is, for a lowering of entry barriers or other restrictions. Basically, it means a reduction in government-set constraints. Deregulation can be at odds with liberalization: the entry of new competitors tends to complicate things much more than an outright monopoly and can lead to a more extensive set of rules. For example, the need to keep an interoperating system functioning requires access and interconnection rules.

Corporatization

Corporatization is the transformation of the PTT into a structure semi-autonomous from government, which may still be state owned, but controls its own managerial and administrative functions. The monopoly status is not touched by corporatization as such, though once the close link to the government is severed, a process is set in motion that makes further changes more likely. Sometimes the corporatized entity is described as a "private" firm, in the sense that it may be organized under private law provisions, which determine its status in, for example, contract and labor law. But that description confuses legal detail with the reality of control, which is still very much governmental. In other instances, a minority or shares may be issued to the public, though control is still retained by the state.

Corporatization may be a first step on the road to privatization. It is often sought by the PTTs themselves, who need greater managerial and budgetary autonomy to pursue long range investment projects and the ability to raise investment capital outside of government borrowing ceilings. Corporatization may also derive from a public desire to inject new life into sleepy monopoly bureaucracies. Because corporatization loosens direct administrative controls, it is usually accompanied by the creation or strengthening of a government regulatory mechanism.

Privatization

Privatization involves the government sale of shares in the PTT to private investors. However, ownership need not affect the monopoly status. In the United States, AT&T was private and a near monopoly for a very long period. In Canada, private regional monopolies exist, and long distance competition has only recently been contemplated. Most European privatizations are only partial.

Privatization may encourage efficiencies of operation. But quality of service may fall if an unconstrained monopolist seeks cost reductions without regard to its captive customers. Privatization can also have the unintended effect of strengthening a monopoly, as shareholders become a political constituency to preserve a monopoly. Widespread shareholder involvement in the United Kingdom created a deregulatory force opposed to curbs on British Telecom's (BT) dominance which might threaten profitability. In Spain, Telefónica is protected by the "widow and orphan" status of its stock.

Ownership strategies depend on national economic development. Privatization in less developed nations derives from a need to raise capital. Indonesia, for example, offered an infrastructure role for private capital. Throughout Latin America, privatization was used as a method to reduce the heavy debt burden. In Eastern Europe, it is led by the need for foreign capital and expertise. In Malaysia, it was part of a national program to increase the ownership share by ethnic Malays in the national economy.

In contrast, in more developed nations, privatization and corporatization aim to overcome borrowing or investment restrictions on public enterprises, and to provide a means to shake up bureaucratized enterprises.

Transnationalization

Transnationalization is a strategy of large and advanced PTTs to expand beyond national markets. As these organizations often renamed Public Telephone Operators (PTOs) achieved universal telephone penetration, they expanded their sights geographically. This strategy has been pursued through acquisitions, international service offerings (such as network software or management) and by establishing foreign subsidiaries.

International alliances offer another method for PTOs to expand their markets. Across Europe, most PTOs have entered joint ventures and service consortia. Such partnerships allow them to gain some access to heavily monopolized markets where they are not allowed to compete with the local operator. Alliances also spread the risk of new service ventures across multiple participants. This has traditionally been the case with consortia such as Intelsat and Eutelsat for satellites, and the transoceanic cables.

Supraregulation

Supraregulation, in the telecommunications context usually known by its variant "harmonization," is the standardization of telecommunications policy among countries. Harmonization may include the creation of common standards for equipment or the development of common policies for provision of service. Harmonization is managed through regional bodies such as the European Commission and multilateral groups such as the International Telecommunications Union and its coordinating body CCITT, as well as through bilateral negotiations. It sometimes may lower barriers to entry in markets by providing a single set of regulations. But in the past, such rules were usually set in a restrictive fashion, such as a cartel-like prevention of certain forms of competition to monopolies. Thus, for many years, harmonization was a code word for international restrictiveness.

Industrial Policy

In almost every country, telecommunications policy is set within larger industrial development, and telecommunications organizations were given a major role in national high-technology. These industrial policies tended to support the establishment of "national champion" electronics firms, and implicitly assured them major shares of public procurement contracts at prices that often shared in the monopoly profits of the operator. In some cases, direct financial support for the electronics and telecommunications sectors was provided by PTTs. They also deployed and supported proprietary technologies and protocols.

Vertical Integration

In some countries, PTOs integrated vertically into the manufacturing of telecommunications equipment. In Spain, Telefónica holds a large stake in Standard Electrica, Spain's largest electronics firm, as well as several other high-tech firms. In North America, AT&T, GTE, and Bell Canada had far-reaching manufacturing operations. Eventually, the divestiture separated AT&T from the local exchange companies, GTE sold its equipment business, and Northern Telecom was partly spun off. In Italy, the network operator and largest equipment manufacturer are owned by the same partly-privatized government holding company. Sweden's Televerket owns the major domestic equipment firm, Teli. Under the new wave of corporatization and privatization, other PTOs, having gained freedom, have sought to expand vertically. British Telecom bought the ailing Canadian PBX manufacturer Mitel. Equipment manufacturers also entered service markets. Alcatel, DEC, and IBM, for example, offered value added services. Generally speaking, vertical integration does not seem to have been a great success.

OUTLOOK

These ten strategies constitute the primary policy menu. They are often described as major steps of reform. Yet how much difference did they really make to monopoly power so far outside the United States.

In the area of *market structure*, liberalization had its limits. The notion of an infrastructure monopoly still has substantial political support almost everywhere. Basically, only the US, Japan, the UK, Sweden, Canada, and New Zealand permit alternative physical non-mobile networks (Noam, 1992b, 1993). Similarly, PTOs most everywhere have also found political support for their monopoly over voice service, and its resale is rarely permitted.

The actual reduction of monopoly tends to be exaggerated. A Danish political agreement illustrates the doublespeak: "There will be competition within all spheres of telecommunications in the next few years, apart from telex, ordinary telephony, radio-based mobile services, satellite services, the infrastructure and the use of the telecommunications network for broadcasting radio and television programs" (DMC, 1990). In other words, "everything" is liberalized, except for the remaining 95 percent.

What have been the impact of changes in ownership and control? Here, too, reforms have increased PTO power. Corporatization and privatization substituted managerial and financial autonomy for the direct governmental operational control and the political accountability that came with it. At the same time, the government ministries which assumed regulatory power tended to be ineffective. These ministries have only a handful of experts to confront the huge and expert telephone organizations.

Thus, the various strategies and reforms meant to have not harmed, and indeed have benefitted, the traditional telecommunications organizations. They have been energized. Their competitors are tiny, their regulators are frequently underperforming, and their role is enhanced by industrial policies domestically and international collaborations globally.

But will the present situation last? Given the dynamic forces of the telecommunications market, it is unlikely. In time, market shares will decline as competitors grow in size and gain interconnection rights; presently unprepared regulators will become more effective; international collaboration will evolve into head-to-head competition; new domestic entrants will seek opportunities in specialized and general markets; foreign entrants will emerge; and specialized entrants such as cellular companies, cable TV providers, and VAN resellers will be active. The dynamics of diversity, interconnection, modularization, and systems integration will take over in other countries. This, too, will in time, move towards modularized personal networks packaged by systems integrators.

The main challenge to policymakers for the next decade is to therefore reconcile the centrifugal pressures with the needs to inter-operate and inter-

communicate. This means to provide a competitive system with tools of interoperation, and to deal with the providers of integration, namely the systems integrators that will emerge, as this article has argued, as the central elements of future telecommunications. In the United States, the past decade has been preoccupied with market liberalization. This will continue, but it will also be inevitable to move beyond this agenda and to assure the functioning of the new structure. Other countries will be affected, often involuntarily, by these changes. Yet they will not be able to contain the unravelling of the traditional system. As the global system of systems emerges, we must rethink its technology, policy, and economics. This will be the challenge of the new communications order.

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