Untangling the Web: The Internet as a Commons

March 1996

(URLs updated June 2007)

Charlotte Hess

Workshop in Political Theory and Policy Analysis
Indiana University
513 N. Park
Bloomington, IN 47408-3895

hess@indiana.edu

Revision of the paper presented at the Workshop "Reinventing the Commons;" Transnational Institute, Bonn, Germany, November 4-5, 1995; adapted from "The Virtual CPR: The Internet as a Local and Global Common Pool Resource;" presented at "Reinventing the Commons," the fifth annual conference of the International Association for the Study of Common Property, May 24-28, 1995, Bodoe, Norway.

Untangling the Web: The Internet as a Commons

Introduction

This paper explores the concept of *reinventing* as "creating anew," with the global network of computer networks called the Internet as a sublime example of a new common pool resource (CPR).[1] A commons is not a resource existing independently in nature but rather a human artifact -- an institution crafted by human beings. Nor is a commons an archaic, old-fashioned, idyllic human arrangement unique to indigenous societies. Rather it is a type of good, a resource, which can have either public or private ownership but which is managed and used jointly by a group. The community in a common pool resource is composed of those individuals who use it and have a vested interest in its success.

It is true that most of the common pool resource literature to date (see Martin 1989, 1992, Hess 1994a) focuses on indigenous or traditional management of natural and some man-made resources. Fisheries, forests, grazing lands, groundwater basins, irrigation systems and roads are frequently studied resource systems. More recently, however, scholars are finding the value of examining many of the new CPRs which are being created every day -- from school budgets, municipal landfills, and interstate highways, to the office water fountain or the family refrigerator.[2]

The Internet is a fairly recently-developed common pool resource which enables rapid transfer of information and communication. It is an extremely dynamic resource: its users are growing at an exponential rate, as are its uses and applications. The Internet is also an immensely complex resource both as an interlinked system of technologies as well as in its nested layers of local, regional, and global regimes which shape the myriad number of interactive levels.

As a new CPR the Internet is unquestionably one of the most complex and least understood common pool resources. It is frequently referred to as a *common pool resource* or more generically as a *commons.*[3] The problem in any analysis of the Internet as a CPR lies in its very size and complexity. This paper sets out to untangle the Internet web by demonstrating that it is, in fact, not just one type of common pool resource but rather *four different resource facilities:* an Internet technology infrastructure commons, an Internet budget commons, a networked information commons, and an Internet community or social commons created by the new technology capability.

The author is particularly grateful to Gerald Bernbom for many stimulating discussions about information technology, and for his helpful suggestions. She is also indebted to Elinor Ostrom, Vincent Ostrom, James Thomson and James Walker for their challenging critiques and very insightful comments. -CH

---

[1] Throughout this paper ***CPR*** is an abbreviation for Common-Pool Resources

[2] Bose (1995), Herzberg (1990), Oakerson (1992), Shepsle (1982), and Witbreuk (1995) are a few of the scholars who have examined non-traditional CPRs.

[3] See Roberts (1994), Lowell (1993), Kollack and Smith (1995), Mackie-Mason and Varian (1994a&b) and others.

The identification of the different Internet resource facilities was made possible from the application of the Institutional Analysis and Development (IAD) framework.[4] This framework, developed by scholars at the Workshop in Political Theory and Policy Analysis at Indiana University, is a powerful diagnostic tool which facilitates greater clarity and understanding of the complex human artifacts, such as the institutional arrangements for the management of resources.

The ensuing analysis also exposes evolving characteristics of the Internet which are cause for great concern--for instance, the perplexing phenomenon of the simultaneous centralization and decentralization of information. More people potentially can have access to electronic information but fewer people control the provision of any one information document. Analysis also exposes the frequently wide gaps between the appearance of the *publicness* of the Internet and the reality of the increasing privatization and centralized control of the Internet.

By drawing upon the research, methodologies and literature of traditional common pool resources and by applying the IAD framework, governing bodies in the hierarchy of Internet decision making will be better able to understand the interconnected institutions, rules and interactions in order to make informed decisions and sustainable outcomes. Such a study opens up a vast and complex research agenda for future exploration by scholars.

The Internet as a Good

Common pool resources or CPRs are distinguished from other types of goods[5] in that they can be either publically or privately owned, but use and sometimes management of the resource is shared by a potentially identifiable group. Typically, the outcomes are based on the limited availability of the resource units and the number of users drawing upon the units. The use of the resource by one person **subtracts** from the amount available to others. With highly valued CPRs, it is necessary to place limitations on the amount of use in order to ensure fair and equitable access to the resource. In the case of Internet, when too many users subtract units at the same time, congestion occurs. This congestion is a traffic jam of data packets trying to use the same bit space on the wire. Such congestion (called "traffic bursts") is usually ephemeral. In cases where congestion becomes chronic, depletion of the resource occurs. Internet depletion occurs when there are never enough resource units (network bandwidth) available for the number of users requesting those units.

The other main quality of a common pool resource is the difficulty of **exclusion** (because of lack of clear property rights). Exclusion of the Internet resources is highly fragmentary and piecemeal. There are no rules of exclusion from the entire resource system. With a complex resource like the Internet, there are various levels of subtractability and exclusivity, depending on which aspect of the resource system is examined. One of the Internet multi-resource systems is the technology-infrastructure which makes electronic communication possible. Partial

---

[4] A bibliography on the IAD framework (Hess 1994b) compiles much of this research over the past twelve years. [See http://dlc.dlib.indiana.edu/cpr/index.php for the most recent version]. Kiser and Ostrom (1982), Oakerson (1992), Ostrom (1990), and Tang (1992) provide particularly cogent descriptions of this framework. Ostrom, Gardner and Walker (1994) give a useful history and expanded definitions of the framework components.

[5] See Ostrom & Ostrom (1978) and Ostrom, Gardner & Walker (1994: 6-8) for a thorough presentation of the different types of goods.

exclusion is possible from some subset of the technology infrastructure, for example, by requiring a user account to connect to some computers or to access certain information or

discussion groups. The technology infrastructure also evidences subtractability, as the network bandwidth used by user *x* can not be used by user *y*. But another type of resource system within the Internet is a local organizational budget which affects the quality and availability of the Internet resource. In this case, money used for technology *x* subtracts its use for project *y*.

Resources as Artifacts

Whether naturally occurring in the world (such as forests) or man-made (such as irrigation systems), both types of resources are human artifacts. Both contain the combination of physical restraint (by natural law) and rules (human law). While the relationship between fisheries or roads and human institutions is readily apparent, that relationship in the structure of fiber, optical pulses and machines as human institutions is more obscure. Yet, computer technology itself is a human artifact. In the case of the Internet, it is the shared use which has been enabled through standards, protocols and rules which most immediately puts it in the category of a common pool resource.

The Internet at the Local Area Network (LAN) level is quite analogous to local roads. At this level there are definable system boundaries, cohesive governing bodies and local-based rules and policies. The complexity of the resource grows at the regional level and beyond to the national and international levels because of the vastly broader boundaries, the increase in heterogeneity and the interplay of several resource regimes or governing bodies. The transition from a local to a globally shared resource requires its own evolved considerations and type of analysis (McGinnis and Ostrom, 1993).

Brief History of the Internet[6]

The Internet is about 25 years old. Originally developed by the U.S. Department of Defense, it was made possible by the design of open systems interface technology which allowed the specifications of computer architectures, computer systems, computer software, and communication systems to be published and available to everyone. Specifically, the success and acceptance of Transmission Control Protocol (TCP) and Internet Protocol (IP) propelled computer communications into a shared resource.

When it was first linked together as a network of networks in 1968, there were seven host machines. Currently, there are over 6,600,000 host machines (Lottor 1995) and scores of millions of people who are technically equipped and using this information service. The number of new users is growing at an exponential rate.

The development of a government network designed to link the military, defense contractors and university researchers for faster exchange of information, into a global "metanetwork" of interconnected networks (Gilster, p.15) used for political, commercial, educational, entertainment, legal and illegal purposes is worthy of study itself, as a new type of gargantuan resource. Today, with high-speed fiber optic networks, its uses have multiplied and are still being defined: transfer of data files, remote login to libraries, classrooms and boardrooms, newspapers, shopping catalogs, multinational videoconferences, real-time video. The

[6] There are many good sources for expanded histories and descriptions of the Internet. See John December's Internet Guides at http://www.december.com/web/text/nar-guides.html
Gilster (1993), Krol (1994), D. Lynch and Rose (1993: 3-14) and Leiner (1993: 15-40) all provide interesting discussions of the development of the Internet.

interactive nature of the Internet brings together new communities of people, new social groups who have self-selected themselves based on commonalities of interests, pastimes, age, gender, religion, ad infinitum. The technological requirements to support this resource have changed budgetary priorities of all educational and information-dependent institutions.

The rapidity of growth and the utter complexity of the Internet as a resource obfuscate clear and informed decisions at a time when problems abound. The problems or outcomes, however, are readily apparent and often experienced by most Internet users: denial of access if too many users are already logged on to the local network; a slowdown of the response time of message retrieval and provision when routing queues build up; the disappearance of valuable information available from one day to the next; uncivil and violent social behavior. The outcomes of ***congestion*** and overconsumption at the technology infrastructure level affect **access** to and **speed** of electronic communication. Other outcomes that are problems on the Internet are ones of ***pollution,*** which affect the **quality** of the resource. There is already an overprovision of information which is unreliable, of unknown provenance, or of low value. Intellectual property rights are poorly defined and not always respected. Electronic communities are disrupted and may fail as rules are ignored or violated. At the same time infrastructure costs are rapidly escalating as usage rises dramatically, while most educational institutions' budgets decline. Too little is understood about the interconnections between the technology, information, and the resulting institutional change on a wide scale.

Applying a Framework

While the Internet is often perceived as a "commons," it is rarely examined methodically as a common pool resource per se. The "commons" label usually seems to arise out of the growing awareness that the Internet is a *shared* resource; that is both publically and privately owned, with diffuse management and no single authority responsible for its governance. The idea is borrowed from Garrett Hardin's 1968 article "The Tragedy of the Commons," which portrays a pessimistic scenario of inevitable depletion of an open-access, shared resource which lacks central authority. The casual reference, so much in vogue at the moment, is often an implied plea for cooperation, civility and social order in an ungoverned environment ripe with the potential for anarchy and chaos. It is also frequently used as a theoretical basis to justify centralized governance of the Internet. And, indeed, no one connected to the Internet is unaware of the problems caused by the lack of central governance, unenforced rules, and lack of monitoring and sanctioning mechanisms, all compounded by an ever-growing competition for its use. On the other hand, the freedom and anarchy of the Internet are considered its most positive characteristics by many of its users. But many of the problems which occur, such as overuse, congestion, and free riding, do parallel those found in the sharing and maintaining of natural resources where access is left open.

The "commons" references in the information technology literature, however, rarely go beyond the Hardin scenario. CPR design principles [7] as first identified in Ostrom's *Governing the Commons*, move well beyond Leviathan-like solutions. They offer a better understanding of rules and institutional designs which are conducive to noncentralized, self-governing cooperation and sustainability. CPR research and literature demonstrate that tragedy

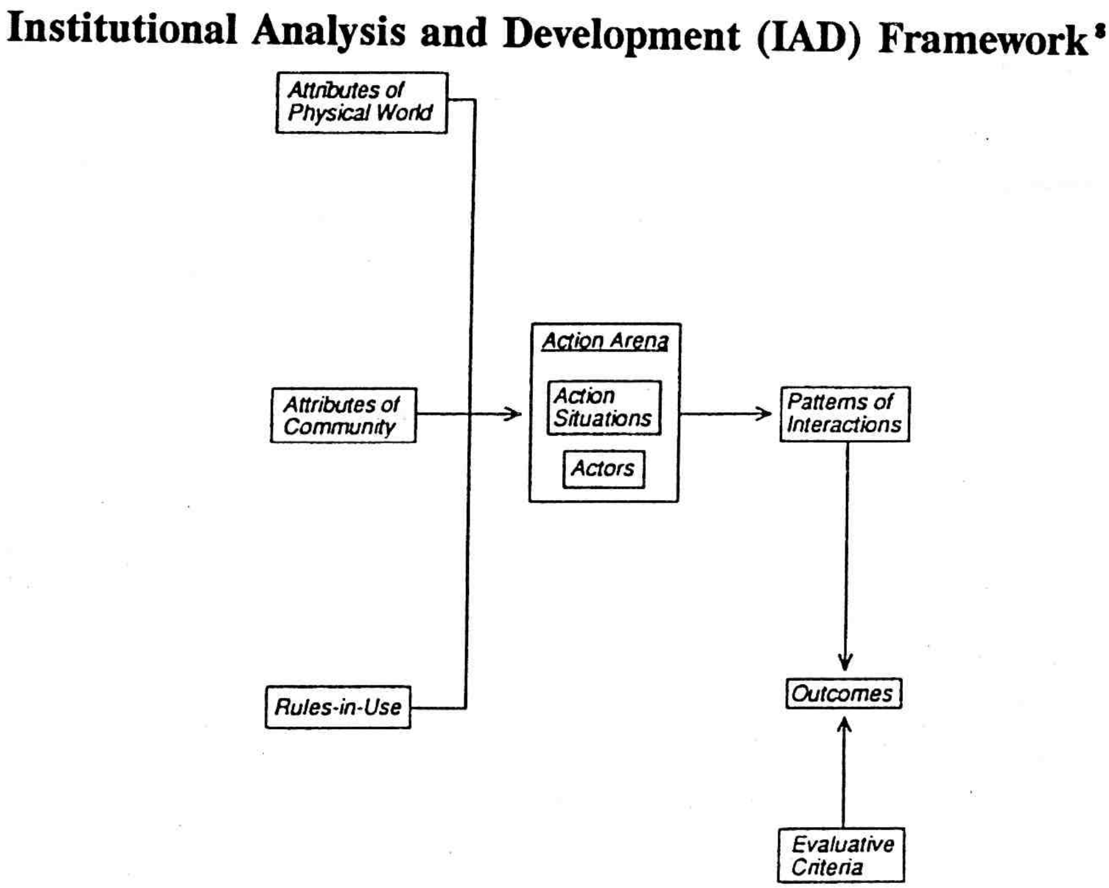
---

[7] The design principles illustrated by long-enduring CPR institutions, identified in Ostrom's *Governing the Commons* (1990) are: (1) Clearly Defined Boundaries; (2) Congruence between Appropriation and Provision Rules and Local Conditions; (3) Collective Choice Arrangements; (4) Monitoring; (5) Graduated Sanctions; (6) Conflict Resolution Mechanisms; (7) Minimal Recognition of Rights to Organize; and (8) Nested Enterprises.

(unsustainability) need not be an inevitable outcome. Cooperation and successful stewardship of shared resource management are not just romantic hypotheses but observable facts

throughout the history of human interaction. Examining the physical characteristics with cultural and behavioral attributes of the participating community produces a better understanding of the transaction costs and resulting outcomes.

Figure A: IAD Framework[8]



In the case of the Internet, applying institutional analysis can prove particularly helpful in exposing the misconception that technology itself drives the resource. In the cyberworld created by wires and switches, rules and standards are all too often invisible not only to users but to decision makers. And, the complex components which make up the Internet can easily obscure any casual analysis.

The IAD framework requires the careful examination of the physical characteristics of the resource at hand in order to establish a firm grasp of its scope, nature and boundaries. At the

[8] This version of the framework can be found in Ostrom, Gardner and Walker, p. 37.

same time it considers the size, homogeneity or heterogeneity, shared belief systems and so forth of the user community, and its decision-making arrangements or rules in use (who decides, by what rules?). The patterns of interactions are how people behave based on the rules and the physical constraints. The people involved (actors) can interact reciprocally, believing that if they are compliant or contribute to the common good–the resource–they will directly or indirectly derive a benefit from their behavior. Or the actors can free ride, taking advantage of the compliance and goodwill of other users, without being compliant or good-willed themselves. Outcomes reflect the results of the patterns of interactions upon the resource itself. Outcomes concern working-order and physical shape of the resource–i.e. whether the resource is overused, leading toward depletion, or functioning efficiently or inefficiently, etc. Perplexing issues such as provision, appropriation, assignment problems and technological externalities occur throughout the Internet system and are worthy of detailed examination (see Ostrom, Gardner and Walker, p.8ff.). One of the consistent findings in CPR research is the connection between overuse and the lack of communication among decision makers (Ostrom 1994:1). Evaluating the outcomes is a separate step in this analytical process which considers such aspects as the transaction costs, sustainability, and equity of distribution.

The normally unsatisfactory metaphor of the "information superhighway" is helpful in this instance, revealing how the Internet really does demonstrate the characteristics of a commons.The metaphorical parallel of the Internet with public roads and highways is the most applicable of the human commons yet studied. The concept of a highway can help us begin to define the parameters of this "virtual common pool resource." The Internet as a network of electronic networks is, therefore, a resource composed of smaller resources. The interconnectivity of both the real and the virtual roads and highways is essential to effective travel. And the comparison extends to the fact that the types, conditions, arrangements and rules for local roads differ considerably from those for interstate and intercontinental highways.

Multi-level Internet Resource Systems

To this point the Internet has been identified as a general type of man-made shared resource, characterized by subtractability and exclusion. It is both a local as well as global common pool resource. It has physical boundaries and attributes, rules which regulate its use and management, the choices resource users make, and the outcomes produced.

In examining the Internet as a CPR, however, the clear definition of the different resource domains or systems within this complex resource is crucial in advancing any kind of systematic analysis. Distinguishing these systems is necessary because they contain different physical attributes and decision-making arrangements, and encourage behaviors which produce different outcomes. The IAD framework is a valuable tool for unraveling the Internet into four distinct (and, at times interrelated) CPR systems. All four of these CPR resources reside at the local LAN level, and most extend to the global WAN level. Space does not permit a thorough examination of the CPR design principles, but they are implicit in the questions posed toward the Internet CPRs.

1. The Technology Infrastructure Commons

Congestion and depletion are among the most problematic outcomes in this network of computer networks, when viewed as a technology infrastructure commons. Congestion is a temporary condition of overuse in which the demand to transport data exceeds the carrying capacity of at least one segment or link of a computer network. Depletion describes a condition of chronic congestion in which there is virtually always insufficient carrying capacity in a network to satisfy the demand to transport data. Congestion and depletion may occur on any scale, local

to global, from the smallest local area network in a single suite of offices to the high-speed fiber backbone network that spans a continent.

Physical Attributes

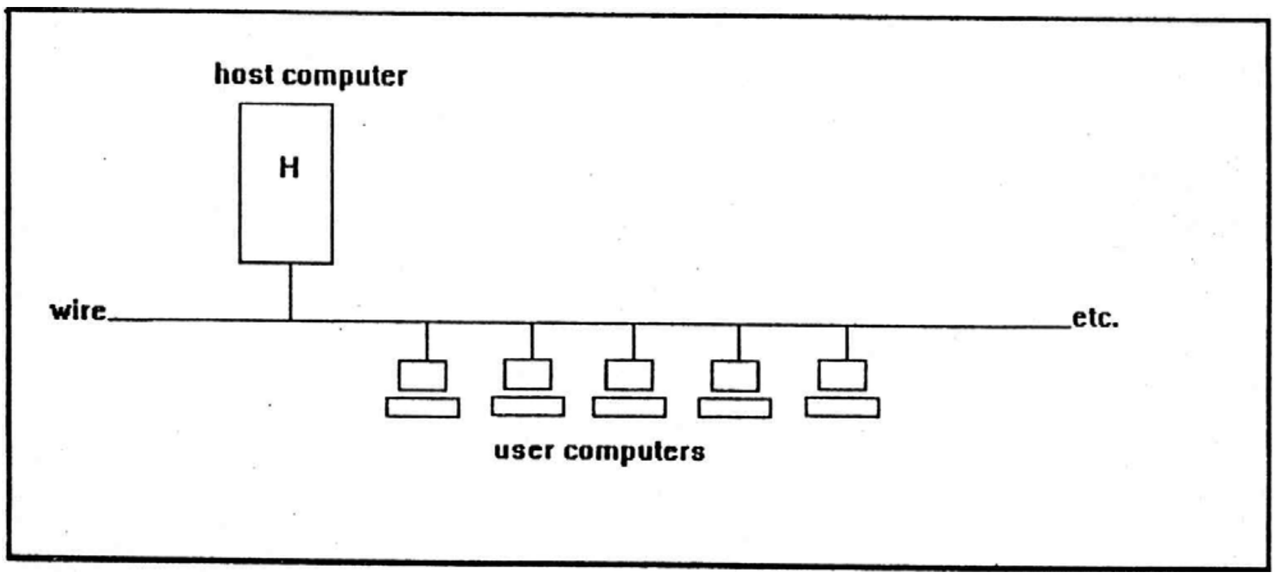
The technology infrastructure commons best parallels the superhighway metaphor. At the most basic level, its physical components are the fiber or copper wires through which the digitized data, organized in packets, is transported. It also includes the routers and switches which connect the wires and the host and the user computers (PCs) at each end. As the traffic route moves from the local area to a wider geographical destination, the size and interconnectivity grows in complexity but the basic components remain constant.

A **network** is a collection of computers connected together by wires, able to send and receive data. The fundamental resource facilities of the network are wires and boxes as depiected in Figure below:

> **User-computers** (personal computers or PCs) are typically desk-top or laptop computers that can be used by only one person at a time.
>
> **Host-computers** (file servers, mail servers, mainframes, etc.) are typically large computers used by several individuals at the same time, often performing some specialized function: storing large files, sending/receiving mail, etc.
>
> **Wires** provide the physical connections between computers, typically copper wire or optical fiber. They are equipped with a signaling system, such as Ethernet, token ring or FDDI (Fiber Distributed Data Interface). These signaling systems determine the speed and capacity of the network and the way in which the wire is shared. For example, Ethernet has 10 megabits per second throughput; FDDI operates at 100 megabits per second.
>
> **Routers** are specialized computers/processors, connected by wire to other computers -- either host computers, user-computers or other routing computers; they are gateways connecting the network. Routers interconnect networks over local or wide areas and provide traffic control and filtering functions when more than one pathway exists between two end-points on the network. Routers read and forward packets toward their intended destinations. In a very large network, a packet may pass through several routers on its path from source to destination. *Switches* and *bridges* are similar devices which perform this read-and-forward function in a network. For the purpose of this discussion, the term *router* will be used for all such read-and-forward devices.
>
> A unit of resource flow of the facility is a **Packet,** which is the smallest meaningful unit of data that is sent between two computers. A packet typically contains a destination address (where the packet is going), a source address (where the packet came from), and the data itself that is being sent. [Note: The term *packet* is technically correct for units of data sent using the Internet Protocol, or IP. In other technologies, the smallest addressable unit of data may be a *frame* or a *cell,* but these have the same characteristics of source, destination and content.] An e-mail message can be made up of several hundred packets; a computer file transferred via File Transfer Protocol (FTP) may be made up of thousands or tens of thousands of packets.

The examination of the physical attributes of the technology-infrastructure must include the structural maps of each system along a path, from the Local Area Network to the Wide Area Regional/National Networks. CPR problems such as crowding, congestion, and free riding can occur at each facility along the network path. The smallest collection of computers and wires that could be considered a common pool resource is a **Local Area Network** or LAN. Minimally, a LAN consists of one host computer or server, several user-computers, a segment of wire connecting these computers, and no routers. It is this minimal LAN construction is presented in Figure B.

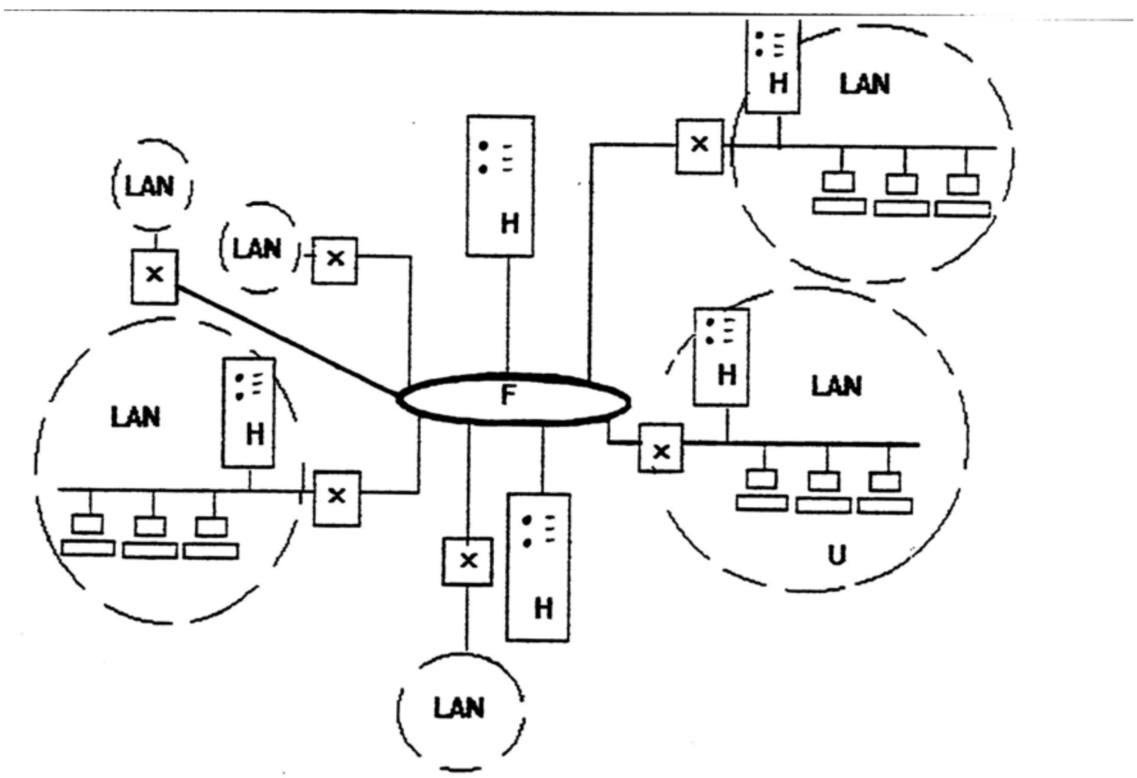
Figure B: Local Area Network



The wire is one of the components for which the most competition exists in this common pool resource. A segment of wire that connects several computers, all of which can send/receive packets, is a shared resource in itself. If the wire is fast enough, many computers connected to that wire can have the *appearance of simultaneous use.* In fact, only one packet of data moves along the wire at one time. The host computer is also a shared resource in this LAN and subject to cases of competition and congestion. It may contain files used by several of the user-computers, all of which might request access to these files at the same time. When too many packets are sent at the same time, congestion -- a slowing down of the data traffic -- occurs.

The local (campus, business, hospital, etc.) network is a conglomeration of the few or numerous LANs located in the various departments or buildings. Such a network, depicted in **Figure C.**, has several host computers (which may perform different functions, for example as a file server or mail service provider), dozens or thousands of user-computers, multiple segments of wire, with each wire shared by a subset of the user-computers, and routers (including switches and bridges) to interconnect the different segments of wire.

Figure C. Campus Network

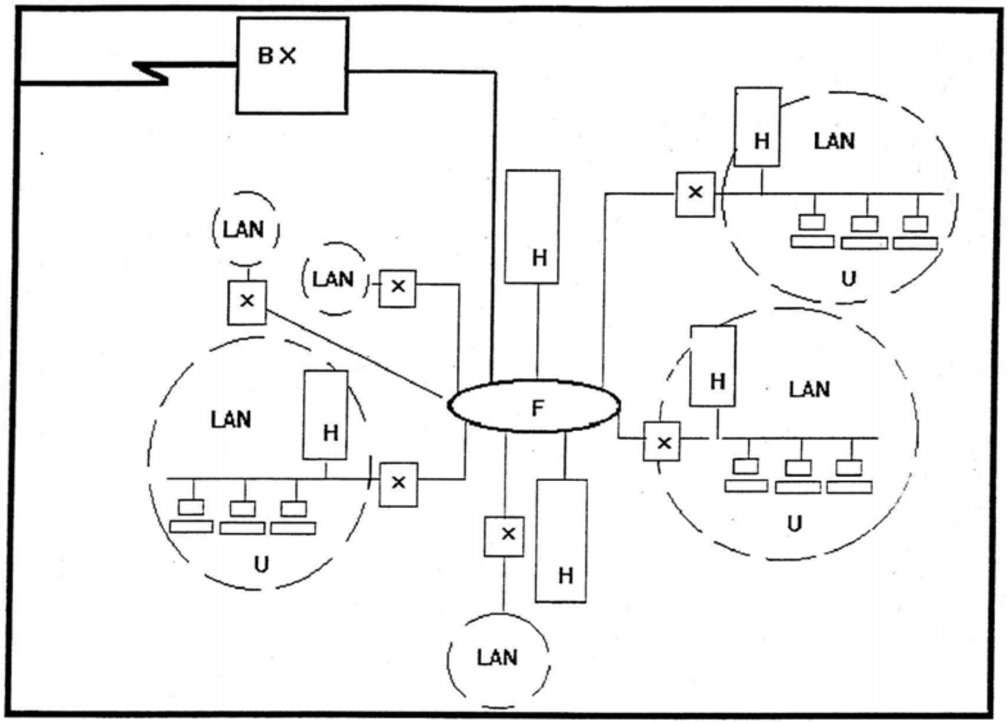


H=host computers   *X*=routers
U=user computers   F=backbone (FDDI)

Figure D. includes the border router (B*X*) that is the switching computer which connects the LAN to Wide Area Networks. In other words, the border router sends the entire local network data traffic on its way to the rest of the world through long-distance wires[9] to its next switching computer station (router), a Regional or National Network. At this level and beyond, the basic structure of the network system is the same throughout the international level.

[9] These wires are usually leased T1 or T3 circuits. T1 has a bandwidth of 1.544 megabits per second. T3 is much faster, equivalent to 28 T1 circuits, providing a total bandwidth of 44.736 megabits per second.

Figure D: Border Router



H=host computers *X*=routers
U=user computers F=backbone (FDDI) B*X*=border router

In its design as a network of networks, the Internet is not hierarchical. Although it can be described as proceeding in scale from local to regional to global, there is, in fact, no top level to the Internet. A message between two points does not need to travel "up" a hierarchy until it finds a connection which both points share. Rather, there are potentially multiple paths that connect any two points. Having multiple transport paths allows a network to adapt to and survive congestion and even total interruption (depletion) of service at various places in the network. The good news is that there is usually no single point of failure in the Internet. The bad news is that there are multiple points of failure, congestions and depletion -- each of which may be under the management or control of a different actor. And just as there is no top level to the Internet web, there is also no highest authority in its management.

Rules and the Decision-Making Arrangements

Analysis of the decision-making arrangements governing resources involves three types of rules: constitutional, collective choice and operational.[10] In the technology infrastructure commons these are often difficult to unravel or identify because many of the rules have been

[10] The constitutional rules pertain to those made outside the resource group which determine who may participate in collective choice decisions and the operational rules; collective choice decisions are made within the group pertaining to the management of the resource; operational rules concern the day-to-day

embedded in the technology itself. The creation of the Internet resource itself was enabled by the agreement of protocol standards of computer architectures, systems and software. Piscitello and Chapin (1993: 54ff.) provide an insightful view of the dual-roles played by protocols as physical structures (syntax) and decision-making arrangements (rules).

Most of the constitutional rules affecting the Internet technology infrastructure are and have been made on the global level. The "external" governance of the networks is usually described as a cooperative endeavor among providers of the many networks of the larger network (Lynch and Rose: 13). The decision-making arrangements at the National / International (global) level would be particularly interesting to study in relation to their agreement/conflict resolution mechanisms. One example of an external decision-making group is the Internet Engineering Task Force (IETF), an international group of technologists and information specialists. This group is comprised of volunteers and representatives from international organizations, governments, private corporations, local network management, and the general public sector. Since 1992, the IETF is managed by the Internet Society (ISOC)[11] and overseen by the Internet Architecture Board (IAB). The IETF is divided into eight functional areas: Applications, Internet, Network Management, Operational Requirements, Routing, Security, Transport and User Services. Each area has several working groups. A working group is a group of people who work under a charter to achieve a certain goal. That goal may be the creation of an Informational document, the creation of a protocol specification, or the resolution of problems in the Internet.

A study of the predominantly successful decision-making bodies of the Internet could be enlightening to other international arenas where cooperation and agreement are scarce commodities.[12] A method of reaching agreements by the IETF is the *RFC* (Request For Comment) papers (borrowed from earlier CCITT decision-making procedures) which are proposals written by a working team or group and distributed to members for collaborative input. All of the IETF RFCs are available on the Internet.[13] RFCs have become so successful as a method of communication, examination and arriving at consensus, that the term and the method are being adopted in other arenas.

When technology infrastructure rules are made, their language is often expressed as protocols. **Protocols** are standards, implemented as programs, which allow computers to communicate with each other in a network. The most basic protocols for intercommunication on the Internet are the TCP/IP protocol suites.

The programming of **routers** at the local, regional and national levels exemplifies collective choices of groups to manage their resource at hand. Consequently, routers play a particularly important role in the decision-making arrangements of the technology infrastructure. In a

---

operations made by the participants. See Oakerson (1992), Tang (1992), Ostrom & Ostrom (1978), and Ostrom, Gardner and Walker (1994) for more complete discussions of types of rules.

[11] The Internet Society (ISOC) was formed in 1992–"concerned with growth and evolution of the Internet worldwide, with the way in which the Internet is and can be used, and with the social, political, and technical issues which arise as a result." (Malkin, 1994:4)

[12] See Piscitello and Chapin (1993: 13ff.) for a thorough description of open systems standards procedures of the International Standards Organization, International Telecommunications Union (formerly CCITT), IETF, and other Internet standards organizations.

[13] IETF RFCs are available at http://www.ietf.org/rfc.html

scarcity-based or competition-based model of wire capacity (i.e., as the resource becomes congested), many decisions that affect performance are at the hands of individual users or groups of users. Routers can be programmed to directly influence the performance of the network by rationing and prioritizing use.

Most of the operational rules at the LAN level concern the provisioning and appropriation of the local resource. At this level, decisions are often made by committees or individuals. Many of the provisioning decisions are made by technologists who have titles or roles like “network manager” or “system administrator.” These technologists typically decide, for instance, what kind of wire, with what capacity, is used in a network.

They also determine or influence decisions about how many and what kind of computers to connect to a segment of wire in the network. Some of the rules made are quite specific to the local situation and determined by objective factors such as the number of users, the capacity of the host computers and routers, the amount of bandwidth. Types of operational rules may be quotas based on projected use and competition for the resource in an attempt to provide equitable access.

As competition for the infrastructure increases, so does the need for rules. Many of the problems brought about by congestion have, at times, been solved by implementing quotas and limiting access. Often, however, the solution to congestion is to simply expand the amount of bandwidth and the switching capacity (a budgetary decision). But the rules in use here are generally limited to institutional arrangements for the size and capacity of the system at hand. As soon as capacity increases, the rules are often modified to adapt to the new level of performance. The difficulty in examining the operational rules of the technology infrastructure commons is the frequency with which new technology is implemented and the effect these changes have on the carrying capacity of the network resource. While quota, restriction or provision decisions may be made by the Internet provider, Internet users also make decisions which affect the network resource and its availability.

Attributes of the Community

There are two main categories of actors involved: Internet providers and Internet users. The Internet providers in the technology infrastructure commons are the groups of information technologists and network managers who work on a daily basis to provide the hardware, software and technology infrastructure to allow users to readily access the networks. These providers are the resource "experts" who have much more knowledgeable perspectives on how to maintain and sustain the resource than the users. The users comprise the large majority of the community. Their interest is in receiving network access, speed and quality service with little awareness about the local resource as a whole or the role they play. Most users do realize, however, that reciprocal arrangements of speed and access are a common benefit in the resource.

Patterns of Interaction at the Technology Infrastructure Level

While use of computer technology develops rapidly, the infrastructure often does not keep pace. Much of the technology used in networks originally assumed an abundance-based model when it was designed. Developers of the networking system, Ethernet, for example, assumed that there would be plenty of bandwidth, and that collisions (two packets attempting to use the same wire at the same time) would be rare. Ethernet, therefore, has no priority-setting or rationing mechanisms. Ethernet also functions on the developers' assumption that all computers on a network segment would have a fair distribution of use, with approximately the same capacity to send and receive data. Now individuals with very fast computers can challenge that assumption by putting more packets on the wire faster than anyone else, thus suddenly skewing the distribution of the resource.

As the Internet grows, more and more concern is being paid to possible monitoring and sanctioning methods–how to program routers, for instance, to monitor appropriate and fair use (interrelated to the content or information resource). At present, there are many cases of free riding at the technology-infrastructure level. Multi-media applications, for example, can use a tremendously large portion of the bandwidth from the available pool. Already, though, international registration of real-time video conferences (Mbone) is a norm, with sanctions to disallow conferences that are not registered.

Outcomes

There are a number of outcomes at the global level of the technology-infrastructure commons which are causing dilemmas for network managers and providers. The examples of some of these problems mentioned here would benefit from a study (by a network technologist) of CPR design principles. A particularly detailed discussion of these problems can be found in Chapin (1993).

Because of the rapid increase in congestion, and the increased use of the TCP/IP protocol suite, routers at the NAP level are having a harder time meeting the demand. In the process of filtering and routing traffic, they must read through more than 30,000 IP addresses for each packet sent through. A cooperative effort among network technologists is underway to deal with this appropriation problem: Classless InterDomain Routing (CIDR) protocol which will aggregate IP numbers so that the whole number need not be read at the NAP level. But as with all cooperative, non-sanctioned measures, there are early cases of free riding -- sites which refuse to aggregate their numbers, which frustrate the progress.

Assignment problems are being discussed by Internet groups more and more frequently. The Internet will eventually (within 10 years) rwn out of IP numbers–the unique addresses given to each host computer on the network. Consideration is being given to short-term solutions of rationing and recycling the limited resource of IP addresses. Longer-term solutions to revise the IP protocol itself will eventually increase the number of possible IP addresses.[14]

The need to aggregate IP numbers or to conserve the shrinking pool of available IP addresses are long-term outcome problems which must be addressed at the global level. But at every level, global to local, the most critical problem of interest to users of the technology-infrastructure facility is the effective resource flow of the wires -- the ability of the network to transport information and enable rapid communication.

2. The Organizational Budget Commons

[14] IP addresses are numeric strings, and increasing the number of digits in the string will increase the number of unique addresses possible.

The “budget commons” encompasses the organizational economic resources concerned with the provision of networked information and its technology. At some level, of course, all Internet resource domains are built on budget arrangements. But this economic resource facility does not follow the local-to-global path that the technology-infrastructure has been shown to follow.

Indeed, common pool resource problems and characteristics exist primarily at the *local* level. The CPR system resides within individual organizational structures which fund computer technology. The commons nature of the budget is particularly evident in educational organizations which are increasingly dependent upon networked information resources. At the global level, the Internet is more predominantly affected by market forces: pricing, competition among wholesale and retail network service providers, etc.

All educational institutions are faced with what Association of Research Libraries (ARL) president Jerry Campbell refers to as the “technology pie collision.” The economic demands for new technologies are taking a larger and larger chunk out of traditional educational budgets. When network technologies are expanded, other (traditional) pieces must be carved out of the pie. The tendency with many budgets is to take more and more slivers out of other pieces of the pie to accommodate the technology piece. Campbell makes a plea for educators and information providers to carefully reconsider the total budget. The assumption that people want more and more information *regardless the cost* may not be true.

This tendency to keep meeting the demands of technology relates closely with the problem of chronic congestion (rivalry + depletability) in respect to the provision of the Internet. A characteristic of the Internet, unlike natural resources, is that when the local resource becomes congested, resource managers have the ability to replenish the resource by expansion of the technology capacity. And unlike other man-made resources, such as highways, resource capacity on the Internet can be increased in days or weeks instead of months or years. If the bandwidth is too slow, more bandwidth can be made available. Larger routers, better switches, etc. can be purchased. Depletion need only be temporary—until budgets are adjusted to provide new technology to supply the demand.

The problem of competition for an organizational budget brought on by the dramatic rise in the demand for networked computer technology is only one area of the growing field of Internet economics. [15] New pricing schemes and mechanism designs as economic measures to ensure equitable and efficient use of the bandwidth and carrying capacity of the networks are being actively discussed and debated (see MacKie-Mason and Varian 1994b; Parris, Keshav and Ferrari, 1992; and others). The transition from “connection pricing” in which organizations pay an annual fee for a fixed-bandwidth connection, to other priority pricing schemes will inevitably affect organizational budgets even further.

To add to the complexity of this budget commons is the fact the Internet is perceived by many as a public good.[16] The call for “a laptop in every household” does much to encourage this thought.[17] And, indeed, much of the information available is, and is likely to remain, a public

---

[15] Some of the most useful analysis in the area of the Internet budget commons has been done by economist Hal Varian. His article with MacKie-Mason "Economic FAQs About the Internet" discusses many issues of importance to the budget commons.

[16] See Rose 1986 for an excellent legal history of “publicness.”

[17] Common political rhetoric includes such soundbites as "universal service." Vice-President Al Gore's speeches on the National Information Infrastructure typically wax enthusiastic about the public "goodness" of the Internet. *The effort to build the GII [Global Information Infrastructure] provides us with an*

good. But great confusion exists about what is public and what is private (and subject to pricing). The metaphor “information superhighway” sounds like a public road, interstate or

international highway built with public funds and upon which all can drive for free, granted they have a car to drive. This highway, however, is not built with public funds. It is, and will continue to be, privately built. In the U.S., the federal government role will primarily be one of research funding and communications regulations.

Physical Attributes

Financial resources are deeply nested in the structure of an organization. Using an educational organization such as a university as an example, the budget path would travel in a vertical direction: University budget--->campus--->schools--->departments--->areas--->subareas, etc. The shared resource is the total budget and its multiple component budgets. In the case of local Internet provision, multiple, competing subbudgets contribute to the building and the sustaining of the resource. The resource unit in this commons is money.

Considering that budgets usually reflect a history of choices, a close examination of the open and hidden budgets supporting local area use would be illuminating for most educators and administrators. The budget resource funds the technical infrastructure, hardware and software of both providers and users, technology education, publications, staff, research and innovation, membership fees, leasing fees, etc. Because of the exponential growth of the Internet and the rapid increase in users and high-speed technology, it would be helpful to have a better understanding of traditional educational budgets for teaching, libraries and educational resources, buildings, staffs, etc.

Community Attributes

Continuing with the example of a university, the community of this commons includes those people authorized to spend money. This community reflects the hierarchy of the budgetary process and can include state legislators, university administrators, and account managers of the sub-budgets and all those who have a vested interest in the success of educational resources. The large number of users are also concerned with successful access and use of the networks. And they can exert an influence on the fund allocators. In that way, the users may also be considered part of the budget commons community.

Rules

Because of the rapid growth of the use of networked information, it is difficult to track the rules affecting the budgetary allocations for this resource. One trend seems to be typical in relation to technology funding within organizational budgets. As the ubiquitous need and acceptance of information technology grows, the increasing costs of the infrastructure are being absorbed by more and more areas of the overall budget. A university computing center, for instance, which formerly supplied most of the organization's technology needs, now may only supply as much as 25% of the total university technology budget, with the rest being provided by other departments. This trend over the past 15 years is a further example of the “technology pie collision.”

Rules pertaining to the organizational budget can be both centralized and decentralized (resulting in different outcomes). For instance, a centralized budget rule might be that all

---

opportunity to reach beyond ideology to forge a common goal of providing an infrastructure that will benefit all the citizens of our nations (Gore 1994).

students must pay a technology fee each semester regardless of whether or not they are active Internet users. One of the questions to be asked is whether technology budgets are distributed as general allocations (decentralized) or designated for specific or restricted purposes (centralized). Decentralized spending requires coordination. Centralized spending lacks the freedom of discretion. Many educational organizations abide by the rule of providing baseline

service -- a guaranteed level of service, speed and access to everyone. As the number of users grows, however, it takes more and more money to guarantee the same level of service to all.

Rapid growth and demand for new information technologies are likely to cause rapid changes in the decision-making processes. In academic libraries, for instance, the two main criteria for fund allocations for collections were formerly to: (1) meet contemporary teaching and research needs of the academic community and (2) provide for future needs of scholars and researchers. Suddenly, with the rise of networked information (as well as the rise in publication costs and decline in budgets), priority is given to accessing information rather than collecting it. In higher education, as well as in many other educational and corporate arenas, the use of innovative technology is more readily funded than scholarly content.

Patterns of Interaction

The effect of all sub-budgets within the university partially supporting use of the Internet may highlight the commons aspect of budgets. Free riding occurs when some budgets support more and faster computers without allocating funds for faster network facilities, which can cause congestion of the resource. In addition, differences in local (schools, departments, divisions, etc.) university decisions about technology budgets create non-uniformity in availability of or access to Internet resources. In other words, all the users of this resource share the same roads and highways, but the number and types of "vehicles" (i.e., size of packets created by varying hardware and software applications) vary dramatically and greatly affect the load and traffic levels. Finally, the relative shift from centralized to decentralized funding of technology is the cumulative result of many individual/departmental budgetary decisions. In the main, this shift increases the technological capabilities (e.g., the number and speed of computers) of network resource users faster than the central budgets of network service providers are expanding the capacity of the network.

Outcomes

The process of allocating funds for technology and networked information in a large organization like a university is a great balancing act. In the early years of networking, allocations were made in anticipation of demand. In other words, technology infrastructure resources were overprovisioned, with more than ample bandwidth, for instance, for the number of users and types of use. Given the rapid growth in use, allocation and provision are now instead chasing demand, trying to keep up. Resource replenishment now frequently occurs after depletion (chronic congestion) outcomes are experienced. Such depletion outcomes as routing queues, dropped packets, decrease in response time, and inaccessibility can occur suddenly and unexpectedly.

3. The CPR Characteristics of Shared Information on the Internet

Loosely defined, the "information commons" is the amorphous, rapidly growing collection of digitized data available on the Internet. At its best, this information is the scholarly and cultural record of human society. At its worse, it is an electronic landfill of useless data. This facility of the Internet, like the social community discussed later, is more difficult to define as a complete

CPR "system." Yet descriptions of CPR problems in the information and social realms are appearing in the literature more and more frequently.

Information as a commons is particularly problematic since information is usually identified as a public good, with no subtractability or exclusion factors. Historically, however, whereas much information may have been a public good, the management and provision of it has not.

Management of information has been in the hands of information specialists: librarians. And provision of scholarly information has been controlled by publishers, editors, and peer-review scholars, as well as market forces.

Unlike printed information which is highly distributed and very robust, a large amount of networked information is stored in a central location with its accessibility (or inaccessibility) subject to market failure, changes in policies (as is often the case with government information) or individual whim (see C. Lynch 1994). But in spite of the *centralized* storage of information, there is also great duplication and *decentralization* of information available from one Internet site to the next, but with no guarantee that one copy is the same as another and no way to determine if any single copy is authoritative or if it has been corrupted. Consequently, much valuable information available on the networks today is vulnerable: it can be available one day and be withdrawn from public access the next. The volume and ephemeral nature of important information, such as bibliographic databases, court records, etc., have redefined the roles and responsibilities of information managers and providers.

The main resource problem of the information commons is one of **pollution,** both in terms of inaccurate and unreliable data and in the overprovisioning of useless data.

Physical Attributes

The information commons is made up of the stored, sent and retrieved data on and via the Internet. It overlaps with and, at times, has parallel issues with the technology-infrastructure, budget and social commons, but the resource facility of the information CPR is the provision, management and retrieval of information on the Internet. The types of information are endless: research papers, government documents, library catalogs, full-text books, encyclopedias and other reference materials, bibliographic databases, articles, journals, reviews, newspapers, opinions, letters, games, movies, maps, weather reports, digitized images (from personal photographs, to art masterworks to pornographic photos).

The amount of information on the Internet increases literally by the minute. The content is in constant flux and, indeed, no one can have a clear idea of the amount, breadth and scope of information which is available on the Internet at any one time. The sheer volume of the information produces a multiplicity of problems, such as finding the desired information (as opposed to making do with the information at hand) or competing for access to information sources. Accessing information stored in some formats (such as audio or motion video images) may also require new software, hardware, and greater network capacity.

Community Attributes

The community in the networked information commons consists of information users and accessors -- those who read and retrieve documents from the World Wide Web, Gopher, newsgroups, FTP sites and so forth; information providers—those who formally or informally publish the whole gamut of information types on the Internet. It also includes information managers (librarians, technologists, etc.) who try to provide useful access to desired information. This community can be local but the majority of information access by any one user is remote and, therefore, on a global commons level.

Rules in Use

Rules and policies regulate the provision of electronic information. But even traditional information managers and providers (librarians, network technologists and managers) have difficulty handling the present information glut. Within an organization, decisions are usually

made by assigned groups or individuals (shaped by budgetary allotments) about many of the information resources available to users.

Rules are made about the optimal management and presentation of information by local and global collaborative groups of specialists (such as the IETF). These new partnerships combine specialists from various disciplines to help identify needs and priorities, share expertise, and collectively engage in information provision and management.

Rules about information selection to offer on a network may be made by local information specialists, scholars, or by the network service providers themselves. Rules of access (allocation rules) may be made by information specialists, often to comply with copyright or licensing restrictions on the information, or by network service providers, perhaps to manage or conserve network resource capacity. Rules of responsibility are the least well-formed and most difficult to monitor and sanction. Much current research is focused on what might comprise an adequate set of descriptive information *about* networked information resources.

Patterns of Interaction

The capacity for every Internet user to publish his or her own information requires the assumption of responsibilities which are often ignored. Without *enforceable* rules, information is frequently mounted on the network without authorship, dates, or citations. Electronic books are frequently mounted on the Internet without publisher, translation or edition information. Many of these problems are in part due to lack of cataloging or other descriptive standards for networked information. Or they may be due to ignorance, defiance, lack of time or indifference.

The type of information problems vary according to the network application. Unsolicited advertising, for instance, can be a form of information pollution on electronic mail or Listserv groups because of the actively intrusive nature of e-mail. Advertising poses less of a problem for more passive applications like the World Wide Web or FTP archives.

Outcomes

The “tragic” outcomes of this information commons include both information **pollution** as well as **depletion,** in the sense of the withdrawal or disappearance of information for a variety of reasons. Congestion in the technology infrastructure might result in information that is unavailable or withdrawn: the technology cannot handle the number of users, resulting in overloaded networks. But information disappears for other reasons, related to the decision-making arrangements with the selection, management and maintenance of this information resource commons. Lynch calls for decentralized archiving of information to ensure against the "burning" of the great electronic libraries. (C. Lynch 1994)

The fact that more and more information is being made available on the Internet also means that the information resource is becoming more and more polluted with inaccurate, mislabeled, unauthorized, uncredited, undated, outdated, offensive and/or illegal information. It is often the case with full-text books which have been published electronically, for instance, that essential bibliographic information is lacking.

A cultural concern with the globalization of information is that the more local institutions rely on access to outside, centralized collections, the less unique and locally suited information resources become. Conversely, potential value can be created by the design of local electronic systems which serve specific user-needs through content, images and language. There are great opportunities to build resources of local knowledge, culture, interests and expertise.

In the information commons arena, special problems surface on both the global and local levels. These problems go beyond equitable access to (i.e., permission to use) the resource. Access to the information resource also requires that users be educated to be effective information retrievers and providers in order to adapt the resource to their needs. And, accessibility is also closely linked to the technology infrastructure and local budget facilities (from basic availability of hardware and network links, to the costs of electricity and phone lines). Selection of an information resource on the local level may have a direct budgetary impact (if there is a license fee for the resource, for instance), and a direct technology impact (if provision of the resource leads to increased congestion on the network).

4. The Internet Community: A Social Commons

Through the use of electronic mail, discussion groups, newsgroups, and interactive games on the Internet, communities of people are able to form groups and communicate with each other in new ways. It is this aspect of the Internet which seems to prompt the label "commons" more than the other three areas mentioned. University courses and scholarly papers examine the "sociology of cyberspace." Kollack and Smith (1995) provide an interesting and useful analysis of the Internet as a social commons in their forthcoming chapter “Managing the Virtual Commons: Cooperation and Conflict in Computer Communities.” Their premise is that Internet communication presents its own sets of cooperation and coordination problems. They focus on Usenet (one of the largest computer-mediated communication systems consisting of several thousand discussion groups) as an example of the Internet as a commons. Their paper provides a good summary of the conditions and types of free-riding and other types of inappropriate behavior of this resource: overuse, unacceptable language, unreliable information and so forth. When Kollack and Smith, however, state that *the key common resource is not an open pasture, but bandwidth,* (p.8) they illustrate the problem of analyzing the Internet as one homogenous resource. Posting the same message five times does, indeed, waste bandwidth and consumes storage space. On a limited basis, however, this is not an overwhelming problem from the technical perspective. The real problem is the infringement on the **limited capacity of human time and attention,** which is considered by some economists as *the scarcest and hence most valuable commodity* (See Gross and Coy 1995: 80+). In other words, when messages sent to the community are too long or inappropriate, the transaction costs–inefficiency of time–become too high for most users. These types of problematic outcomes are ones of resource **pollution** and lie in the realm of the *social* commons.

The Community of Users

The community of users in the social commons are all those who actively (send) or passively (read) messages on the Internet. The ability for people to communicate without limits on geographical, class, race, national or political boundaries creates a new social phenomenon in human civilization. It enables and empowers through participation, so while social, it is also a powerful political tool. It also enables invasion of privacy, rude or aggressive verbal behavior (flaming), junk mail, and can be an enormous waste of time.

Physical Attributes

The physical attributes of the social commons are the *messages* exchanged among the community of users. It includes groups or communities of users who remain entirely or semi-autonomous but engage in the activity of logging onto the Net and exchanging messages. The type and amount of communication affects the technology infrastructure, but it is a different

shared resource. The physical characteristics can be one-to-one communication, one-to-many communication, and many-to-many communication.

Some discussion groups are passively stored—i.e., participants only receive the messages they select, as with usenet groups. When the communication is active with each message sent directly to all participants, the messages are more intrusive or demanding of the user's attention, and the enforcement of rules becomes more necessary.

Rules in Use

The rules established for membership behavior in the social commons are referred to as ***netiquette***. Many summaries of these rules are available on the Internet. Often, discussion groups will send them automatically to new subscribers. These rules start with: "Remember the human" (i.e., remember that through this machine in front of you, you are engaging in a human interaction). They emphasize ethical behavior, use of the Golden Rule and some of the consequences of that behavior in the virtual environment. (See Shea 1994)

For the most part, one-to-one communication is still considered an unregulated area of the Internet. Anyone can send a message to anyone else with a correct address. The use of mail-filters (programs that automatically discard e-mail messages based on the sender or the subject) is a partial technological solution (Kollack and Smith, 1995: 14). Monitoring and sanctioning on both the local and national levels are becoming more and more frequently applied (such as "sting" operations by the FBI).

One-to-many communication may also be regulated in the following ways. Regarding rules of membership, members may subscribe and unsubscribe to a listserv/discussion group at will, and requests to subscribe may be filled automatically or requests may be first reviewed and approved by a list-owner or list-moderator. Also, discussion groups may require specific criteria for membership. Regarding rules of member participation, the ability to post messages to a discussion group may be restricted to subscribed members, or open to anyone. And, messages posted to a discussion group may be reviewed and approved by a list-owner or list-moderator, or be distributed automatically to all group members.

Rules of membership, such as those in closed groups, and rules of participation, as in monitored groups, may provide the mechanism to monitor and sanction communication in this arena. But, the technology and method of doing so typically vests this authority in a single individual who is expected to act "for the good of all," though his or her decisions are themselves unmonitored.

Patterns of Interaction

Adherence to rules such as civility, relevance or brevity is ensured mainly by use of the honor system. Sanctioning mechanisms often include peer pressure -- verbal recriminations against the sender of the offending message. Seabrook (1994) describes the gamut of rule-breaking, anti-social behaviors possible over the network. After being flamed (verbally insulted) the author observed:

> *...I had assumed, without really articulating the thought, that while talking to other people through my computer I was going to be sheltered by the same customs and laws that shelter me when I'm talking on the telephone or listening to the radio or watching TV. Now, for the first time, I understood, the novelty and power of the technology I was dealing with. No one had ever said something like this to me before: in any other medium, these words*
>
> *would be, literally, unspeakable.* (p.71)

A particular dilemma for this ungoverned, anarchic community is educating all the community members (such as subscribers to an electronic discussion group) about the rules of behavior. This situation is not unique to the electronic environment, but rather, true of all social groups. This task, however, is much more difficult in an anonymous environment. In a broader context, Vincent Ostrom (1991: 14) writes about the fundamental need for shared understandings of rules:

> *Since the rules of associated relationships are not self-formulating, self-applying, and self-enforcing, people need to share a common vision (understanding) and know what they are doing as they set the terms and conditions of associated relationships. Setting and maintaining these terms and conditions is the critical issue in the constitution of democratic societies. Knowing how to act appropriately to diverse situations is fundamental to a democratic way of life.*

The most serious cases of social transgression in the commons combines (anti)social behavior with technological expertise: electronic vandalism, which includes the intentional transmission of computer viruses onto the network, and computer hacking: the unlawful breaking of a security system to enter (and damage or destroy) private computer databases, files and records. These are recognized crimes, however, and are punishable by the standard legal system.

<u>Outcomes</u>

An important attribute of this commons is the time and attention of the community of users. The issue of subtractability is variable and, at times, obscure. A message from one user on a Listserv, for instance, is usually a positive externality. Contributing to the forum discussion can add richness and variety and increase the size of the community. On the other hand, misuse of the posting of messages (too lengthy, irrelevant, redundant, etc.) subtracts from the time and attention of the group and from the general quality of the communication. In some cases, Listserv discussion groups fail and are discontinued. In other cases, the amount of traffic in the group causes users to sign off the list.

When the social commons functions well, it brings together new communities of people who can share their interests, thoughts, expertise, problems. New avenues of communication are opened up, bringing with them possibilities for better understandings and shared visions. Both the successes and failures of the social commons frequently appear as feature stories in the press: Home-bound senior citizens who are “virtually” able to socialize again; happy couples who have met in an Internet discussion group; K-12 students who learn directly about foreign cultures through Internet penpals; a heart-attack victim's life saved through the quick action of an e-mail correspondent. Conversely, the media abounds with stories of loner hackers, virtual rapes, network pornography, and gross breaches of confidentialities.

The social commons, specifically those defined by membership in a group (such as a listserv), can be thriving sites of communication among members. Or, such groups may fail, whether through disuse (too few messages of interest), overuse (too many messages consuming too much time and attention), or inappropriate use (too many irrelevant or offensive messages).

Conclusion

There is much to be gained in studying the Internet as a set of new common pool resources. Because of the multi-level complexity of this resource, however, the Internet must not be examined as a homogenous whole but rather be broken down into well-defined resource facilities, to understand more deeply the nature and outcomes of this gargantuan shared resource. The boundaries of the resource at hand must be clear. The IAD framework, as well as the CPR design principles, can be especially useful in this endeavor.

Much has been omitted from focus: the impact of Asynchronous Transfer Mode (ATM), as well as other high-speed technologies, on local infrastructure, information access, social interactivity and total budgets; the issues of security, confidentiality, privacy, and the future of the democratic process of information exchange. A study of the impact and ramifications of encryption technology on equity, accessibility, and privacy would fit well into this discussion. And the impact of electronic information on institutional change within education and other spheres of contemporary life is of major importance.

In the end, is concerted research of the Internet as a common pool resource important? Overwhelmingly, it must be. The technology infrastructure commons is developing at a rate that, without close understanding of the interconnections of greater bandwidth, faster computers, and increased number of users, informed decisions about the future cannot be made.

The budget commons presents the growing dilemma of making economic choices in the broader framework of general educational (or business, community, etc.) goals. The social commons requires new ways of establishing trust and civil behavior in an anonymous environment. The information commons has the capacity to replace library buildings, classrooms, and traditional halls of learning with a grab-bag mountain of unsifted data. Will it ever offer the knowledge and tools for learning that have been available historically in hard-copy form? The momentum is moving more and more quickly toward electronic and shared information. Better communication and greater understanding of the rules and patterns of interaction must be met. Monitoring and sanctioning methods are primitive to nil at date, although some methods are in the process of being developed. Will they be effective?

Because of the potential importance of this resource – access to information at its most basic level -- and the complexity of the resource, concerted efforts need to be made to share understanding and expertise in the enterprise of interdisciplinary analysis. The simultaneous trends of centralization and decentralization of networked information and the dichotomy of the appearance of publicness with the reality of increased privatization are representative of the complex nature of this resource. It is clear that the successful development and maintenance of the Internet will necessitate much better communication and more active collaboration efforts between educators, librarians, economists, technologists, government and corporate leaders, and the growing body of users in order to sustain and continue to reap the benefits of this resource.

References

Barlow, John Perry. 1994. “Forward.” In: Ruten, P., A.F. Bayers and K. Maloni. *Net Guide*. NY: Random House.

Berkes, Fikret, ed. 1989. *Common Property Resources; Ecology and Community-Based Sustainable Development.* London: Belhaven Press.

Berners-Lee, T. et al. 1994. “The World-Wide Web.” *Communications of the ACM,* 37,8 (August):76-82. http://portal.acm.org/citation.cfm?id=179671

Blomquist, William. 1992. *Dividing the Waters: Governing Groundwater in Southern California.* San Francisco, CA: Institute for Contemporary Studies Press.

Bose, Anuradha. 1995. “Garbage as a Commons? The Case of Calcutta.” Presented at the fifth annual meeting of the International Association for the Study of Common Property, Bodø, Norway, May 24-28, 1995.

Bowman, C. Mic et al. 1994. “Scalable Internet Resource Discovery: Research Problems and Approaches.” *Communications of the ACM,* 37,8 (August):107-107. http://portal.acm.org/citation.cfm?id=179606.179704&coll=GUIDE&dl=GUIDE&CFID=687394&CFTOKEN=27258663

Campbell, Jerry D. 1994. “Key Issues Affecting the Management of the Networked Organization.” Synergy Session. Fall 1994 Meeting of the Task Force of the Coalition for Networked Information, Orlando, FL, November 29-30, 1994.

Catlett, Charles E. 1993. “Internet Evolution and Future Directions.” In: Lynch, D.C and M. T. Rose, eds. *Internet System Handbook.* Greenwich, CT: Addison-Wesley.

Cerf, Vinton. 1994. “Guidelines for Conduct On and Use of Internet.” Internet Society http://www.isoc.org/internet/conduct/cerf-Aug-draft.shtml

Chapin, A. Lyman. 1993. “The Billion-Node Internet.” In: Lynch, D.C. and M.T. Rose, eds. *Internet System Handbook.* Greenwich, CT: Addison-Wesley.

Claffy, Kimberly C., H.W. Braun and G.C. Plyzos. 1994. “Tracking Long-Term Growth of the NSFNET.” *Communications of the ACM,* 37,8 (August):34-45. http://portal.acm.org/citation.cfm?id=179616&dl=ACM&coll=portal

Davidson, Robert P. 1994. *Broadband Networking ABCs for Managers; ATM, BISDN, Cell/Frame Relay to SONET.* NY: Wiley.

Dowling, Sherwood A. 1994. “Information Access: Public Goods or Private Goods?” *Social Science Computer Review,* 12,3 (Fall) 333-350.

Eidnes, Havard. 1994. “Practical Considerations for Network Addressing Using CIDR.” *Communications of the ACM*, 37,8 (August):46-53. http://portal.acm.org/citation.cfm?id=179606.179622&coll=GUIDE&dl=GUIDE&CFID=687394&CFTOKEN=27258663

Feeny, David. 1995. "Optimality, Sub-optimality, Nirvana, and Transaction Cost: Foraging on the Commons." Presented at the fifth meeting of the International Association for the Study of Common Property, Bodø, Norway, May 24-28, 1995. http://dlc.dlib.indiana.edu/archive/00002119/

Gibbs, W. Wayt. 1994. “Software's Chronic Crisis.” *Scientific American,* 271,3 (Sept.):86-95. http://selab.csuohio.edu/~nsridhar/teaching/fall06/eec521/readings/Gibbs-scc.pdf

Gilster, Paul. 1993. *The Internet Navigator*. New York: John Wiley and Sons.

Goffe, William L. 1994. “Computer Network Resources for Economists.” *Journal of Economic Perspectives,* 8,1 (Summer):97-119.

Golich, Vicki L. 1991. “A Multilateral Negotiations Challenge: International Management of the Communications Commons.” *Journal of Applied Behavioral Science,* 27,2 (June): 228-250.

Goodman, S.E. et al. 1994. “The Global Diffusion of the Internet: Patterns and Problems.” *Communications of the ACM,* 37,8: 27-31. http://portal.acm.org/citation.cfm?doid=179606.179733

Gore, Albert. 1994. “Remarks (as delivered) by Vice President Al Gore via Satellite to the International Telecommunication Union Plenipotentiary Conference, Kyoto, Japan, September 22,1994.” http://web.simmons.edu/~chen/nit/NIT'94/94-Gore-Kyoto-379.html

Gross, Neil and Peter Coy. 1995. “The Technology Paradox: How Companies Can Thrive and Prices Dive.” *Business Week* (March 6):76-84. http://www.businessweek.com/1998/35/z3414001.htm

Greenwald, Jeff. 1994. “Wiring Africa.” *Wired* (June): 60-62. http://www.wired.com/wired/archive/2.06/africa.html

Hardin, Garrett. 1968. “The Tragedy of the Commons.” *Science,* 162 (Dec. 13): 1242-1248. http://dieoff.org/page95.htm

____________. 1994. “The Tragedy of the Unmanaged Commons.” *TREE,* 9 (May):199.

Herzberg, Roberta. 1990. “When Does a Budgetary Commons Become a Tragedy: Evaluating Budgetary Reform in the U.S. Congress.” (Workshop in Political Theory and Policy Analysis Working Paper).

Hess, Charlotte. 1994a. *Common-Pool Resources and Collective Action.* Vol .3. Workshop in Political Theory and Policy Analysis, Indiana University. Vol 3. (no longer available online. See instead: http://dlc.dlib.indiana.edu/cpr/index.php

_____________. 1994b. “Institutional Analysis and Development Framework: A Bibliography." http://www.indiana.edu/~workshop/wsl/iad.html

____________. 1995. “The Virtual CPR: The Internet as a Local and Global Common Pool Resource.” Presented at the fifth annual meeting of the International Association for the Study of Common Property, Bodø, Norway, May 24-28, 1995. http://dlc.dlib.indiana.edu/archive/00002236/

Kahn, Robert E. 1994). “The Role of Government in the Evolution of the Internet.” C*ommunications of the ACM,* 37,8 (August): 15-19. http://www.nap.edu/readingroom/books/newpath/chap2.html

Kelly, Brian. 1994. “Becoming an Information Provider on the World Wide Web.” *Internet Society News,* 3,1:20-24.

Keohane, Robert O. and Elinor Ostrom, eds. 1995. *Local Commons and Global Interdependence; Heterogeneity and Cooperation in Two Domains.* Thousand Oaks, CA: Sage.

Kiser, Larry L., and Elinor Ostrom. 1982. “The Three Worlds of Action: A Metatheoretical Synthesis of Institutional Approaches.” In: *Strategies of Political Inquiry.* Ed. E. Ostrom. Beverly Hills, CA: Sage.

Kollock, Peter and Marc Smith. 1995. "Managing the Virtual Commons: Cooperation and Conflict in Computer Communities." In: *Computer-Meditated Communication* (Forthcoming). Ed. Susan Herring. Amsterdam: John Benjamins.
http://www.sscnet.ucla.edu/soc/faculty/kollock/papers/vcommons.htm

Krol, Ed. 1994. *The Whole Internet User's Guide and Catalog*. 2nd ed. Sebastopol, CA: O'Reilly.

Leiner, Barry M. 1993. "Globalization of the Internet." In: Lynch, Daniel C. and Marshall T. Rose, eds. *Internet System Handbook.* Greenwich, CT: Addison-Wesley.

Libecap, Gary. 1995. "Conditions for Successful Collective Action." In: Keohane, Robert O. and Elinor Ostrom, eds. *Local Commons and Global Interdependence; Heterogeneity and Cooperation in Two Domains.* Thousand Oaks, CA: Sage.

Liebowitz, S.J. and Stephen E. Margolis. 1994. "Network Externality: An Uncommon Tragedy." *Journal of Economic Perspectives.* Vol. 8, 2 (Spring):133-150.

Lottor, Mark. 1992. "Internet Growth (1981-1991)." SRI International, Network Information Systems Center, Network Working Group, (RFC:1296).
http://www.faqs.org/rfcs/rfc1296.html

__________ .1995. "Internet Domain Survey." Internet Society and Network Wizards.
http://www.isc.org/index.pl?/ops/ds/

Lowell, Gerald R. 1993. "The Bibliographic Commons." Presented at the OCLC Users Council, October 10, 1993.

Lynch, Clifford A. 1994. "Rethinking the Integrity of the Scholarly Record in the Networked Information Age." *EDUCOM Review,* 29,2 (March/April).
http://www.educause.edu/pub/er/review/reviewArticles/29238.html

Lynch, Daniel C. and Marshall T. Rose, eds. 1993. *Internet System Handbook*. Greenwich, CT: Addison-Wesley.

Lyris, Sonia Orin. 1992. Crime and Punishment in Cyberspace." In: Miller, R.B. and M. T. Wolf, eds. *Thinking Robots: An Aware Internet, and Cyberpunk Librarians.* Chicago: American Library Assoc., Library and Information Technology Association.

McCay, Bonnie J. 1992. "Everyone's Concern, Whose Responsibility? The Problem of the Commons." In: *Understanding Economic Process.* S. Ortiz and S. Lees, eds. New York: University Press of America (Monographs in Economic Anthropology,10).

MacKie-Mason, Jeffrey K. and Hal Varian. 1994a. "Economic FAQs about the Internet." *The Journal of Economic Perspectives,* 8,3 (Summer):75-96.

___________________ 1994b. "Pricing the Internet." IN: Kahin, Brian and J. Keller, eds. *Public Access to the Internet.* Englewood Cliffs, NJ: Prentice-Hall.

McGinnis, Michael and Elinor Ostrom. 1993. "Design Principles for Local and Global Commons." In: Keohane, Robert, Michael McGinnis and Elinor Ostrom, eds. *Proceedings of a Conference on Linking Local and Global Commons; Held at Harvard University, April 23-25, 1992.* Cambridge, MA: Center for International Affairs, Harvard University and Bloomington, IN: Workshop in Political Theory and Policy Analysis, Indiana University.

Malkin, G. 1994. "The Tao of IETF: A Guide for New Attendees of the Internet Engineering Task Force." Internet Engineering Task Force, Requests for Comments: 1718; FYI:17.
http://ietfreport.isoc.org/rfc/rfc1539.txt

Marine, A., J. Reynolds and G. Malkin. 1994. "FYI on Questions and Answers: Answers to Commonly Asked `New Internet User' Questions." IETF, Request for Comments: 1594; FYI: 4. http://delivery.acm.org/10.1145/rfc_fulltext/RFC1594/rfc1594.txt?key1=RFC1594&key2=0565352811&coll=GUIDE&dl=GUIDE&CFID=22082290&CFTOKEN=45037289

Martin, Fenton. 1989,1992. *Common-Pool Resources and Collective Action: A Bibliography, Vols.1-2.* Bloomington, IN: Workshop in Political Theory and Policy Analysis. Incorporated into: http://dlc.dlib.indiana.edu/cpr/index.php

Martin, Lisa. 1993. "Common Dilemmas: Research Programs in Common-Pool Resources and International Cooperation." In: *Proceedings of a Conference on Linking Local and Global Commons. Held at Harvard University, April 23-25, 1992.* Cambridge, MA and Bloomington, IN: Center for International Affairs, Harvard University and Workshop in Political Theory and Policy Analysis, Indiana University.

Mason, Richard O. 1987. "The Value of Information: Toward a Model of Values and Costs." In: Achleitner, Herbert K., ed. *Intellectual Foundations for Information Professionals.* Boulder, CO: Social Science Monographs.

Mogul, Jeffrey C. 1993. "IP Network Performance." In: Lynch, Daniel C. and Marshall T. Rose, eds., *Internet System Handbook*. Greenwich, CT: Manning. pp.575-675

Oakerson, Ronald J. 1992. "Analyzing the Commons: A Framework." In: Bromley, Daniel W.,ed. *Making the Commons Work; Theory, Practice and Policy.* San Francisco: ICS Press. Earlier version available at: http://dlc.dlib.indiana.edu/archive/00000973/

Oakerson, Ronald J. and S. Tjip Walker.1994 "Analyzing Policy Reform and Reforming Policy Analysis: An Institutional Approach." In: Brinkerhoff, Derick W.,ed. *Policy Analysis Concepts and Methods: An Institutional and Implementation Focus.* Greenwich, CT: JAI Press.

Ostrom, Elinor. 1977. "Collective Action and the Tragedy of the Commons." In: Hardin,Garrett and John Baden, eds. *Managing the Commons*. San Francisco: W.H. Freeman.

_____________. 1992. *Crafting Institutions for Self-Governing Irrigation Systems*. San Francisco: Institute for Contemporary Studies Press.

_____________ . 1990. *Governing the Commons.* New York: Cambridge University Press.

_____________. 1994. "Self-Organizing Resource Regimes: A Brief Report on a Decade of Policy Analysis." *Policy Currents; Newsletter of Public Policy Section APSA*, 4,3 (August 1994).

Ostrom, Elinor, Roy Gardner and James Walker. 1994. "Institutional Analysis and Common Pool Resources." In: Rules, Games and Common-Pool Resources. Ann Arbor: University of Michigan Press.

Ostrom, Vincent. 1991. *The Meaning of American Federalism.* San Francisco: ICSP Press.

______________. 1980. "Artisanship and Artifact." *Public Administration Review*, 40,4:309-17.

______________. 1996. "The Meaning of Democracy: The Vulnerability of Democracies." (Manuscript Draft) Workshop in Political Theory and Policy Analysis, Indiana University.

Ostrom, Vincent and Elinor Ostrom. 1978. "Public Goods and Public Choices." In: Savas, E.S., ed. *Alternatives for Delivering Public Services; Toward Improved Performance.* Boulder, CO: Westview.

Parris, Colin, Srinivasan Keshav and Domenico Ferrari. 1992. "A Framework for the Study of Pricing in Integrated Networks." International Computer Science Institute (ICSI), Berkeley, CA. ftp://tenet.berkeley.edu/pub/tenet/Papers/PaKeFe92.ps

Piscitello, David M. and A. Lyman Chapin. 1993. *Open Systems Networking: TCP/IP and OSI.* Reading, MA: Addison-Wesley.

Reinhardt, Andy. 1994. "Building the Data Highway." *BYTE* (March): 46-74.

Rheingold, Howard. 1993. *The Virtual Community; Homesteading on the Electric Frontier*. Reading, MA: Addison-Wesley.

Roberts, Michael. 1994. "Building the NII: Challenges for Higher Education." *EDUCOM Review,* 26,2 (March/April).

Rose, Carol. 1986. "The Comedy of the Commons: Custom, Commerce, and Inherently Public Property." *The University of Chicago Law Review,* 53,3 (Summer):711-781.

Rutkowski, Anthony M. 1994. "Today's Cooperative Standards Environment For Open Information and Telecommunication Networks and the Internet Standards-Making Model." *Internet Society.* http://www.isoc.org/internet/standards/papers/amr-on-standards.shtml

Sassen, Saskia. 1995. "Society, Economics and Politics–The Global City: Place, Production and the New Centrality." Presented at the 7th National Conference of the Association for Research Libraries, Pittsburgh, PA, March 29-April 1, 1995.

Seabrook, John. 1994. "My First Flame." *The New Yorker*, (June 6): 70-79.

Shea, Virginia. 1994. "Core Rules of Netiquette." *EDUCOM Review,* (Sept./Oct.)

Sheldon, Tom. 1994. *LAN TIMES: Encyclopedia of Networking.* Berkeley, CA: Osborne McGraw-Hill.

Shepsle, Kenneth A. 1983. "Overgrazing the Budgetary Commons: Incentive-Compatible Solutions to the Problem of Deficits (Discussion)." In *The Economic Consequences of Government Deficits*. L. Meyer, ed. Boston: Kluwer-Nijhoff.

Smith, Vernon L. and Arlington W. Williams. 1992. "Experimental Market Economics." *Scientific American* (December):116-121.

Soroos, Marvin S. (1995) "Managing the Atmosphere as a Global Commons." Presented at the fifth annual meeting of the International Association for the Study of Common Property, Bodoe, Norway, May 24-28, 1995.

Tang, Shui Yan. 1992. *Institutions and Collective Action: Self-Governance in Irrigation.* San Francisco: ICS Press.

Tarrow, Sidney. 1995. "Fishnets, Internets and Catnets: Globalization and Social Movements." Presented at the Conference on "Structure, Identity and Power: The Past and Future of Collective Action," Amsterdam, June 2-4, 1995.

Wildavsky, Aaron. 1979. *The Politics of the Budgetary Process.* 3rd. ed. Boston: Little, Brown.

Witbreuk, Marc.1995. "Collective Action and Regional Transport Policy." Presented at the fifth annual meeting of the International Association for the Study of Common Property, Bodoe, Norway, May 24-28, 1995.