The Virtual CPR:
The Internet as a Local and Global Common Pool Resource

May, 1995
(URLs updated June 2007)

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This paper outlines a new research agenda to study the Internet as an intricate and complex common pool resource, both on the local and global level. It identifies four different and, at times, overlapping types of commons within the Internet, each of with have distinctive properties and require different institutional arrangements: a social commons, an information commons, a budget commons and a technical infrastructure commons. Several conditions are contributing to the growing competition for this resource: every member is able to be an information provider (publisher); the number of users is rapidly increasing; many newcomers do not know or understand the rules; there is increasing competition for supporting funds of new information technologies; the technical infrastructure is not growing at the same pace as the growth in use; the introduction of resource-demanding applications (like the graphic images and hypertext linkages of the World Wide Wed) is growing rapidly; and there is poor communication and ill-defined roles among network operators, corporate owners, governing bodies and the different types of users. Indeed, the rise of these dilemmas illustrates the need for closer examination of the connections between the physical arrangements, the community of users, and the rules in use which contribute to the issues of speed and access. By studying the Internet as a common pool resource, it may be possible to understand the problems more clearly in order to arrive at sustainable solutions.

Presented at the Fifth Annual Meeting of the International Association for the Study of Common Property, Bodoe, Norway, May 24-28, 1995

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In June 1994 the Library at the Workshop in Political Theory and Policy Analysis, mounted its Common Pool Resources (CPR) bibliographies and text files electronically on the Indiana University Library gopher (**=See Glossary). The simple activity of converting bibliographies in machine readable form to ASCII** files, then linking them to the gopher system moved a local research resource to a globally shared resource. Instantly, these library resources were accessible to a large international community of people connected to the Internet.

When the new gopher server was announced at a Workshop meeting, the advantageousness of this new service was put into question. During the same period of time that the Workshop Library files were mounted on the gopher, colleagues were experiencing increasing problems in conducting laboratory experiments they were running over the Internet through a telnet** application called NovaNet**. The response time to NovaNet had slowed down considerably and, at times, users were denied access to the system. Newer applications like gopher and World Wide Web** seemed to be slowing down more traditional applications like NovaNet. As an information provider, this was a serious question which I decided to explore. Are we, in fact, in the information services, inadvertently creating competing resources? What was causing the slowdown of NovaNet? What makes good performance of the network?[1] Who makes the decisions about the development of the local Internet system? What rules and standards are in use? What factors contribute to the quality of the electronic resources? These deceptively simple questions were the seeds of this paper.

Definition

The Internet is a global network of computer networks 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 its in its nested layers of local, regional, and global regimes which shape the myriad number of interactive levels.

Brief history[2]

The Internet as such is about 25 years old, originally by the U.S. Department of Defense, and made possible by the design of open systems interface technology and specifically by

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[1] See Mogul pp.576+ for an interesting discussion of different types of performance measures of Internet systems and applications.

[2] There are many good sources for expanded histories and descriptions of the Internet. See John December's list of electronically available Internet Guides at:
http://www.rpi.edu/Internet/Guides/decemj/text.html
Gilster (1993), Krol (1994), Lynch (1993:3-14) and Leiner (1993:15-40) all provide interesting discussions of the development of this resource.

Internet Protocols (IP) and Transfer Control Protocols (TCP) which developed 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 approximately 5,000,000 host machines (Lottor, 1995) and scores of millions of people (Gilster p.13) who are technically equipped and paying (either directly or indirectly) for this information service. The number of new users is growing at exponential proportions. John Perry Barlow, co-founder of the Electronic Frontier Foundation writes: *"Some months, the number of its host machines increases by as much as 20%. If the Internet continued to expand at present rates, every human being on the planet would have an Internet address before the turn of the millennium.*"(Barlow, p.xvii). This phenomenal growth, regardless of actual numbers in 2001, is a unique factor of this dynamic resource.

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 the 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 interactive nature of the Internet has brought together new communities of people, new social groups who have self-selected themselves based on commonalities of interests, pastimes, age, gender, religion, ad infinitum. Not only has this resource produced a new type of appropriator, but the way we think about *information* has changed through the burrowing-function of hypertext links on the World Wide Web. The way we learn and teach and even think is being redefined by the phenomenon of this electronic medium. The technological needs 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: access is denied if too many users are already logged on to the local network; routing queues slow down the response time of message retrieval and provision; valuable information available one day disappears the next; searching tools are primitive and the competition for them fierce; much information is unreliable or of unknown provenance; copyright laws need to be rewritten; there are basic problems of unequal access with the creation of a cyber-elite class; the infrastructure costs are rapidly rising, 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.

This paper suggests the value of analyzing the Internet as a common-pool resource. Drawing upon the research, methodologies and literature of traditional common-pool resources such as fisheries or irrigation systems, governing bodies in the hierarchy of Internet decision-making will be better able to deeply examine this new CPR(s) and better able to create desired outcomes. It identifies several types of common-pool resources at play within this electronic network of networks. The premise is that by applying CPR design principles to this complex resource, we can better understand the interconnected institutions, rules, and communities in order to better make informed decisions and sustainable solutions. And ultimately it opens a vast and complex research agenda for future exploration by scholars.

Applying a framework

The Internet is referred to more and more frequently as a "commons" but is rarely examined methodically as a common-pool resource per se. (Roberts, Lowell, Mackie-Mason & Varian, etc.). The "commons" label usually seems to arise out of the growing concern 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 pessimistic scenario of inevitable depletion of an open-access shared resource which lacks central authority in his 1968 article "The Tragedy of the Commons." 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. 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 which are all compounded by an ever-growing competition for its use. And, of course, many of these problems do parallel those found in the sharing and maintaining of natural resources where access is left open, such as overuse, congestion, and free riding. In addition, a possible outcome is the depletion of the resource base itself: information sites which are too popular become fugitive, removed from the Internet, "victims of their own success" they cannot accommodate the demand.

On the other hand, rarely do the "commons" references in the information technology literature go beyond the Hardin scenario. What deeper study of the CPR design principles can bring is a better understanding of rules and institutional designs which are conducive to cooperation, comedy and sustainability. CPR research and literature demonstrate that tragedy need not be an inevitable scenario. Cooperation and successful situations of shared resource management are not just hypotheses but facts throughout the history of human interaction.[3]

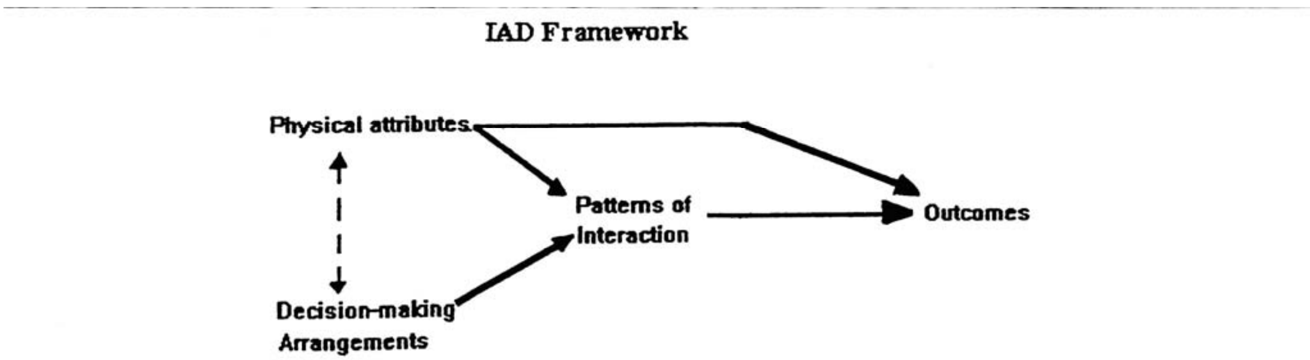
The factors contributing to Internet problems are vast and complex so that it is increasingly difficult to make informed decisions or even useful analysis without a systematic methodology. The study of CPRs has been enhanced by the application of the Institutional Analysis and Development framework developed at the Workshop and applied by hundreds of scholars and practitioners in the international arena.[4] There is much to be gained from drawing upon the method of examining the physical conditions

[3] See: Martin (1989 & 1992) and Hess (1994) for bibliographies of this literature, divided by resource type.

[4] A bibliography of works on the IAD framework (Hess 1994b) pulls together this research done by Workshop scholars. See Oakerson (1992), Ostrom (1990) Tang (1992) provide particularly cogent descriptions of this framework. Ostrom, Gardner & Walker (1993) give a useful history and expanded definitions of the framework components.

of the resource, the institutional arrangements, the rules in use, in order to create sustainable outcomes or to better understand complex problems.

Fig. 1: IAD Framework[5]



In the case of a technology resource like the Internet, applying institutional analysis can prove particularly elucidating because of the often misperceived notion 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 Attributes in order to establish a firm grasp of the scope, nature and boundaries of the resource at hand. It then connects the Decision-making Arrangements, which focus on the governance (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 donate to the common good to 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 good-will of other users, without being compliant or good-willed themselves. Outcomes display the results of the patterns of interactions upon the resource itself. Outcomes concern working-order and physical shape of the resource--i.e. if the resource is overused, leading toward depletion; if the resource is functioning efficiently or inefficiently, etc. Common dilemmas as provision, appropriation, assignment problems and technological externalities occur throughout the Internet system and are worthy of detailed examination. Drawing upon the work of Ostrom, Gardner and Walker (1993) and Oakerson (1992), these are briefly defined:

[5] The structure is taken from Oakerson (1992).

Appropriation Problems occur when user *x*'s amount of consumption of the resource subtracts from user *y*'s.
Assignment Problems occur when there are significant changes in the number of users.
Technological Externalities occur when the use of one technology handicaps the use of another.
Provision Problems occur when the supply of the resource does not meet the demand.

One of the consistent findings in CPR research is the connection between overuse and depletability with the lack of communication involved decisions makers (Ostrom 994:1). The issue of depleteability, which will be discussed further on, is an extremely interesting one in relation to information technology and worthy as a research topic in itself.

The relation between computer network technology and a fishery may not be readily apparent. The normally unsatisfactory metaphor of the "information superhighway" is helpful in this instance. 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 resource." As described above, the Internet is a network of electronic networks. In other words, the resource under discussion is, in fact, a resource 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 fact that the types, conditions, arrangements and rules for local roads differ considerably from those for interstate and intercontinental highways.

The Internet as a Good

The chart below illustrates the four main types of goods. There is often a perception voiced that the Internet was originally a public resource, funded by the government, and has recently been privatized. In fact, components of the Internet fall into each of the four categories. But it is the shared aspects of the Internet, those which fall under the common pool resource category which are the most problematic and poorly understood.

Fig. 2: Types of Goods[6]

EXCLUSION	SUBTRACTABILITY: low	SUBTRACTABILITY: high	
	public goods national defense much information on the Internet	**common pool resources** fisheries Usenet, Listservs, bandwidth, routers	difficult
	toll goods cable tv Compuserv, fiber optic cable	**private goods** bread LAN hardware	easy

Most common pool-resources have elements of both public and private ownership. Management and use of the resource is shared by a designated group. In a CPR, the amount of the available resource is limited. The use of the resource by one person **subtracts** from the amount available to others; i.e. user *x'*s use of bandwidth subtracts from the amount of bandwidth available. With CPRs it is necessary to place certain limitations on the amount of use in order to insure fair and equitable access to the resource. In the case of Internet resources this can be through quotas on the number of bytes a user may store on the host machine, limitations on the amount of time the user can use the resource. The other main quality of a common pool resource is the difficulty of **exclusion** (because of lack of clear property rights). In the case of the Internet partial exclusion is possible through required membership account. Some groups are restricted access to certain information or certain discussion groups. Technology itself excludes some users who do not have the hardware to support sound and real-time video. But in general, once a member has joined a group or arrived at a WWW home page, the access is open.

Whether naturally occurring in the world or man-made, 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 fish or roads and human institutions is readily apparent, that relationship is often more obscure in the structure of fiber, optical pulses and machines as human institutions. Yet, 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.

[6] See Ostrom & Ostrom (1978) and Ostrom, Gardner & Walker (1993, pp.6-8) for a thorough presentation of the different types of goods.

Fig. 3: Types of Common-Pool Resources

NATURAL	**HUMAN-MADE**
forests	roads
fisheries	budgets
groundwater basins	irrigation systems
grazing lands	Internet--LAN

LOCAL	**GLOBAL**
groundwater basins	oceans
state park	tropical rain forests
office air	ozone layer
Main Street	Interstate 70
Internet-LAN	Internet-WAN

The above comparative lists attempt to place the Internet within traditional categories of common pool resources. The Internet at the Local Area Network (LAN) level is quite analogous to local roads. At this level there are definable 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 global shared resource requires its own evolved considerations and type of analysis. (McGinnis and Ostrom)

Four types of Internet resources

To this point I have identified that the Internet is a shared resource, which has subtractable and exclusionary characteristics; that it is both a local as well as global common pool resource; that it has physical boundaries and attributes, rules which correspond to its use and management, the choices resource users make, and the outcomes produced. The Internet, however, has several different types of physical attributes and decision-making arrangements, and behaviors which produce different outcomes. These different characteristics within the Internet system require that they be treated and analyzed as separate resources. In this paper I identify four distinct (although, at times, interrelated) types of common pool resources which exist under the entity of Internet: A Technology-Infrastructure Commons, a Budget Commons, a Social Commons, and an Information Commons. Each has distinct physical attributes, decision-making arrangements and patterns of interaction which produce different outcomes.

Focus

Drawing from the author's frame of reference, the focus of computer networked systems, Internet resources and each of the types of common pool resources in this paper will be on the university, research and scholarly communication and general educational and academic arenas. In particular instances, the Indiana University system will serve as the referent.

1. The Technology-Infrastructure Commons

Physical Attributes
The technology-infrastructure commons best parallels the superhighway metaphor. At the most basic, 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 may grow in complexity but the basic components remain constant.

At its most basic, a **network** is a collection of computers connected together by wires, able to send and receive data. These basic components of the network are:

> **User-computers** (personal computers or PCs) are typically desk-top or laptop computers that are used by 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** are the physical connection between computers, typically copper wire or optical fiber. They are equipped with a signaling system, such as an Ethernet** token ring or FDDI.** These signaling systems determine the speed and capacity of the network and the way in which the wire is shared. [Note: In the case of modems, the wire is not shared. The shared resource is the limited number of modems on the network to which the user-modem can connect.]
>
> A **Packet** 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 is came from), and the data itself that is being sent. [note: The term *packet* is technically correct for units of data sent to 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 FTP** may be made up of thousands or tens of thousands of packets.
>
> **Routers** are very specialized computers/processors, connected by wire to other computers -- either host computers, user-computers or other routing computers. 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-

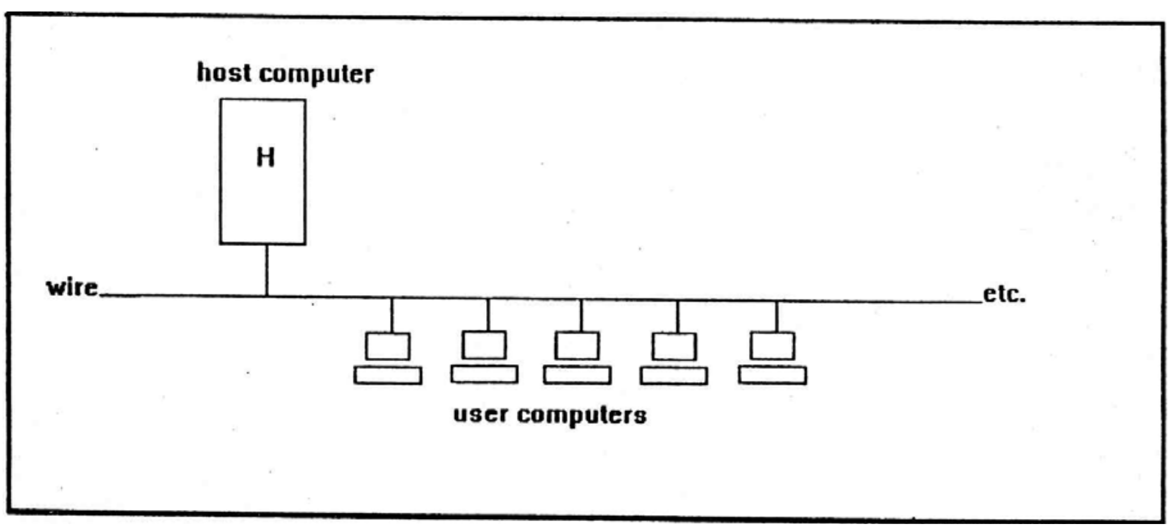
and-forward function in a network. For the purpose of this discussion, the term *router* will be used for all such read-and-forward devices.

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 Transfer Control Protocol/Internet Protocol(TCP/IP) protocol suites. TCP/IP sends packets between host computers on the Internet. Internet Protocols and standards are generally the results of decision-making processes at the global level.

Local to Global

The examination of the physical attributes of the technology-infrastructure must include the structural maps of each system along data path, from the Local Area Network to the Wide Area Regional/National Networks. 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. This minimal LAN construction looks like this:

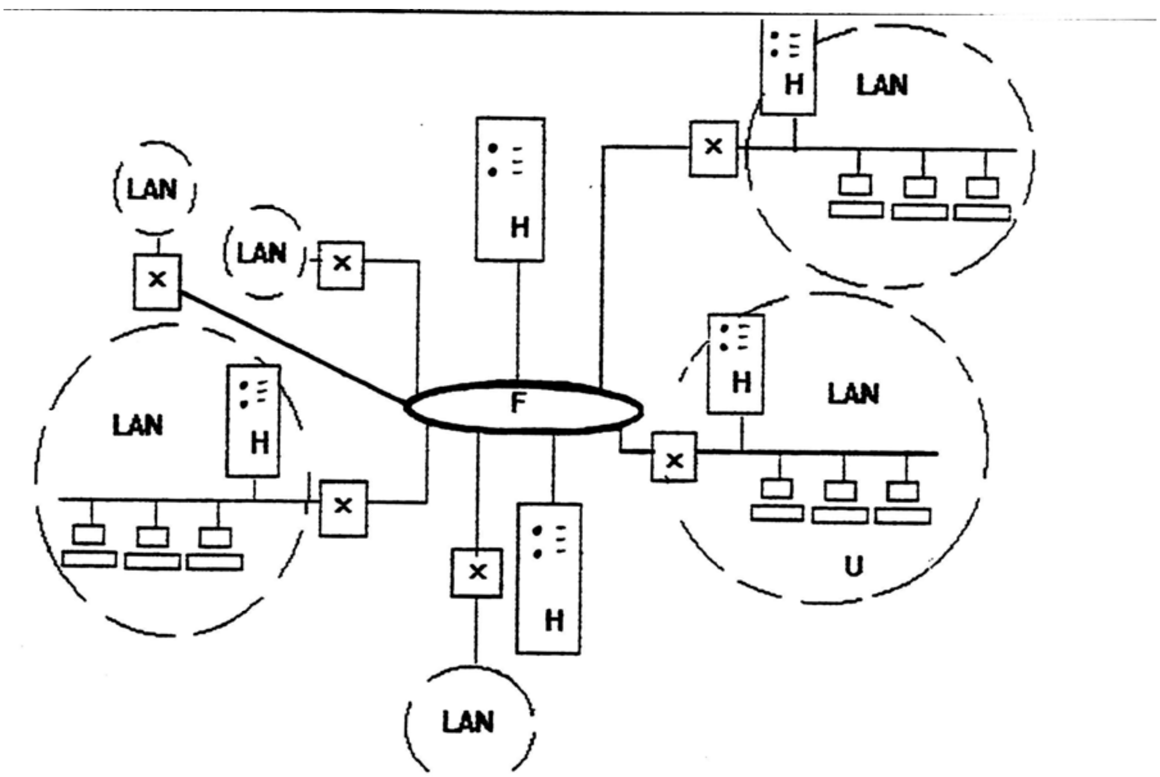
Fig. 4: Local Area Network



The wire is one of the most competed for components of 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. It may contain files used by several of the user-computers, all of which might request access to these files at the same time.

The local campus (business, hospital, etc.) network is a conglomeration of the few or numerous LANs of the various departments or buildings. A campus network, depicted in Figure 5 has several host computers (which may perform different functions, for example as a file server or mail service), 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 5: Campus Network



At the edge of a campus network the data travels through a switching computer called a border router (see Figure 6), that sends the entire local/campus network data traffic on its way to the rest of the world through long-distance wires (leased T1 or T3 circuits) 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.

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

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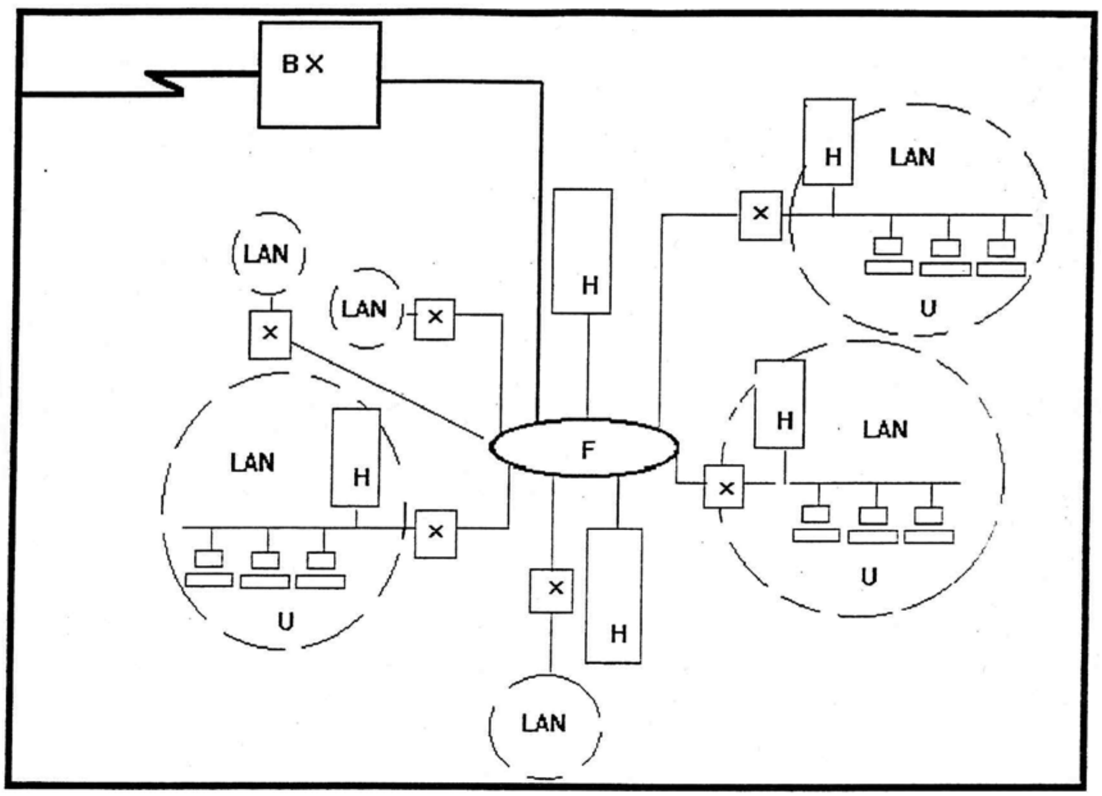
Fig. 6 Border Router



B*X*=border router

<u>Wires and boxes vs. protocols</u>
The geographical movement of the data is one way to examine this resource as it moves from a local to a global arena. Another way to view the resource is in the structural components of the communications technology itself: i.e. how the computers and wires connect on a local to a world-wide basis.

Data is able to travel in any desired direction from user-computers through wires to host computers through wires to switching and routing computers because of compatible "open system" technologies. Open Systems technologies are the language used by computers to communicate. It is the protocols, mentioned above, which are the rules for conversing between computer systems. Piscitello & Chapin (pp.54+) provide an insightful view of the dual-roles played by protocols as physical structures (syntax) and decision-making arrangements (rules).

B. Decision-Making Arrangements

The rules-in-use need to be examined at each level of the data traffic route. There are two main categories of actors involved: Internet providers and Internet users.

Local

What are the rules in use at the LAN level? What decisions are made in the provisioning and appropriation of this local resource? Who decides? Examples of operational rules made about the technology infrastructure by providers are

*the speed of the wire determining how many bits of data, assembled as packets, can move along the wire at what appears to be the same time.

*how many computers can be connected to the same wire. (Note: The more computers, the more the competition for the wire).

*what kind of computers are connected to the wire. A faster host computer can speed up the response perceived by a user computer that requests data. But, faster computers (host or user) increase the rate at which packets are put onto the wire, and that wire has a finite capacity. (Note: Spending money on more computers and faster computers can deplete the resource).

*how many user-computers are permitted to connect to a host computer at the same time. Some applications require a sustained exchange of packets between user and host computers (e.g. a terminal connection to a mainframe-type computer). The host computer can limit the number of such connections, conserving its own resource and conserving the capacity of the wire.

*where to store data (i.e. on which computers). Putting a single copy of some very large files on a host computer can make sense, but the more users who access that site, the more they consume the capacity of the wire moving packets of data and the more they consume the processing power of the host computer.

A question worthy of extensive investigation from the local to the global level of networks concerns the constitutional rules and "who decides." At the local 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 “network operator.” These technologists typically decided what kind of wire, with what capacity, is used in a network, for instance. They also decide 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. A semi-anonymous announcement of such a quota rule appeared one morning on the local e-mail system at Indiana University (from the “IU EZmail Operator”):

> *Quotas have always been part of the administrative plan for EZmail ... Since disk space is a limited resource, quotas are necessary to prevent a few individuals from abusing a resource that must be shared between the approximately 10,000 users who now have EZmail accounts...*

As competition for the infrastructure increases, so do the rules. Time restrictions and limited entry to a university Internet account are also rules which tend to be more strongly enforced as the number of users rises. Generally rules such as these are easy to enforce because they are issued from a central authority -- either a person or committee charged to manage the operation of the networks.

So far, many of the problems brought about by congestion have been solved by expanding the amount of bandwidth and the switching capacity (leading into the Budget Commons situation). 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 technical-infrastructure commons is the frequency with which new technology is implemented.

<u>Wires and Users vs.Routers</u>

Routers play a particularly important role in the decision-making arrangements of the technology infrastructure. In a scarcity-based or competition-based model of wire capacity, most 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. Much of the technology used in networked originally assumed as abundance-based model when it was designed. Ethernet assumes that there is plenty of bandwidth, and that collisions will be rare and, therefore, has no priority-setting or rationing mechanisms. Ethernet also assumed that all computers on a network segment would have a fair distribution of use, with approximately the same capacity to send and receive data. A very fast computer, however, can change that assumption by putting more packets on the wire faster than anyone else.

<u>Regional/National [Global] Level</u>

Regional/National Networks have the same physical attributes with differing types of decision-making mechanisms. Indiana University is connected to the CICNet (Committee on Institutional Cooperation Network). The CICNet hubs (central routers) are located in Downer's Grove, IL. The central offices are located in Ann Arbor, MI. The CICNet long-distance wires are leased from the telecommunications company, MCI. CICNet decision-making bodies are the Board of Directors and the Technical Board, a committee made up of representative technologist from each of the main sites.

Local networks pay an annual fee to belong to the regional network In return, CICNet provides two T-1 circuits. Running two circuits between the local and the regional networks provides a minimal amount of redundancy, in case one of the circuits is down or overcongested.

The decision-making arrangements at the National/International level would be particularly interesting to study in relation to their agreement/conflict resolution mechanisms. Lynch writes that the "Internet is a cooperative effort among all the diverse networks that make up the larger network." (Lynch, p.13) Identifying these diverse networks and the decision-making bodies on the global level is no easy task: these bodies are made up of volunteers and representatives from international organizations, governments, private corporations, local network management, and the general public sector.

A study of the predominantly successful decision-making bodies of the Internet could be enlightening to other international arenas where cooperation and agreement is more of a scarce commodity.[7] One of the effective standards-making bodies of the Internet is the Internet Engineering Task Force (IETF), an international group of technologists and information specialists. Since 1992, the IETF is managed by the Internet Society (ISOC)[8] 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 one or two area directors. 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... "There is no membership in the IETF. Anyone may register for and attend any meeting..." (Malkin,p.3+)

A method of reaching agreements by this group is the *RFC* (Request For Comment) papers 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.[9]

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[7] See Piscitello and Chapin pp.13+ 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

[8] 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 p.4)

[9] IETF RFCs are available electronically at http://www.ietf.cnri.reston.va.us/home.html

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.

It is at this global level of the Internet that most policies are made. Since the privatization of the NSFNet which began in 1994, many of the policies are in a state of flux. The Acceptable Use Policy which so much dominated Internet rules when the U.S. backbone was run by the NSFNet is still in place but it has become essentially irrelevant and consequently unenforced. This policy was originally enforceable through the metrics programmed for routers. If a communication was not from an approved site (government or education, it was not transmitted further). Now groups are working on redefining the router metrics to consider factors such as cost and efficiency rather than use.

<u>Patterns of Interaction at the Technology-Infrastructure Level</u>
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.

There is a form of inequity practiced by the IETF and others that will have increasingly problematical outcomes as the number of international Internet users grows. Piscitello and Chapin (p.65) summarize this situation eloquently:

> *The work of all the major international standards organizations, including ISO[International Standards Organization] and CCITT [now the International Telecommunications Union], is conducted almost exclusively in English; non-English speaking delegates are expected to either learn to cope in `English-as-a-second-language' mode or provide their own translations of documents (a daunting prospect, considering the enormous amount of documentation that attends even the simplest standardization effort). The result is to give a significant practical advantage to native English speakers--and fluent non-native English speakers--in the formal standards-development process. In effect, ISO and CCITT have adopted English as the `standard' language for standards development, with a significant penalty for noncompliance.*

<u>Outcomes</u>
There are a number of outcomes at the global level of the technology-infrastructure commons which are causing dilemmas for network managers and providers. I mention a few of these here as examples of problems which 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.

Because in 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.

Another problem is that the increase in national and international use is requiring more and more routers.As a result, each packet of data is read and forwarded by a larger number of routers, thus delaying the transmission time.

Assignment problems are being discussed by Internet groups more and more frequently. The Internet will eventually (within 10 years) run 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.[10]

2. Budget Commons

The Budget Commons is closely related to the technology-infrastructure commons. It encompasses different types of economic resources all concerned with the provision of the networked information and its technology. Of course, all the other Internet commons are built on budget arrangements somewhere along the line. I identify the budget commons as unique because I think it has unique properties as a resource.

<u>Bigger piece of the pie</u>
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 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 may not be true."

This tendency to keep meeting the demands of technology relates closely with the issue of depletability in respect to the Internet resource. A unique characteristic of the Internet, unlike natural resources, is that when the local resource becomes depleted or close to depletion, resource managers have the ability to replenish the resource by expansion of the technology capacity. And unlike other man-made resources, such as roads and highways, resource capacity on the Internet can be increased in days or weeks instead of months or years. In this sense the Internet resource well reflects the old French root of the

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

word "resource" *resoudre* – "to rise again." If the bandwidth is too slow, more bandwidth can be made available. As well as larger routers, better switches, etc. can be purchased. Depletion need only be temporary-- until budgets are adjusted to replace new technology to supply the demand.

<u>The Price tag</u>

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 (MacKie-Mason & Varian, 1994) discusses many issues of importance to the budget commons: pricing schemes of the Internet are changing rapidly, especially with the relatively recent hand-over of the Internet backbone to the private sector. MacKie-Mason and Varian (p.84) point out that the value of effective pricing for Internet services is as a possible solution for problems of congestion -- the growing competition for the resources.

> *...The problem [of congestion] is more serious for data networks than for many other congestible resources because of the tremendously wide range of usage rates. On a highway, for example, at a given moment a single user is more or less limited to putting either one or zero cars on the road. In a data network, however, a single user at a modern workstation can send a few bytes of e-mail or put a load of hundreds of Mbps (megabytes-per-second) on the network. Within a year, any undergraduate with a new Macintosh will be able to plug in a video camera and transmit live videos home to mom, demanding as much as 1 Mbps. Since the maximum throughput on current backbones is only 45 Mbps, it is clear that even a few users with relatively inexpensive equipment could bring the network to its knees.*

There is a growing literature on Internet pricing schemes and mechanism design which explores economic measures to insure equitable and efficient use of the Internet bandwidth and capacity. (MacKie-Mason & Varian, Parris et al.)

To add to the complexity of the Internet Budget Commons is the fact the Internet is perceived by many as a public good.[11] The call for "a laptop in every household" does much to encourage this thought.[12] And, indeed, much of the information available is, and is likely to remain a public good. But there seems to be a great deal of confusion about what is public and what is private (and subject to pricing). The metaphor "information superhighway" sounds like Interstate 70, which was built with public funds and upon which all can drive for free, granted they have a car to drive. The information superhighway, however, is not a public good. It is, and will continue to be, privately built. The federal government role will primarily continue in research funding and communications regulations.

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[11] A useful reference to the nature and history of "publicness" can be found in Rose 1986.

[12] 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 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)

Physical Attributes[13]

Aaron Wildavsky defines a budget as “a document, containing words and figures, which proposes expenditures for certain items and purposes.” (Wildavsky 1979:1) The financial resources are deeply nested in structure of a university, with the dispersion following a traditional hierarchy: university budget--->campus--->schools--->departments--->areas--->subareas etc. The shared resource is the total budget and the carved budgets. In the case of the Internet, multiple, competing budgets contribute to the resource.

Considering that all budgets reflect a history of choices, a close examination of the open and hidden budgets supporting both local and wide area use would be elucidating for most educators and administrators. The budget resource funds the technical infrastructure, hardware and software or 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. How does this growth affect Wildavsky's claim that “the largest determining factor of the size and content of this year's budget is last year's budget?” (Wildavsky, 2979:13) Taking the budget pie at Indiana University as fairly typical of contemporary university budgets, it is noteworthy that the technology department (University Computing Services) only supplies 25% of the total university technology budget. 75% is funded by other departments. Fifteen years ago, before the ubiquitous use of personal computers and computer networks, the numbers would have been reversed.

Decision-Making Arrangements

Budget allocations normally fall within a hierarchical structure in an institution. Rapid growth and demand for new information technologies is 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 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 that collecting it.

It is an observation that in higher education, as well as many other educational and corporate arenas, the use of innovative technology is more readily funded than scholarly content.

Patterns of Interaction

[13] The focus of discussion here is on the Local Area Network, campus level. An IAD analysis of the global budget commons would be a splendid dissertation topic.

The affect of all sub-budgets within the university partially supporting use of the Internet may make the commons aspect of budgets more apparent. Free riding occurs when some budgets support more and faster computers without allocating funds for faster network facilities, which can cause depletion 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.

Outcomes

The process of allocating funds for technology and networked information in a large institution 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 over-provisioned. Given the rapid growth in use, allocation and provisions is now often following demand, trying to keep up.

3. Social commons

The social commons is created by the *use* of the Internet: electronic mail, discussion groups, newsgroups, interactive games, etc. It comprises new communities of people who are able to communicate electronically because of the technology infrastructure and their own investment of time and money. The purpose of the communication may be for business, scholarship, entertainment or many other ends. This commons includes, but is not limited to, the "virtual community" defined by Howard Rheingold:

> *`Virtual communities' are social aggregations that emerge from the Net when people carry on those public discussions long enough, with sufficient human feeling, to form webs of personal relationships in cyberspace.* (Rheingold 1993:5)

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 also a powerful political tool. It also enables invasion of privacy, rude verbal behavior (flaming), junk mail, and can be an enormous waste of time.

Peter Kollack and Marc Smith provide an interesting and useful analysis of the Internet as a social commons in their forthcoming chapter. (Kollock and Smith, 1995) The Internet resource they focus on is the Usenet** as a social commons. They give a good summary of the conditions and types of free-riding and other types of inappropriate behavior of problems of this resource such as overuse, unacceptable language, and information "pollution."

Physical Attributes

The social commons is about ***communication.*** 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. This commons includes the people and the messages which connect them.

The physical characteristics are:

*one-to-one communication (such as person-to-person e-mail)
*one-to-many communication (such as individual postings to a discussion group -- a listserv, Usenet newsgroup, etc.)
*many-to-many communication (such as the collected messages of a listserv of newsgroup)

Some groups are passively stored -- i.e. participants only receive the messages they select, as with usenet groups. When the communication is active (i.e. each message sent directly to all participants), the enforcement of rules become more necessary.

Decision-Making Arrangements

The rules established for membership behavior in the social commons are referred to as ***netiquette***. There are many summaries of these rules available on the Internet. Often discussion groups will send them automatically to new subscribers. Virginia Shea gives good, solid discussions of the thinking behind the rules. (Shea 1994) These are broad-ranging informal rules. Rule 1, for instance is “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. Rule 4 is “Respect other people's time and bandwidth” which draws attention to individual choices and behaviors and the technical constraints of the medium. Kollack and Smith refer to the abuse of this rule as using up bandwidth. But it is not always the bandwidth that is at risk. 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 limited capacity of human time and attention, which is identified by the financial press as “the scarcest and hence most valuable commodity.”(Gross p.80)

One-to-one communication is almost always unregulated. Anyone can send a message to anyone else with their correct address. The use of mail-filters, however, is becoming more common. Mail-filters automatically delete messages from specific senders. This is only a partial protective medium, since mail-filters cannot filter out all of the ensuing discussion about the offending communication. (Kollack and Smith)

One-to-many communication may be regulated in the following ways:

*members may subscribe and unsubscribe to a listserv/discussion group at will.

*requests to subscribe may be fulfilled automatically, or may be first reviewed and approved by a list-owner of list-moderator.

*discussion groups may require specific criteria for membership.

*the ability to post messages to a discussion group may be restricted to subscribed members, or may be open to anyone.

*messages posted to a discussion group may be distributed automatically to all members, or they may be reviewed and approved by a list-owner or list-moderator.

*The ability to read/receive messages or browse the message collection may be restricted to subscribed members, or open to anyone.

*there may or may not be the ability to find our who else is subscribed to the discussion group...and even where this feature is available, individuals may or may not have the ability to make their membership anonymous.

Patterns of Interaction

Adherence to the rules is mainly by use of the honor system. Sanctioning mechanisms are often 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 education of all the community members (such as subscribers to an electronic discussion group) about the rules of behavior.[14] This situation is not unique to the electronic environment, but rather, true of all social groups. The assignment, however, is much more difficult in an anonymous environment. Vincent Ostrom writes about the fundamental need for shared understandings of rules in his book American Federalism.

> *Since the rules of associated relationships are not self-formulating,*

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[14] Surveying the literature of educational planning of technology substantiates the growing awareness of the social responsibility involved in the use of electronic information. Sample planning documents of U.S. schools are available from the Naitonal Center for Technology Planning (NCTP) LSA1@Ra.MsState.edu. The planning documents contained in the report are "perceived to be of such exemplary high quality that it is due consideration by technology planning committees." The Statement of Technology Philosophy of the North Adams Community Schools (Indiana), for instance, reads as follows: *The planned use of technology within the North Adams Community Schools is of primary importance and will have a profound impact upon education and society in general. All students and North Adams Community Schools employees will be expected to become proficient in the ethical use and application of technology.*

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. (p.14)

Many groups automatically send new subscribers information about the rules of behavior and guidelines about the focus of the group when they first join. Computer ethics as a subject of study is gaining more attention.

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.

Outcomes

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 the possibilities for better understandings and shared visions. Both the successes and failures of the Social Commons are frequently feature stories in the press. Bed-ridden senior citizens who are "virtually" able to socialize again; happy couples who have met in a 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, and gross breaches of confidentialities.

3. Information commons

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 social commons (as well as the budget and technology-infrastructure commons) but the focus of the information common pool resource is the ***content,*** the provision and retrieval of information, rather than the communication process and the communities created by use. 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 digitzed images (from personal photographs, to art masterworks to pornographic photos).

The amount of data on the Internet increases literally by the minute. The content is in a constant state of 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. There is also a great amount of duplicate information available from one Internet site to the next. The sheer volume of the information produces a multiplicity of problems, such as finding the information desired (as opposed to making to with the information at hand) or competing for access to information sources. Information stored in some formats (as audio or motion video images) may also require new software, hardware, and greater network capacity in order to be accessed.

<u>Decision-Making Arrangements</u>
There are rules and policies which address the provision of electronic information. On the local level, information providers (librarians, network technologists and managers) are the predominant designers of scope, focus and breadth of local information resources. Decisions are made by groups or individuals (shaped by budgetary allotments) about:

*the selection and implementation of which databases to mount on the local network

*the subscription to a database service

*the rules of access to an information resource: personal identification, presumed membership in a group (by a network location)

*the rules about the personal responsibility in providing accurate and complete information about the information being provided.

*the means of *accessing* the information (i.e. types of instruction as keys to the information)

On both the local and wider-area networks, certain groups of users can be denied open access to information on the networks. This can be a formal or informal arrangement through the requirement of a password to an application process to access certain information. Policies about acceptable use and censorship are being addressed more and more often at the local network levels.

Global issues about electronic information concern the complex questions of access, licensing and intellectual property rights.

<u>Patterns of Interaction:</u>
The growing emphasis on collaboration between information specialists, technologists, teachers and researchers to identify needs and priorities, share expertise, and collectively engage in information provision and management.

The capacity for every Internet user to publish 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 credits. Electronic books are mounted without publisher, translation or edition information. Many of these problems are in part due to lack of cataloging standards. In part there are due to ignorance, defiance, lack of time or indifference.

The type of information problems vary according to the network application. Unsolicited advertizing, for instance, can be a form of information pollution on electronic discussion groups, but not for World Wide Web applications.

Outcomes

A cultural concern with the globalization of information is that more local institutions rely on access to outside (virtual or hardcopy) collections, the less unique and locally suited information resources become. The potential value will be local electronic systems that are locally user-centered designed for content as well as for image and language needs. There are great opportunities to build resources of local knowledge, culture, interests and expertise.

There is no doubt that networked information makes information resources accessible to a much greater number of people. There is a belief often expressed that the Internet makes access to information more equitable by bringing valuable resources to people in remote areas. It allows every member to be a publisher. The use of hypertext and digitalized graphic images spawns innovation in information management and provision. And, overlapping with the social commons, the interactivity of information seekers and providers brings new interest groups together.

Information resources are subject to congestion and potential depletion. To the user all of the resources are unstable and fugitive: some resources are taken off the Internet after becoming too successful. The local system cannot accommodate the remote demand. This was the case of the Rock Lyrics Archives database (now “virtually” extinct) which one day gave the following message when users tried to enter the resource:

> *We have a situation of an archive being too successful. UNTIL further notice: Due to system and network load, the Music Archives at uwp.edu will no longer be made available via Gopher...*

Other great resources are taken off the Internet because of realization or discovery of copyright violation. This has been the case with the Wilson databases, Civil War photo archive, the Oxford English Dictionary, and many other copyrighted sources.

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.

In the information commons arena, special problems surface on both the global and local levels. These problems go beyond equitable access to the resource. The Internet, although international in membership is US in origin and design, western in culture. This is not an issue of language per se. While English is the dominant language in the standards process, vernacular language is becoming more and more frequent as international use increases.

Accessibility to the information resource requires education of the users to be effective information retrievers and providers in order to adapt the resource to their needs. Accessibility is also closely linked to the technology infrastructure (bandwidth and capacity).

Other information commons outcomes include the problem of access without ownership or possession.[15] License arrangements such as pay-per-use, set economic limits on the information that is even examined by most users, so that browsing as a searching strategy becomes less and less of an option. The overwhelming volume, redundancy and lack of organizational structure also contribute to the reduced ability to browse for information.

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Conclusion

This paper proposes a research agenda of studying various components of the Internet as common pool resources as a means to more deeply understand the nature and outcomes of this gargantuan shared resource. My perspective is as an information specialist, not as an economist or technologist. The hope is to inspire specialists to apply what has been learned from common pool resource analysis. And, as has been illustrated repeatedly, the IAD framework can be especially useful in this study.

Many other issues of related interest have been skipped over in this paper: 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 issue of security, confidentiality, privacy and the future of the democratic process of information: the impact of electronic information on institutional change within education and other spheres of contemporary life is of major importance.

Better understanding of the Internet as a complex common-pool resource through institutional analysis will allow users to:

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[15] Computer scientist Clifford Lynch has written extensively about the potential problems of scholarly research because of licensing practices of electronic information.

> *...information cannot be shared among libraries through the interlibrary loan system in the way that printed works historically have been shared, thus substantially reducing access to the body of electronic information. Further, since much electronic information is licensed only for a limited term, the ability of the libraries to preserve the information is threatened by concern about continued funds for licenses and even by the ongoing willingness of rightsholders to offer the material for license at reasonable rates*. (Lynch, C. 1994:1-2)

- Better understand who governs, who should govern
- Solve problems of speed and access caused by overcrowding and general competition for the resource
- Adopt appropriate rules and institutional arrangements needed to provide reciprocal services
- Increase the communication about the rules
- Facilitate the decision-making process of information providers

Is, in the end, 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 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 knowledge and the tools for learning that are available in historically 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. 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 levels -- and the complexity of the resource, concerted efforts need to be made to share understanding and expertise in the enterprise of interdisciplinary analysis. It is clear that the development of this complex information resource has necessitated 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.

GLOSSARY

ASCII (American Standard Code for Information Interchange) – "A binary code for data that is used in communications, most minicomputers and all personal computers." (Freedman p. 22)

Asynchronous Transfer Mode (ATM)--a cell-switching technology for high-speed networks (See Davidson and MacKie-Mason & Varian p.82)

Bandwidth--Transmission capacity of a computer channel (cable or wire), usually stated in bits or bytes per second. (Freedman p. 33)

Bit--A binary digit (1 or 0). Typically eight bits make up one byte.

Byte--One byte is equivalent to one ASCII character. (See also Packet)

Circuits --The T-carrier services deliver digital data and voice transmission over local or wide areas at rates as high as 45 megabits (million bits) per second. T1 is the most common digital leased-line service with bandwidth of 1.544 megabits per second. T3 is equivalent to28 T1 circuits and provides a total bandwidth of 44.736 megabits per second.

Congestion--at the infrastructure level, the situation when use exceeds the capacity. When multiple packets are sent at the same time, a queue forms at the router causing delays and even packet loss. "Demands on network capacity are always increasing, as the user population and the speed of computer systems increase. This is often the main cause of performance rot, when a system engineered for one workload becomes congested as the workload increases." (Mogul p.582)

Ethernet--A networking system which has 10 megabits per second throughput and "uses a carrier-sensing access method in which workstations share a network cable (wire), but only one workstation can use the cable at a time." (Sheldon p.332)

FDDI (Fiber Distributed Data Interface)--A fiber-optic cable standard which operates at 100Mbits/sec and uses a dual-ring topology that supports 500 nodes over a maximum of 100 kilometers. (Sheldon p.358)

FTP (File Transfer Protocol) --protocol which allows for the transmission and retrieval of data files from databases linked to the networks.

Gopher-- is an Internet information retrieval program and its associated protocol which arranges information by menus, with browsing and search capabilities.

Hops--The number of routers a packet passes through in transport from sender to receiver.

Host--Large timesharing computer or central computer.

IP (Internet Protocol) – "IP is a datagram protocol. That means that there is no attempt made to guarantee reliable delivery, and so performance issues related to IP are fairly simple: does a packet arrive at all, and if so, how long does it take?" (Mogul p. 807)

Listserv--a "software system for maintaining mailing lists (and more) without human intervention..Specialized listserv servers give access to a specific set of files at one location." (Krol p.121-123)

NovaNet is the former PLATO system built and operated by the University of Illinois-Champaign-Urbana, now owned by UCI (University Communications Inc.). It is a computer-assisted instruction system, a telnet application on the Internet, that provides "thousands of hours of individualized instruction in more than a hundred subject areas."

MUDs (Multi-User Dungeons) -- interactive role-playing games on the Internet.

Open Systems—"computer architectures, computer systems, computer software, and communication systems in which the specifications are published and available to everyone." (Sheldon p. 675)

Packet—"a package of data that is exchanged between devices over a data communication link." The package includes bit(s) with headers (source and destination addresses + control information to handle errors) and a payload (actual data transported) The size of packets varies. (Sheldon p.690)

Performance--at the technology infrastructure level, how Internet protocols and implementations behave, affecting speed and delivery; determined by a number of complex factors: bandwidth, routing paths, the maximum length of a packet (Maximum Transmission Unit).

Protocol—"A definition for how computers will act when talking to each other. Protocol definitions range form how bits are placed on a wire to the format of an electronic mail message." (Krol p.361)

RFC-- Request for Comments--.Procedural papers for proposed communications standards and protocols.

Router--gateways connecting the networks -- packet switches (or Network layer relays) that operate in the Network layer of the OSI protocol model. 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.

Speed—"...`faster' refers to sending more bits of information simultaneously in a single data stream (usually over a single communications line), thus delivering *n* bits faster." (MacKie-Mason & Varian p.81) (See also Circuits)

Telnet--An early network protocol allowing remote login to a computer and interactive communication. (Gilster p.22)

TCP (Transmission Control Protocol)—"One of the protocols on which the Internet is based." (Krol p.362)

Usenet—"One of the largest computer-mediated communication systems in existence... [which] consists of several thousand discussion groups [termed newsgroups]." (Kollack and Smith, p.3)

Universal Resource Locator (URL) -- the data or document locating system on the Internet. Example: http://www.indiana.edu/

Virus—"Software used to infect a computer." The effect may be a minor annoyance (such as a message suddenly popping up on screen) to the "actual destruction of programs and data." (Freedman, p.544)

World Wide Web (also referred to as WWW and W3)—"A hypertext-based system for finding and accessing Internet resources." (Krol p.363)

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This paper has a single author, yet it is also a collaborative work. I would like to thank my interdisciplinary colleagues who have shared their ideas and expertise with me. Political Scientist Elinor Ostrom for her enduring encouragement and intellectual exchange about the nature of common pool resources. Economist James Walker for his recognition of the Internet as a CPR. Tjip Walker for his useful discussions about the IAD framework. Technologists Allen Robel and Brent Sweeny at the University Computing Services for sharing their expertise on network technology infrastructure. Political Scientist Vincent Ostrom for his writings and discussions on the interconnectedness of systems and the importance of language. Technologist-librarian Jian Liu for teaching me much about Internet applications. And most especially my colleague and friend, Gerald Bernbom at the Office of Information Technology, for sharing his unusual depth of analysis and vision, for his careful editing of this paper, and his expert help in translating the world of wires and boxes into human institutions.