The Evolution of the Net

The Evolution of the Net:

Networked Infrastructure from Telephony to Telesophy

By

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This book is **dedicated**

to my **father**, who lived through the 20^{th} century,
Living his last 7 years in the 21^{st},

and

to my **daughter**, who is living through the 21^{st} century,
Living her first 7 years in the 20^{th}.

My father saw Telephony emerge into infrastructure during his lifetime.

My daughter is seeing Telesophy emerge into infrastructure during hers.

CONTENTS

PREFACE: BUILDING NETWORKED INFRASTRUCTURE

The Net is the Structure of the World. We live in an always connected world, long predicted but finally realized. Immediate Interaction with All the World's Knowledge is now our existence, and could become our salvation. This book explains how we got here and how we could get there. It focuses on the fundamental technologies for networked infrastructure to explain what was possible in the past and what is possible in the future.

The book discusses the Evolution of the Net. This is the transition of networked infrastructure from telephony to telesophy, from dealing with data to dealing with wisdom. The book structure describes the theory then the practice, with Principles in Chapter "a" then Prototypes in Chapter "b". Chapter 0 introduces Telephony and Telesophy, while Chapters 1,2,3,4 deal with the Evolution of the Net in the Waves for Data, Information, Knowledge, Wisdom (DIKW).

My working career spans the 20th and the 21st century, during the Second and Third Millennium. This account of evolution uses my personal story as a framing device since I was fortunate to work at the historical nexus of scalable prototypes for each Wave of the Net. The original Telesophy document was published in 1984, hoping The Light of Global Net could overcome the Dark of Big Brother.[1]

This current book summarizes 4 decades of pioneering technologies for infrastructure research. It covers the 20th century, the 1980s and 1990s for the Internet of Waves 1 and 2 which support Access and Organization. Then the 21st century, the 2000s and 2010s for the Interspace of Waves 3 and 4 which will support Analysis and Synthesis, realizing Telesophy.

telesophy (Noun)
literally "wisdom at a distance". The networked infrastructure beyond the current Internet, which supports analysis and synthesis of all the world's knowledge. Compare to "telephony", literally "sound at a distance", the current global networked infrastructure.
Usage: Telesophy provides the way for ordinary people to solve their problems by discovering helpful knowledge and using it as appropriate to their current situation.

This book focuses upon communications infrastructure, the global connection network. This infrastructure evolves through stages to reach deeper levels of functionality. New standalone technologies are developed by the research computing community. Integrative technologies then combine multiple standalone technologies into new systems for research infrastructure. This is the key stage towards new paradigms for new infrastructure, although little recognized and rarely heralded. This research stage is the first that **scales**, which is the key issue in global infrastructure.

Within development of research infrastructure, technological context merges with social context, to support user needs. That is, new technologies are developed which are capable of efficiently operating across the global network, to eventually reach everybody with new services. After maturation periods, standards emerge for the paradigms and these are incorporated into commercial products for mass consumption. The leverage of research infrastructure catalyzes such products and changes the world. This book is about the process and the contents of networked infrastructure, how research infrastructure created the global Net.

The Net used to be the stuff of science fiction, immediate interaction with all the world's knowledge. At present, the level is far beyond the past of telephony ("sound at a distance"), persons talking with others around the globe. The next generations will evolve from the present, and new paradigms will raise the level far beyond the present once more. The future is telesophy ("wisdom at a distance"), persons seeking knowledge from global sources to solve their problems. This book discusses technologies and applications which will result.

The paradigm of the Net makes all the world's knowledge appear to be immediately available for interactive utility. So the technologies federate all the sources together into a unified whole, at increasing levels of deeper interaction. The levels of federation thus form the stages of evolution of networked infrastructure, and are always presaged by research systems which integrate now available technologies into new federation paradigms.

The key transition in the continued evolution of network infrastructure occurs when the volume increases to the breaking point, when the old technologies that provide essential services for the rich are too expensive for the poor. The rich can afford the best services as provided by expert persons. But the poor can only utilize such services, when these persons are replaced by machines, which are not quite as good but much cheaper, when supplemented by the poor themselves.

Every infrastructure scales by this process of having automation provide support enabling all persons to provide the service themselves, without the need for an expert. For example, in transportation, trains are driven by expert operators on fixed tracks but cars are driven by people themselves going anywhere if they can steer safely and navigate successfully. In communication, the same transition occurred, when manual operators placing phone calls were largely replaced by automatic switching machines which enabled ordinary persons to place their own calls. That is, the networked infrastructure improved to provide deeper functionality for necessary support.

The Waves of the Net discussed in this book all exhibit the fundamental scaling property. The new technologies developed at the stage of research infrastructure enable ordinary persons to perform new services themselves without requiring human experts. This is equally true for Wave 1 and 2 of browsing and searching in the present, as for Wave 3 and 4 of analysis and synthesis in the future. For each Wave, I was privileged to be at the historical nexus to help create the new services at the beginning of the stages of research infrastructure, to enable scaling to the masses. The book describes basic principles underlying each wave, followed by concrete examples from research prototypes within historical context to serve as future models.

The basic metaphor of the network paradigm is that of the Universal Library. The Library is the place where knowledge is stored and organized. In the past of the Internet which catalyzed Wave 1 and 2, telephony switches transmit requested information from multiple sources to you. This is much like a librarian, a reference expert who interacts with users making requests and uses general techniques to browse and search, resulting in the retrieval of desired information.

In the future of the Interspace which will catalyze Wave 3 and 4, telesophy switches cluster potential information from multiple sources, which are then compared to the current situation for transmission to you. This is much like a curator, a classification expert who has special knowledge about the current subject matter and patron situation, so can provide targeted results for special problems deeper than general searches. They help users navigate information spaces, rather than search document collections. That is, a reference librarian is an expert in searching general materials, while a collection curator is an expert in searching special materials.

A curator is thus able to match the solutions to the problems for the user. Curated knowledge connects people with deeper methods than archived knowledge. It is not surprising the applications for librarians who do reference are in multiple subjects, while the applications for those who do curation are in specific areas only. These stages of progressive deepening are accordingly true of the automatic machines that enable infrastructure.

This same progression can be seen in the present hype for artificial intelligence. I studied with the leaders during the first coming of AI, focused upon static heuristics improving search results. This is how an Internet search service provides better results than general search for certain queries of commercial value. The "new AI" is focused upon machine learning of common situations through large numbers of concrete examples. Such learning can personalize results for particular users in particular situations. Automatic curation will be how an Interspace service exhibits situational awareness with clustering and statistics rather than indexing and heuristics.

This book gives historical context of research infrastructure which led to Internet search and is leading to Interspace analysis. The new mass services arose as a result of research infrastructure. This transition from Internet to Interspace represents a transition from TEXT to CONTEXT, from dealing with information in isolation of the individual to dealing with knowledge in surrounds of the population. Research technologies catalyzed the evolutions which mass commercialization has embedded into global usage.

The federation of the Internet is focused upon Syntax, upon the words appearing in the documents with subsequent consideration of structure where they appear. The federation of the Interspace is being focused upon Semantics, upon the meanings underlying the words with subsequent consideration of the practical utility in particular situations. This is called "pragmatics" in linguistics and deals with concepts as they are actually used, which can only be incorporated into infrastructure with enormous numbers of concrete examples of actual usage.

In the Age of Syntax, the network infrastructure supports Browsing and Searching. This is true at present in the Internet. In the Age of Semantics, the network infrastructure supports Analysis and Synthesis. This is becoming true in the Interspace, as it emerges into mass reality. That is, the support at present for the Internet to serve as general librarian will transform into the support in the near future for the Interspace to serve as situational curator. The focus of present research into digital libraries is on curated knowledge to connect people in deeper ways.

Future Waves of the Net will curate knowledge for personal situations towards interactive support for the world's decisions. Thus, we begin in the pre-history of the Waves with telephony "sound at a distance" and end in the post-history of the Waves with telesophy "wisdom at a distance". In the transition of research of infrastructure, the historical progression logically follows from physical to logical, from technology to philosophy, from Access and Organization of Data and Information, to Analysis and Synthesis of Knowledge and Wisdom.

ACKNOWLEDGEMENTS

This book has taken 40 years to research and gives 4 waves to describe the Evolution of the Net. As the writing is being completed during the worst pandemic in a century, it has become clear that the Net is the Structure of the World. Some continuance of daily living is only possible due to global networked infrastructure, from the Wave 1 of Access with interactive video conversation to Wave 4 of Synthesis with worldwide social media.

I was fortunate to be born in 1954 so my career spans the 20th and the 21st century, the Second and Third Millennium. This account of evolution uses my personal story as a framing device since I was fortunate to work at the historical nexus of scalable prototypes for each Wave of the Net. I foretold Telesophy in 1984 at age 30, hoping The Light of Global Net could overcome the Dark of Big Brother. This book is my attempt to summarize 4 decades of pioneering technologies for infrastructure research, hoping to realize Telesophy in 2024 at age 70.

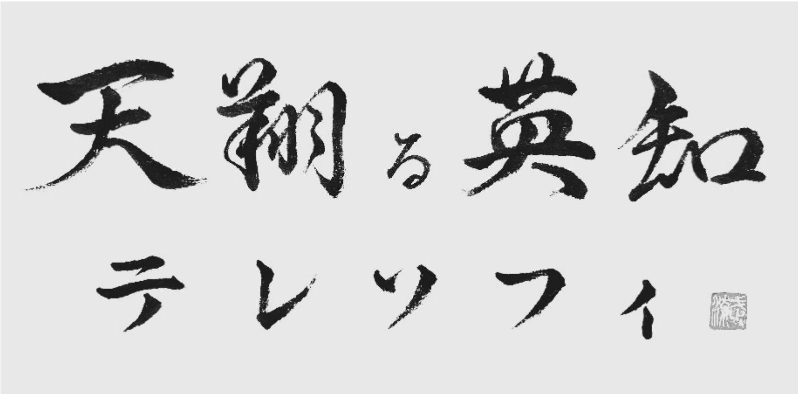
For many years, I have explained *HOW SYSTEMS WORK.* This book attempts to describe in self-contained language how the technology operates, and thus how to catalyze evolution. The personal stories hope to explain how you must think to catalyze the Evolution of the Net. These examples cover the 20th century, the 1980s and 1990s for the Internet of Waves 1 and 2 which support Access and Organization. Then the 21st century, the 2000s and 2010s for the Interspace of Waves 3 and 4 which will support Analysis and Synthesis in the future.

Many people have helped me along the way, kindly clearing confusions in my understanding and serving as colleagues to overcome the difficulties. Some of these are explicitly thanked in the book, but all who have taught me deserve a big dose of warm thanks.

I am particularly grateful to those persons who supported and mentored me along the way. Some are explicitly mentioned throughout the book. A special thank you to Sam Ward, who enabled academic respect in the 20th century, during my transition from industrial engineer to academic scientist. Also thank you to John Wilkin, who enabled academic freedom in the 21st century, hosting me as independent scholar allowing writing of this book.

My brother Steve Schatz, published novelist, kindly read several versions and provided insightful comments, which I have tried to use to improve the contents of the stories.

INTRODUCTION –
FROM TELEPHONY TO TELESOPHY



Telesophy classical calligraphy: “Ama kakeru Eichi”.
Japanese literal meaning: “Space soaring Wisdom”.

CHAPTER 0a

TELEPHONY: SUPPORTING GLOBAL NETWORKED INFRASTRUCTURE

0a.1 Voice and Data Calls 0a.2 Addresses and Gateways 0a.3 Packages and Protocols 0a.4 Digital Libraries as Network Infrastructure 0a.5 Metaphors and Companies

The telephone system was the first global network in the modern sense. It was point to point interactive. You could directly talk to another person anywhere anytime by using the phone device. It was in fact “sound at a distance” with total transparency. Furthermore, in the United States, the Bell System pioneered the notion of universal service, where any person any where could have a telephone device plugged into the network for transparent access. In the present day, the mass availability of mobile devices such as smart phones makes “plugging into the Net” simply an issue of connecting to a wireless provider with an appropriate device. The basic notions of telephony are still the basic notions of the Internet of the present. So understanding the architecture of telephony is essential to understanding networked infrastructure.

In The Evolution of the Net, the underlying infrastructures are largely those of telephony, as previous systems provide the foundations for subsequent systems. Thus, to understand the Internet of the present, it is necessary to understand the architecture of telephony, the Telephone System of the past. Thus, to understand the Interspace of the future, it is necessary as well to understand the architecture of the past. So the architecture here at the beginning in Pre-History will focus upon Telephony. While the architecture there at the ending in Post-History will focus upon Telesophy. Accomplishing the evolution into Telesophy assumes the foundations of Telephony already exist, as do the foundations of the Waves of the Net from Access to Organization in the Internet and from Analysis to Synthesis in the Interspace.

I was fortunate to spend a decade as an engineer in the Bell System, so have detailed knowledge of the workings of the telephone system. This tenure included serving as chief architect of switching machines for office business and as project lead for research prototypes of network services. Thus I was privileged to learn first hand about switching and addressing for both voice and data, the topics which will be explained in this chapter as infrastructure background. The projects in New Jersey were on switching machines in development at Holmdel and on information systems in research at Morristown. The workings of telephony were covered in the basic course I took shortly after joining, which was taught by the authors of the standard internal textbook called Engineering and Operations in the Bell System, published just two years before.[1]

0a.1 Voice and Data Calls

How does a telephone call work? You specify a phone number, the network connects, and you talk. Each step involves extensive technologies which were originally developed in the 19th century and widely deployed in the 20th century. This is true of landlines, which are fixed phone devices connected with wires to the telephone network. Mobile devices, which have now become the standard, were originally developed in the 20th century and now widely deployed in the 21st century. This section explains the process for making the connections from here to there, from the caller to the callee, from sender to receiver. The next section explains the process for specifying the number itself, how the support for addressing works.

At the beginning of telephony, all switching was done manually by human operators. An operator was a human who talked to the caller and determined to whom they wished to speak. The operator then made the connection for the call through a plugboard. This is a big grid of slots into which wires can be plugged, hence a plugboard. The operator had a pile of wires with plugs on the ends. Suppose in a small town there were 100 phones. Then the board would be a grid with 100 slots, say 10 by 10 square, each with a light underneath to indicate a phone is being used to talk. Each person with a phone is hardwired to a slot, e.g. a person with a phone has a wire going from their house to the switching office where the operator is. When a person makes a call, they pick up the phone and the light under their slot, say 17, goes on. Then the operator puts one end of a plug wire into slot 17 and asks the person who they want to talk to. The person might say Priscilla Preston, whom the operator knows is slot 39, from looking her name up on a list. So the operator puts the other end of the plug wire into slot 39, which creates a connection from phone 17 to phone 39. The two persons can now talk together on their phones.

This process works within a small town. What if you want to talk with someone in another small town? Then more network is needed and more switching is needed. The network connection needs to go from one plugboard in one town with one operator to another plugboard in another town with another operator. This situation can be solved with the start of hierarchical networks. That is, the level 1 plugboards directly connect phones to phones. But there are now level 2 plugboards that connect plugboards to plugboards, not phones to phones. The plugboard in town A has a special slot that is always connected to the higher level plugboard level 2, as does the plug board in town B. So the operator in town A connects the wire plug from the caller in slot 17, to the special slot for the level 2 plugboard. Similarly the operator in town B, if they are notified there is a call for Priscilla in town B, connects the wire plug from the special slot for the level 2 plugboard to their plugboard slot 39. This is how the level 2 plugboard works to connect level 1 in town A to level 1 in town B.

To evolve to the stage of scalable infrastructure where national networks are feasible, human operators have to be replaced by automatic machines. That is, mechanical switches were developed in the early 20th century, which simulated the human operators and made multiple connections using a mechanical plugboard. The phone number specified the necessary connections to the switching machines, and the machines turned the switches to simulate the effects of the operators putting a plug wire between appropriate slots. Essentially, each part of the phone number specified which slot to connect to which slot, and the switching machine mechanically "ate" the number to make the connections to the right "slots". The necessity for implementing hierarchical switches with automatic machines was the pathway towards covering larger areas with phone devices, on the way to a national telephony network.

By the early 20th century, the telephone had become an essential device and the volume of calls was rapidly increasing. The manual process lasted with extensions from about 1880 to about 1930, for 50 years across the boundaries of the 19th century to the 20th century. Projections of future volumes of phone calls showed that every person in the country would have to be an operator to handle the entire process. But with the introduction of automatic switching machines, this is in fact what happened in the next 50 years. Each caller dials the number themselves, perhaps with automatic support from their phone device, but without relying on a human operator to retrieve the number from a list. Then a hierarchy of switches connects the caller to the receiver for talking, rather than a human operator putting a plug wire into the right slots. This is the standard process for an infrastructure to volume scale, having the users themselves do the work that expert humans used to do, but with significant support from automatic machines to carry out the routine operations necessary for the tasks required. *Automating the operator was the metaphor for easy access in the telephony infrastructure.*

The emergence of the Bell System, the national telephone network in the United States, occurred during the first half of the 20th century. It consisted of multiple levels of automatic machines, which were arranged in hierarchical networks. There were actually 5 levels in the hierarchy, numbered from 1 (most global) to 5 (most local). The telephone number used to be a numerical description of the route taken to the physical phone instrument. The local exchange switch supported 10,000 lines for level 5 the end office (phone number), with each phone numbered in order. The national switch supported 1000 exchanges for level 4 the toll center (area code), with each exchange numbered in order. Thus, for my region of central Illinois, my telephone number of 328-9403 meant that my section of Urbana had exchange 328 within the region and my home used to have telephone 9403 within the exchange. This is how the lowest level class switches for trunk lines connecting phones handled addressing for plugboard simulations.

The higher levels had a much heavier call volume and most of the calls were routed based on load availability. Thus the area codes were handled by a more complicated system within the class 4 switching offices. Thus to reach my full phone address within the United States, a person must dial (217) 328-9403, implying I am in area 217. Each area code still did correspond to a specific geographic region with a limited number of possible connections. The highest level switches for class 1 and 2 and 3 are used for connecting together different areas of the country to ensure routing all calls is possible efficiently. In today's world of widespread cellular phones and private exchanges, the numbering plan is somewhat more complicated. For example, there are private company sub-networks with additional automatic switches beyond national networks.

The 7 digit numbering plan meant that a region could only support 10 million phone numbers. This from the 10,000 lines in the exchange and the 1000 exchanges in the region. In the first half of the 20th century, 10 million seemed an enormous number of telephones in one area. But in the second half, codes in densely populated areas were already filling up, and regions such as New Jersey, the center of Bell Labs, had to split their area codes at the higher level switching offices to handle the demand. And sub-networks were introduced for more potential numbers.

To efficiently implement point to point communications, the number of lines had to be much less than the number of wires. On the average, most of the people were not talking on the telephone, and so the system had to be engineered only for the average number of users at any one time. In a telegraph system, the trained operators were assumed to be using their instruments all the time, since they were consolidating the usage of many ordinary persons. In a telephone system, the ordinary people could directly access the instruments and were assumed to be using these part of the time so that the lines could be timeshared and only used when actively needed.

The telephone network supports this partial access using a hierarchy of switching machines. Many wires are connected into a switching machine but only a few lines are active at any one time. The local exchange is the lowest level of the telephone network, individual phone lines at homes and offices are directly connected into it with physical wires. A typical local exchange is supported by a switching machine with 10,000 lines. But the switch is engineered for 10% capacity. This implies that only 1000 lines can be active at any one time. If more than 1000 phones in the same exchange wish to connect at any one time, some must wait until a line is free.

Technically, the switch blocks the call until there is adequate capacity to handle it. The 10% non-blocking rate works well on the average and allows lower phone charges. But the switching machines overload during heavy call volume, such as Mother's Day or major disasters. The average rate comes from extensive measurement of average calls, which last two minutes. As data calls became more common, the numbers based on voice calls needed to be adjusted. A typical voice call is only two minutes (to talk to a person) but a typical data call is much longer (to talk to a computer) so that the computer is connected for extended periods.

The same sort of blocking switches are used at the higher levels of the hierarchical network. The local exchanges are connected into regional networks. Each switch in a regional network is physically wired to each exchange switch, but only a few connections are supported at any one time. Similarly, the regional switches are connected into statewide networks and the statewide networks connected into national networks. The telephone network in the United States was established during the first half of the 20^{th} century and transmits via physical wires and microwave relays. As noted, the network hierarchy contains 5 levels of switching machines and there are 10 centrally located class 1 machines at the very top. These route calls to the largest regional switches with hundreds of machines at class levels 2 and 3. Each call is switched from the sending to the receiving phone using a route of available lines on available switches.

The function of the higher level switches is to support least cost routing. That is, which route of switching through the network would be the fastest to connect and the most reliable to maintain. The switching machines are in different physical locations and there is a finite time required to transmit signals through each one. So routing the call through nearer switches makes the connection more quickly, which is good. However, remember that the number of possible routes through the switch is limited, typically a switch can connect only 10% of the trunks going into it at the same time. So the network also needs to make connections that are least likely to cause call blocking later. For example, an unusually busy switch might be bypassed in least cost routing, in favor of a less busy switch. Even though the less busy switch might be further away in physical locations, using it offloads routes from the busy switch and thus prevents future blocking of calls. Blocked calls slow down the routing, more than longer routes, with current speeds of transmission. The goal of a well-tuned network is to minimize the average time to connect calls.

Telephony in the 20th century made the transition from manual operators to automatic switches, then from mechanical switches to computer switches performing the same function of call routing across the hierarchical network. Telephony in the 21st century has already made the transition to primarily mobile smartphones. This reflects an addition in significant ways for the mechanism of transmission and for the nature of what is transmitted. These are worth additional explanation for how cell phones work and how phones transmit data as well as voice.

Traditional telephony has the telephone device in a fixed place connected to the exchange switch with wires in the house then in the ground. Sometimes the phone instrument itself can be carried around since it transmits radio signals to a base station, so the person can carry it around in their house while the base station is connected via wires as with a traditional landline. But wireless telephony has reached mass popularity in recent years, where the phone device can be carried anywhere, not just within a house. The equivalent of the base station for wireless phones serves a much larger area than just a house, typically covering a whole town or section of a whole city for mobile telephony.

The phone connection to the base station is also via radio waves, but with a large enough spectrum that many calls can be handled simultaneously by the single station. This is similar to the time sharing of the wired switches in the telephone network. The physical area supported by the base station is called a "cell", hence the terminology of wireless phones being cell phones. As the person changes their physical location, the cell phone can maintain transmission, although the cell being covered might change. When the phone crosses a cellular boundary, the base station routing the call changes correspondingly. In any case, the base station serves as an additional level in the switching hierarchy, being itself connected to higher class switches.

This is why with mobile devices, many more phones can be supported than possible with 10 digit numbers, since the wireless network supports call switching in tandem with the wired network.

For many years, cell phones only made voice calls. But these flip phones have been largely displaced in the present day, by smartphones which are highly portable miniature computers. They do make voice calls and also send text messages through the voice network. But they also make data calls, to function effectively for electronic mail and internet browsing.

Unlike voice calls, data calls are typically long – a browsing session might take 20 minutes while a phone call might take 2 minutes. So the network routing would often fail, if the same strategy was used with data as with voice to ensure non-blocked network transmission. Recall with voice, the wired network dedicates a switched line to the call, thus must block new calls if all the lines are in use. Telephony supports voice using circuit switching, where the connection is made continuously throughout the entire call. In contrast, Telephony supports data using packet switching, where the connection is made only in short bursts until the entire data is transmitted.

That is, the data object to be transmitted is divided into much smaller fixed size pieces called “packets”, and the network is used to transmit those packets individually, one by one, while time sharing packets for one transmission with those for other transmissions. Such strategy enables the network to support many data calls at the same time, being effective while still being efficient in utilizing the limited bandwidth. In the transition from Telephony to Telesophy, data transmission dominates with progressively more abstract objects being transmitted. So infrastructure for packets is fundamental to future generations of the Net, and is therefore covered in more detail in a later section in this chapter.

0a.2 Addressing and Gateways

The telephone number used to be a numerical description of the route taken to the physical phone instrument. The local exchange switch supported 10,000 lines and each phone was numbered in order. The regional switch supported 1000 exchanges and each exchange was numbered in order. The number in the local region is thus 7 digits of exchange-line, such as 328-9403. To span multiple regions, there is the area code, which specifies the class 3 switch number. So the total number is 10 digits with 3 for area, 3 for exchange, 4 for line, e.g. 217-328-9403. This implies that the total number of phone numbers is 1000x1000x10,000 or 10 billion within the country, which is likely enough for quite some time still, at least in the United States with current population of 300 million persons, many of whom have many phones. There is another level of numbering with the country code, and no country is close to 10 billion inhabitants, as the world population is 8 billion.

As the telephone devices became more sophisticated, the addressing became more abstract. In some sense, this is typical infrastructure progression where the automatic technology replicates the manual operation in a cheaper and scalable fashion. The human operator with telephone plugboard could perform high level abstract addressing as a matter of course. For example, if the caller said that they needed to talk with a doctor, the operator knew how to locate all the doctors, find the best one for the situation, and look up the number from the names on a phone list. In a small town, with only a few hundred numbers, the operator could likely correctly connect when the caller made personal requests, such as "call my mom". This was possible because the operator knew from the plugboard who the caller was, knew from their community memory who the mom was, and knew from the phone list what the number was.

The advent of phones with memories and processors enabled automatic support of this progression of abstraction from numbers to names to groups. In the latter half of the 20th century, it was common to have landline phones with speed dialing, where a list of numbers that were frequently called was specified upfront. For example, there were buttons on the phone which could be programmed into the memory to call specific numbers. So when the button for "mom" was simply pushed, the phone itself dialed the complete number and sent it into the switching network. This illustrates the underlying process, where a table of the numbers versus the names is used to automate the calling, similar to the manual list that a human operator uses. The abstract addresses could be names ("Bruce Schatz"), symbols ("Mom"), or even groups ("Doctors"), since any of these could easily be resolved to a phone number for calling purposes, by a human operator or a machine translator.

In essence, the evolution of infrastructure in the Net provides resolution of higher and higher levels of symbolic addresses. Rather than requiring specification of an exact number, the user can specify names or descriptions relevant to their problem. For searching in a library, covered in more detail later in this chapter, these might correspond to relevant keywords or subject descriptors that can be attached to the words in the texts. Even more abstract levels could be useful for many situations with phone calls. Moving higher in abstraction levels from objects to concepts to categories to features. For example, "Bruce Schatz" is a particular person of interest, not merely any such person with that name. Or "Telesophy Architect" is a description of the concept describing a person, and can be resolved to a particular person who is the author of this book. Or "Infrastructure Expert" is a general class of persons who could be called, one of whom is the author of this book.

The computer system would have to include the local context, so that which person could be resolved, much as the human operator uses their list of local persons with special properties. At the highest level is situational awareness, which is the true analogue of the manual operator. They assess the situation and connect to an appropriate person. This is still true of specialized operators, such as handling emergency calls ("911"), who must talk with the caller and evaluate which class of receiver needs to be connected to, whether policeman or fireman or medical professional or social worker as appropriate to the situation.

The original computer networks were built directly upon the telephone network and simply copied many of its conventions. The ARPANET built in the 1960s used telephone lines as the physical medium but transmitted digital packets across these wires. The original intention of the ARPANET was to remotely share computers across the network. The U.S. Department of Defense had funded the development of large supercomputers and the ARPANET could be used to enable researchers to login from remote sites. The addresses of the large computers could simply be numbers corresponding to their location on the network, much as with the hierarchy of switching machines in the telephone network.

When the Internet Protocol (IP) was developed to unify the ARPANET, it enabled a uniform numbering scheme for the packets being transmitted.[2] The protocol placed a package with appropriate headers around each packet. This enabled uniform packages to be transmitted across different types of machines connected via different types of networks. Some of the headers dealt with the packets themselves, for reliable transmission, and some dealt with the addresses to which the packets should be delivered. The addresses were originally numbers corresponding to the machines that served as switches for the hierarchical network. For example, "192.17.19.65" is the physical address of the machine in my faculty office via the campus backbone network.

As the number of machines on the Internet increased, it proved convenient to introduce symbolic addressing. Each symbolic address corresponded directly to a physical address, but provided a ready reference for the administrative location of each machine. The symbolic addresses were typically laid out by administrative domains to indicate the logical structure of the world supported by the physical structure of the network. The symbolic address of my office machine is "satori.lis.uiuc.edu" (not the same order as the physical). This indicates an ".edu" domain for an educational institution, whose domain name is "uiuc" for University of

Illinois at Urbana-Champaign. The subdomain “lis” is for the author’s department at that time, Library and Information Science, who actually maintain the local area network within the building containing the office. The symbolic name of the machine on which this chapter is being typed is “satori”. Note that the physical location is not explicitly contained anywhere in this address.

Symbolic addresses get around a major problem with numeric addresses, where the numbers are no longer uniform across the entire range, due to adding and deleting of machines. There was a similar problem with library classification schemes, which filled up within popular categories, as discussed later in this chapter. With Internet addresses, there is a Directory that gives the physical address for each logical address. The physical numbering plan can be rearranged for consistency, without affecting the symbolic addresses, given that the Directory is appropriately updated. This is similar to a telephone book where a person can always be called by name, but the current phone number is actually called, given that the directory is appropriately updated.

The process for addressing for data is thus similar to that for voice. These abstract addresses are implemented within the global network by hierarchical gateways, such as indicated previously, although the symbolic nature enables even higher levels of abstraction to be supported. The traditional standard protocols were developed before the period with the Waves of the Net discussed in the remainder of this book. These are incorporated into the Open System Interconnection (OSI) model, which defines a networking framework to implement protocols in 7 layers. Each layer takes care of a specific job and passes the data onto the next layer.

The bottom 4 layers deal with the general transmission of the data from one node to another in the network. These include the physical layer (e.g. wires or wireless), the link layer (e.g. dividing the variable size data into fixed size packets), the network layer (e.g. switching the packets into specified network addresses), the transport layer (e.g. resending packets until correct). The top 3 layers deal with the specific interaction with the data enabling the user to query and the system to display. These include the session layer (e.g. managing connections for user commands), the presentation layer (e.g. the syntax layer where display formats are supported), the application layer (e.g. the semantic layer where network services are provided).

A well-known example for the bottom layers is TCP over IP, the transmission protocols for the internet protocols. A well-known example for the top layers is HTTP over FTP, the hypertext transfer protocols over the file transfer protocols. These interconnection protocols support transparent access across the network, from remote nodes to local nodes.

The Waves of the Net are higher layers on top of the Applications Layer which is Level 7. That is, the evolved services are reaching towards higher levels of abstraction with standardized protocols, as these services are incorporated into the infrastructure. Other services in the Internet are higher levels above these 7 data layers, such as information search supported by the Wave 2 protocols of organized indexes. Since there are multiple search engines in the Web today, the protocols for search have still not yet been standardized, to be incorporated into the OSI model. Generally, standards are results of international standards organizations, although the effective monopolies of major technology companies can essentially provide de facto standards. The Bell System was broken up, so universal protocols for communications became necessary for future evolution. However, universal protocols for computers have never emerged since the monopolies such as IBM or Microsoft were never broken up so could enforce their own de facto standards.

The still developing protocols for the Interspace have yet to achieve mass popularity, and thus be subjects for standards. The Internet has largely been standardized for the Waves of Access, as well as the protocols for the Web above the Internet itself, such as HTTP above FTP, for following hypertext links using file transfers. That is, the progress of the World Wide Web has standardized the display of documents and the following of links. Earlier research systems developed the original functions and demonstrated their utility with scalable technology. My own contribution to this progress was the first hypertext system to search documents across the network and display them with full multimedia. This Telesophy System showed that linked documents could be handled at global scale, and catalyzed the technologies which became the Web in Waves 1 and 2.

0a.3 Packages and Protocols

Each Wave of the Net is network infrastructure that supports transparent connection to diverse sources across the network. Each new wave represents a deeper level of abstraction evolution. Each item selected is transmitted across the network from remote sources to the local users. Once there are multiple sources, federation must be supported as well, where equivalent items are merged from heterogeneous sources, so that the diverse sources can be combined during an operation into a unified whole. To implement such support, the items must be wrapped inside packages with enough context to handle the appropriate levels of deepening connection. These packages wrap the items so they can be transmitted as unified wholes during the access stages. Plus then they can be properly and accurately selected during the search and analysis stages. Accordingly, each wave has a different package for its items, which is more powerful than previous waves which are subsumed. The package stages are listed in the following table.[3]

Wave 1	Packet is Unit	Browsing as Paradigm (Access)
Wave 2	Object is Unit	Searching as Paradigm (Organization)
Wave 3	Concept is Unit	Pathways as Paradigm (Analysis)
Wave 4	Feature is Unit	Regions as Paradigm (Synthesis)

Since Wave 1 is the Data level, the wrapping is simple due to the function being fetching only. The source must be identified along with the size, so that the entire item can be transmitted properly. Often, for efficient transmission, the complete package is divided into individual smaller packages traditionally called "packets". The item must be divided on the sending end and then reconstructed in proper order on the receiving end. Such packages are largely covered by existing standards in protocol design, since telephony pioneered transparent connections.

Since Wave 2 is the Information level, the wrapping is slightly more complicated. The packaging must include metadata that enables the internal bits to be externally interpretable. That is, the data must be displayed to become information, along with other operations. And a variety of metadata fields included to support better searching for information retrieval beyond data fetching. Such packages are traditionally called "objects", to include that software for the operations is bundled in, in addition to the bits for the data itself. Objects enable multimedia data to be properly transmitted from the remote sources and then displayed to the local users.[4]

Since Wave 3 is the Knowledge level, the wrapping becomes equally important with the content itself. That is, the context surrounding the objects is used to properly interpret the meaning. This wave introduces the abstraction of classification, which is discussed in the next section as critically important to the classification schemes within physical libraries. In digital libraries, such abstraction implies that equivalent terms are semantically related, even though they are not syntactically related. For example, "Unix" is an "operating system" but not the same word or some variation. Or an "Android phone" is a physical device running the virtual machine for the Android operating system for mobile devices, so similarly searching for "Android" could retrieve objects that mention only "operating system". That is, rather than search for objects, the infrastructure supports search for concepts. These are units containing similar meaning, not necessarily similar content. In the Interspace, the packaging must be deeper than that in the Internet, so contains context in addition to keywords for indexing purposes.

Since Wave 4 is the Wisdom level, the wrapping of concepts needs to be supported with situational awareness. That is, a particular concept may have different meanings in different situations. Such facility is necessary to support practical categorization, of utility for the current need. That is, rather than retrieving objects appropriate in some generic way, the retrieval is based upon specific categorization for your particular situation. For example, the term “system” has many possible meanings, so that its usage for computer systems differs from its usage for government systems. But the context in the discourse makes the meaning clear to the reader.

Objects that are the same for practical purposes are often quite different than those that are the same for classification purposes. The examples in daily living are myriad, especially those related to healthcare as discussed in detail later. An 80-year-old woman with rheumatoid arthritis may have little in common with a 20-year-old man with tennis injuries, but to treat their knees they may take similar medicines and consider similar surgeries.

The current Internet supports the protocols for Wave 1 of Access and Wave 2 of Organization. The future Interspace will support the protocols for Wave 3 of Analysis and Wave 4 of Synthesis. Existing research prototypes have developed the Interspace protocols across the global network. My own research systems developed the first Interspace Prototype with scalable technologies for concept extraction and navigation. These are discussed at length in the chapters in Part II covering the evolution of Internet to Interspace, with historical discussion.

My research systems successfully tested these new semantic technologies, which compute contextual frequency within community repositories, on discipline-scale, real-world collections. These systems supported semantic indexing of tens of millions of items with concepts and categories. In the 1990s, such prototypes indexed static collections where the system fixed the classification of which collections were available for community indexing. In the 2000s, such prototypes indexed dynamic collections where the users chose their own classifications for each situation, which represented the knowledge of their community. So a user specified a special collection relevant to their problem and the system generated a new index for this collection, approaching pragmatics by implementing semantics of concepts and categories.

With the Interspace, the global information infrastructure will, for the first time, directly support interaction with abstraction. This infrastructure uses technologies that go beyond searching individual repositories to analyze and correlate knowledge across multiple sources and subjects. The Interspace will offer distributed services to transfer concepts across domains, just as ARPANET used distributed services to transfer files across machines and the Internet uses distributed services to transfer objects across repositories. Standard protocols for the emerging infrastructure will support searching knowledge collections maintained by specialized communities and residing directly on users' personal machines. These protocols will automatically interconnect related logical spaces, letting individuals navigate across community repositories rather than search for interlinked objects within physical networks. These more abstract semantic levels will lead to closer matching of meanings in the user's mind to the world's objects.

0a.4 Digital Libraries as Networked Infrastructure

As an extended example of modeling the networked infrastructure, consider library catalogs which are the indexing methods for physical libraries.[5] Physical libraries are organized via catalogs to facilitate browsing and searching. That is, similar books on similar topics are shelved together so users in a particular section can browse for related books. The particular section itself can be located using the classification of the books in the catalog, such as the author and title, but especially by the subject matter. For example, books mentioning computers are now so common, they would be shelved in multiple places depending on their usage.

The simplest classification scheme is assigning a single number which represents the unique location of a book on a shelf. If there are, say, 1000 books, you might just assign them the numbers 1 to 1000 corresponding to the different positions of spaces on the shelves. Given the number of a book, it is then easy to find that location on the physical shelves and retrieve the book itself. This is much like phone numbers in a small town. However, a fixed set of numbers would make it difficult to add or delete books, since many of the numbers would have to change when another was added or deleted in appropriate place. To also make the numbers invariant, you need to have a classification scheme which also grows and shrinks as needed.

The Dewey Decimal Classification commonly used in public libraries is one such scheme. When this scheme was originally proposed in the late 19th century, there was room for 1000 major categories 0-999 which represented what was then thought to be the major classifications of knowledge in books. In a simplified example, 500 is the general category number for science and 538 the general category for computers. So all books about computers were assigned category code 538 and distinguished from each other with letters "a", "b", etc. Thus 538c is the 3rd book classified under computers and located in the 500s section of the library shelves. Then a book can easily be fetched from its shelf using its category code.

The mapping of books to codes is called a catalog. The card catalogs familiar from the early days of public libraries were for a long time the implementation of the library catalog. The Dewey system dates from Melville Dewey in the 1890s. The physical cards have now largely been displaced by electronic cards handled by computers, but with almost the same functionality. Much of the research work in information retrieval improves interaction with information beyond the level possible with card catalogs. For example, faceted classification enables a book to be simultaneously classified in multiple places, corresponding equivalent of multiple cards.

The codes are assigned by professional librarians similarly called "catalogers". Their general job is to classify all of human knowledge to support retrieval of books in libraries. Their specific job is to assign a unique category code to each book as it is initially received. A major classification such as Dewey commonly has an entire organization devoted to classifying new books as they are published and selling that classification scheme to libraries, who then actually place books on shelves corresponding to that classification. The volume of books has forced specialization so that there are teams of catalogers corresponding to the major subparts of the classification (e.g., science and technology, philosophy and religion) with each knowledgeable about the subject matter in their area in addition to being a trained classification librarian. For databases, such special librarians are called "curators", human experts in both subject matter and classification scheme who serve as exemplars of waves in the Interspace beyond the Internet.

The original goal of a catalog was simply to ensure that every book could be placed in a unique location by assigning it a unique code. All of the major classification schemes in use today have this as their goal – one book one location. This solved the major organization problem of a physical library. Determining the major topic of a book is not always easy, particularly for topics new to the classification scheme. Is the present book about libraries or networks or computer technologies or situational analysis? There was always some hope of facilitating browsing by clustering books on similar topics close together–so that looking around a fetched book might also locate other books of potential interest.

As the volume of books grew greater, the classification schemes became partitioned more finely. A book on computer networks might be classified as 538.237 SCH, representing a subdivision of computers in the 538s and the author's last name to distinguish between all books within the same