FEATURE ARTICLE

Technical Standards: Foundations of the Future

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Without the cubit, the pyramids could not have been built. Technical standards are the foundation of each technological advance; each innovation is linked by reference to prior technical standards. Each successful innovation furthers the flow of progress. Most innovations cause only a small ripple in that flow, but a few bring about more profound change, and are perhaps the beginnings of a whole new wave.[1] Technical standards are a means to chart these rising waves of change. In this article, three classes of technical standards are identified and the changes they influenced are described. A fourth class of technical standards is postulated and some of its effects are predicted.

An early example of a standard is the written alphabets developed by the Egyptians and Babylonians around 4000 BC.[2] Thus the setting of a standard marks the start of recorded Western history. The Western alphabet continued to evolve for about 3000 years until the Greeks completed the task with the addition of vowels (and the writing of the Homeric tales).[3]

Alphabets were so desirable that many other, incompatible, alphabets were also developed in other cultures. The creation of multiple alphabets appears to have been caused by minimal communications between different cultures and the desire of each culture to control its own alphabet. So each culture developed its own standard alphabet, many of which survive today.

While the alphabet was being developed so were unit standards for length and volume, setting the stage for the next wave of change, the trading wave. Trading, the major activity of merchants, is facilitated by the acceptance of public standards[4] for unit measure. Initially, different cultures created different unit standards. Over time, trading (a form of communication) reduced the number of systems of weight and measures significantly.

Waves of human progress, technology, and standards are related and overlapping. As humans and technology do, standards follow an evolutionary path. Multiple standards are created and over time are winnowed down to the most desirable and culturally acceptable standards that codify the technical requirements developed during the preceding wave. Later waves build upon previous technical work by referring to the standards.

Even the information wave, first described in 1980, has already evolved sufficiently to suggest further division into linear and adaptive phases. Table One describes the periods most relevant to the creation of new classes of technical standards. It is not meant to describe all the waves of progress that have occurred.

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1 Developed as a concept by A. Toffler in *The Third Wave,* 1980. He describes three waves: agrarian, industrial, and information.
2 Bertrand Russell, *A History of Western Philosophy,* 1945.
3 Rostovzeff, *History of the Ancient World,* Vol. 1, 1926.
4 Public standards are those that are accepted across multiple jurisdictions.

Table *One*—**The Relationship of Standards, Communications, and Technology to the Ongoing Waves of Society**

Waves of Change	Trading Wave	Industrial Wave	Information Wave Linear	Adaptive
New technology	Definition of weights and measures	Logistics (assembly line)	Computers (linear processes)	Adaptive processes
New communications	Trade routes	Mechanized transport	Electronic	Wireless
Class of standard	Units (metrology)	Similarity and methodology	Compatibility	Etiquette

A New Phase of the Information Wave

The adaptive phase of the information wave began with the completion of the U.S. government-funded Internet during 1982–83.[5] As soon as a technology strong enough to create a new wave is identified, the powerful seek to appropriate the technology to maintain or increase their power. So each wave begins with those who would control the technology and ends with the technology dispersed to all who would use it. Now that the personal computer provides linear information processing to millions and IBM no longer dominates the field, the final phase of the linear information wave has arrived. The wide dispersion of personal computers thus sets the stage for the beginning of the adaptive information wave.

During the linear information wave, large organizations' information systems were private. Limited information transfer took place between two or more private systems. Like a tribal society, each linear information system had its mores and customs that could not be challenged by the system users. This lack of adaptability limited system users to rote functions; unique customer problems could not be addressed rapidly. In such a constrained environment, businesses were likely to suffer if competitors were more versatile. Currently, concepts such as client/server computing and re-engineering are being introduced to provide more adaptive information processes.

Today's First World societies are awash in linear information: TV, cable, periodicals, radio, movies, mail, newspapers, and books. Most of these media were created for entertainment and are not appropriate for information processing. They rapidly become obsolete (i.e., not efficient to maintain), difficult to use (i.e., not machine-searchable), or undesirable (i.e., junk mail). The Internet is an example of a communications system capable of supporting adaptive applications. Internet applications provide information storage, search mechanisms, and common presentation formats, with potentially more features to come. Fundamentally, Internet applications are adaptive to the user: accepting of input, searchable, automatically updated, continuously expanding, selectable, and changeable.

The adaptive information wave is beginning with adaptive applications such as agents.[6] It will be implemented with adaptive processes for the layers of communications as well as the applications, since without open adaptive communications the applications themselves are constrained.

As the Internet indicates, providing fully adaptive applications requires near real-time communications. Batch processing is definitely not adaptive. Given the bi-directional operation of adaptive communication processes and the change from central information processing to a peer-to-peer or client/server environment, it appears that a bi-directional (near duplex) communications environment is necessary as well. These requirements for near real-time duplex communications to support the adaptive information wave may impact plans to provide public asymmetrical communications via cable or wireline (ADSL[7]) services.

Splitting the information wave into linear and adaptive phases highlights the importance of adaptive information and the many ways in which it differs from linear information. It also demonstrates that adaptive processes require open communications[8] systems.

Open Communications

Until the 1980s, almost all implementation of wide area public networks[9] was handled by regulated public utilities. While these utilities are theoretically public, in practice current design, regulations, and bureaucracy severely limit the adaptability of such networks. The privatization of international public telephone utilities (British Telecom in 1984, DBT Telekom (Germany) starting in 1989) is an indication of the societal trend toward opening public networks. This opening is seen as fostering competition and also requires standard interfaces that support open communications.

"Open communications" in this article denotes "freely available to connect to." It also connotes a flexibility or independence of connection. To achieve such flexibility, interfaces need to be adaptable, as any large communications system mutates over time. Mutation of communications systems is most often caused by new application requirements, but also occurs through error and because of increasing needs for compatibility with other systems. An example is the change evidenced after the Carterphone deci-

5 Period of transition from NCP (Network Control Protocol) to TCP/IP (Transmission Control Protocol/Internet Protocol) is used to indicate the completion of the Internet.

6 Active distributed network applications such as those created by General Magic's Telescript.

7 Asymmetric Digital Subscriber Line supporting up to 6.144 Mbit/s to the user and up to 640 kbit/s to the network.

8 Open communications is a broader term than open systems from Open Systems Interconnect (X.200/ISO 7498).

9 Formally termed Public Switched Telephone Network (PSTN) prior to 1984 and General Switched Telephone Network (GSTN) after 1984.

The wide dispersion of [PCs] sets the stage for . . . the adaptive information wave.

sion[10] in 1969. Previously only a few different telephones from the Bell System could attach to the network. Now the U.S. public telephone network connects to an amazing array of telephones, PBXs, computers, fax machines, answering machines, cellular phones, and cordless phones. Another example is the Internet, which allows flexibility of function above the OSI transport layer. The World Wide Web and an expanding but compatible range of Web applications are the result.

Adaptive communications processes are OSI-layer processes that may change operation, based on the information or control signals returned. The difference between adaptive processes and linear processes is feedback. Feedback is too powerful a concept to treat simply as an aspect of processing. In a communications system the use of feedback between remote ends to initialize a process is termed "negotiation." The ability of a user/system to access usenet, ftp, or www on the Internet is a form of negotiation. The ability of two remote fax machines to select data rate and page format is another form of negotiation. Successively more complex negotiation (i.e., feedback) becomes necessary in a rapidly changing open public communications system.

Fundamentally, public communications standards are necessary for openness.[11] However, it is often difficult to achieve a single communications standard. When a standard becomes ubiquitous, as did the telephone RJ-11 jack, for example, it offers flexibility of use because it is ubiquitous. When a communications standard is being developed, standards only limit the designers' flexibility. So different systems designers, for reasons Darwin would appreciate, create different implementations of the same process. Over time and with guidance from market forces, standards committees try to coalesce these multiple versions into one standard, with varying success.

Adaptability can also help minimize the problems caused by the creation of multiple incompatible implementations. With adaptability and negotiation a communications system can operate according to one implementation and then change, in response to a request, and operate according to a different implementation. The ability of a V.34 data modem to also work as a V.32bis data modem is adaptability. The ability of a proprietary modem (such as Telebit multicarrier) to also work as a V.32 modem is adaptability. Adaptability maintains the flexibility necessary for open communications.

The transition from linear processes to adaptive processes in communications systems requires evermore complex negotiation. Adaptive processes at each layer of the OSI model support more potential variability. The most dramatic case is when the physical layer is wireless; then the range of adaption possible is not constrained by any physical interface. In wireless systems, a new technology called "software radios"[12] will make possible wireless communications systems that can access multiple wireless frequency bands and modulations. This technology, and the associated negotiation, will do much to overcome the log-jam of technologies being proposed for wireless personal communications services.

In the linear information wave, the telephone system was run as a single public utility and did not provide open communications; the telephones connected to the ends of the network were certainly not adaptive in any way. IBM computers, with IBM software, connected by IBM-specified protocols to IBM terminals also did not offer open communications, and offered only limited adaptability at the central host location. Now the widespread deployment of personal (i.e., changeable by user) computers, high-level programming languages, and the beginnings of adaptive applications (e.g., HotJava[13]) support the adaptive information wave.

The adaptive information wave is carried on the rising tide of open adaptive processes in communications, often wireless, with other open adaptive processes. The passage of information between non-adaptive or non-independent processes is linear information transfer. The linear information wave was a significant step forward, but it is now being succeeded by the adaptive information wave.

Classes of Technical Standards

Until the information wave began, there was no need to delineate technical standards into multiple classes. All technical standards basically defined similarity of entity or process. During the information wave, technical standards designed specifically for compatibility have emerged. Now the requirements of new waves of society seem to be expanding sufficiently[14] to suggest the need to define a new grouping of standards.

As Table One indicates, the term "standards" has been used for a range of different technical requirements. The initial standards for weights and measures in early Western civilization were necessary to support trading. Later the industrial wave expanded the requirements for similarity standards such as wheel sizes. During the industrial wave, early physical com-

10 The FCC in 1969 found that the Carterfone electrical connection to the telephone network (for wireless phone calls) did not adversely affect the telephone system. This decision became the basis of direct connect, FCC Part 68, connection to the public telephone network.
11 "A Five Segment Model for Standardization," by Carl Cargill, published in *Standards Policy for Information Infrastructure,* 1995.
12 A concept described in *IEEE Communications Magazine,* May 1995.
13 Internet application developed by Sun Microsystems.
14 "Recommendations for the Global Information Highway: A Matter of Standards," by Ken Krechmer, 1995.

Table *Two*—The Four Classes of Standards

Classes of Standards	Examples	Purpose	Effect
(1) Units	Meter length, ounce (metrology)	Sameness	Replication
(2) Similarity	AS[15] metal gauges, methodology stds, character sets, X.3 PAD	Repeatability	Compatible with like
(3) Compatibility	Group 3 facsimile, V.32 & V.34 modems, X.25 interface, NIUF ISDN implementation agreements, wireless air interfaces	Interworking	Transmitter compatible with receiver
(4) Etiquette	Aloha protocol, CSMA/CD, modem handshakes, WINForum spectrum etiquette	Expandability	Negotiate the variation

patibility standards also emerged for train-rail spacing, nut-to-bolt fit, etc. While written as similarity standards, i.e., no separate interface standard was created, these standards were the seeds of later compatibility standards.

The linear information wave required virtual similarity standards for character sets, protocols such as HDLC, operating systems, applications and databases. During the later stages of the linear information wave, more complex public communications systems using modems, facsimile, and ISDN dramatically expanded process complexity and the need for compatibility standards. Now in the adaptive information wave, many kinds of wireless services, public and private, are creating the need for additional compatibility standards. This expansion in communications compatibility standards gives rise to a need to implement etiquette standards.

Table One proposes four classes of standards; Table Two delineates these classes. Note that each class of standards is related to the previous one, and may reference it, but defines a range of variation that was not previously delineated separately.

(1) Unit standards define measurable physical qualities, e.g., meter, mile, liter, gallon, gram, pound. This allows different physical entities to be compared to a single reference.

(2) Similarity standards define (possibly with the use of unit standards) the variation permitted within a set of similar entities, e.g., thread gauge, DOS operating system, paint color. In similarity standards, the primary reference is a definition of the entity to which similarity is maintained. Unit standards, if employed, are a secondary reference.

(3) Compatibility standards define the interface between two or more mating elements that are compatible rather than similar, e.g., a plug and a socket, a transmitter and a receiver. The primary reference is to a definition of the allowed mating entity. Modem standards (V.32, V.34) are examples of compatibility standards: they define most aspects of the transmitter and a few aspects of the receiver to ensure compatibility. Compatibility standards define the difference allowed between the plug and the socket, the transmitter and the receiver, the protocol generator and the protocol receiver. The OSI model (X.200) defines the mating layers necessary to pass information between computers (adaptive or linear). OSI layer protocols may be defined by similarity standards, but each protocol likely has options. The effect of such options has been to create the need for compatibility standards, called "interfaces," "templates," or "implementation agreements," which define the allowed range of options necessary for compatibility. The X.25 is an example of an OSI-based compatibility standard between a DTE and a DCE (X.3 Packet Assembler Disassembler similarity standard) connected to a packet data network.

Some of the difficulties experienced in deploying ISDN came to pass because the initial standards that defined ISDN were similarity standards rather than compatibility standards. Later, when the National ISDN User Forum (NIUF) developed compatibility standards (implementation agreements), usage began to expand. A counter-example is the rapid acceptance of Advanced Mobile Phone System (AMPS) cellular telephone standards in North America. AMPS standards included compatibility standards (air interfaces) in the initial standards work.

(4) Etiquette standards define the initial negotiation between independent communicating processes for the purpose of establishing communications.[16] The primary reference is to a definition of the variability of negotiation allowed. Such a definition may be open-ended to support future compatibility. An etiquette does not terminate an OSI layer, it only negotiates aspects of a layer's function. This usually means that the function that performs the etiquette must be associated with the process that terminates the related OSI layer (otherwise problems may occur). Etiquettes are being used to support physical node change (Ethernet CSMA/CD), backward compatibility (V.32, V.22bis, V.22 handshaking) and wireless access (WINForum spectrum etiquette). In these cases, the value of the etiquette is its ability to negotiate variable aspects of the physical layer process.

15 American Standard.
16 A good example of a human communications etiquette is "hello." It was Thomas Edison who suggested to Alexander Graham Bell that the term "hallo", used to hail a ferryman, be used by the answering party to indicate that they had answered the telephone. It also indicates the language spoken.

Summary

Initially, standards defined physical things. Then they evolved in support of the industrial wave to define the physical relationship between things. Later, standards used for information transfer in the information wave defined the virtual relationship between things (a radio transmitter and a radio receiver). More recently, the opening of public wide-area communications systems has engendered the need for interoperations across an ever-expanding range of communications networks and equipment. This creates the need for etiquette standards.

From cubit to CSMA/CD, the creation of standards makes possible new waves of change. The next wave is emerging: the adaptive information wave. It is being carried forward by open adaptive processes and will operate over near real-time wireless communications. The linear processing wave created a tribal information society. The adaptive information wave will be more like the ferment of a modern society. Considerable freedom will be possible and considerable responsibility will be necessary. In such environments, future innovations and the progress they foster will flourish even more. **SV**