1800 *1900* *2000*

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45 Internet

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In a book chartered to demonstrate intellectual property in objects, what concrete thing can represent the Internet, a phenomenon that exists only as a well-elaborated idea? Perhaps the best physical representation of the genius of the Internet—and in particular, "Internet Protocol"—is found in an hourglass.

Internet Protocol is the essence of today's global worldwide network, and it's a very different kind of "IP" than the one this book is about. The Internet Protocol suite is a freely available set of standards for how digital devices and the software running upon them might talk to one another, and the internet exists because the makers of those devices and software, and the networks to which they're connected, have decided to implement those standards. The internet is a collective hallucination that functions because millions of people and companies believe in it.

The hourglass on the left is from late 18th-century Italy, a time before the waisted glass shape could be blown as a single piece of glass. Instead, two glass ampules were joined by wax, covered with cloth, and secured by threads. That junction, which Jon Evans calls a "bubble-gum-and-baling-wire" construction, is where Internet Protocol can be found.

The metaphor of hourglass architecture is fundamental to understanding how the internet works, though its origins are a bit obscure. The US National Research Council's magisterial *Realizing the Information Future: The Internet and Beyond* from 1994 is one of the earlier conceptions, and it introduces the idea of a network built in layers. The number and nature of the layers has evolved over time, but its essence is three, mapping to the top, middle, and bottom of an hourglass. The bottom represents the range of physical media, wired and wireless, through which communications can take place. It's broad because it's meant to encompass any form of physical conveyance of data.

The top represents applications—what we might do when we can exchange data with one another, whether email, web browsing, or videoconferencing. It grows every time someone comes up with a new use for the internet.

On the left: A late 18th-century Italian hourglass. (Harvard University Collection of Historical Scientific Instruments)

And the middle is the "bearer service," the translator that links the top to the bottom without either having to know anything about the other. Companies can build networks without needing to know specifically how they'll be used; developers can write software without having to know anything about how the network that the software depends on is supposed to work. So long as each side knows a small amount about Internet Protocol, they're good to interoperate.

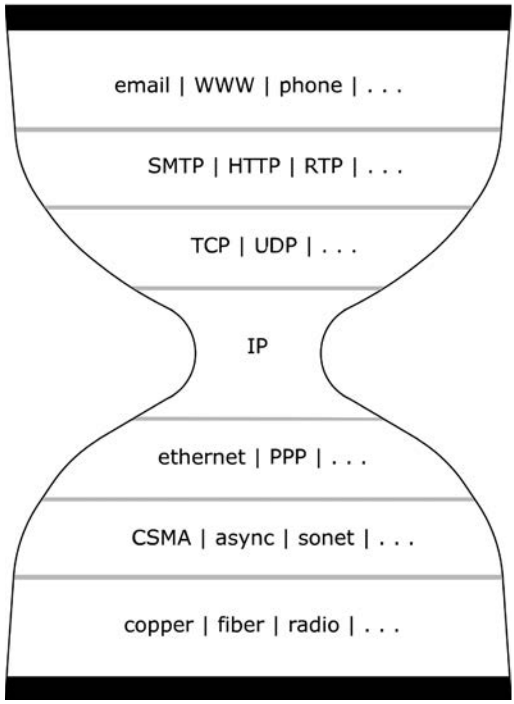
This technical design reflected not only the desire to occasion a network that would be ecumenical about the pipes it could run upon, and the applications that could in turn run upon it, but it also embedded the values of the cooperative and academic environment from which Internet Protocol sprang. As the 1994 NRC report put it:

> This separation of the basic bearer service from the higher-level conventions is one of the tools that ensures an open network; it precludes, for example, a network provider from insisting that only a controlled set of higher-level standards be used on the network, a requirement that would inhibit the development and use of new services and might be used as a tool to limit competition.

So the hourglass represents layers designed to operate independently from one another—while still interconnecting thanks to the middle. And that middle is meant to be narrow. Steve Deering unpacked that narrowness in a 2001 presentation to the Internet Engineering Task Force, or IETF, which is the open, non-membership organization that develops and stewards internet protocols. According to Deering, the middle layer is narrow because it "assumes [the] least common network functionality to maximize [the] number of usable networks." By keeping the protocols simple and straightforward, and evolving very slowly, many unrelated parties who build networks and software can easily adapt to use Internet Protocol. As Bob Braden put it in 2001: "The lesson of the Internet is that efficiency is not the primary consideration. Ability to grow and adapt to changing

Above, left: The top and the bottom of the hourglass. (Harvard University Collection of Historical Scientific Instruments)

Above, right: The "bearer service" of the hourglass. (Harvard University Collection of Historical Scientific Instruments)



Above: Hourglass architecture of the internet. This version of the hourglass is derived from "The Internet's Coming of Age" by the Computer Science and Telecommunications Board of the National Academies of Sciences, Engineering, and Medicine, The National Academies Press (2001).

requirements is the primary consideration. This makes simplicity and uniformity very precious indeed."

This principle of simplicity goes hand in hand with the principle that new features for users are typically best implemented not as additions to Internet Protocol, which would expand the waist of the hourglass, but rather through a given piece of software built on top of it, running at two or more communicating endpoints.

Unlike the textbook story of IP-driven innovation, where creativity is inspired by the prospect of the creator monopolizing its fruits for a while, today's global network only exists thanks to its far-flung inventors disclaiming any property interest in its success.

Internet protocols have been devised by an open, unincorporated group—the IETF—which has sought to make those protocols as freely usable by the world as possible. That's a near-inversion from previous network architectures, which were built by a single company or consortium and then protected as much as possible to allow for exclusive rights in selling deployments of those networks. By contrast, in copyright terms, participants in the IETF grant an irrevocable and perpetual non-exclusive license to an IETF Trust which, in turn, grants that license to everyone else in the world. Patent rights are a bit more complicated; here the IETF seeks maximal disclosure of rights implicated by a technology proposed for inclusion in an internet standard, with an opportunity for IETF participants to weigh whether the burdens of such rights are worth it. But according to the IETF's Best Current Practice Memo, the overall thrust remains that "IETF working groups prefer technologies with no known IPR claims or, for technologies with claims against them, an offer of royalty-free licensing."

As a competitor to proprietary network models and services, the internet not only offered a particular technology that the market might determine to be superior, but at least as important, a technology that could be adopted by anyone without concern for demands for licensing from its progenitors. (The risk of patent

Above: The middle part of an hourglass consisting of one piece of glass. (Harvard University Collection of Historical Scientific Instruments)

claims by third parties remains for any technology.) Internet Protocol was designed to be ubiquitous and invisible, an all-important transparent glue piecing together disparate networks, devices, and applications. And that vision has not only been realized, but replicated among some of the still-most-common applications and services running at the "top" of the hourglass: the servers and clients following the protocols of Tim Berners-Lee's World Wide Web—described by James Gleick as the "patent that never was"; the mediawiki software and Wikipedia, a global encyclopedia in multiple languages to which anyone can contribute, and for which all contributions are licensed freely; and bitcoin, a cryptocurrency whose underlying blockchain protocols can be themselves found in a wiki, based on a paper written by a pseudonymous author who licensed them freely.

The signal disruption to the status quo as the internet became mainstream was its impact upon copyright enforcement. The move from analog to digital meant that the physical vessels of books, CDs, and DVDs that lent themselves to the scarcity on which IP is premised became unnecessary to convey their contents. A different network architecture—one designed and managed by a single company, for example—could have facilitated the design of digital bottles meant to decant their contents at least as discriminatingly as their analog forbears. The NRC's pro-competitive idea behind the layers of the internet hourglass translated to a reality that anyone could write an application to convey data, and network providers would serve no gatekeeping role.

Thus in 1999 an 18-year-old college student could devise "Napster," a song-sharing program, and freely share the program itself over the internet. The program was not one friendly to limiting access to music only to those who paid for it, and those who ran it soon found themselves able to trade music back and forth. When Napster was shut down, that broad and open top of the hourglass meant that any number of successors could take its place, many using fully peer-to-peer technologies such that once a copy of the software was obtained from any source, users could communicate directly with one another to swap files, making enforcement of any successful infringement claim difficult because there was no one central point of intervention to halt the activity. This resulted in some enforcement actions by the music and movie industries against individual users rather than intermediary software writers or service providers. Over time, it appears that the carrot of simple (and significantly cheaper) legal licensing schemes, such as those occasioned through the Spotify music subscription service, have had more of an impact on users' behavior than the stick of direct threat of lawsuit for using peer-to-peer services to trade copyrighted material.

For material born digital and intended to be shared by its makers, the free software movement pioneered licenses that would permit the sharing of software and the making of derivatives—so long as those derivatives, if shared, would be similarly free. Creative Commons came about in 2001 to facilitate the sharing and remixing of text, photos, and other non-software creative works. In 2016 Creative Commons reported 1.2 billion licenses in use. In the meantime, legally blessed repositories that could index and aggregate old books in new ways—as compared to music and movies—have been difficult to achieve.

Internet Protocol has proven extraordinarily resilient as it has gone from experimental to universal, and even as its openness to innovation elicited seismic counter-reactions from incumbents whose interests or rights have been threatened, with copyright as a bellwether. By keeping its narrow waist, neither trying to optimize for particular applications, nor adding features to address concerns by rightsholders, Internet Protocol and the values of openness behind it have reigned.

These values are now tested as some applications at the top of the hourglass have become so popular as to constitute

constructive networks unto themselves. In 2017 Facebook crested two billion active users, including some who think it to *be* the internet, according to surveys conducted by *Quartz*. For better or worse, the internet's structure is akin to a monolith rather than an hourglass: innovation is channeled as business relationships by Facebook rather than anything goes, and bad behavior can be defined by the company and monitored and acted against in a way not possible on the internet at large. Bad behavior itself constitutes another test for the open internet; if the open tools to preclude it are outstripped by the tools to facilitate it and the energy to conduct it, users themselves may be driven away. There have been open implementations of social networks to compete with those like Facebook, and none have succeeded.

Finally, the Internet of Things confronts us with design choices originally made for the transport of "mere" bits. It's one thing for my 1998 PC to crash because of too much generativity in its amenability to running malware; it's entirely another for my car to crash for the same reason. The eccentric openness of groups like the IETF will be hard to apply in the world of traditional devices and vendors. The things joining the internet might yet be linked to their vendors by Internet Protocol, but not to one another in the free-for-all of the 1990s and early 2000s. ◆

On the left: An early 19th-century French hourglass (1800–1850) without a bearer service. (Harvard University Collection of Historical Scientific Instruments)

Further Reading

Scott Bradner (2003) "A Short History of the Internet" (presentation, NANOG, February 9), http://www.sobco.com/presentations/n30.history.pdf. Archived at https://perma.cc/U36F-66JB.

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The US National Research Council (1994) *Realizing the Information Future: The Internet and Beyond.* Washington: National Academies Press. www.nap.edu/read/4755/chapter/4. Archived at https://perma.cc/G56F-BFV8.

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