One

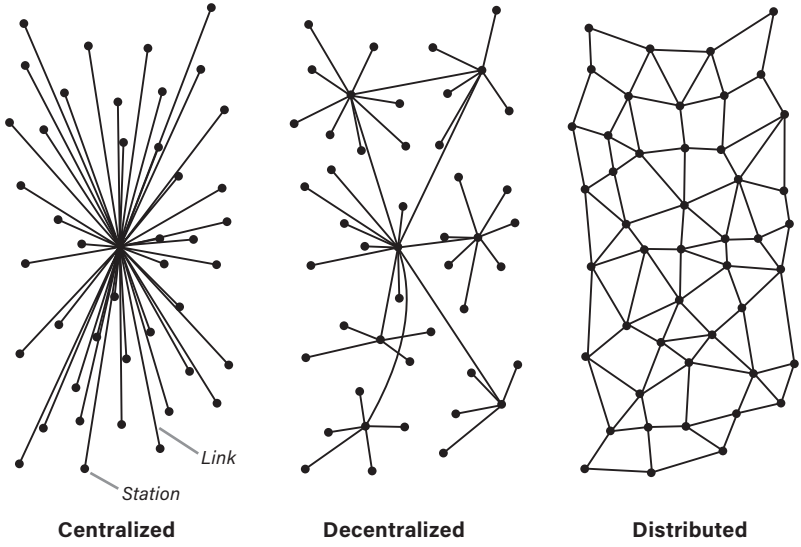
Connections Have Consequences

The marriage of computing and communications was a shotgun wedding. This time, however, the shotgun was a nuclear bomb.

At the height of the Cold War, the United States relied on the telephone network to deliver commands to its nuclear strike forces. This meant, however, that the launch of bombers and missiles was vulnerable. Because the telephone network was a series of centralized hubs at which messages were switched from one path to another, all an adversary had to do was take out a few of those hubs and the nation's ability to launch a retaliatory attack would be impaired.

The U.S. government commissioned a California think tank, the RAND Corporation, to develop a solution for this soft spot. RAND's answer was a new network architecture that eliminated the vulnerable central switching points. The new network resembled a fishnet. If one knot on the fishnet was eliminated, there were multiple other routes the message could follow to reach its final destination.

The new network typology: centralized, decentralized, and distributed networks.



Source: Paul Baran, "On Distributed Communications: I. Introduction to Distributed Communications Networks," Memorandum RM-3420-PR (Santa Monica, Calif.: RAND Corporation, August 1964). Reproduced by permission.

The visionary behind this idea was a Polish immigrant named Paul Baran. In his 1964 paper, Baran proposed digitizing a voice phone call and then breaking that digital information into small packets of data. Instead of being sent over an end-to-end telephone circuit, the packets would be dispatched into a network of interconnected computers that would read the packet's address and then pass it on to the next computer in the direction of its destination. If one computer was knocked out, the packets would work their way around the problem by being re-sent to other nodes.[1]

It was an idea as big as the bomb itself.

Communicating computers handing packets of data to each other across a distributed network would become the hardware and software model driving our current network revolution. Contrary to urban legend, it was not the internet. However, digitizing information into packets in order

to move the functions of the network out of central points and closer to the network's edge is the technological concept that underpins the internet.

Paul Baran's visualization of a new network architecture reconfigured network concepts that had existed for millennia. It started us on the path to the third great network revolution.

We are a network-centric species; the networks that connect us have always defined us. The most powerful external force in the human experience is the manner in which we link ourselves together. The most transformative technologies, therefore, have been those that changed the nature of that interconnection.[2]

The early networks were built around nature—rivers, mountains, even continents. Human social structures formed to exploit these natural networks, as well as to defend against network-based threats as diverse as starvation and war. As the basic technologies of life expanded, however, the flow of information remained limited by crude communication tools.

The first technology-based information network did not appear until the fifteenth century with the advent of the movable-type printing press.[3] Its arrival hastened the end of the medieval world and the birth of the modern era.

For centuries, knowledge had been kept barricaded within handwritten manuscripts. A stable and secure container for cultural and scientific information, these records required a large, expensive infrastructure to be produced and maintained. To accomplish this, nobles and priests, who made up "the Establishment," constructed a thick vault of high costs and mystic traditions around their priceless libraries. It was a system that not only protected the knowledge but also exploited it to perpetuate its owners' position.

Johannes Gutenberg picked the lock that had kept knowledge confined for centuries. The result was an intellectual explosion that shook the foundation of the Establishment's power and propelled a new inquiry-driven trajectory.

By reducing the cost of reproducing and disseminating information Gutenberg moved ideas from the protective vault into a commercial envi-

ronment that promoted its dissemination. Merchant printers created an information network by moving texts among themselves for reproduction, distribution, and profit.[4] That network, in turn, sparked the Reformation and spread the innovations of the Renaissance throughout Europe.

It would be 400 years before a new network technology disrupted the status quo once again. While Gutenberg's technology unlocked information and allowed it to travel, the journey remained physically constrained. From the beginning of time, distance had created walls between groups of human beings equal to or greater than the barriers created by the jealous guarding of scientific knowledge and intellectual expression. Early in the nineteenth century the steam locomotive powered through those walls to allow humanity to overcome geography's grip.

The iron horse dissolved the geographic isolation that had created independent, self-sufficient, local resource–based communities. By economically transporting high-bulk products, the railroad broke the connection between the location of the resource and the site of its consumption. In the process the railroad pulled both products and people off the land, feeding the pace of the Industrial Revolution. Towns that were once too far from rivers or the sea to engage in extensive commerce became hubs of activity tied together by ribbons of steel. The growth of the railroad transformed the landscape, remade cities, and disrupted the lives of millions.

As the railroad supplanted traditional pathways, the telegraph rode alongside. The two technologies experienced symbiotic growth as telegraph lines built along the railroad's rights-of-way carried messages that not only managed railroad activities but also introduced instantaneous communications into other aspects of life and business.

Whereas the railroad compressed distance, the telegraph condensed time. From the beginning of history, the fact that information moved physically meant that it moved slowly, limited to the same speed as human travel.[5] The telegraph separated the transfer of information from the transportation of hard copy. This virtualization of information further expanded the marketplace economy, brought forth unparalleled personal interaction, and laid

the technological groundwork for the network that now defines the human experience.

As history's first electronic network, the telegraph was the internet of its time.[6] The only thing faster than a speeding locomotive, the telegraph controlled movement on the rails. But its impact was much more pervasive than managing train schedules. Information speeding faster than the wind made possible the creation of the Weather Bureau. News reports delivered from afar at lightning speed redefined both the nature of news and the news business. Electronic messages coordinated industrial production, created a new managerial class, and enabled the rise of powerful market-controlling corporations.[7]

The collective effect of these network revolutions was to gradually form an economy and a society of mass. The printing press created the first mass information economy. By one estimate, more books were printed in the first fifty years after Gutenberg's discovery than had been copied by all the scribes in Europe in the previous thousand years.[8]

The railroad then expedited the path to industrial mass production and a mass market. Before the railroad, production and processing activities were small operations distributed widely in locations adjacent to the raw materials. By making it possible to economically transport those raw resources to a central point for processing, the railroad fed ever-growing industrial complexes. Riding the rails in the opposite direction, the results of this mass production were delivered to a newly interconnected mass market.

The telegraph, and later its offspring, the telephone, tied together the new industrial activity. Mass production required coordination among the sources of raw materials, production facilities, and mass-market distributors. The telegraph was also the initiating force behind interconnected mass communications. When the newspaper publishers of New York banded together in 1846 to create the Associated Press, they were taking advantage of the telegraph's ability to collect information quickly from afar. In the process, they built the twentieth century's model of mass communications in which networks bring information to a central point for curation prior to its subsequent redistribution for mass consumption.

We may think we know the narrative of those earlier times, but our understanding is incomplete absent an appreciation of the linkage of that history with our lives today and, most important, our tomorrow. From a technological point of view, the earlier network breakthroughs are the roots from which grow today's "new" technologies. Sociologically, the changes driven by the earlier networks echo in the dislocations we experience today.

The evolution of network technology mimics the step-by-step natural evolution of living things. When Charles Darwin wrote that "it is the steady accumulation, through natural selection, of such differences . . . that gives rise to all the more important modifications of structure," he could have been describing technology as well as biology.[9]

New technology is an accretive process. While inventions are often described in terms of one person's inspiration, in reality they are typically a new assembly of accrued knowledge in a heretofore unrecognized manner for a previously unappreciated purpose. As we will see, Gutenberg's movable type was the coming together of a collection of known capabilities; the steam locomotive was a new way of dealing with a power understood since ancient times; and the concept of messaging through electromagnetic signals had been around for almost a century before Morse's "What hath God wrought."

"The process of technological development is like building a cathedral," Paul Baran observed. "Over the course of several hundred years: new people come along and each lays down a block on top of the old foundation, each saying, 'I built a cathedral.' Next month another block is placed atop the previous one. Then comes along a historian who asks, 'Who built this cathedral?' . . . But the reality is that each contribution has to follow onto previous work. Everything is tied to everything else."[10]

This is a book about our cathedrals, about the continuum of both additive and repetitive technological and sociological progress that lays the foundation for our future.

The first two network revolutions began with a centralizing force that expanded outward to create secondary and tertiary centralized hubs of

network activity. Printing presses were originally centralized in academic and commercial centers. As printing expanded, it dispersed into multiple centers of activity. Similarly, the railroads brought people and products to a central point to be switched to the track leading to their destination. As the rails expanded geographically, switching also moved to satellite transfer points. The same topology held true for the railroad's partner, the telegraph, and then the telephone, with the switchboard performing the same function as the switching yard to route a call from one line to another.

It was the technological reiteration of the traditional pattern of networks. Historically, the initial impetus of a network was to create a central point from which its activity radiated. As it grew, that activity dissipated into decentralized hubs. The current network revolution is being driven by the ultimate expansion of network dispersal to further move activity away from central points to become fully distributed, ultimately right down to the individual.

While networks moved outward structurally, the economic activity they enabled moved in the opposite direction. Businesses seized on the network to build new centralized economic power. Rockefeller's Standard Oil, Carnegie Steel, Montgomery Ward and Sears, Roebuck mail order, Swift and Armour meatpacking, and others built centralized empires using the railroad and telegraph. Today we see the same pattern. As the distributed digital network pushes its functions outward, new businesses such as Google, Facebook, and Amazon ride that network to create new centralized powerhouses.

Whether historical or present day, the manner in which network-driven change develops is more redundant than revolutionary. Each of the network revolutions that on prior occasions redefined the nature of the human experience followed a similar pattern. First, a new technology breaks the ongoing incremental, linear evolution of the old technology by reformulating components that have been around for some time. Then the new nonlinear assembly is seized on by others to produce nonobvious results.

At the time of Gutenberg, for instance, the process of creating a book was going through such a linear evolution. The monks in the scriptoria

were losing their monopoly on the reproduction of knowledge to the new business of commercial manuscript production. Yet, because it was merely the expansion of the existing high-cost, low-volume system, this logical, linear advancement had little transformational potential. It took Johannes Gutenberg's nonlinear thinking to create the nonobvious opportunities that accompanied an abundance of texts.

In the five and a half centuries following Gutenberg, his concept went through similar linear advancements—but it was still a process of putting stains on paper. It wasn't until Jeff Bezos took advantage of the arrival of a new network that the book was redefined to violate that incremental pattern. In the ultimate nonobvious innovation, Bezos's Amazon e-reader broke 550 years of precedent by separating the act of publishing from putting ink on paper.

The new network that allowed e-readers to upend half a millennium of ink on paper was itself the convergence of two previous examples of nonlinear thinking and nonobvious results. As we will see, the computing engine that powers an e-reader traces its lineage to the steam engine. And the network of binary electronic impulses that transports the contents to the device links to the telegraph.

Such nonobvious results create another socially relevant secondary effect. Because new networks dispatch old traditions, they trigger opposition from those who have grown comfortable with the old patterns. The stories we will visit demonstrate that a typical response to the effects of a new network consists of fear and resistance.

The Catholic Church, threatened by the unlocking of information it had always controlled to produce individual conclusions it could not control, attempted to suppress the output of printers.

The canal companies, stagecoach and haulage firms, tavern owners, and others who were bypassed by the speeding railroad used everything from political muscle to vigilantism to derail the iron horse.

Messages delivered by "lightning" became fodder for pastors to frighten the faithful about how it could only be black magic, while the U.S. Post Office resisted its opportunity to adopt a technology faster than the mail.

Ultimately, however, such responses proved to be the rearguard of a retreat in the face of those who saw opportunity in the new networks.

Martin Luther leapt from being an unknown monk to lead the Protestant Reformation by harnessing the power of the new printing shop network to deliver his message.

Chicago became the Second City of a growing nation, displacing St. Louis as the link to the West, because its city leaders aggressively embraced the railroad at the same time St. Louis was resisting it.

The newspaper business transformed itself from a collection of local political rags of limited scope into an electronically interconnected medium that made previously scarce information plentiful.

Though no small amount of social convulsion and dislocation accompanied the creation and promulgation of each of these network revolutions, their secondary effects nonetheless became comfortable and commonplace until each network was upset by the next new network. The network-driven upheaval of today is behaving similarly to upend the comfort that followed the standardization of what had been previous upheavals.

The centralized structures of the nineteenth and twentieth centuries in which networks assembled masses—of people, production, products, and information—is today yielding to a network through which forces move in the opposite direction to disaggregate and disperse activity.

The networks of history commanded the user to come to them: Come to the book. Come to the railhead. Come to the telegraph or telephone. The wirelessly distributed force of the new network does just the opposite. Now users command the network to come to them wherever they may be. It may seem a simple inversion, but its effect is this era's nonlinear, nonobvious result. It is nothing less than the transfer of the nexus of power from the network to the user.

The little-known and poorly understood secret of all the previous network revolutions was that the network was in control to create hierarchies and define activity. For the first time in history, the new network puts its user in control.

Behind this new network effect is the linkage between the technologies driving today's changes and the technologies of earlier networks. Our new network was spawned by the earlier technological breakthroughs.

Those breakthroughs began with Gutenberg—and Gutenberg's innovation was not simply a method for transferring ink to paper. His enduring insight was that for information to be automated and made "mass," it had to be disassembled into small units and then reassembled. It was a groundbreaking discovery about the interface between information and machines. The concept lives on at the heart of the internet's digital network, which breaks information into small packets for subsequent transmission and reassembly.

The success of the steam locomotive not only redefined production economies but also energized the belief that if engine power could replace muscle power, it could also be harnessed to replace gray matter. A spectator at the inaugural run of the first scheduled railroad, the British mathematician Charles Babbage, conceived of harnessing the same steam power to compute logarithmic tables. Thus began a developmental spiral that led from analog calculating engines to digital processors and ultimately to today's ubiquitous computing engine, the microprocessor.

By decoupling information from its physical form, the telegraph introduced the kind of virtual delivery that characterizes the internet. The dots and dashes of the telegraph's on-off signals are rearticulated by the binary signaling protocol of today's digital networks and processors.

Today's network echoes the networks of history in economic and behavioral aspects as well. The history of the networks that connect us is also the economic history of the world. When the economist Angus Maddison attempted in 2001 to estimate the growth of world gross domestic product (GDP) over time, the growth spurts he identified corresponded to the introduction of new network technologies.[11]

The first burst of sustained economic activity coincided with the era in which the printing press exponentially expanded the free flow of information. The book-fed Renaissance, Reformation, and the age of inquiry stimulated economic dynamism and recast the patterns of life.

The next spike in economic growth coincided with the railroad and the Industrial Revolution. As railroad track mileage and speed increased, so did economic development. The handmaiden to that expansion, the telegraph (and later the telephone), continued the network-driven economic spurt.

The relatively recent digital network era is consistent with the axiom that a new network stimulates new economic growth. The expansion of the digital economy also manifests another force that, while operational in the previous revolutions, has grown in significance: the increasing speeds of networks correlate with the acceleration of innovation and the pace of life.

From the dawn of the Christian calendar, it would take a millennium and a half for the printing press to emerge. From Gutenberg to the railroad and telegraph was only about 400 years. The period from the railroad and telegraph to the digital revolution was less than half that time.

We can see a direct relationship between the speed of a new network and the rate of innovative growth that speed stimulates. The acceleration of network speeds maps to the pace of technological change and the acceleration of economic and social change.

When information moved on horseback, it traveled at about four miles per hour.[12] Measured in terms of data throughput, this was about 0.03 bits per second.[13] The first network revolution, the movable-type printing press, increased the volume of data moved, but not its speed.

The railroad introduced speed into the equation. Moving five to ten times faster than animal power in its early iterations and later up to forty times faster, the iron horse accelerated the pace of life. The exponential growth of the railroad itself was a multiplier of the effect of its speed. In 1830 there were thirty miles of railroad track in the United States; by 1860 there were 30,000 miles of steel rails.[14] Before the end of that decade, 1869, the steam railroad had spanned the heretofore unbridgeable American continent, speeding change to the remotest regions.

The first electronic network, the telegraph, accelerated the flow of information yet again. At the time of the founding of the American republic it took twenty-two and a half days for information to move between New

York City and Charleston, South Carolina.[15] Four score years later, news of the dissolution of that republic in Charleston Harbor moved instantly to New York by telegraph. "The speed of the telegraph is about as wonderful a thing as the noble invention itself," observed *Scientific American* in 1852.[16]

A talented telegraph operator could transcribe at the rate of around three bits per second.[17] Making information instantaneously available everywhere at a speed 100 times faster than delivery by horse further hastened the pace of life and the rate of change.

Today's networks turn on the afterburners. Change is flying at us with gigabit connectivity (1 billion bits per second) and headed higher. That is more than 300 million times faster than the telegraph and 30 billion times faster than horseback.

As the velocity of the network increases, so does the speed with which it introduces change. In the process, twenty-first-century networks have destroyed the buffer that helped previous generations transition through change. Whereas previous new networks took years, if not generations, to mature, the current network revolution destroys old institutions and practices before it has ripened the capabilities necessary to replace them.

Data is speeding to us wherever we may be. On today's digital wireless networks not only does information fly fast, it flies to wherever the user wants it.[18] Giving the user, rather than the network, control to call forth the high-speed information he or she creates or consumes defines the era we are pioneering.

By definition, a network hub is a point where in-and-out activity occurs. Such hubs were formerly rail yards or switchboards, newsrooms or assembly plants. By emphasizing the virtual over the physical, our current network revolution not only makes information the preeminent product but also places in the hands of each person the ability to determine his or her own in-and-out patterns for that information. In these individual hubs users determine what they want to consume and with whom they want to connect. They create and distribute their own content as if they were the *New York Times* or NBC. And they perform their information-based jobs from locations of their choosing.[19]

In the pockets and purses of each individual hub is a powerful computer, colloquially called a "phone." The processing power of any one of these devices is greater than that once provided by huge machines locked in special rooms. These pocket computers speak a lingua franca that allows the information being delivered to be independent of both the network on which it travels and the device on which it is displayed.

The introduction of new technology that transforms the way in which we connect has thus come full circle. Gutenberg built the first information network by seeing information in terms of its smallest parts. Now the network has become the interconnected sum of its smallest parts—its users.

The act of publishing was previously centralized in the hands of those who owned the presses and the means of distributing their output. Today any individual can be an author and content creator with access to worldwide distribution.

Railroads pulled economic activity out of the hands of individual artisans and into massive industrial institutions. Now the skilled individual is returning to prominence, thanks to the ability to connect to a massive market without the need to be massive oneself.

The telegraph and telephone extended the user's reach but at the price of being tied to a wire coming through the wall. Now individuals can access wireless networks to deliver connectivity where the user is rather than where the wire is.

The mechanized productivity of information that began with Gutenberg, the power of engines that began with the harnessing of steam, and the binary transmission of information by electrons that began with the telegraph have all combined to create the third great network revolution. Accompanying this is the same kind of upheaval, opposition, opportunity, and stress that attended preceding network transformations.

History has been clear in the expectations it sets for our future. The innovations created by new networks topple old institutions and accelerate the pace of life. The demands of the new and the absence of traditional moorings generate frustration and bewilderment.

Like those who lived during earlier network changes, we are walking

where there is no path. The stories of those who made the earlier paths are relevant not as "how-to" manuals but as landmarks. They are what navigators call a "back azimuth"—a known point to anchor and guide while we progress into the unknown.

The stories of previous network revolutions establish that "normal" is the institutionalization of what yesterday was inconceivable. They teach that in a time of technological turmoil, the greatest danger is not the turmoil itself but the attempt to cling to the comfortable ideas and institutions that remain from the last network revolution. Nonlinear thinking produced the technological change; its successful exploitation requires nonobvious innovation.

The challenge, of course, is the successful identification of the nonobvious. Later we will explore some of the issues created by our new network: the disappearance of privacy, the threat to jobs, the demands put on education, the rise of misinformation and its effects, both domestic and international.

But first we need the predicates of history.

How we connect defines who we are. The story of the human experience is how new means of communicating created new economic and social institutions. What follows are the stories of those connections. They are the history of our future.