

THE FIRST LINK

Introduction

FEBRUARY 7, 2000, SHOULD HAVE BEEN a big day for Yahoo. Instead of the few million customers that daily flock to the Internet search engine, billions tried to enter the site. Such exploding popularity should have turned the company into the most valuable asset of the new economy. There was a problem, however. They all arrived at the exact same time and not one of them asked for a stock quote or a pecan pie recipe. Rather, they all sent, in scripted computer language, the message "Yes, I heard you!" Yahoo, as far as it could tell, had said nothing. Nevertheless hundreds of computers in Yahoo's Santa Clara, California, headquarters were kept busy responding to these screaming ghosts, while millions of legitimate customers, who wanted a movie title or an airline ticket, waited. I was one of them. Naturally I had no idea that Yahoo was frantically busy serving ten billion ghosts- I was patient for about three minutes before I moved to a more responsive search engine. The next day the royals of the Web. Amazon.com, eBay, CNN.com, ETrade, and Excite, fell under the same spell: They too were obliged to serve billions of ghosts making the same fruitless inquiry that had handicapped Yahoo. True consumers, with shiny credit cards ready for purchases, were forced to wait on the sidelines.

Of course, getting billions of real computer users to type "Yahoo.com" into their browser at precisely 10:20 Pacific Standard Time is impossible. There are simply not enough computers around.

Early news reports construed the shutdown of the leading e-commerce sites to be the work of a group of sophisticated hackers. The consensus was that these renegade geeks, fascinated by the challenge of outsmarting sophisticated security systems, had hijacked hundreds of computers in schools, research labs, and businesses and turned them into zombie;, telling Yahoo thousands of times, "Yes, I heard you." Every second, huge amounts of data were thrown at this prominent Website, much more than it could ever handle. The massive denial-of-service attack Yahoo was experiencing set off a much-publicized international hunt for the hackers responsible.

Surprisingly, the high-profile operation of the Federal Bureau of Investigation did not lead to the much-anticipated cyberterrorist organization. Instead, the FBI arrived at the suburban home of a Canadian teenager. Investigators eavesdropping on an Internet chat room overheard the teen soliciting suggestions for new targets to attack. He was caught bragging.

Hiding behind the pseudonym MafiaBoy, this fifteen-year-old successfully halted the operations of billion-dollar companies with access to the best computer security experts in the world. Was he a contemporary David who, armed with the humblest of home computer slingshots, beat the mega-Goliaths of the information age? In hindsight, experts agree on one thing: The attacks were not the work of a genius. They were executed using tools available to anybody on various hacker Websites. MafiaBoy's online antics revealed him to be a rank amateur, whose sloppy trail led the police right to his parents' door. In fact, his actions were more reminiscent of a Goliath than David: Lacking the know-how to penetrate any of the sites he attacked and clumsy and slow on his feet, he only managed to take down easy targets, obviously vulnerable computers from universities and small companies, which he simply instructed to bombard Yahoo with messages.

One can imagine a fifteen-year-old boy behind his bedroom, door, in the glow of his computer, finding sweet satisfaction in the protracted "Yes, I heard you!" hurled at Yahoo. He must have screamed that phrase himself a million times when Mom or Dad called him to come to dinner or take out the trash. The attack succeeded with brute force, a lot of nerve, and little sophistication. But this is exactly what makes us wonder, how could this teenager's actions take out the largest corporations of the new economy? If a mere youth can wreak havoc on the Internet, what could a small group of trained and skilled professionals achieve? How vulnerable are we to such attacks?

I,

The early Christians were nothing more than a renegade Jewish sect. Regarded as eccentric and problematic, they were persecuted by both Jewish and Roman authorities. There is no historical evidence that their spiritual leader, Jesus of Nazareth, ever intended to have an impact beyond Judaism. His ideas were difficult and controversial enough for Jews, and reaching the gentiles seemed particularly hopeless. As a starter, those non-Jews who wanted to follow in his footsteps had to undergo circumcision, had to obey the laws of contemporary Judaism, and were excluded from the Temple — the spiritual center of early Jewish Christianity. Very few walked the path. Indeed, reaching them with the message was almost impossible. In a fragmented and earthbound society news and ideas traveled by foot, and the distances were long. Christianity, like many other religious movements in human history, seemed doomed to oblivion. Despite the odds, close to two billion people call themselves Christian today. How did that happen? How did the unorthodox beliefs of a small and disdained Jewish sect come to form the basis of the Western world's dominant religion?

Many credit the triumph of Christianity to the message offered by the historical figure we know today as Jesus of Nazareth. Today, marketing experts would describe his message as "sticky" — it

resonated and was passed down by generations while other religious movements fizzled and died. But credit for the success of Christianity in fact goes to an orthodox and pious Jew who never met: Jesus. While his Hebrew name was Saul, he is better known to us by his Roman name, Paul. Paul's life mission was to *curb* Christianity. He traveled from community to community persecuting Christians because they put Jesus, condemned by the authorities as a blasphemer, on the same level as God. He used scourging, ban, and excommunication to uphold the traditions and to force the deviants to adhere to Jewish law. Nevertheless, according to historical accounts, this fierce persecutor of Christians underwent a sudden conversion in the year 34 and became the fiercest supporter of the new faith, making it possible for a small Jewish sect to become the dominant religion in the Western world for the next 2,000 years.

How did Paul's efforts succeed? He understood that for Christianity to spread beyond Judaism, the high barriers to becoming a Christian had to be abolished. Circumcision and the strict food laws had to be relaxed. He took his message to the original disciples of Jesus in Jerusalem and received the mandate to continue evangelisation without demanding circumcision.

But Paul understood that this was not enough: The message had to spread- So he used his firsthand knowledge of the social network of the first century's civilized world from Rome to Jerusalem to reach and convert as many people as he could. He walked nearly 10,000 miles in the next twelve years of his life. He did not wander randomly, however; he reached out to the biggest communities of his era, to the people and places in which the faith could germinate and spread most effectively. He was the first and by far the most effective salesperson of Christianity, using theology and social networks equally effectively. So should he, or Jesus, or the message be credited for Christianity's success? Could it happen again?

2.

There are huge differences between MafiaBoy and Paul: MafiaBoy's was an act of destruction. Paul, despite his initial intentions, became a bridge builder between early Christian communities. But the two have something important in common: Both were masters of the network. Though neither of them thought about it in these terms, the key to their success was the existence of a complex network that offered an effective medium for their actions. MafiaBoy operated on a network of computers — the Internet is the fastest and most effective way to reach the largest number of people at the turn of the third millennium. Paul was a master of first-century social and religious links, the only network at the beginning of the modern era that could carry and spread a faith. Neither of them fully grasped the forces that aided them in their actions. But nearly 2,000 years after Paul we are making the first inroads toward understanding what made Paul and MafiaBoy

successful. We now know that the answer lies as much in the structure and topology of the networks on which they operated as in their ability to navigate them.

Paul and MafiaBoy succeeded because we are all connected. Our biological existence, social world, economy, and religious traditions tell a compelling story of interrelatedness. As the great Argentinean author Jorge Luis Borges put it, "even-thing touches everything."

3.

"There be dragons there!" wrote the ancient mapmakers, marking off the frightening unknown. As adventurous explorers penetrated every region of the globe, these monster-marked patches gradually disappeared. But there are still lots of dragon-infested areas in our mental map of how the different parts of the world fit together, from the microscopic universe locked within a cell to the unbounded world of the Internet. The good news is that recently scientists have been learning to map our Interconnectivity. Their maps are shedding new light on our Weblike universe, offering surprises and challenges that could not even be imagined a few years ago. Detailed maps of the Internet have unmasked the Internet's vulnerability to hackers. Maps of companies connected by trade or ownership have traced the trail of power and money in Silicon Valley. Maps of interactions between species in ecosystems have offered glimpses of humanity's destructive impact on the environment. Maps of genes working together in a cell have provided insights into how cancer works. But the real surprise has come from placing these maps side by side. Just as diverse humans share skeletons that are almost indistinguishable, we have learned that these diverse maps follow a common blueprint. A string of recent breathtaking discoveries has forced us to acknowledge that amazingly simple and far-reaching natural laws, govern the structure and evolution of all the complex networks that surround us.

4.

Have you ever seen a child take apart a favorite toy? Did you then see the little one cry after realizing he could not put all the pieces back together again? Well, here is a secret that never makes the headlines. We have taken apart the universe and have no idea how to put it back together. After spending trillions of research dollars to disassemble nature in the last century, we are just now acknowledging that we have no clue how to continue — except to take it apart further.

Reductionism was the driving force behind much of the twentieth century's scientific research. To comprehend nature, it tells us, we first must decipher its components. The assumption is that once we understand the parts, it will be easy to grasp the whole. Divide and conquer: the devil is in the details. Therefore, for decades we have been forced to see the world through its constituents. We have been

trained to study atoms and super-strings to understand the universe; molecules to comprehend life; individual genes to understand complex human behavior; prophets to see the origins of fads and religions.

Now we are close to knowing just about everything there is to know about the pieces. But we are as far as we have ever been from understanding nature as *a whole*. Indeed, the reassembly turned out to be much harder than scientists anticipated. The reason is simple; Riding reductionism, we run into the hard wall of complexity. We have learned that nature is not a well-designed puzzle with only one way to put it back together. In complex systems the components can fit in so many different way that it would take billions of years for us to try them all. Yet nature assembles the pieces with a grace and precision honed over millions of years. It does so by exploiting the all-encompassing law; of self-organization, whose roots are still largely a mystery to us.

Today we increasingly recognize that nothing happens in isolation. Most events and phenomena are connected, caused by, and interacting with a huge number of other pieces of a complex universal puzzle. We have come to see that we live in a small world, where everything is linked to everything else. We are witnessing a revolution in the making as scientists from all different disciplines discover that complexity has a strict architecture. We have come to grasp the importance of networks.

With the Internet dominating our life, the word *network* is on everybody's lips these days, featured in company names and popular journal titles. After September 11, witnessing the deadly power of terrorist networks, we had to get used to yet another meaning of the term. Very few people realize, however, that the rapidly unfolding science of networks is uncovering phenomena that are far more exciting and revealing than the casual use of the word *network* could ever convey. Some of these discoveries are so fresh that many of the key results still circulate as unpublished papers within the scientific community. They open up a novel perspective on the interconnected world around us, indicating that networks will dominate the new century to a much greater degree than most people are yet ready to acknowledge. They will drive the fundamental questions that form our view of the world in the coming era.

This book has a simple aim: to get you to think networks. It is about how networks emerge, what they look like, and how they evolve. It shows you a Web-based view of nature, society, and business, a new framework for understanding issues ranging from democracy on the Web to the vulnerability of the Internet and the spread of deadly viruses.

Networks are present everywhere. All we need is an eye for them. As you move from link to link within this book, you will learn to see society as a complex social network and to grasp the smallness of this great world in which we live. You will come to understand how and why Paul succeeded and how, despite some obvious differences, his

social milieu was similar to the one we experience today. You will see the challenges doctors face when they attempt to cure a disease by focusing on a single molecule or gene, disregarding the complex interconnectedness of living matter. You will be reminded that MafiaBoy is not alone in attacking networks. You will come to appreciate how the Internet, often viewed as entirely human in its creation, has become more akin to an organism or an ecosystem, demonstrating the power of the basic laws that govern all networks. You will see how the emergence of terrorism is also ruled by the laws of network formation and how these deadly webs take advantage of the fundamental robustness of nature's webs. You'll wonder at the amazing similarities, among such diverse systems as the economy, the cell, and the Internet, using one to grasp the other. This will be an eye-opening trip across disciplines that I hope will challenge you to step out of the box of reductionism and explore, link by link, the next scientific revolution: the new science of networks.