International Journal of Social Science and Economic Research

ISSN: 2455-8834

Volume:08, Issue:09 "September 2023"

THE EVOLUTION OF THE INTERNET: THE ARPANET TO THE WORLD WIDE WEB

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DOI: 10.46609/IJSSER.2023.v08i09.017 URL: https://doi.org/10.46609/IJSSER.2023.v08i09.017

Received: 10 September 2023 / Accepted: 21 September 2023 / Published: 24 September 2023

ABSTRACT

This article traces the remarkable evolution of the Internet from its inception with the ARPANET in the early 1960s to the global platform we know today as the World Wide Web. The ARPANET, initially conceived as a secure means of communication for military and academic institutions during the Cold War, faced numerous challenges that ultimately led to groundbreaking innovations. Packet switching, time-sharing, and the Interface Message Processor were pivotal developments that formed the foundation of reliable data transmission. The layering of technologies, including Ethernet, TCP/IP protocol, and DNS, revolutionized network access and interoperability. User feedback played a crucial role in the transition from complex site access to user-friendly emailing, marking a shift from developer-driven technology to user-centric design. The emergence of commercial networks further democratized Internet access, making it available to a wider audience. The National Science Foundation Network and regional networks played a pivotal role in expanding Internet connectivity, eventually leading to the privatization of the Internet. The transformative impact of the World Wide Web revolutionized information access through hyperlinks and easy navigation. The Internet evolved from a military and academic network into a global platform for communication, commerce, and information exchange, fundamentally reshaping the way we live and interact in the digital age.

Keywords: ARPANET, Internet, National Science Foundation Network , Networks, World Wide Web

1. Introduction

With the development of the first public packet-switched computer network the ARPANET (Advanced Research Projects Agency Network) along with other commercialized networks, the Internet was born. The ARPANET, created by the Advanced Research Projects Agency (ARPA) in 1963, was initially designed to provide a secure and reliable means of communication between

ISSN: 2455-8834

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military and academic institutions[1]. The Cold War of the 1960s-80s increased investment in technologies across the United States. Initially, ARPA faced many challenges during its developmental phase, but these challenges led to major innovations that influence our current Internet. The development of the ARPANET played a significant role in the creation of the Internet. The ARPANET influenced a range of network innovations such as packet switching, time-sharing, and the creation of the IMP (Interface Message Processor)[2]. It stored these new technologies in layers of a network along with stacks of technology made up of Ethernet, TCP/IP (Transmission Control Protocol/Internet Protocol), and DNS (Domain Name System)[2]. These technological network advancements increased user interaction on networks and were a critical factor in the introduction of commercial public email services. As user interaction increased, the creation of commercialized and regional networks also increased, transforming the Internet from a military and academic network to an accessible and user-friendly global platform. Finally, the need for user-friendly network access led to the interface of our current Internet: the World Wide Web. The World Wide Web connected the Internet's sites through hyperlinks and opened a new era of entertainment, education, and communication[2]. The development of the ARPANET and other networks from 1963-1991 significantly impacted the creation of the Internet in that it led to improvements in military standings, network access, user interaction, and commercial innovation.

2. Body

2.1 ARPA

The USSR's launch of Sputnik and Sputnik II in 1957 brought to attention the technological unpreparedness of the United States[1]. In light of this crisis, President Eisenhower hoped to create a research program, ARPA, that would inform both himself and the military of any technological threats before they become surprises, such as the launching of Sputnik[1]. ARPA hired researchers from many fields of science, including physics, computer science, and mathematics. These researchers were tasked with developing advanced technology that could give the United States an edge over other countries. The introduction of ARPA was also meant to incentivize competition between branches of the military and the upcoming scientific research program[1]. This led to increased development and improvement in the technology sector due to each group challenging the other. ARPA's creation informed the country of its scientific weaknesses because the military was not able to inform President Eisenhower of the launching of Sputnik. However, because the military had been previously responsible for technological advancement, the creation of ARPA was an insult to the military's accomplishments[1]. Due to this threat, the military attempted to subdue ARPA, but ARPA negotiated unlimited scope of research and contracting authority[1]. With the boundaries set, ARPA shifted its focus to a new problem: creating "survivable communication."[2]

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2.1 Packet Switching

In order to create durable technology, the invention of packet switching was used to build the base of networks. During the 1960s there was a need for communication networks to operate even if some of their components or links were damaged or destroyed[2]. This was especially important in the context of the Cold War, when the possibility of nuclear attacks posed a serious threat to the communication infrastructure of many countries[2]. Packet switching, invented by Paul Baran and Donald Davies, was a solution to this problem[2]. It involves breaking down data into small packets of data that could be sent across a network of computers using the most efficient route available[2]. Each packet is labelled with its destination and then sent through the network, with each computer along the way only handling and forwarding the packet to the next computer[1]. This process can be described with a simple example:

> "The best way to describe packet switching technology and the way it behaves is to just remind you that packets are just like postcards. You know, they've got 'to' and 'from' addresses and they've got a finite amount of content on them. And like a postcard, you know, you put it into the post box. If you put two in, you don't know what order they're going to come out. They might not even come out on the same day. Some of them get lost. That's true of packets. They don't necessarily follow the same paths to get to the destination."[3]

In this example, computers act as the post office that receives, sorts, and forwards the postcards to their destination. When a computer receives a packet of data, it reads the destination address and forwards it to the next computer on the path. But, as the quote states, this can be a disadvantage in terms of processing the order and final destination of these packets. Each computer along the way only needs to know where to send the packet next, not the entire path to the final destination[2]. This allows the packets to take different routes and be processed in different orders, which helps to optimize network efficiency.

2.3 ARPANET

The military's involvement in the development of the ARPANET was seen through the use of packet switching and the IMP (Interface Message Processor). The ARPANET was created in the late 1960s as a means of allowing researchers and academics to share information and resources across long distances. Within this process of creating the ARPANET, military goals were considered: "The need to develop alternatives for military communication systems having lower cost, lower delay and higher bandwidth capabilities than those currently in use, while still providing the end-to-end security and reliability needed."[4] The idea was to create a decentralized network that could still function in the event of a catastrophic event, such as a

ISSN: 2455-8834

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nuclear attack[2]. The technology of packet switching, first used in the ARPANET, was one of the solutions to the need for intangible connections. Packet switching helped with these connections, but it did not work in every case: "Even though many different and complex problems must be solved in the design of an individual packet switching network, these problems are manifestly compounded when dissimilar networks are interconnected."[5] Even with the introduction of packet switching, differently constructed computers could not communicate with each other. The solution was provided with ARPA's creation of the IMP (Interface Message Processor). The IMP allowed computers with different hardware and software configurations to communicate with each other. Each IMP was a specialized computer that acted as a communication node on the network, connecting individual computers and other IMPs[6]: "The message is passed from IMP to IMP through the Network until it finally arrives at the destination IMP, which in turn passes it along to the destination Host."[6] The IMPs were designed to handle the packet-switching of data between different computers and network nodes[6]. They were responsible for routing and re-routing data packets through the network to their final destination. Each IMP had its own unique address, allowing it to be identified and located by other nodes on the network[7]. The IMP "translate[d] data from various computers into a common network language."[8] This allowed different computers to communicate with each other, eventually from long distances. With the use of techniques such as packet switching and IMP, ARPA hoped to create a decentralized network. ARPA's goal: "The network was designed to provide efficient communications between heterogeneous computers so that hardware, software, and data resources could be conveniently and economically shared by a wide community of users."[9] In order to achieve this vision, the ARPANET used a combination of packet switching and IMP to improve network access. With these network-building tools, the ARPANET was able to connect different types of computers with users for the purpose of academic and scientific research.

The ARPANET utilized its connections with universities which allowed researchers to share resources and collaborate on projects. But as years passed ARPA's mission was to utilize research in a different manner: through universities. ARPA realized the universities and programs contained the top scientific minds and with the application of programs could contribute to the advancement of technology. Some of the first research centres to be created were at Carnegie Mellon, UCLA, and MIT[2]. Along with communication over resources, these university's researchers used the ARPANET and reported back corrections to be made with the network to make it more user-friendly[2]. The collaboration between the ARPANET and universities paved the way for a new era of technology development and innovation to be passed down to future generations[10]. ARPA influenced universities, developed the field of computer science, and contributed to time-sharing operating systems.

2.4 Time-sharing

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Along with their military and academic influence, ARPA also introduced inventions such as time-sharing in the 1960s. ARPA utilized inventions such as time-sharing, packet-switching, and the IMP in order to provide easy interaction with computers. Time-sharing solved the problem of inefficiency in the typical programming cycle. Before time-sharing, users used batch processing that involved writing the code on program cards, which were fed into the computer one batch at a time by an operator[2]. Users had to wait hours for a chance to run their program and collect the results, and if the program had errors, the process had to be repeated from the start several times[1]. This problem was fixed with time-sharing, many users were able to access the computer at the same time, making the process more efficient and reducing wait times for users. Time-sharing allows multiple users to use the same computer efficiently by quickly filling the pauses of one user with the activities of another[1]. It helped increase our speed by using the speed of the computer, "By sharing the computer's processor among multiple users, time sharing addressed the mismatch between the pace of human action and the much faster processing of the computer."[2] Time-sharing allowed people to use computers in a more interactive way, rather than having to wait for long periods of time while their programs were processed.

2.5 Layers and Stacks

Packet switching and time sharing provided the foundations of network access, but there was layering architecture needed to further the development of the Internet. Networks are made up of layers of capability that allow for communication between devices at different levels. Layers are ordered such that "each higher-level function builds on the capabilities provided by the layers below."[2] These layers are built upon each other to form a stack. The term "stack" refers to the way these layers are organized, with each layer "stacked" on top of the one below it. The main stack talked about in this paper is built up of the Ethernet, TCP/IP(Transmission Control Protocol/Internet Protocol) layers, and the DNS (Domain Name System) layer[11]. In 1973, Bob Metcalfe invented the first layer: the Ethernet[1]. Multiple people communicating at the same time over a network caused data packets to collide and delay or inhibit the data from reaching its destination[8]. Ethernet solved this problem; it allowed multiple devices to transmit data packets over the network without interfering with each other[1]. Ethernet added a safety mechanism to transmitting packets: collision detection. This collision detection technique would pause the data from being transmitted for thousandths of a second ensuring an efficient sending of data[1]. Another problem of data transportation was fixed with the invention of TCP. TCP "verified the safe arrival of packets using acknowledgments, compensated for errors by re-transmitting lost or damaged packets."[2] Going back to the post office example, mail, or in other words data, can be jumbled or lost through packet switching. So, the invention of TCP made it so that data reached the right destination. The splitting of the TCP protocol into TCP/IP utilized the most efficient way to transmit and receive information[12]. Their tasks were separated: "IP would simply pass

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individual packets between […] TCP would be responsible for ordering these packets into reliable connections between pairs of hosts."[13] The use of TCP/IP defines how data is transmitted over a network, including how data is addressed, routed, and received. SATNET (Atlantic Packet Satellite Network) was a network connecting satellites and PRNET (Packet Radio Network) was created to connect radios[2]. Ethernet allowed for a common language between SATNET, PRNET, and the ARPANET networks, making it possible to interconnect them[2]. The use of the TCP/IP protocol suite allowed for communication between these different networks through the standardization of transmitting data packets across networks, including routing packets from one network to another[2]. It became possible to connect different networks together into a single network. The invention of Ethernet and TCP/IP allowed for the interconnection of the ARPANET, PRNET, and SATNET, becoming the universal standard for network access.

The final layer of the stack, DNS (Domain Name System), simplified network access for users. It was introduced in 1983 by Paul Mockapetris to convert IP addresses into understandable domain names[1]. Before DNS, numeric IP addresses were hard to remember and manage. DNS was made to connect to network hosts easily by allowing users to write in domain names like "Amazon.com" and not "208.216.182.15"[14]. The establishment of DNS solved various challenges linked to the growth and administration of the Internet[2]. It enabled the adoption of more human-friendly domain names, making it easier for users to access websites and other network resources. DNS also increased the network's efficiency by lessening the amount of traffic necessary to resolve domain names into IP addresses, which lowered the burden on the network's infrastructure[2]. With the addition of DNS, the final layer was added to the stack of technology making up a network. These stacks contained layers made up of Ethernet, TCP/IP, and DNS[11]. As these technological advancements and layering architecture developed, user interaction became increasingly important[2].

2.6 The users

User involvement was critical to the development of the ARPANET as the introduction of commercial public email services and user suggestions radically changed the user-friendliness of networks. The first users of the ARPANET were the researchers who were responsible for developing it[2]. This also included students from universities: "During the ARPANET's first decade of operation, fundamental changes in hardware, software, configuration, and applications were initiated by users or were made in response to users' complaints or suggestions."[2] Changes in user interface and convenience were inspired by the feedback of users. But people that wanted access to this network, outside of these researchers, had to go through a complicated process to connect to the network. Users had to have a research contract with ARPA to make a site connected to the ARPANET[2]. Additionally, there had to be a manual addition of hardware

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and software to the network which would result in its own complications regarding who was able to access the site and whether it was meant for resource sharing or other purposes[2]. This was soon changed with the introduction of the email. The ARPANET's original goal had been resource sharing, but the discovery of the usefulness of email in 1971 by Ray Tomlinson, led to the change in the use of the ARPANET[2]. Users said that messaging "significantly [changed] the "feel" of collaborative research with remote groups."[7] The information was used to report hardware and software problems and report data from the ARPANET sites. But, as the use of email increased, users changed resource-based communications to everyday conversations[1]. The ARPANET was seen as a communications network instead of a computer network[2]. Users viewed email as a superior mode of communication in comparison to post mail and telephones due to the fast response and user-friendliness[2]. The progression from complicated site access for users to user-friendly emailing showed the progression of technology from being solely controlled by developers and researchers to a more user-cantered approach, where user feedback and suggestions played a significant role in shaping the direction of technological development. This highlighted the importance of user involvement in the evolution of technology and the recognition of user needs in the design of user-friendly systems.

2.7 Commercial networks

Over time, other networks emerged from the technology that the ARPANET developed in the mid-twentieth century. One of the first commercial networks to emerge was TELENET, which was established in 1974 and used many of the same underlying technologies as the ARPANET[1]. TELENET offered a variety of services including email, file transfer, and remote login capabilities[1]. USENET was another commercial network that emerged in the late 1970s for researchers who were not able to connect to the ARPANET[1]. It was created for messaging and file exchange purposes, and it quickly became popular among the academic community[2]. Another academic network, introduced in 1981, was the CSNET (Computer Science Network). As its name indicates, the CSNET universities provide computer science researchers with access to network resources[2]. There were additional networks such as the BITNET (Because It's Time Network) that connected universities and research institutions within particular geographic areas[1]. Together these networks helped introduce the concept of networks to the public potential for global communication and collaboration. Additionally, as the ARPANET became more widely used for civilian purposes, there was a growing concern that it would become less secure and less reliable as a means of communication for military operations. To address these concerns, the ARPANET was split into two separate networks: one for military use, the MILNET (Military Network), and one for civilian use, ARPANET[2]. The reason for this split: "had been to separate the military's operational and research communities so that they could manage their respective networks according to their own needs and priorities."[2] This

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separation allowed for greater control over the security and reliability of the military network, which was critical for military operations.

By 1990, the ARPANET was decommissioned by ARPA due to the NSFNET's (National Science Foundation Network) pavement of greater commercialization with the rise of regional networks. One of the most significant impacts of this shift towards regional networks was the greater accessibility of networks to a wider audience. The increased connectivity was made possible by regional networks like the NSFNET. The NSFNET was inspired by the CSNET in that "the professional advantages to be gained from the ability to communicate with one's peers was incalculable."[1] The NSF (National Science Foundation), the founder of ARPA at the time and the creator of the NSFNET believed that communication was a key step to important discoveries in scientific fields[2]. With the need to connect supercomputers regionally, in 1985, and the success of the CSNET, the NSFNET was created as a base to communicate regionally and locally[2]. With the concept of regional networking the already used term "the Internet" was more widely used[1]. The creation of the NSFNET as the first regional network prompted the creation of regional networks like the NYSERNET (for New York State Educational Research Network) and the BARRNET (in the San Francisco Bay area) all over America[2]. And since the NSFNET was considered the "backbone"[1] of these regional networks, the recently created networks mentioned would connect to NSFNET. At the time the ARPANET was costing millions of dollars to maintain and upgrade, making it impractical for widespread use[2]. The regional networks, on the other hand, were able to provide reliable and affordable internet access to educational and research institutions. Because of this, NSF and ARPA decided to make the ARPANET the foundation of the Internet[2]. And this was practical until the growth of the Internet showed the weaknesses of the ARPANET. The ARPANET had been functioning for twenty years and the speed at which it operated was not designed for the traffic that users created on the Internet[2]. The solution to this problem was the decommissioning of the ARPANET with all its users being transferred to NSFNET[2]. With this transfer of users, the Internet was put under government control through the NSF[2]. With the privatization of the Internet in the next few years, its use was for "purely commercial, social, or recreational activities."[2] During the early years of the Internet, the focus was primarily on academic and research uses, but with the government's transfer of control to the NSF and the eventual privatization of the Internet, it became a platform for commercial and social activities as well. This paved the way for the introduction of the World Wide Web, which changed the view of the Internet.

2.8 The World Wide Web

The World Wide Web transformed the existing Internet into an easy-to-use global platform. The Internet, of which the World Wide Web was built on top of, stemmed from the development of the ARPANET in 1960[2]. At the time, the Internet's features included email and file transfers as

ISSN: 2455-8834

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well as additional applications, but there was a problem. The Internet used its “drab text-only interface”[2] and had difficulty “locating and retrieving online information.”[2] The features, or lack thereof, made the usage of the Internet difficult. But, like other problems within the creation of the Internet, there was a proposed solution: the World Wide Web. Created by Tim Berners-Lee to organize “all the people, projects and computers at the lab […] he wrote a program to keep track of the connections between them.”[8] The World Wide Web allowed for easy access to sites through hyperlinks that connected information on different pages. By the mid-1990s, the World Wide Web had grown in popularity, and web browsers such as Netscape Navigator and Internet Explorer allowed users to easily navigate the web[14]. This explosion of the World Wide Web led to the growth of e-commerce, social media, and the ability to access information from all over the world[2]. The creation of the World Wide Web not only transformed the Internet but also revolutionized the way people communicate, work, and access information.

The Internet was transformed from a military, research, and academic network to a global platform for communication and commerce. It evolved through the military’s continuous involvement, the technical development of network access, user interactions, as well as the commercialization of the ARPANET and other networks. The introduction of network access technologies such as packet-switching, time-sharing, and the IMP, established the foundation of reliable data transmission[2]. The layering of stacks made up of Ethernet, TCP/IP protocol, and DNS led to our current ability to transmit information from computer to computer[11]. With the success of adding new technologies to the ARPANET, the creation of commercialized networks such as TELENET and CSNET provided affordable alternatives[1]. Regional networks, such as NSFNET, soon formed the backbone of the Internet. The introduction of the World Wide Web also was an important moment, as it made the Internet more user-friendly[2].

3. Conclusion

The creation and rise of the Internet was a national project that included support from several industries and is composed of innovations from a variety of fields. It is becoming an essential aspect of modern life, with people all over the world using it for work, education, entertainment, and communication[2]. The Internet has evolved dramatically over the last few decades, and it will continue to impact and modify our world in ways we cannot yet comprehend.

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Abbreviations and Acronyms

ARPA, Advanced Research Projects Agency;

ARPANET, Advanced Research Projects Agency Network;

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BARRNET, Bay Area Regional Research Network;

BITNET, Because It's There Network;

CSNET, Computer Science Network;

DNS, Domain Name System;

IMP, Interface Message Processor;

MILNET, Military Network;

MIT, Massachusetts Institute of Technology;

NSF, National Science Foundation;

NSFNET, National Science Foundation Network;

NYSERNET, New York State Educational Research Network;

PRNET, Packet Radio Network;

SATNET, Atlantic Packet Satellite Network;

TCP/IP, Transmission Control Protocol/Internet Protocol;

UCLA, University of California, Los Angeles;

USENET, User's Network;

WWW, World Wide Web.

