CS144
An Introduction to Computer Networks

What the Internet is
A very brief history of networking
and the Internet

Nick McKeown
Professor of Electrical Engineering
and Computer Science, Stanford University

You will have heard people say many times that the Internet has transformed society in profound ways, not seen since the invention of the printing press.

In this video, I will give you a brief background on the history of networking leading up to the invention of the Internet in the 1960s.

Outline

Brief history of networking

Brief history of the Internet

Let's start with a brief history of how messages were communicated over long distances.

Martin Bodman

Lokilech

Fire Beacons
Carrier Pigeons
Human Messengers
Horse Relays ...

Flags
Heliographs: sun's rays & reflector
Telescopes

Semaphore telegraphs
Chappe (France)
Edelcrantz (Sweden)

Telephone

Internet

1,000 BC

0

1800 AD

Today

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While today we think nothing of sending an email to the other side of the world, 3,000 years ago it was very hard to communicate over long distances.

The first recorded long distance communications are from about 1,000 BC and were mostly put in place for military offense and defensive purposes.

Fire beacons were used to signal the arrival of an enemy, or to synchronize an attack. <click> This is an example of a fire beacon in the south of England.

Fire beacons carry information fast, work particularly well at night when danger is greatest, but they carry very little information. Generally, they are on or off, signaling danger.

Carrier pigeons, human messengers and horse relays have been used around the world for thousands of year because they can carry more information. But the information travels more slowly than a fire beacon, and messengers are prone to interception along the way. The message could be read, tampered with or blocked completely.

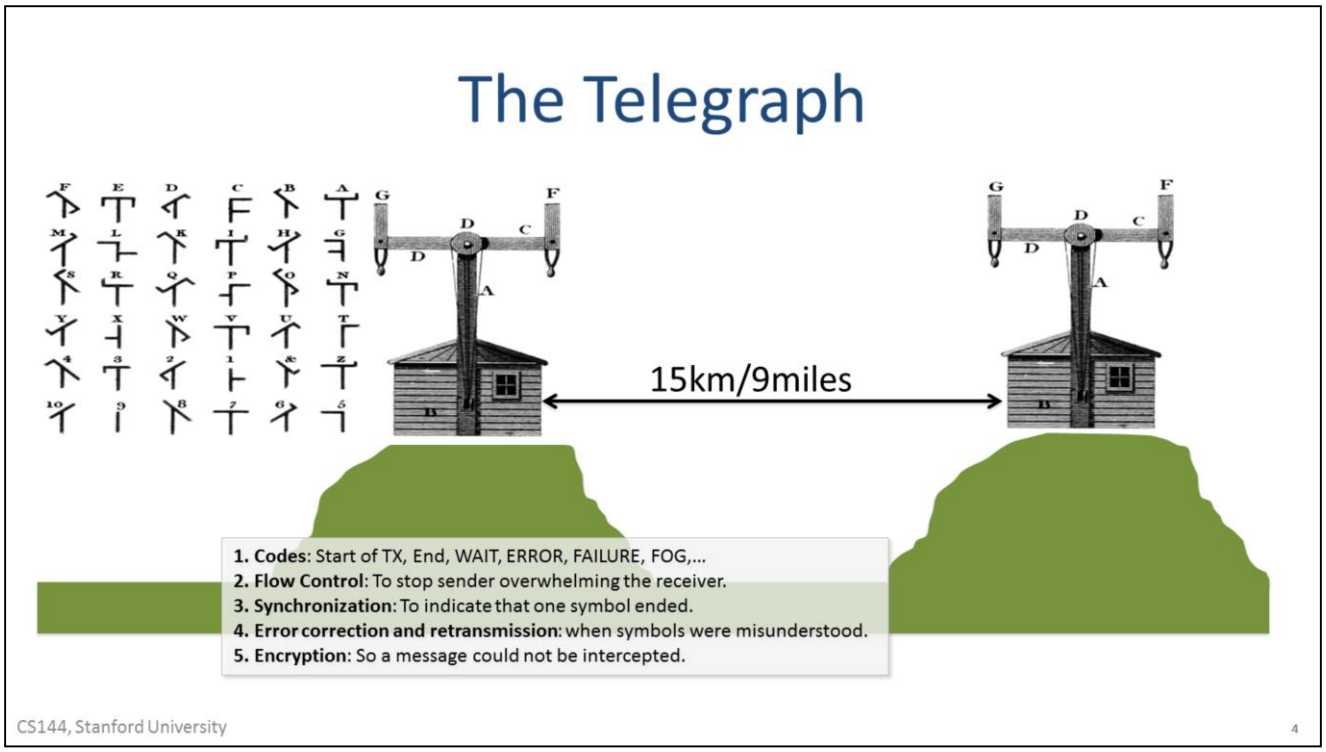
The earliest recorded relay systems were horses in Egypt and China 2-3 thousand years ago. They were common throughout history. In 13th C, Marco Polo described how the great Mongol ruler Kublai Khan used horse relays. His army had relay stations every 40km, with 400 horses waiting for relay riders. Horse relays were used all the way up to 19th century for mail delivery in the famous Pony Express across the USA. These early systems were limited in the information they could carry (fires) or by the speed of delivery (horses, humans, pigeons).

Around 2,000 years ago, optical methods started to be used, such as FLAGS, and HELIOGRAPHS, which encoded digital information such as letters, words and numbers.

These systems transmit data at the speed of light, over limited distances, with limited information --- they are basically simple encodings.

Perhaps the biggest advances in optical communications happened in France around the time of the French Revolution in 1793 when Claude Chappe invented and

starting building a semaphore telegraph network.



Claude Chappe built towers with a large HORIZONTAL beam (the REGULATOR), with two smaller arms called INDICATORS.

It looked like a human being giving different signals with their arms. The location of the arms indicated a SYMBOL.

In 1793, the French government built 15 stations to cover 190km, or 13km per station. By 1804, a 370km network stretched from Paris to Dijon.

The system was used to send a variety of messages, including military information and fast-breaking news. Most went towards Paris to report information from the

provinces.

The operators became quite skilled: The fastest messages could be signaled by one station every 10-20seconds, and could cross France in less than 30 minutes! They could send about 3,000 signs per day, corresponding to a few hundred messages.

To make the network function properly, the optical telegraph systems in France and Sweden developed a number of concepts that are used in networks to this day:

They needed to develop five concepts in particular: <click>

The first were CODES. These are symbols to indicate characters, and control signals like: START OF TX, END OF TX, "WAIT" or "CONFLICT (When two signals arrived at the same time!)", ERROR (cancel last code), PRIORITY (between conflicting messages), FAILURE of TOWER, Acknowledgment (of ciphered text from far end), RAIN/FOG to say "we can't see you!".

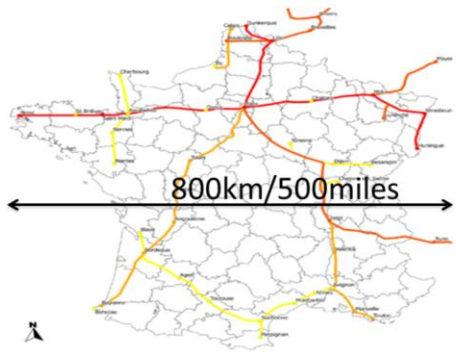
The second was FLOW CONTROL, to stop the sender overwhelming the receiver. Basically, the receiver tells the sender to slow down because it can't keep up

Third was SYNCHRONIZATION, to tell when one symbol ended and the next one started. This helps delineate words made up of several symbols.

The forth concept was ERROR CORRECTION AND RETRANSMISSION to tell the sender when symbols were misunderstood. This allows the sender to try sending the symbols again.

Finally, they used ENCRYPTION so that messages could not be intercepted. They were particularly worried about news of the stock market beating the newspapers.

Chappe Network in France (c 1830)



Source: Jeunamateur

By 1830 the Chappe optical telegraph network was very extensive, covering most of France.

Four steps of invention

(2,000 BC) Systems to signal a small set of pre-defined messages, e.g. beacons.

(1600s) Systems to transmit arbitrary messages, e.g. by encoding the alphabet.

(1700s) Numeric codes for common words and phrases. "Compression".

(1700s) Codes for control signals. "Protocols".

We can characterize four main steps of invention in communication networks up until the 1700s.

First, from about 2,000 BC, humans used systems to signal a small set of pre-defined messages, for example using fire beacons.

<click> Second, starting in the 1600s, people developed systems to transmit arbitrary messages, by encoding the entire alphabet.

<click> By the early 1700s, numeric codes started to be used for common words and phrases. This was the earliest form of compression, because it required less information to be sent over the link.

<click> During the 1700s, codes were developed for control signals. They could communicate when to start and stop sending, when to slow down, how to retransmit and so on. This was the birth of what we call today "Protocols" – the agreed upon rules governing how two or more parties communicate.

Protocol Signals by 1800

1. Initialization
2. Error control: erase, resend, stop/wait, selective-repeat.
3. Flow control: “faster/slower”.

By 1800 there were a number of different optical telegraph systems deployed across Europe, using a variety of different protocol signals, such as these.

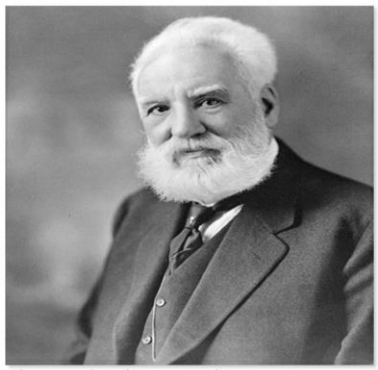
1.Initialization – to indicate we are about to start communicating.

2.Error control: erase, resend. stop/wait, selective-repeat. These are used to retransmit data that is corrupted along the way, as you’ve already seen in videos about different retransmission strategies.

3.Flow control: “faster/slower”. To tell the sender we can or can’t keep up.

Telephone networks in 1900

(1876) Alexander Graeme Bell made the first telephone call



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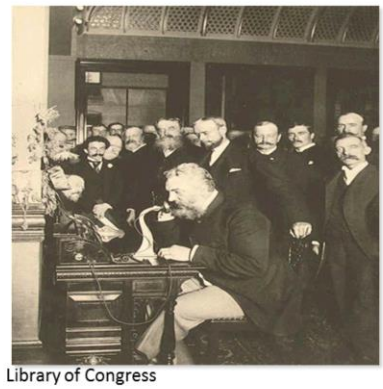

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Clearly there was an enormous step forward in communications when the telephone was invented at the end of the 19th century.

For some time, there had been many attempts to increase the capacity of the electrical telegraph network that now connected many towns across the United States.

Alexander Graeme Bell – a Scottish born inventor – transmitted the first voice call in 1876 in the very celebrated phone call to his colleague, Thomas Watson.

While his patent was challenged many times, most notably by fellow inventor Elisha Gray, the patent stood up to the legal challenges and we generally attribute the

invention to Bell.

Within 10 years over 150,000 people owned telephones, and by 1915 the first transcontinental phone call was made from New York to San Francisco.

Outline

Brief history of Networking

Brief history of the Internet

The series of events and inventions that eventually led to the internet started in 1960.

Parallel beginnings

J.C.R. Licklider describes an Intergalactic Network connecting everyone on the globe.

Four nodes interconnected (UCLA, SRI, UCSB, Utah)

RAND (Paul Baran) Packet switching for survivable networks.

MIT (Kleinrock) First paper on packet switching theory.

DARPA (Roberts) plans for "ARPANET".

NPL, UK (Davies) Packet network.

WAN connects two time-sharing computers

First "IMPs" (BBN).

1960 1965 1966 1968 1969

In 1962, J.C.R. Licklider at MIT started to write memos and give talks about his concepts of an Intergalactic Network, in which everyone on the globe is interconnected and can access programs and data at any site from anywhere. He talked of being able to communicate with his own 'Intergalactic Network' of researchers across the country. This is widely thought to be the first recorded description of the social interactions that could be enabled by a large communication network - very much like the Internet of today. Licklider became the first head of the computer research program at DARPA - the Defense Advanced Research Projects Agency - from 1962. While at DARPA he convinced Ivan Sutherland, Bob Taylor, and MIT researcher Lawrence G. Roberts, of

the importance of his new networking concept, and they took up the mantle when they succeeded him at DARPA.

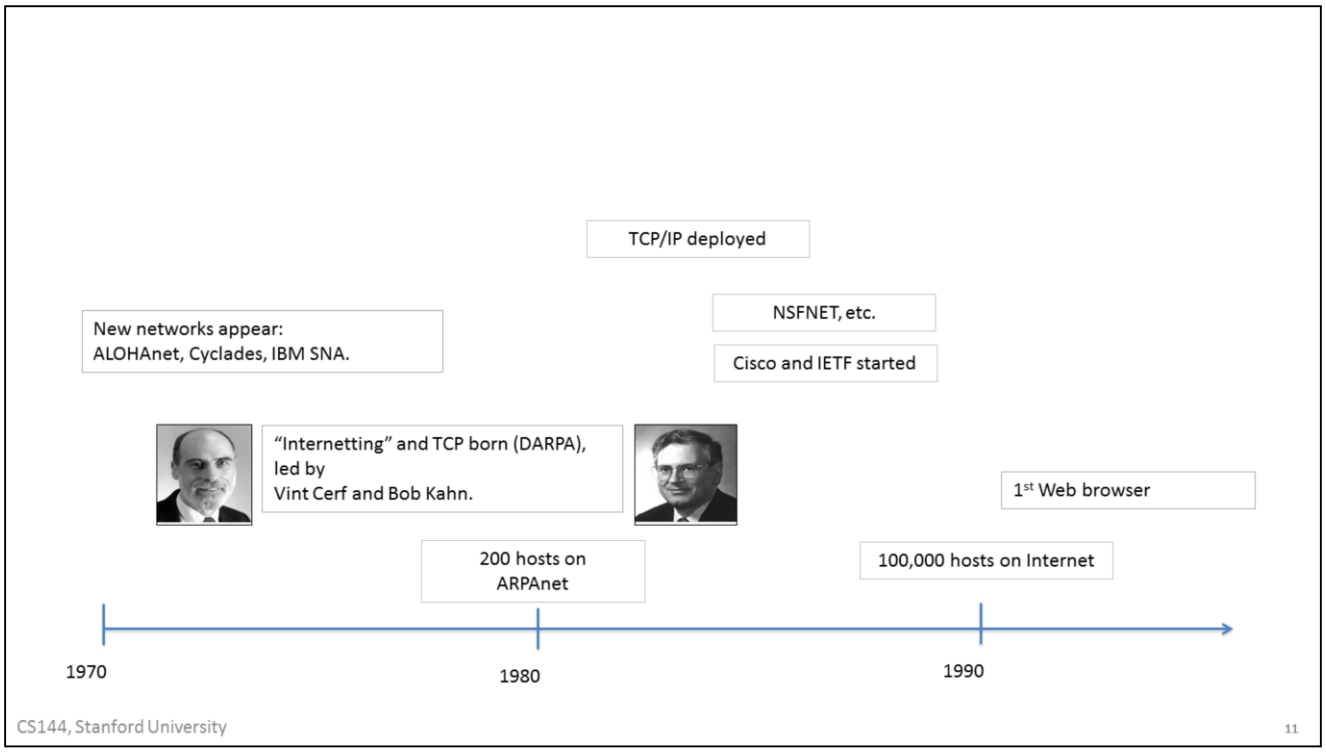
In 1964 researcher Paul Baran wrote what is now considered the first academic paper about large scale communication networks. The paper is titled: “On Data Communication networks”. At about the same time, Leonard Kleinrock’s thesiswas published on queueing theory. Donald Davies was working on very similar ideas at the National Physical Laboratory in the UK.

in 1965 working with Thomas Merrill, Larry Roberts connected the TX-2 computer in Mass. to the Q-32 in California with a low speed dial-up telephone line creating the first wide-area computer network ever built.

Larry Roberts joined DARPA in 1966 to help develop the first ARPANET plans, which were published in 1967.

In 1969 the first four nodes were installed at UCLA, SRI, UCSB and University of Utah and the very first messages sent.

This is what the Internet looked like in 1969 – it was called the ARPANET and was a single CLOSED, PROPRIETARY network.



By the early 1970s a number of different packet-switched data networks started to appear.

In 1971, the first packet radio network was built between the Hawaii Islands, called AlohaNet. The mechanisms developed for the ALOHA protocol have influenced pretty much every wireless network since.

Also in 1971 the Cyclades research network was built in France. It was the first to give the end hosts the responsibility for reliable communications, and heavily influenced the design of the Internet.

In 1974 IBM introduced an entire data network stack called SNA, which stands for Systems Network Architecture. Its goal was to reduce the cost of building

large time-shared computers with many teletype terminals, rather than batch processing with punch cards.

DARPA sponsored work on “Internetting” to create the first “networks of networks” to connect together networks around the world. The protocols needed for Internetting were first described by Vint Cerf (Stanford) and Bob Kahn in a now famous paper in 1974, with the title: “A Protocol for Packet Network Intercommunication”.

TCP called for reliable, in-sequence delivery of data and included much of what we call today the Network layer. In the early days there was no notion of congestion control; it was added to the Internet about 15 years later.

By the end of 1970s, TCP and IP were separated, making room for UDP to be added as an unreliable transport service as well, originally for packetized voice.

At the time, Vint Cerf was an Assistant Professor here at Stanford. He moved to DARPA in 1976 to help shepherd the new Internet project. He is now the Chief Internet Evangelist at Google.

Bob Kahn was already at DARPA when the paper was written. Together, they are considered the fathers of the Internet.

In 1983 TCP/IP was first deployed across the ARPAnet in a flag day when everyone upgraded to use the new protocols.

By 1986 NSFNET was created by the US National Science Foundation to interconnect supercomputers at universities across the US, using links running at 56kb/s. Other small networks started to pop up all over the place, connecting to the Internet.

By the end of the 1980s, there were about 100,000 connected hosts.

And then, around 1990 Tim Berners-Lee at CERN invented the world wide web, with the first browsers appearing in 1993 – most notably the Mosaic browser written by Marc Andreessen.

I can still remember the day I first saw a web browser in 1993 when I was a graduate student. We knew immediately it would change everything – but we didn't realize how huge that change would be. For many people, this is the dawning of the Internet, although of course we all know it goes much further back than the world wide web. But within a year, over a million people round the world were using the Web. And before the end of the 1990s, Yahoo, Google, Amazon and eBay would all be household names.

Useful References

1. The Early History of Data Networks
   G. J. Holzmann, B. Pehrson, IEEE Press 1994.

1. The Design Philosophy of the DARPA Internet Protocols.
   D. Clark, ACM Sigcomm 1988

2. Brief History of the Internet
   B. M. Leiner, V. Cerf, D. D. Clark et al.
   http://www.internetsociety.org/internet/internet-51/history-internet/brief-history-internet

If you would like to learn more about the early days of networking and the Internet, here are three excellent references that I really enjoy.

I'd highly recommend you read them to learn more about what led to an amazing transformation of modern society.

<The End>