CONVERGENCE

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It's hard to imagine a world without the internet. A world where mails would take days to reach, where information was either spread through word of mouth or was locked up in books. Telephones and more recently, mobile phones, have moved on from being luxuries to necessities. Telephones were invented more than a century ago and computers more than half a century ago. Though both these technologies seem to fit like a puzzle to give us the mighty internet, the convergence of telephony and computing together to form a global communication network was hardly a given. Voice and data do not flow separately through networks; Voice is just another type of data. In a world where it's hard to draw the line where telephony ends and computing begins, it's very important to know what shaped such a convergence of technology. What gave rise to the Info - Communications Industry which has this convergence of technologies at its heart. In this essay, I try to summarize my views about the convergence of telephony and Computing and also highlight essential milestones that were to shape this phenomenon.

I shall start of by highlighting the computing and software industry and then go on to telephony. The disorder in chronology is intentional as I try to relate advancements in telephony to computing which make little or no sense without knowing what was happening in parallel in the computing industry. The last section will talk about convergence of these two industries to become the internet and the network of networks.

Computing and Software

As the name suggests, a Computer is nothing more than a computing device. What has changed since the early days of computing is the remarkable improvement in speed and application of computing. This has been facilitated by the advancements in technology and more importantly semiconductors - little pieces of silicon that make up most of the computing infrastructure.

Computing has its origins in defense and warfare. Wartime efforts required calculating missile trajectories, analyzing inventory and logistics etc and more often than not, the fate of a war usually depended on how fast and efficiently you could perform these computations. As an aid to this, companies like IBM sold machines which could be given data and these machines would calculate results at humanly impossible speeds. These computers had a profound role in the victory of many nations during the Second World War. The ENIAC was one of the first computers to be used in defense. It was used to calculate Artillery firing tables.

The very first computers, not in defense, were used for census, billing and monetary calculations. It was this inherent need that people like Eckert and Mauchly recognized and started developing machines that were fast and reliable. Eckert and Mauchly were part of the ENIAC team and carried the knowledge out of Moore School to their company Eckert and Mauchly Computer Corporation. Coming out of universities and setting up commercial ventures using its research would eventually become a trend in the computing industry. The West coast would become the pioneer in the computing industry for the next 30 years with companies set up around Boston's Route 128, thanks primarily to MIT, its talent pool and the venture capitalists around the Boston area.

Another west coast company was IBM. Founded in the 19th century , IBM was in the business of selling tabulating machines. IBM was the first to introduce their punched card machines, but these machines only served for a particular type of problem. The machines would be cost effective only for a single program with very large data. IBM's influential relationship with the defense and their role in the Semi Automatic Ground Environment (SAGE) project helped IBM dominate the field of computing. As IBM grew, it got involved in many lawsuits for trying to monopolize the market.

IBM 701 users lacking resources and support started SHARE, the first computer user group. This group would meet often to discuss commonly occurring problems, share solutions and tips.

The UNIVAC was definitely a forerunner in its class of machines. Built on vacuum tubes, this machine was faster than the existing punched card machines and was more reliable. But its genius was in its difference from existing machines. The UNIVAC was the first stored program computer, a concept that would shape the next fifty years of computing. The concept that was first proposed by Alan Turing as a solution to the Hilbert's Entscheidung problem . Univac was practically a religion amongst its large community of users and the social implications of owning a computer were beginning to surface.

This era also saw the birth of the mainframe, which even to this day controls a lot of critical businesses. Core memory which provided random access, registers, input output and the various other parts of computer architecture were developed during this time. With the development of these resources came the need to develop software to control these resources. The best example would be the softwares that would run on mainframes written in COBOL. Due to the popularity of the COBOL language and also the amount of software written in COBOL, forced the Short Range Commission to standardize the language in 1960.

If the development of computing in the 40's and 50's was attributed to warfare, during the 60's and early 70's it was fuelled by the race to put a man on the moon or the American

Space program. Though contract work was not new for American defense projects, the space program and the defense programs started collaborating with reputed universities in the US for their research and innovation in computers. This collaboration would go onto create a necessity for building a communications infrastructure amongst these members called the ARPANET.

Back in computing, the problem of size and affordability of computers was still an issue. Monopolies like IBM had a huge market share and computer manufacturers needed new markets to sell their products to. The change in trend was brought by the Digital Equipment Corporation and their revolutionary bus architecture based PDP minicomputers. Room sized computers were sized down to table tops and computers became more affordable to everyday users.

The PDP machine is also credited to the birth of the first operating system, UNIX at the AT&T Bell labs. This probably was the first instance where the stored program in the computer was not to solve an applicative problem but to support the development of these programs – a concept that shaped Operating systems as we know it today. The PDP's were small, affordable and inventions like the teletypes and printers made interaction with the minicomputer easier.

While all these advancements were taking place in computing, in parallel, semiconductors were beginning to take shape at Fairchild Semiconductors and TI. The Aviation industry was the first to put chips to practical use. Gordon Moore was the first to realize more and more transistors could be placed on these chips. If enough transistors could be fit onto a single chip then you could build a computer using this chip. Intel developed the microprocessor in 1971. This was a general purpose chip with a few instructions and most other operations were realized by a combination of these instructions.

IBM had a monstrous market share. There was a growing sense of discomfort amongst many users and computer manufacturers about IBM practices. It was almost impossible to shift your existing software and hardware away from an IBM machine as it was tightly bundled. The computer manufacturers filed an anti-trust violation against IBM for usage of unfair means to monopolize the market. IBM was forced by regulatory authorities to unbundle their hardware from their software, giving the option to software providers to write software for IBM based hardwares. This opened up new doors to people who could now write software for IBM based machines, a fact that Microsoft would profit heavily from.

Since computers were expensive during those days, it wasn't practical in a university setting for every student to have a computer. It wasn't practical that each would spend a specified amount of time on it. The solution was to provide each student with a terminal, a

monitor and keyboard, with which he/she could connect to the computer which would work on a time sharing basis to provide its computing service. This is important as it spawned concepts like resource sharing, network monitoring, inter terminal messages etc which went on to be extended to the internet and has remained an integral part of many networks.

With unbundling came the forking of the computing industry into two verticals, hardware and the software vertical. The arrangement meant that people proficient in writing software could write general purpose software for IBM and the rest could concentrate on hardware. Emulators and general purpose platforms like UNIX also meant that the same software could run on a multitude of hardware's with little or no reprogramming effort. General purpose applications while providing benefits of automation with software for word processing, spreadsheets also introduced this inherent need to share the artifacts or results delivered by those software's. ARPANET was built with the intention that colleges with defense research projects needed to share research results and also share information amongst them. There was more of a social need rather than a technological angle, which made such a blue skies research possible.

What followed next was an era that was predominantly software based. Companies like Apple, IBM were still selling the software that went along with the hardware whereas companies like Microsoft were making software's for machines of all types of hardware. The era of personal computing started with small and affordable computers becoming available to everyday users. Computers like the Altair , Apple brought computers to every home in America. The evolution of the internet made sure that people's inclination towards buying customized software or hardware was dampened as they didn't see any value add. Instead the network externalities forced everyday software vendors to build software that could offer and derive value out of network of users. The introduction of the world wide web and the Netscape browser was yet another landmark in computing software history. Now all computers, no matter what platform, what hardware had a window to the world of networked computers out of which they could query and share information.

Telephony

Ever since Alexander Graham Bell made his first prototype, transmission of voice has been possible. The infamous company he founded, Bell Telephones, made sure that telephony

would sustain its speed in innovation and would churn out better and better products to connect American homes and offices. Experts realized early on the need for communication as an infrastructure and made every effort possible to make the telephone reachable to the general public. It wasn't until late that many countries realized a connected country would be an essential leverage for economic growth. In case of America, our example, the Herculean task of setting up a country wide network meant lots of research not only on telephones, but also communications and transmission technology, switching, routing and many other facets that go into making a telephone network.

Data was being transmitted over electrical lines in telegraph, but voice being transmitted was new. Bell started the infamous Bell Telephone Company (BTC) to manufacture telephones and the company was responsible for innovation in the telecom domain for almost a century. With telephones came the need for switching, which in the early days was achieved manually with the help of telephone operators. As the number of telephones scaled, so did the need for switching and manual switching was slowly replaced by electromechanical switches. The Strowger switch introduced during the 1890's would dominate the switching industry for more than half a century. As telephones became increasingly popular amongst people, there was an exponential growth in the telephone industry. More and more countries, towns, homes, offices wanted to be connected. This phenomenal growth in telephony forced inventors and entrepreneurs alike to innovate to make the system scale and perform more efficiently. The electromechanical switches were bound to have wear and tear and introduced maintenance overhead on exchanges. Cross bar switching was the first sign of change where the issue of scale was addressed, but the mechanical component and its maintenance was still unresolved.

The introduction of electronic switching in the 1960s brought a radical change in scheme of things. This was to be the first signs of convergence of telephony and computing, though this was never the intent of the inventors. Since computing was rapidly automating most industries by the early 60's, folk at Bell Labs envisioned a system of using a computer to perform the task of switching and used a Stored Program Computer as a switch. The result was extremely fast and scalable switching with very less maintenance. Semiconductors or Chips were made not to build computers but to build faster switches. Even UNIX the first operating system was developed in 1968 in AT&T Bell Labs. The intent was to build a stored program computer for switching. You can see here that two of the most important inventions that led to computing being what it is today, Chips and Operating systems, have both come as bi-products of telecom research. The telecom industry leveraged computing to scale and in turn contributed to networking which would later benefit the computing industry.

The most critical step in telephony history which has probably had the biggest impact on computing was the digitization of signals. The problems with analog signals were apparent from the early days of telephony. A frequency division multiplexing scheme was the first to be adopted and given the available bandwidth it would scale very gracefully. Reducing the frequency range would affect call quality. A time division multiplexing scheme wasn't that effective either due the constraints on the real time delivery of each call. The efforts in digitization started as early as the 1930's but it became commercially used only in the 70's. If it wasn't for digitization of data, computers would not exist.

Digital switching emerged commercially during the 1970's and from then on many analog exchanges internationally are being converted to digital exchanges. Advancements in digital transmission technology, primarily the Optical fiber has improved the transmission speeds of data dramatically. National backbone networks ran Optical Fibers and the process of digitization continued rapidly.

Bell Telephone Company which had become American Telephone and Telegraph was a regulated monopoly which controlled the fate of telephony in the US. The 1968 Carterphone decision allowed for third party phones to be connected to AT&T lines. Their monopoly further eroded in 1982 when DOJ's antitrust lawsuit forced AT&T to accommodate other networks locally. Regulation helped open the monopolized market to new telephone providers. American consumers didn't have to wait for AT&T for telephone connections.

Convergence and the coming together

The principal reason for the birth of the internet was defense research. During the 60's and 70's at the height of the Vietnam War and the cold war, defense money was being used extensively in universities across America. In order to keep America ahead of USSR in the space race, the Department of Defense set up ARPA (Advanced Research Projects Agency). ARPA had the job of conducting research though academia and contract workers with no research facilities of their own. When it was observed that the 15 institutes ARPA was working with was not drawing from the research findings of each other, a plan to network these 15 institutes to form local centers of excellence was proposed.

This would have to be a nationwide network that would work without the traditional message switching technology, prevalent during those times. Packet switching, work by American Paul Baran and Donald Davies from UK came to the rescue. Baran had suggested packet switching as means to building a highly reliable long distance network that didn't use circuit switching. Also, it wasn't practical to build a nationwide network for this

purpose alone so one of the existing networks had to be used. The telephone network, which had penetrated even the remotest places in America, seemed a good choice and the plus side was that packet switching could be achieved over the existing telephone network. The first step towards convergence was taken in this way. ARPA built the ARPANET, a system to interconnect the 15 institutes involved in ARPA research and the Internet was born! The early development of the internet was influenced a lot by social factors. The coming together of research and expertise from Britain and America, the formation of ARPA which had no research facility of its own but depended on the co-operative work of many different institutes were important milestones.

Different machines were connected to the ARPANET and a standard protocol was to be used to effectively interconnect these disparate machines. TCP/IP, a protocol developed by Cerf and Kahn, was to be used for this purpose. This was an important step considering the fact that all the 15 institutes agreed to use this common protocol instead of using their own variants. TCP/IP later proved a boon in connecting different networks which talked different languages, different data formats etc. It would go onto become the fabric of the internet.

People also realized that trying to make these machines talk to each other would be a fairly complex task and there couldn't be a single program or application that could achieve the breadth of requirements that the procedure required. A decision was taken to layer the procedure and split the work so that each of them could be abstracted from the functionalities of the other. This meant that people working on the application level could work in that level only without having to worry about TCP/IP send receive. The OSI model was proposed but never implemented. The TCP/IP model had an inherent layering to it, which could be mapped to the OSI model. It made TCP/IP the natural choice for the layers. This was a very important step because it created so many verticals in the computing industry where people developed their own applications for each layer in the model. This layering is what gave people the freedom to develop the Ethernet technology that gave home users the technology to network with each other.

It was surprising that even though the ARPANET was setup, the traffic inside individual institutes far exceeded the traffic between institutes. This observation reinforced the fact that computers even within a network needed to connect to each other.

It was users who realized the opportunity in ARPANET and a sense of community amongst its users is what improved the ARPANET. There were huge sources of information on the ARPANET but finding the information you wanted was tough. A bulletin board was set up where people could inform the whole community about the availability of information.

The application that a big hit was Email – developed in 1975, it became a major means of communication amongst users of the ARPANET. The original intent of ARPANET for resource sharing was in low demand but users on the ARPANET had redefined what networking meant to them. Meanwhile at Xerox Palo Alto Research Center Metcalfe had developed a new technology termed as the Ethernet, which were a fast and an efficient way of transmitting packets for small distances. Ethernet was an important step as it gave a networking option to personal and low end computers. By the 90's Ethernet was the preferred medium for local area networking.

The users made ARPANET better with more variety of applications. Soon bulletin boards, forums, chat and email had new found uses. The department of defense decided to separate out ARPANET from the defense network and made the MILNET. Now that ARPANET was completely open to public plus the invasion of ISP's, better applications on the internet, users flocked into the network to be a part of it. The invention of a browser and hypertext added fuel to fire. A common platform independent humanly navigable view of the internet was widely welcomed in the early 90's. Search engines, web directories only helped to make the internet more structured and offered people more reason to plug into the network and it has never stopped growing since.

No one institution was responsible for the growth of the ARPANET; it was due to the aggregation of talented young people who contributed to the betterment of the network. Right from its day of inception, internet has been a social phenomenon. Its unwise to be talking about the myth that internet has started becoming more social in the recent past.

Its hard to say the internet would not have existed if ARPANET was not formed; it would not have had the quality that it possesses today.

Conclusion

The internet is a social phenomenon. It's the community that built the internet and made serious attempts to bring quality to the network. The community also increased the value of the network by contributing more and more towards the betterment of the network. America's strong presence on the internet has surely helped build a vast industry around the internet infrastructure. Thousands of jobs are created every year to satisfy the local internet savvy market. Though America's industrial strength cannot be undermined, but technology based industries are a very big boost to America's economic growth. That is probably the reason why America is chosen as a seat to view this convergence from. Other developing countries like India are trying to mimic the economic and regulatory environment in the hope that technology based exports would become a driving force in the country's economy.

Convergence

It's ironic that technology that shaped today's computers, ie Semiconductors, operating systems , C language etc were all created as a need for telecom industry. If it weren't for disruptive technologies like packet switching, personal computers, Ethernet internet would not be what it is today. Convergence was due to simple dependency on the part of the computers, in which they had to rely on a nationwide network to interconnect. Telephone networks were a natural fit. The wide spread penetration of telephony into homes and office together with the popularity of personal computers made the internet accessible to every home user. Networking couldn't have relied on any other network during the time of the ARPANET, given the advancements of technologies. Acceptance of a common protocol TCP/IP and the inherent layering built into its architecture helped in the vertical segmentation of the networking industry.

Today wireless is a popular medium for internet access, resulting in greater convergence. Experiments are being conducted to use other networks like Power Lines, cable Television networks and Satellite network to transmit data so as to remove the strong dependency on telephone networks. If this continues there will be more convergence. Rapid advancements in transmission technology have made multimedia data on the internet really popular. Technologies like DSL and Optical fibers have realized gigabit speeds in transmission. Given the wealth of information on the internet and the fact that every new person plugging into the network derives and contributes to the networks value makes becoming a part of the internet that much more necessary. It's not very far when electricity, public broadcasting, and the internet would all be accessible through a single cable.