

Assignment #2 - Design the Internet, part 2

Software Systems Architecture

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Abstract

This paper compares an imagined Internet architecture designed in 1970 with the actual architecture that has emerged since. It delves into the theoretical underpinnings and potential implications of the imagined design, contrasting it with the realities of today's Internet infrastructure. This comparative analysis reveals both similarities and disparities, shedding light on the paths taken and the roads not travelled. The examination highlights the value of speculative thinking in innovation and informs future directions in network design.

1 Introduction

In the annals of technological innovation, few achievements rival the transformative power of the Internet. As a ubiquitous medium connecting individuals, businesses, and nations across the globe, its impact on society, commerce, and communication is unparalleled. However, the genesis of this monumental invention can be traced back to humble beginnings, with its conceptualization necessitating visionary foresight and creative ingenuity.

In the early 1970s, amidst a swiftly evolving technological landscape, a formidable challenge emerged: designing an Internet architecture. Against this backdrop, the task presented itself as an opportunity for speculative exploration. Leveraging the knowledge and constraints of the era, an imagined network was conceived, poised to revolutionize the exchange of information and ideas.

The design, crafted amid the dawn of digital connectivity, embodied audacious aspirations. Grounded in principles of decentralization, scalability, and interoperability, it aimed to transcend existing communication frameworks, envisioning a truly interconnected world. However, the true measure of this invention lies in its comparison with the Internet architecture that has since become the standard in the digital age.

In navigating this comparative journey, the underlying principles and trade-offs shaping Internet architecture's evolution over decades are sought. Through critical assessment of imagined and real architectures, lessons are gleaned to inform future directions in network design, engineering, and policy-making. Thus, this retrospective examination serves as both a testament to visionary innovation and a forward-looking exploration of the Internet's evolving nature and its profound impact on humanity.

2 Rationale and Insight

The success of the Internet as a global network can be attributed to a series of pivotal decisions made during its design phase. In this section, attention is directed towards two such decisions that have fundamentally shaped the Internet as it stands today.

2.1 Modesty

The adoption of a modest and general service model for the Internet has been crucial for its success. This approach, rooted in the principle of modesty, focuses on flexibility and adaptability rather than specific requirements. By avoiding a rigid service model, the Internet allows a wide range of applications with distinct purposes and functionalities, such as **Streaming services, Social media platforms, E-commerce**, etc.

Thus, having a less restrictive service model has proven to be a strategic move that lets the Internet evolve dynamically empowering new applications to thrive. It also enables applications to remain relevant and adaptable, avoiding becoming obsolete in the dynamic landscape of technology and aiming for long-term success.

The combination of modesty and modularity in the Internet’s architecture makes it possible to incorporate different technologies in different layers of the OSI model, adapting to the requirements of the applications in the upper layers and to economic viability in the physical layer. Although it may seem paradoxical, in certain situations it is more advantageous to opt for slower transmission technologies in the physical layer, especially in regions with challenging socio-economic and geographical conditions, where the implementation of high-speed infrastructures, such as optical fiber, would be economically unfeasible. For example, in Portugal, less densely populated rural areas far from urban centers often make it impractical to install fiber optics. In these cases, the choice of more modest technologies, such as ADSL or GSM, can be a viable solution, offering Internet connectivity to populations

As mentioned in the paper [2]: *Being modest in performance requirements allowed the Internet to be ambitious in the speed and scope of its deployment.*

In summary, the Internet owes much of its remarkable success to the adoption of a modest service model. By prioritizing flexibility over rigid performance requirements, the Internet has fostered an environment where innovation thrives and new applications emerge. This adaptability has allowed the Internet to evolve rapidly, meeting the changing needs of users and technologies. As noted in the paper [2], this willingness to eschew strict performance demands has enabled the Internet to achieve ambitious levels of deployment, solidifying its position as a cornerstone of modern society.

2.2 Assuming Failure is the Normal Case

One of the crucial decisions highlighted in the article is the principle of assuming failure as the normal case in Internet design. This decision underscores the importance of efficient handling of failures as a fundamental scalability requirement. By acknowledging that failures are inevitable, especially as systems scale in size, the Internet’s architecture prioritizes resilience and robustness.

This design choice manifests in various aspects of Internet mechanisms. For instance, in basic routing algorithms, the calculation of routes remains consistent whether due to a link failure or periodic recalculations. Similarly, in

transport protocols, such as TCP, packet loss is treated as a common occurrence necessitating retransmission, rather than a special case.

Embracing failure as the norm has been instrumental in ensuring the Internet’s success. It allows for the development of mechanisms that can adapt and recover seamlessly from disruptions, contributing to the overall reliability and stability of the network. This approach has not only facilitated the Internet’s ability to scale but has also laid the groundwork for the resilient infrastructure that underpins its global connectivity.

By adopting a mindset that anticipates and effectively addresses failure, the Internet has been able to withstand the challenges of its dynamic and ever-expanding environment, ultimately cementing its position as an indispensable tool for communication, commerce, and innovation worldwide.

3 Rationale behind the decisions

This article places significant emphasis on elucidating the underlying reasoning behind the key design choices shaping the current Internet architecture, rather than merely detailing the choices themselves. This approach enables readers to gain valuable insights into the foundational principles guiding the Internet’s structure. In this section, two fundamental insights elucidated in the article are explored.

3.1 Reliability Delegated to Transport Layer

The strategic decision to delegate the responsibility for ensuring reliability to the transport layer, rather than enforcing it within the initial three layers of the Internet architecture, offers valuable insights into the network’s design philosophy. The rationale behind this decision, as explained in the article, lies in the inherent challenges faced by the lower layers, primarily concerned with routing and packet forwarding, in guaranteeing against packet loss due to overloaded links or malfunctioning routers.

By opting not to enforce reliability at the lower layers, the Internet architecture prioritizes flexibility and efficiency. This design choice recognizes that different transport protocols may be better suited to ensure reliable delivery depending on the specific application needs. Consequently, the Internet’s approach acknowledges the diversity of use cases. It allows for the adaptation of transport protocols to meet varying reliability requirements, thus ensuring the network’s adaptability and resilience in diverse operating environments.

3.2 Hierarchical Domain Name System (DNS) Structure

Another key design choice of the Internet is the adoption of a hierarchical naming structure known as the Domain Name System (DNS).

The decision behind it is a thoughtful response to the scalability and administrative challenges posed by the vast number of names on the Internet. As

mentioned in the article, any application-level naming system must: (i) assign administrative control over each name to a unique authority that decides which IP address(es) the name resolves to; (ii) handle a high rate of resolution requests; and (iii) provide both properties at a scale of billions of application-level names. This hierarchical structure allows for highly parallel name resolution and fully decentralized administrative control, both of which are crucial for handling the scale of Internet naming.

Understanding the "why" behind this decision provides insight into the Internet's design philosophy, emphasizing the need for a system that can scale effectively and be managed in a decentralized manner.

4 Deciphering the Title

The title "Extracting The Essential Simplicity of the Internet" not only succinctly encapsulates the article's focus on distilling the core principles that define the Internet's architecture but also reflects the authors' underlying motivations. As explained by Scott Shenker (one of the article's authors) [1], this paper was born out of a "long-time frustration" stemming from their perception of the Internet as "interesting" and "inspiring," contrary to the opinions of many research colleagues. Therefore, the title signifies the authors' intention to delve beyond the surface complexities of the Internet, aiming instead to uncover the foundational design choices that enable its functionality.

By emphasizing key elements such as a service model, a four-layer architecture, and three crucial mechanisms (routing, reliability, and resolution), the article adopts a "why, not how" approach. This methodology allows readers to gain a deeper understanding of the underlying rationale behind these design choices, rather than getting lost in the intricacies of specific protocols. Ultimately, the title suggests that by extracting and understanding the essential simplicity of the Internet, readers are not only equipped to comprehend its structure but also empowered to envision and design new iterations with comparable properties.

5 Comparative Reflections: Our Design vs. Reality

Upon reflection of our original design in comparison to the actual Internet architecture, a nuanced evaluation reveals both strengths and weaknesses.

Our initial design, crafted under the premise of simulating 1970s technological constraints, adopted an iterative approach. Starting with a rudimentary, idealized solution, we incrementally addressed emerging challenges, leading to a hierarchical router design spanning cities, countries, and continents. This hierarchical structure aimed to streamline data transmission across geographic regions, reflecting foresight into scalability and administrative control.

However, our design lacked comprehensive detailing, particularly concerning the intricacies of communication protocols from point A to point B. This

oversight underscored the importance of considering network communication pathways comprehensively, a facet that our subsequent exploration illuminated. In addition, after a careful review process, it was concluded that the diagrams presented in our proposal lack clarity, as they do not include explanatory legends for the arrows that connect the different components, and there is the use of different types of arrows to represent the same function.

One notable strength of our design was the recognition of the necessity for a hierarchical Domain Name System (DNS). Our approach aimed to enhance scalability and decentralize administrative control, aligning with principles of robust network architecture. This hierarchical DNS structure was essential in mitigating the limitations of centralized hostname translation.

In conjunction with this hierarchical DNS, the incorporation of a proxy server played a pivotal role in managing data flow within our architecture. Positioned as an intermediary between users and the broader network, the proxy server regulated and optimized traffic. Its function ensured efficient distribution of resources while minimizing latency, thereby enhancing the overall performance of the network.

Finally, to establish a robust and scalable Internet infrastructure, our comparative research highlights the iterative nature of network design and the significance of taking into account a variety of elements, such as administrative control and communication paths.

6 Conclusion

The exploration of the imagined Internet architecture of the 1970s and its comparison with the real Internet architecture has provided valuable insights into network design evolution. Analyzing key design choices like the service model, four-layer architecture, and crucial mechanisms such as routing and reliability has deepened our understanding of the Internet’s functionality.

The article’s emphasis on elucidating the rationale behind these decisions, rather than delving into technical specifics, has shed light on the strategic thinking that has shaped the development of the Internet. Concepts such as assuming failure as the normal case and adopting hierarchical structures like the DNS have emerged as pillars of Internet resilience and scalability.

The title ”Extracting The Essential Simplicity of the Internet” encapsulates the theme of uncovering fundamental design choices enabling Internet functionality, emphasizing simplicity amidst complexity.

Reflecting on the design in comparison to the actual Internet, strengths and shortcomings emerge. Although the design may have lacked detail and realism, the iterative problem-solving process outlined in the article has contributed to a deeper understanding of network design principles.

In summary, the exploration of both imagined and real Internet architectures enhances comprehension of the technological landscape, providing valuable insights for future network design, engineering, and policy-making endeavors.

References

- [1] Association for Computing Machinery (ACM). February 2023 cacm: Extracting the essential simplicity of the internet. <https://www.youtube.com/watch?v=XY6fJVMaawI>, 2024. [Online; accessed on 16th February 2024].
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