# Reading Assingnment #2: **The Design Philosophy of the DARPA Internet Protocols** - David D. Clark\* Massachusetts Institute of Technology Laboratory for Computer Science Cambridge

2023065350 DoHyun Kwon

## **Introduction**

This paper describes the evolution of the Internet design based on the author's research at the Advanced Research Projects Agency of the U.S. Department of Defense over the past 15 years. The early Internet architecture led to important advances such as connectionless services and the IP/TCP layered architecture, which are still evolving today. These advances contribute to the effective interconnection of multiple networks and the integration of various transmission media.

## **Fundamental Goal**

The main goal is to develop effective technologies that leverage existing connection blocks by multiplexing them. In the process of multiplexing networks, we decided to include existing networks to make them more practically useful. The multiplexing method used was packet switching, and the network to be integrated was a packet-switched network. Finally, it was necessary to assume specific technologies for connecting the networks. The final assumption was that the networks were interconnected by Internet packet switching layers called gateways. After all this, the basic structure of the Internet is derived: a packet-switched communications facility where several distinguishable networks are connected using packet communications processors called gateways.

## **Second Level Goals**

In the main goal mentioned in the "Fundamental Goal", what are the specific goals for being "effective" in "effective technology"?

1. Internet communication must continue despite loss of networks or gateways.

2. The Internet must support multiple types of communications service.

3. The Internet architecture must accommodate a variety of networks.

4. The Internet architecture must permit distributed management of its resources. 5. The Internet architecture must be cost effective.

6. The Internet architecture must permit host attachment with a low level of effort.

7. The resources used in the internet architecture must be accountable.

For military purposes, the above sub-goals are listed in order of importance. Changing the order of importance of these sub-goals would result in a completely different Internet architecture. For example, if the purpose is commercial, the importance of these sub-goals should be the opposite. It should be noted that coordinating the order of the above seven subgoals is an important part of Internet architecture design.

## **Survivability in the Face of Failure**

A key goal of DARPA's Internet architecture is continuity of communications services. Communication must continue without the connection state being initialized or re-established at higher levels even after temporary network outages or reconfigurations. To achieve this, state information must be protected at the lower layers of the network. Instead of the complex and unreliable approach of storing intermediate packet switching nodes, we chose an approach called fate-sharing. It stores information on the host and at the end of the communication rather than in the middle. The advantages of fate sharing are that firstly, information is protected even in the event of an intermediate node failure, and secondly, it is easy to implement.

## **Types of Service**

A second goal of the Internet architecture was to support diverse types of services. To accommodate the diverse needs of different services, TCP was used. As immediate processing and continuity become more important, TCP alone is no longer sufficient. Eventually, TCP and IP (Internet Protocol) were split into two independent layers, with TCP providing a reliable, sequential data stream, and IP providing a basic datagram service (best-effort delivery), providing the building blocks on which many different types of services could be built.

## **Varieties of Networks**

A key element in the successful evolution of the Internet architecture has been the ability to integrate and leverage diverse network technologies. The flexibility of the Internet architecture is built on the fundamental assumption that networks must be able to forward either packets or datagrams. Because it was inefficient for each network to be reliable, functions such as reliable transmission were provided at the transport layer.

## **Other Goals**

1. Allowing for decentralized management
2. The Internet must be cost-effective
3. Accountability

First, the Internet's multiple gateways are not managed by the same organization; instead, multiple management centers operate each gateway. It is designed to enable routing table exchange even in a distributed management environment, and to allow the Internet to operate normally even if mutual trust between multiple management units is not complete.  
  
Second, reflects a sacrifice in efficiency due to the design decision to keep the network interface simple. The cost of connecting a host to the Internet may be higher than in other architectures. As programmers gain experience, they become capable of implementing complex protocols, and this goal has been achieved.  
  
Finally, a third objective is being studied to monitor resource usage in the current context of Internet use by non-military consumers.

## **Architecture and Implementation**

To increase the flexibility of the Internet architecture, implementation is needed in the engineering of specific networks, gateways, and hosts, rather than in the architecture itself. The diversity of implementations makes a big difference in the services they provide. The Internet architecture is designed to allow for these different implementations. However, while providing this flexibility, it leaves many engineering challenges for the designers of each implementation. Existing network design tools focus on whether implementation is feasible rather than on performance optimization, which is disadvantageous for performance optimization. Internet architecture has been criticized for focusing only on logical correctness and ignoring performance issues, but there has been great difficulty in formalizing performance constraints within the architecture. This problem has been exacerbated by the fact that the architecture aims to allow diversity rather than restrict performance. This problem remains one of the challenges that still need to be solved.

## **Datagram**

A fundamental feature of the Internet architecture is the use of datagram as the basic unit of transmission over the network.

Why Datagrams Are Important?  
1. No need to maintain connection state  
2. Flexible service implementation 3. Minimum network service assumptions

However, one of the misconceptions about datagrams is that they are designed to provide the same functionality as higher-level services. That is, it is often thought that datagrams directly support the unreliable datagram services that applications require, but this is not true. Most Internet applications want a more sophisticated transport model than a simple datagram. In conclusion, datagrams are not intended to provide services in and of themselves but are used as basic elements for building services. This allows the Internet architecture to meet diverse service requirements.

## **TCP**

TCP went through several major versions before becoming a stable standard, and some design decisions were made after much discussion among its founders.

1. Byte-based flow control (vs Packet-based flow control)
   1. Inserting control information into the byte order
   2. Packet sizing
   3. Byte consolidation during retransmission
2. Evolution of the End-of-Letter Flag

## **Conclusion**

The Internet architecture has been successful, but it has limitations in resource management and accounting. The datagram model has difficulty solving these problems because it does not recognize packet flow. The concept of flow has been proposed as a new building block, which can recognize packet sequences while maintaining service flexibility. The concept of soft state can minimize service interruption even in the event of a failure. These alternative approaches are currently being researched.

## **My impressions**

I thought that the development process of Internet architecture was very similar to the development of science. It was impressive that they set clear goals from the initial design and discovered new challenges and defects in the process of achieving those goals and solving them. I felt that Internet architecture, like scientific inquiry, is not static but a constantly evolving system. The process in which TCP's initial design decisions were modified and developed through experiments was similar to the way hypotheses are verified and evolved in science. Through this paper, I realized once again that the Internet was able to achieve its current success based on design flexibility and adaptability.