

Lecture 29

Active Networks

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Stanford University – Clean Slate Project

...explore what kind of Internet we would design if we were to start with a clean slate and 20-30 years of hindsight.”
<https://web.archive.org/web/20070614003630/http://cleanslate.stanford.edu/CleanSlateWhitepaperV2.pdf>
<https://web.archive.org/web/20080626030541/http://cleanslate.stanford.edu:80/>



The roots of SDN can be traced to the Clean Slate Project. This was an interdisciplinary research program at Stanford University, started by Nick McKeown and his group; the entire theme was that the internet is broken, and there was a need to reconsider the design of the internet in a fresh approach and started from Ground-up or the Clean Slate model. And this had to be done in a way that we put together the learnings that we have had from the past 2 to 3 decades of the internet evolution and set aside the complexities that have been borrowed over in building such an internet infrastructure as they saw in the early 2000s. And in a very what it meant is we should not continue to rely on a network that is often broken, or having frequent issues with being disconnected or providing unpredictable behavior. And also, the search of security threats were rampant with malicious users, lots of malicious users joining in, and all these aspects also meant going forward, the internet would just become economically not sustainable.

Further, when we think from design philosophy, there was also widespread use or adoption of what we call the end-to-end principle or the end-to-end design philosophy where the internet, which was smart, was only confined to the end hosts, while the network in itself or the middle

pipe was just plain or dumb wherein this dumb infrastructure helped rapid evolution of the Internet with lots of new applications that could emerge and tried out. But on the other end, if we think it also inhibited any of the developments or any of the innovations that could happen within the network itself. And hence, it was also a case where the widespread use of the end-to-end principle or our reliance on it is a means of network ossification.

Consider, for example, the deployment of IPv6. And if we question back why it took so much of time for the deployment of IPv6, it was operationally infeasible unless we added the intelligence to facilitate the entire infrastructure to manage the v4, to v6, v6 to v4 bytes. And hence, what this also meant is that there is a need for some sort of intelligence within the network. Also, we learned about the diff services or integrated services and what we see them like Why have been a failure? Because if you have to support them, then you need some sort of intelligence within the network, which stands against the much-celebrated end-to-end design philosophy.

And hence, sticking to the end-to-end design philosophy, in a way, made the deployment of several of these ideas just hard enough. And deploying any radically new architectures was just unthinkable. So instead, the researchers here wanted to bring forward and see if not, what would enable us to rebuild the internet. And they had two key research questions in mind.

One, how would we design the internet? If, with what we know today, but we start all over again. Two, the internet that is economically sustainable and feasible, and what would it look like in the next 15 years? And the overall vision here was for a global network, and it was fast, predictable in its services, be it reliable or unreliable delivery, provide means to evolve to newer technologies, and enable a robust internet that is robust against failures of any infrastructure or the endpoints and also secures against any of the attacks. So, all these aspects were envisioned through this project. And this project eventually led to what we know of as SDN and the open flow as a means for southbound communication.

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If a Clean Slate is the solution, what was the problem?

I think this effort is misguided and doomed.

In '78 a computer was a resource. Today information is a resource & our myriad computers are just tools to help manage & move it.

– Van Jacobson

<http://yuba.stanford.edu/cleanslate/jacobson.html>

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Software-Defined Networks

Advanced Computer Networks

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Nonetheless, this project also saw many of the detractors or having notion of why we should be doing a Clean Slate approach. If we have to do then we have to also see what is the problem. And Van Jacobson wisely saying that this effort is misguided and doomed. In a way that when you see the evolution of the Internet, and the very early principles that were put forth by Vinton Cerf and Robert Kahn in the early 70s, were so elegant that they were able to address and facilitate what we see today as an Internet as large-scale infrastructure and rapid deployment.

And as we move forward, we have seen that many of the applications have emerged. And that is only possible because of the clean solutions provided by the end-to-end principle. And the works of Vinton Cerf and Robert Kahn in putting together the key networking objectives, but now we are questioning the same. So, in what sense should we be going forward in addressing these problems? That was exactly the concern.

And here, what an important aspect Van Jacobson also brought was when the network started in the early 70s and till the late 80s, it was computers that were seen as a resource. But then things changed. And what we see today, or even starting from the early 2000s, it was information that is seen as a resource. And computers or networks were just a means to ensure that a user is able to access those resources and is able to manage them as his needs be.

And hence, we have to rethink about what is our key objective? Or what are the things that we want to put forth in this clean slate solution? Definitely, if there is a small dent to a vehicle, you

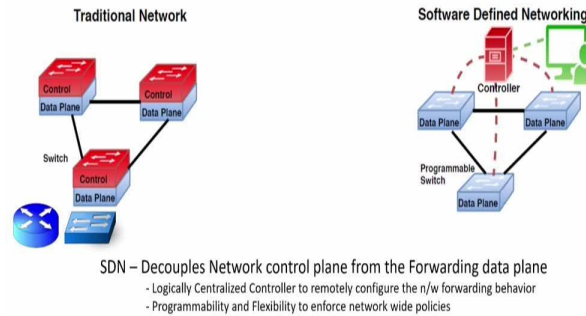
will not sell it off and buy a new vehicle or make a new maker; you want to just patch it, but ensure that things work in the long run; that is the key here.

Nonetheless, the Clean Slate approach, in fact, led to very profound outcomes. And most of them, what we can see is basically this software-defined networks, which did not laterally change the entire network internet infrastructure, but it showed what can be made as a change to ensure sustainable networks as we go forward. And this is where one of the outcomes from this clean slate project was the software-defined networking principles, the open flow as a control data separation aspects.

Further, it also led to three other important outcomes, which enabled us to rethink, redesign the data center networks in a better way, add to the mobile IP solutions in terms of how you could support the users when they are on the move with the IP network and also the aspects of social networking.

Let us focus on the aspects of SDN alone and see what it meant. But, just to give you a hint, like I have shared some of the resources here in either a couple of slides, which put forward the vision of the Clean Slate architecture that PDF link is in the earlier slide, which is a nice read to see like okay, what were the exact problems, what are the key pieces where we need to update and adapt and what are the learnings that we should be taking forward and it very nicely elaborates those aspects. And also, I put here the link on what Jacobson said about this project. But as we said, we see this clean slate project as a major success. And in fact, this has revolutionized the way that we see the networks today, if not changed it drastically in a clean slate manner.

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So, let us try to understand what this SDN is all about. If we start with a traditional network, and when we say confined to the network, we are decoupling ourselves from the end hosts and the applications and looking at just the network infrastructure as the core elements and the core elements being the routers and switches.

And we are trying to look into their operations of how they would work and what is it that we are now trying to change in the network as such. So, the picture here shows basically that the routers and switches have two distinct planes of operation. One we call as a control, and the other has a data plane, and to put ourselves into the context of what we mean by this data or control plane, what we are referring to is the data plane talks about what to do when it receives a packet. And the control plane speaks about how to do that particular aspect.

In essence, we had tried the device as a switch as it gets the packet, it will forward, so the forwarding is what to do. But as these devices have multiple ports and have the same packets take a decision on where to send these packets; that decision of how is what is being dictated by the control plane. And when we take these routers or switches, they are all in the same device that these two planes operate.

And what SDN tries to do is to decouple this network control plane from the forwarding data plane. In essence, all these routers or the switches, which used to have the notion of a logic to say how to do things embedded within those devices, is now being taken out from those devices. And these routers and switches now merely act as the data plane entities which only know what

to do, but how to do aspect has been shipped out to an external entity or externalized the control from these devices so that this can be controlled from one place rather than controlling at each of the devices independently.

And also, if you have one control, you can also make that control as a program that can run, and this provides a lot of flexibility in how you can apply the same logic across multiple data between entities like switches and routers. And this is exactly what software-defined networks started with.

And we will see there is a lot more to this SDN from what it actually originated from what we see it in today's world. But in order to get this information and understand this in a lot more context, we need to understand what it really means to say this control and data plane, and more importantly, we should also be seen why is it that we would want to do this in the first place?