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Clean Slate Design and Interoperability:

Future Network Experiments from China's IPV9 Research

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1. Introduction

This document is a technical research report authored by Chinese experts. It is intended for distribution to ISO/IEC JTC1 SC6's WG7 Tokyo meeting on Future Network standardization.

Future Network research in ISO/IEC has taken the position that it would seek a clean slate design approach to create a brand new network to meet the needs of year 2020 and beyond. However, there are lingering concerns about this approach. Interoperability is one of the major concerns that we often here about. People are worried that if the clean slate designed Future Network were not backward compatible with the old generation IPV4 based networks, it would lead to the destruction of old networks and huge cost to build the new networks. This conception of conflict between the clean slate idea and the need for interoperability is a major barrier in Future Network research and development. If this problem were not resolved, the development of Future Network would be a slow and difficult work.

This paper tries to reduce the concern on interoperability. We will provide theoretic analysis and will examine thoroughly the issue whether clean slate design must end in conflict with interoperability. We believe the Future Network may resolve the issue of backward compatibility while preserve all the benefits of a clean slate design. This opinion has the support from successful engineering operations in China's IPV9 project, an exemplary third generation network operation.

2. from Evolution to Clean Slate Design

The idea to rebuild the IP networks (including internet) with a clean slate approach appeared about 10 years ago. While China was quietly conducting a clean slate research on a futuristic network (the Decimal Network Standard Group in China's Ministry of Information Industry was established in 2001), Western scientists were also thinking and talking about such an approach, although the term they used was "new architecture" instead of "clean slate".[1]

At the turn of the century, this kind of new emerging revolutionary forces was small and isolated. The dominant interests were still in favor of the evolutionary approach. The major players of network technology development such as American National Science Foundation, IETF and ITU-T were all committed to preserving the integrity of old structures and limiting technology research to short-term need analysis and gradual modifications and enhancements. This kind of conservative approach

leads to the emergence of IPV6 (from IETF) and its derivative Next Generation Networks (NGN) from ITU-T.

However, not for long, industry and technical experts became disgruntled with IPV6. The second generation (also called next generation) internet protocol brings limited benefits such as more IP addresses, but carries most of the structural problems in the old internet which was designed 40 years ago. Looking at the fast changing technology and the inadequate performance of IPV4 and IPV6, more and more people realize that without a structural overhaul the networks would not be able to meet future demands.

Nevertheless, the interest in preserving the old architecture was so strong that the clean slate design approach needs something special to obtain the mainstream position. The emergence of a disruptive technology is one of the forces to prompt such a change.[2]

In 2004, China announced that a new network protocol with new architectural designs named IPV9 has been successfully developed. [3] This is a significant development. It means that clean slate design of a new generation (the third generation) internet/network is no longer a theoretical presumption but an engineering reality. It also means that if the developed countries stick with the conservative evolutionary policy, other developing countries such as China could take the lead in the race for a new generation internet because they have smaller burdens in adopting a new architectural design.

China's announcement of IPV9 disrupted the evolution of networks and speeded up the switch to revolutionary approach. In July 2005, one year after China's IPV9 announcement, United States NSF suddenly announced that it was creating GENI project to conduct research on a clean slate design for a new generation of networks. [4]In 2006, NSF announced a new initiative FIND to study the need for a new generation of internet.[5]

The U.S. action opened up the road for other players into new internet structural design work which had been for some years limited to U.S. based IETF. In April 2007, ISO/IEC JTC1 SC6 passed a resolution initiating work on Future Network and then held the first Future Network meeting in Paris in October 2007. In 2008, 350 European scientists produced Bled Declaration, calling for stronger European governmental support to completely redesign the networks.[6] ITU also changed title of its SG13 from to "NGN" to "Future Networks including Mobile and NGN".[7]

All these events show clearly that by 2008, a clean slate design for future networks has become the dominant theme in network research across the world. A shift in network research strategy has taken place, from short-term, conservative, evolutionary, piecemeal modifications to bold, long-term, demand focused, revolutionary and fundamental structural changes.

3, Addressing Lingering Concerns over interoperability

Despite the fact that network research is going in the direction of a clean slate design, the concern over interoperability still remains. Interoperability has been one of

the major blocks delaying the acceptance of clean slate concept. People see the benefits of fast internet development. There were concerns that new disruptive technologies or architectural changes may lead to the destruction of existing networks and disintegration of the global network system. There were concerns that clean slate designed networks may not be compatible with old networks (backward compatible). There were also concerns that if backward compatibility is not worked out, the huge investment by telecom companies in old networks may loose its values. This is one of the reasons ITU-T which is basically composed of telecom companies has been in favor of evolutionary NGN approach.

Even though clean slate design has become the mainstream concept, the worry over interoperability does not diminish. Moreover, some statements about the clean slate design may have intensified such concerns. For example, a Stanford Whitepaper in 2006 has this statement:

"We don't believe that we can or should continue to rely on a network that is often broken, frequently disconnected, unpredictable in its behavior, rampant with (and unprotected from) malicious users, and probably not economically sustainable. … We believe the Internet's shortcomings will not be resolved by the conventional incremental and "backward-compatible" style of academic and industrial networking research. The proposed program will focus on unconventional, bold, and long-term research that tries to break the network's ossification."[8]

In above statement, it gives an impression that the old incremental approach is "backward compatible" while the new approach would not. Furthermore, a research report in the GENI project made even a more explicit statement on this issue.

"In considering future architectures, we ignore issues of backward compatibility with the current Internet but seek to benefit from the experience gained by analyzing both the strengths and weaknesses of the current design."[9]

Such a statement indicates that the issue of "backward compatibility" is not even considered in the future network development. It would surely intensify the concern on interoperability between the old network and new generation future networks.

This kind of concern would continue to hamper the efforts to amass support for the clean slate design future network research. In China, we have often face this question and policy makers have shown a strong position that if the issue of backward compatibility were not resolved, the new networks would have a hard-time to get interests and involvement of telecom operators.

Realizing the significance of this issue, the ISO/IEC Future Network project tries to reduce the concern. When discussing the draft of mission statement for the Future Network project, SC6 agreed to Frence national body expert Valerie Barnole's suggestion to add one sentence stating that "the Future Network research will not bring any harm to existing networks".

This "no intention to harm" gesture may help a little to reduce resistance to the new Future Network initiative. However, to totally resolve the issue, some more works are needed.

After thinking about this issue for some time, we believe that there are a few useful approaches to address the interoperability issue.

Firstly, we (as Future Network developers) should recognize that the interoperability is a real issue and a legitimate concern. The concern is real and blocks the path for Future Network development. It won't disappear automatically. We have to do something about it.

Secondly, we need to take the issue seriously and give careful consideration to it. Rather than say "ignore the backward compatibility", we should say that we will pay close attention to the issue and try every effort to revolve it.

Thirdly, in addition to stating no intention to harm the old networks, we have to explain how we could avoid it.

Fourthly, the conflict between clean slate design and backward compatibility is a complicated issue. We should study this thoroughly and avoid making simplistic statement of stressing the need for bold approach while dismissing the interoperability issue.

Fifthly, since incremental approach is no longer a valid approach, we have to insist on the new clean slate design.

Sixthly, we should avoid been put into a dilemma to make a choice for either backward compatibility or a clean slate design. Instead, we should do as much as we can to find a way to balance and harmonize the two parties.

Seventhly, we need to convince people that clean slate design does not necessary mean destruction of and incompatibility with the old networks. The two kinds of networks – old networks and a new clean slate designed future network – could coexist and interact with each other harmoniously.

Eighthly, we found that the concern over interoperability was partly because of some misconception about the term of clean slate design. If the real meaning of clean slate design is fully explained, the concern would decrease dramatically.

Lastly, other than theoretical analysis, we should also show people how the two networks can coexist peacefully and interoperate seamlessly.

From experiences in China's IPV9 research and deployment of workable systems, we are fully confident that the two types of networks can coexist and interoperate even though the new network utilizes the clean slate approach.

4. The destroy and Reconstruction cycle

When people hear about "clean slate design", they would immediately think about the "destroy and reconstruction" model we see in housing projects. This "destroy and reconstruction" scenario is often seen in construction sites. In order to build a high rise building, the old ghettoes need to be destroyed so that the ground work can begin.

People would assume that clean slate approach means to design and build a system from a scratch; but the old networks have already been built. If a network revolution took place, the existing networks would be shut down, scratched, destroyed to make room for the new networks to fulfill its clean slate ambitions.

However, this "destroy and construction" scenario is only one option. There is another clean slate approach which does not destroy anything. We call it the "parallel

highway" approach.

If we compare the old networks with an old country road which is too narrow and limited potential to fit modern high speed automobiles. Instead of destroying the old road and making endless and futile efforts to modernize it, an easier approach is to build a new highway along with it. The new highway would design the road according to the needs of modern transportation and could use bridges or tunnels to avoid sharp turns and to would allow higher speed.

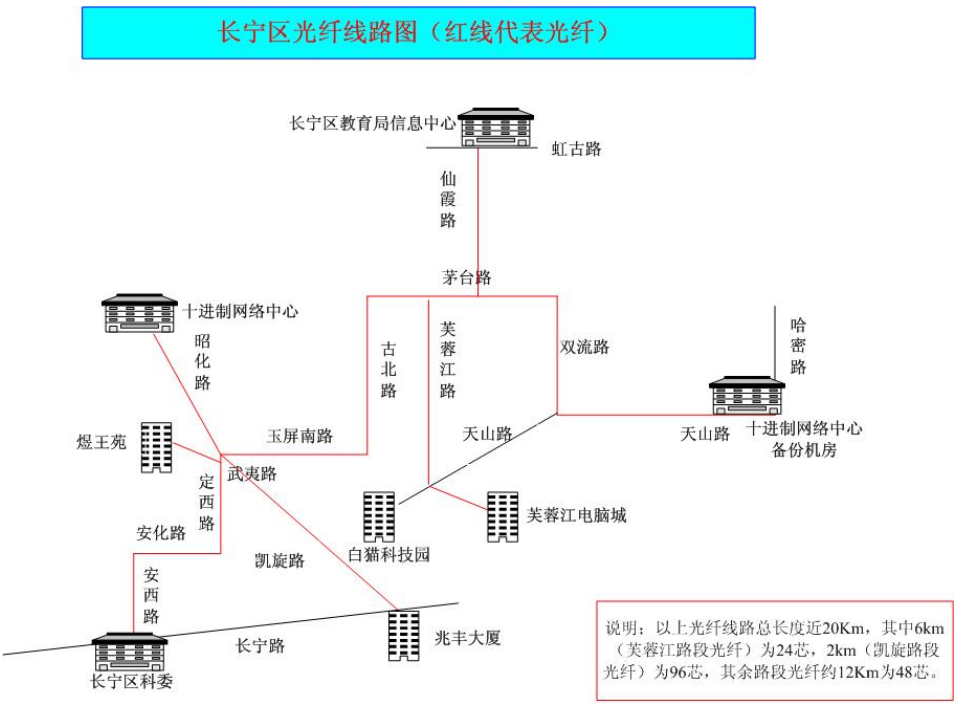
The highway is a clean slate design because it is built on open field. The highway does not harm or destroy the old road because they are parallel road systems. The highway would also cooperate with the old road because crossroad intersections can allow vehicles to switch from one system to the other. The highway would bring all the benefits of modern design allowing vehicles to run 70 miles per hour. The two parallel roads would also perform different functions. For example slower vehicles such as farm contractors would only run on country roads and not allowed to run on highways.

The Future Network could be a future network highway. Instead of destroying old networks, we could build a parallel network with a clean slate approach alongside with the old networks. The new network could start with a dedicated line between two computers. Then, more and more computers will be added to form networks. This network would increase in size and then form a complete network system. In this system, all clean slate design concepts are tested and experimented. Finally, a totally new network system is built alongside with the old systems.

Will the new network make the old network obsolete? Our answer is unlikely. If we look at the transportation examples, the old roads were still often used even though the new highways have been built. Sometimes, vehicles take the old road to avoid traffic jams in highways. The old road can also have some benefits such as finding an exit more easily，while in highways you have to drive miles to find an exit. Even though new networks would have huge advantages and benefits, it may never make the old networks totally obsolete because the two networks may compliment each other.

This parallel network approach is not a theoretic hypothesis. We have seen major Future Network research projects moving in this direction. For example, when China was developing the IPV9 technology, a specially designed fiber network over 30 Kilometers long was built in Shanghai Changning district (See Chart 1). Clean slate concepts such as IPV9 protocol and decimal domain name systems were studied on this experimental network. In the United States, National Science Foundation has established the GENI project which is going to be a test-bed for future network research. Such a test-bed may well lead to the core structure of new generation of U.S. network in parallel to the old networks.

Chart 1, IPV9 Fiber Testbed in Shanghai Changlin District



Therefore, in the future, when faced with questions about whether the new network would cause destruction of old networks, we should explain that the clean slate design does not scratch the old networks; that clean slate means totally new concepts and new structures; that the new network be constructed gradually; that the new network will be a parallel system to coexist with the old networks; that the two networks may compliment each other; that the new system will be self contained system but not necessary a closed system; the new network would provide all benefits to systems inside the network and would also allow inside-outside communications.

5. Realizing Backward Compatibility

Theoretically, the parallel scenario is plausible, but people would need to see hard evidence such as life example of working models to demonstrate the feasibility of coexistence and cross communication between the old and new systems to fully resolve the interoperability concern. In this regard, China's IPV9 project can make a significant contribution.

China's IPV9 system is a typical clean slate design project. It changes the address and DNS structures, abandoning domain name translation scheme and adopting a revolutionary pure decimal domain name structure. Along with these addressing and naming scheme changes, other systems such as protocols and routing will also undergo fundamental changes. For example, with the decimal domain name system, the complicated name-address translation process will become obsolete and network speed would be greatly enhanced.

China's IPV9 not only creates a clean slate third generation network system, but also has successfully achieved interoperation with the old networks. Therefore, China's IPV9 is the first third generation network that can coexist with old networks.

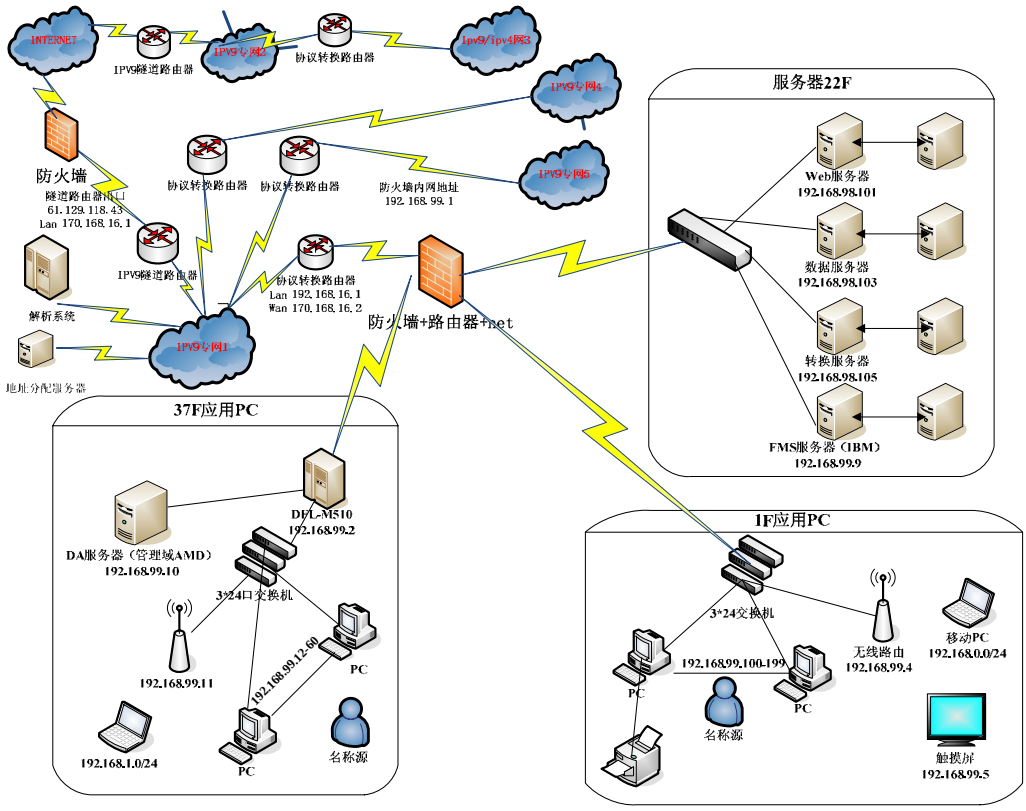
IPV9's routers contain two kinds of routing mechanism (stacks of switches) along

with a message type identifier. When a message is received, the machine reads the header and identifies whether it is intended for old network (IPV4 type message) or new network (IPV9 type message). Messages in IPV4 format will be routed through the IPV4 switch and delivered to old networks. Messages in IPV9 format will be routed through the IPV9 switch and delivered to old networks.

IPV9 has also resolved message exchange between the old network and the newly design networks. There won't be problem in sending message from IPV4 to IPV9 since the later is IPV4 compatible (containing mechanisms to process both IPV4 protocols and the new IPV9 protocols). Sending IPV9 messages to IPV4 networks is also possible because IPV9 has find ways to convert IPV9 message into IPV4 format so that it can be transmitted through the old networks.

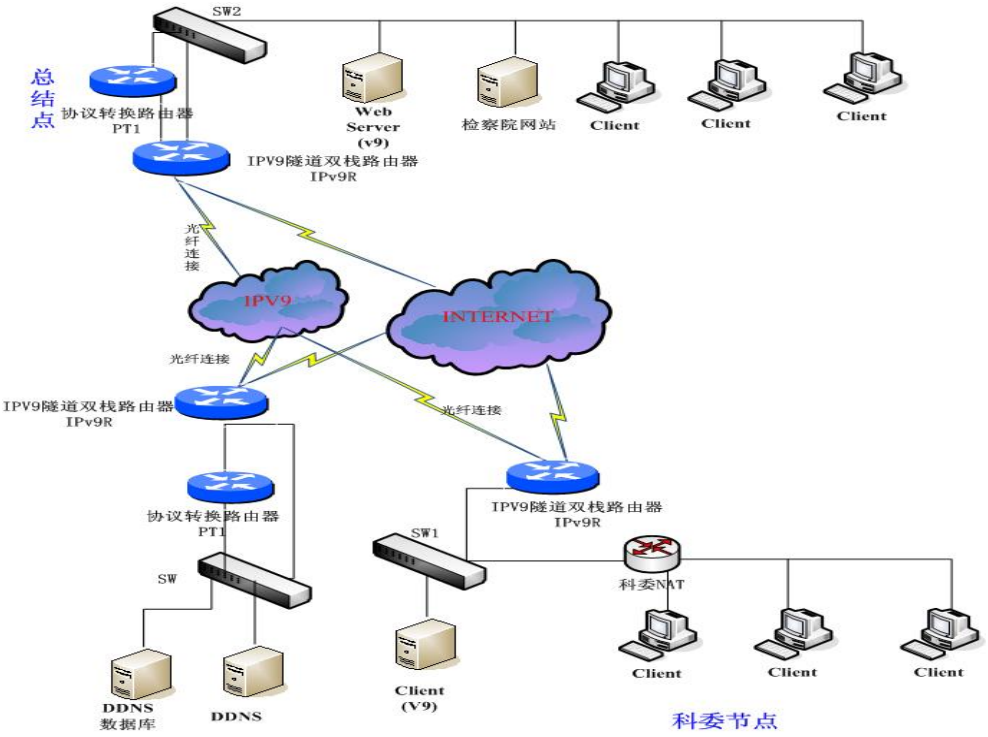
With these two methods (dual stack router design and message type conversion), IPV9 has successfully achieved seamless transmission of messages between old and new network systems. Life demonstrations and commercial applications are now available at a Shanghai based special IPV9 site (see Chart 2). [10] Coexistence of old networks and new clean slate designed third generation networks are no longer a myth, but a reality.

Chart 2: IPv4-IPV9 Dual Stack Router Deployment in Shanghai Wenxin Media



There was a concern that the IPV9 to IPV4 conversion or vise versa could create new kind of bottleneck between the two networks. We believe that this is not a big issue. At the exit to IPV4, there will be a little slow down, just like the cars slow down on the ramp of highway interconnections. However, messages in pure IPV9 network will enjoy all the speed that the clean slate design brings (See Chart 3).

Chart : Pure IPV9 Network



6. Outlook in Forward Interoperability

Interoperability has two dimensions, backward compatibility and forward compatibility. The formal has been discussed and addressed. The forward compatibility is a remaining concern.

Forward compatibility means the interoperation between the ongoing development projects or technologies that would mature and deployed in the future. In the past, network development and maintenance organizations such as ICANN and IETF can assure the compatibility among technical solutions. In the future network scenario, forward compatibility is uncertain and would be a difficult problem to resolve.

By 2008, there are many future network research projects across the world. China, U.S. Korea, Europe and International Standard organizations are involved in future network research. Even in Europe, several member states have started their own future network initiatives. This creates a chaotic situation.

In a few years, we may see a bunch of prototypes of future networks emerge. Since these networks are all clean slate designed and there are no common binding rules among them, these networks may not be compatible with each other. No one would know what is going to happen. Would the world be divided by several competing networks just like what have happened in 3G (WCDMA in Europe, CDWM2000 in U.S. and TD-SCDMA in China). Or, would one technology become a winner to dominate the world and kept the global networks as an integrated system? Where will that technology come from?

The problem is that no one knows which system is the best and the final winner

until networks have been built, run and tested for a long time. When final conclusions are reached, the various networks would have been fully established and hard to switch to other systems. It seems inevitable that global networks will be divided into several regional networks. How these networks achieve interoperability? This is a hard question to answer.

One possibility is to find a common place to harmonize regional network technologies into international standards. IETF is not a good place to harmonize third generation standards. IETF is committed to preserving old architectures. [11]Clean slate design is out of IETF's scope. Furthermore, IETF is a volunteer based organization. It is likely that third generation networks are government driven projects. It is unlikely that governments would send their new network technologies to individually based organizations to standardize. ISO/IEC would be an ideal place. It has started Future Network research. It has no investment burdens and has adopted clean slate design approach. It has cooperation with ITU-T. And, ISO-IEC is national body membership based international organization.

Therefore, there are uncertainties about forward compatibility and interoperability among new third generation networks. However, these problems would not prevent nations to put huge investment into third generation network research. The benefits of a new clean slate design network are enormous, and a leading position in this new field would greatly increase national prestige and competitiveness. Policy makers will go after the benefits and let the issue of interoperability to be decided later.

Conclusion:

The concern over interoperability is unwarranted. A clean slate design for third generation future network (including future internet) would bring huge benefits. Clean slate design does not mean incompatibility with old networks. The new networks will be a parallel network to coexist with the old networks. The two generations of networks can be complimentary to each other servicing different needs. These are lessons learned from China's IPV9 research which has established the first system to allow coexistence and communication between old systems and a newly clean slate designed IPV9 system.

Regarding the issue of forward compatibility (the interoperability of various emerging third generation regional networks), International Standard organizations such as ISO/IEC may provide an opportunity to harmonize third generation standards into a globally compatible system.

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