Prologue: Unified Polymorphic Routing Towards Flexible Architecture of Reconfigurable Infrastructure

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Abstract. Today's Internet architecture was designed and proposed in the 60s and 70s with the intention to interconnect several computing resources across a geographically distributed user group. With the advent of substantially various Internet businesses, traditional Internet is increasingly powerless to satisfy the unprecedented demands. This paper probed the polymorphic routing prototype based on proposed Flexible Architecture of Reconfigurable Infrastructure (FARI) which attempts to emerge as a clean-slate revolution of future Internet and resorts to centralized control manner. Routers in FARI were reconfigurable to adapt to different businesses in terms of identifier type. Moreover, a preliminary framework of FARI is proposed in the end of the article.

Keywords: Polymorphic routing · Prototype · Reconfigurable · Clean-slate

1 Introduction

The over 40-year-old Internet has become an incomparable important component of our daily life in contemporary society and is now facing many unprecedented challenges especially from the market demand. Though its enduring success continues today, the contradiction between single function of Internet and diverse internet business increases day by day. More and more study, work and entertainment rely on the networks which makes the idea of smart terminals and stupid networks unsuitable for the development of Internet. As a result, two opinions represented by clean-slate revolution and incremental evolution have been proposed by the research community to build the future Internet. The former opinion deems that novel network architecture should be built to satisfy the brand-new demands [1], while the latter considers improvement and integration as a better manner for the large scale of current Internet [2].

Actually, Internet experts have been exploring the improvement of Internet including IPv6, firewall, mobile IP, IPsec and so on. Therefore, great development has put on the stage and presented in front of us. However, patchwork is not a thoroughly solution to the defect of Internet, which may even complicate the networks and result in more difficult problems. For example, network address translation

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(NAT) is introduced to solve the exhaustion of IPv4 address and network security separation, which makes many end-to-end applications disabled and brings in another program called Cross-NAT. Hence, a consciousness to lots of Internet experts is that completely different network architecture must be proposed as quickly as possible.

Future Internet Design (FIND) [3], as a major new long-term initiative research, was announced by National Science Foundation (NSF) several years ago. It was executed by affiliated Computer and Information Science and Engineering (CISE) administrative committee. FIND solicits research across the broad area of network architecture, principles and mechanism design, and helps conceive the future by momentarily letting go of the present - freeing our collective minds from the constraints of the current state of networking. Besides FIND, Future Internet Research and Experimentation (FIRE) [4] from European Union and AKARI [5] from Japan are also clean-slate revolution as FIND.

In this paper, we are going to probe the polymorphic routing prototype in Flexible Architecture of Reconfigurable Infrastructure (FARI) proposed by us as a clean-slate revolution. The rest of the paper is organized as follow. Some useful definitions with proposed FARI are introduced in Section 2. The polymorphic addressing method of FARI is discussed in Section 3. The working mode is given in Section 4. Finally a conclusion together with future work is presented in Section 5.

2 Flexible Architecture of Reconfigurable Infrastructure

The design of novel architecture for future Internet should not only keep open, simple and robust features as traditional one, but also follow some new principles such as interaction, variety and selectiveness. It is interaction rather than a simple expansion of current Internet or extension of telecommunication network. As more and more businesses and demands appear in the Internet, variety and selectiveness are essential to choose the proper service type according to users' demands. In our proposed FARI, the concept of reconfiguration will cover all the features above. As it known to all, demands are multiple and changing, while network service is relatively finite and stable. Thus, the significant discrepancy between them became a bottleneck which has restricted the current network to be a better one. FARI which adopts centralized control can provide flexible, universal, customizable and variant network service.

We introduce definitions that will be useful throughout the paper.

Definition 1 (*Atomic Capability*, *AC*): It is the minimum function abstraction of basic transmission capability such as forwarding, fragment, safety etc.

The atomic capability is composed of two parts, the basic and expanded. It is notable that AC cannot be used alone and it only makes sense once combined together according to certain rule. This leads to the following definition.

Definition 2 (*Atomic Service*, *AS*): The atomic service consists of several kinds of atomic capabilities according to certain rule and is identified by upper businesses for understanding atomic capability.

In order to realize reconfiguration, polymorphic addressing methods, derived from the ground state addressing method, are essential to adapt to different businesses.

Definition 3 (*Basic Addressing Method*, *BAM*): It is an AC set of current addressing methods including location, content and the possible future addressing methods.

The BAM is an all-inclusive set which can meanwhile adjust the addressing method corresponding to specific business. It is more like a full described framework or abstraction before specializing to certain addressing method.

Definition 4 (*Polymorphic Addressing Method*, *PAM*): Polymorphic addressing method is derived from BAM and has different header formats which are used to business distinction during data transmission.

Actually, the mapping between BAM and PAM is a relationship of framework and example, while AC and AS stands for realization and demand.

The BAM in FARI supports four kinds of addressing methods for now which bases on location, identity, service and content as shown in Fig. 1. The specified PAM has a unified format including identifier type prefix and identifier value, and replaces the traditional IP addressing.

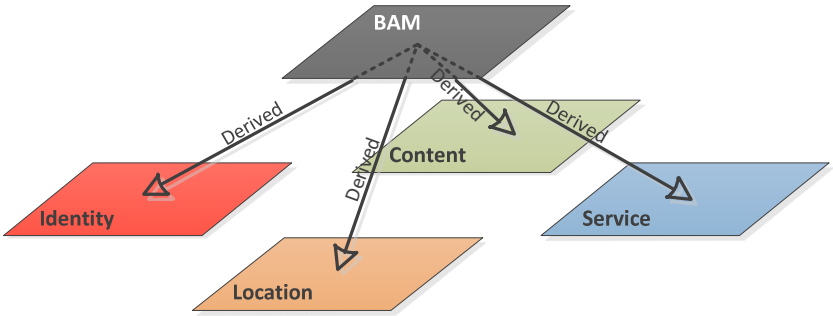

Fig. 1. Four kinds of addressing methods are supported by FARI for now

Definition 5 (*Polymorphic Routing*, *PR*): The path calculation and updated procedure according to PAM and specific demand is called polymorphic routing.

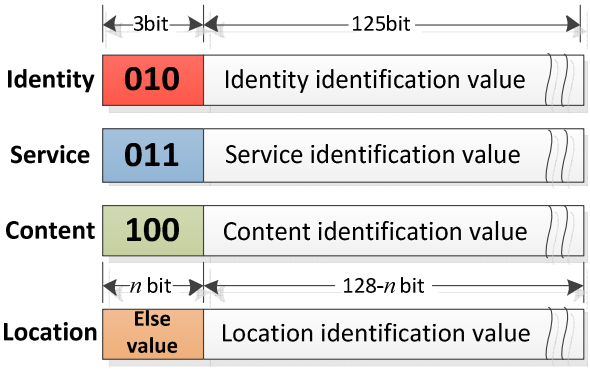

Fig. 2. The source and destination address for PR

In order to achieve PR, a unified Internet protocol we call it Polymorphic Internet Protocol (PIP) is needed to compatible with traditional IP networks. The PIP is based on IPv6 and uses a variant of IPv6 header. Depended on the identifier type prefix in the packet header, the type of addressing method can be ascertained right away. In the 128-bit source and destination address, 3 bits are allocated to the type prefix and the rest bits are used for identifier value such as structural characters for further information as shown in Fig. 2.

3 Polymorphic Routing Methods in FARI

In this section, we are going to discuss the four kinds of PRs mentioned above.

3.1 Location Based Routing

The location based routing corresponds to the traditional IP address. Compatibility is considered in FARI to realize smooth transition to the new architecture as mentioned in the last section.

3.2 Identity Based Routing

The current way to support the expansion of network brings about many problems. To maintain the gradation of IP address, the Internet Assigned Numbers Authority (IANA) [6] allocates prefixes to ISPs, each of which operates a network providing connectivity to customers and other ISPs. It is hard to reduce the size of inter-domain routing table by careful consideration in allocation. What's more, multi-home host and mobility are also difficult problems in current network.

Fortunately, problems mentioned above can be well solved by identity based routing [7]. In the solution, a unique identifier is allocated to each node which can be used to direct routing instead of requiring gradation or address information [8]. A more concrete instruction is described as follow:

(1) Each node has a unique identifier which should not include geographical information, and the uniqueness only has to be guaranteed by assigned numbers authority.

(2) Each node maintains the $r/2$ closest virtual neighbor nodes according to its own value of identifier. r stands for the number of virtual neighbor nodes and virtual neighbor means the node which has the closest number of identifier in the network.

(3) A routing table including the next hop of virtual neighbor is maintained in each node. Virtual neighbor nodes may not adjacent in geography, as a result the next hop of the virtual neighbor node is also maintained in the routing table. Moreover, each node may have the chance to be a middle node and maintain routing information for the other nodes.

3.3 Service Based Routing

Service means the solution of some demand proposed by individual or group. It needs some price to achieve and sometimes with certain restrictions. Moreover, service can be regarded as a logical cell which has the following properties:

(1) Functionality: service has a specify function.

(2) Combination: service can be combined with each other what means different services can be requested at the same time.

(3) Descriptiveness: the function of service can be defined clearly.

(4) Visibility: services are visible to the requesters.

Due to the limited function of single service, demands may be difficult to be satisfied with. As a result, service combination is an important technical approach in the future service oriented network. Service combination refers to combine the services which are independently developed to obtain stronger new service. Service combination is also an important thought in the service oriented architecture (SOA) [9]. Network can provide customized service by defining and constraining the interaction between different services. For example, if a packet header is constructed through service combination, any running node in the network can add control module to the header according to the demand of specific network function. Actually, similar idea as service combination is adopted in Just-In-Time protocol by communicating with Silos instead of TCP/IP [10].

3.4 Content Based Routing

As an important branch of PR, content based routing is also a major research topic in Content Centric Network (CCN) [11].

There are three kinds of information tables in CCN's router: forwarding information base (FIB), content store (CS) and pending interest table (PIT). FIB stores the next port of getting to the CS. CS preserves the buffer content and PIT records the Interest packet that hasn't been responded and the face it arrived on in order to send a Data packet back (a face in CCN is corresponding to a port in router).

The procedure of forwarding model in CCN is as following:

When a node receives an Interest packet, if there is already a Data packet in the CS that matches, it will be sent out the face the Interest arrived on and the Interest will be discarded. Otherwise, if the Interest is not in the PIT, it will be added in and then forwarded according to the FIB.

Content based routing mainly cares about two problems:

(1) How to represent infinite name space with finite state routing.

(2) Multi-path forwarding strategy.

As the widely used routing protocol in the Internet, Open Shortest Path First (OSPF) [12] has high-quality open-source implementations. However, OSPF only finds out one shortest path in the network which may not suitable for content centric network. As a result, multi-path forwarding is needed to choose the suboptimal path when necessary.

4 Working Mode for Polymorphic Routing

Due to centralized control of FARI, A three-plane model including manage plane, control plane and data plane, which interacts with each other for common goal, is used to describe the functional structure of polymorphic routing.

The manage plane is realized by intra-domain server and is responsible for perceiving and maintaining the network. It allocates the PR identifier and differentiates the type of communication subject. Moreover, as the management center of the structure, it is also in charge of the realization of PR and provides basis to the control level for business cognition.

The control plane sustains responsibility of establishing PR path, collecting and monitoring routing resources which is realized in the routers. On one hand, it provides guidance of transmission path for data through current routing table entry updated in terms of network state information. On the other hand, it judges from the communication subject result provided by the manage plane and identifier type by executing PIP to achieve PR scheme. Actually, the control plane exists as an executer in the structure.

Data plane, the lowest plane in the structure, plays a simple but important part in the routing realization. It is mainly responsible for data forwarding. When data is transmitted in the network, the data plane will respond respectively base on different identifier.

There are four kinds of routing tables corresponding to four PRs maintained by each router. After a host joined in a network, it immediately informed its node property and identifier type to the intra-domain server on manage plane, and then a unique identifier was allocated to it by some manager instantiated by the server.

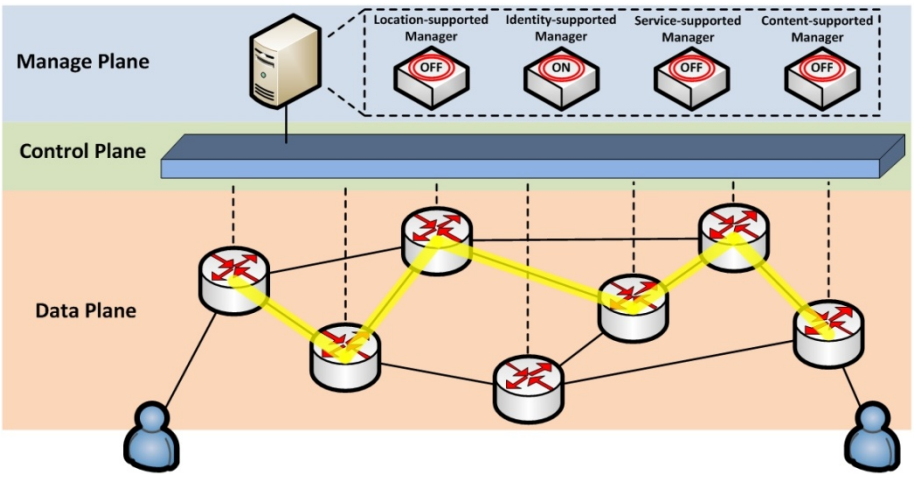

Fig. 3. An example of identity routing in FARI

Here is an example shown in Fig. 3 of identity routing in FARI. Assuming a host (on the left side) wants to communicate with another host (on the right side), it first connects to the nearest router and sends a packet with identity identifier to it. Due to unconsciousness of the next hop, the router will hand the packet to identity-supported manager (which is labeled ON in Fig. 3). Then the identity-supported manager will help calculate the shortest path to the destination according to specific business (identity based in this example) by providing the basis of updating the routing table to the control plane. Once routing table is finished updating communication can be carried on along the path (as shown by yellow in Fig. 3).

Actually, different managers can be instantiated to support diverse business simultaneously with FARI. The working mode mentioned above only happens in one domain. It is more complicated when communication takes place between different domains and it will be the future work.

5 Conclusion and Future Work

In this paper, we probed the polymorphic routing based on proposed FARI which attempts to emerge as a clean-slate revolution of future Internet and resort to centralized control manner. Once instantiating different managers, it is convenient for network to choose a proper routing manner in terms of specific demand. Depending on the identifier type prefix in the packet header, routers can ascertain the next hop by looking up corresponding routing table. The routing tables in each router are updated based on the current network state information provided by the control plane.

However, it is a preliminary framework of FARI and communication only in the same domain is considered in the paper. There is still a huge development space for FARI. In the future, we will continue to research the polymorphic routing method and take inter-domain communication into consideration. Moreover, emulation system of FARI will be built up to test the novel architecture.

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References

1. Feldmann, A.: Internet Clean-Slate Design: What and Why? ACM SIGCOMM Comp. Comm. Review **37**(3), 59–64 (2007)
2. Rexford, J., Dovrolis, C.: Future Internet Architecture: Clean-Slate versus Evolutionary Research. Comm. of the ACM **53**(9), 36–40 (2010)
3. NSF NeTS FIND Initiative. http://www.nets-find.net
4. European Future Internet Portal. http://www.future-internet.eu/activities/fp7-projects

5. AKARI Architecture Design Project for New Generation Network. http://akari-project.nict.go.jp
6. Internet Assigned Numbers Authority (IANA) Home Page. http://www.iana.org
7. Caesar, M.C.: Identity Based Routing. Ph.D Thesis, University of California, Berkeley (September 2007)
8. Caesar, M.C., Condie, T., Kannan, J.: ROFL: Routing on Flat Labels. In: ACM SIGCOMM (September 2006)
9. Papazoglou, M.P., Georgakopoulos, D.: Introduction to a special issue on Service-Oriented Computing. Communications of the ACM **46**, 24–28 (2003)
10. Wei, J.Y., McFarland, R.I.: 'Just-in-time signaling for WDM optical burst switching networks. Journal of Lightwave Technology **18**, 2019–2037 (2000)
11. Content Centric Networking. http://www.parc.com/work/focus-area/content-centric-networking
12. Moy, J.: OSPF version 2. RFC 2328 (April 1998)