Towards an Evolvable Internet Architecture

Thomas Lohmüller
lthomas@student.ethz.ch

December 19, 2007

Towards an Evolvable Internet Architecture

Topics:

- How to evolve from IPv(N-1) to IPvN
- How to use overlay networks in legacy applications

Goals:

- Show some nice ideas for evolvability
- Describe needed technologies
- Show *creative* way how to use legacy applications with new network technologies

Outline

Outline

- Introduction
- Requirements for Evolvability
- Mechanisms for Evolvability

Introduction

Today everyone wants to change the Internet.

- Why is it so hard to change?
- Why did the different approaches not work?
- How can we make the Internet changeable?

Once upon a Time...

In the early days of commercial Internet (mid 1990's)

- Great faith in Internet evolution.
- Many believed ISPs would soon deploy new versions of IP

But it came different...

Today

- Success of the Internet surpassed our wildest imagination
- Deep pessimism about evolutionary architectural change
- ISPs have little incentive to deploy new architectures
- Most operating systems do not support new protocols
- Costs of universally deploying a new architecture are immense

Requirements

What is required to make the Internet evolvable?

- Foster independent innovation
- Enable customer choice
- Allow ISPs some degree of control

Basic Assumptions 1/2

_A1_: Assume partial ISP deployment.

- Not all ISP's will deploy a new version of IP at the same time.
- Must work with only a subset of an ISP's routers implementing it.

_A2_: Assume partial ISP participation.

Not all ISP's are willing to participate.

Basic Assumptions 2/2

_A3_: Assume the existing market structure and agreements.

Clients should not need a contract with an additional provider.

_A4_: Assume revenue flow.

Assume that IPvN attracts users.

Require Universal Access

All clients can use IPvN if they choose regardless of whether their ISP deploys IPvN or not.

Open Problems

Problems on our way to IPvN:

Client-Side

1. Locate IPvN router
2. Move packets to IPvN router
3. Get IPvN address

Network

1. Topology construction
2. Addressing
3. Routing

Option I: Application-Level Redirection

Why this is not a good choice.

- Application queries a lookup-service for IPvN router
- Application has to tunnel packets to IPvN router

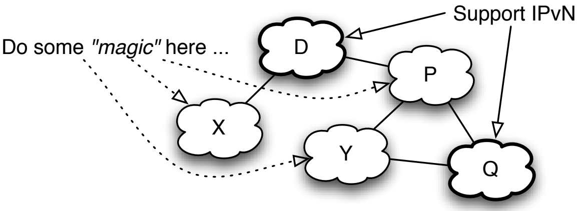
Problems:

- Who runs this lookup service?
    - Current ISPs
    - Third-party broker
- How to reach lookup-service?
- Who pays for this service?

Option II: Network-Level Redirection

The better solution.

- Every router in network (whether IPvN or not) *knows* how to forward an IPvN packet to an IPvN router
- Works with current market structure
- How can a client in a non-offering ISP be guaranteed access?



IP Anycast

- Host transmits to an anycast address
- Network is responsible for delivery to one of possibly multiple servers
- Described in *RFC 1546*
- Today in use for root DNS name servers

- Enables seamless spread of deployment
- Does not require any change in current routing infrastructure

IP Anycast

Today, this system does work.

```
< lthomas@optimus-ws5:101 > traceroute 192.88.99.1
traceroute to 192.88.99.1, 30 hops max, 40 byte packets
 1 rou-rz-1-service-inf-isg-rz.ethz.ch (129.132.216.33)
 2 rou-ref-hg-service-inf.ethz.ch (10.1.18.38)
 3 rou-fw-cla-service-inf-isg.ethz.ch (10.1.18.34)
 4 rou-fw-rz-fw-cla.ethz.ch (192.33.92.185)
 5 rou-rz-gw-fwrz-gwrz-core.ethz.ch (192.33.92.170)
 6 swiez2.ethz.ch (192.33.92.11)
 7 swiLS2-10GE-1-1.switch.ch (130.59.36.205)
 8 swiEL2-10GE-1-2.switch.ch (130.59.36.70)
 9 swiCE3-10GE-1-3.switch.ch (130.59.37.65)
10 swi6netCE1-G0-0.switch.ch (130.59.35.137)
```

Anycast Routing I
Intra-Domain-Routing

- IPvN router advertises link to anycast address
- Link-state routing (OSPF)
  - High-cost link to prevent routing through anycast address
  - IPvN router can easily identify other IPvN routers
- Distance-vector routing (RIP)
  - Zero-cost link
  - Distance-vector routing routes packets to closest IPvN router
  - Requires additional discovery-mechanism for IPvN routers to see each other

Anycast Routing II

Inter-Domain-Routing

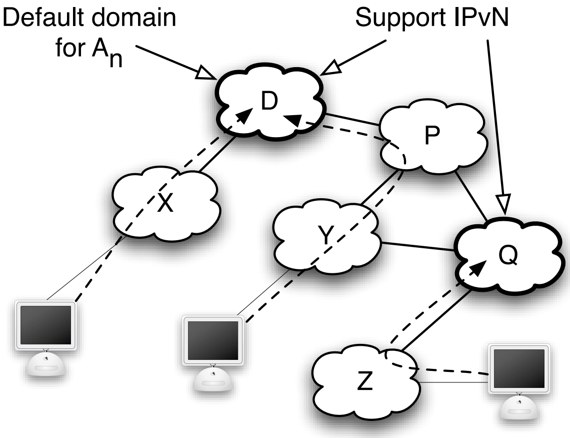
Option 1: Use anycast address

- Non-aggregatable addrs.
- Global routes
- Propagate route in BGP
- Requires change in policy
- One additional route per anycast address

Option 2: Use unicast address

- Aggregatable addresses
- Default routes
- BGP already knows IP
- No change in policy
- Use an IP of first IPvN provider
- Additional traffic for first provider

IP Anycast Example



Open Problems

Problems on our way to IPvN:

Client-Side

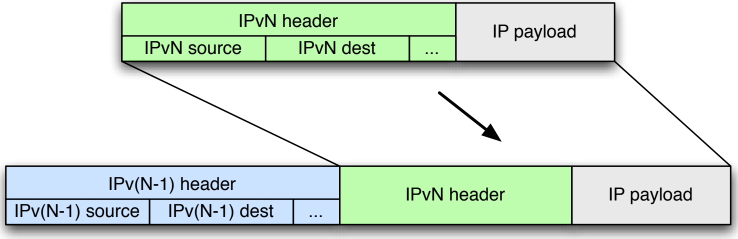
1. Locate IPvN router
2. Move packets to IPvN router
3. Get IPvN address

Network

1. Topology construction
2. Addressing
3. Routing

IP in IP-Tunnel

- Very easy...
- Described in RFC 1853 from 1995
- Supported by most routers even today



Open Problems

Problems on our way to IPvN:

Client-Side

1. Locate IPvN router
2. Move packets to IPvN router
3. Get IPvN address

Network

1. Topology construction
2. Addressing
3. Routing

Outline

Open Problems

Problems on our way to IPvN:

Client-Side

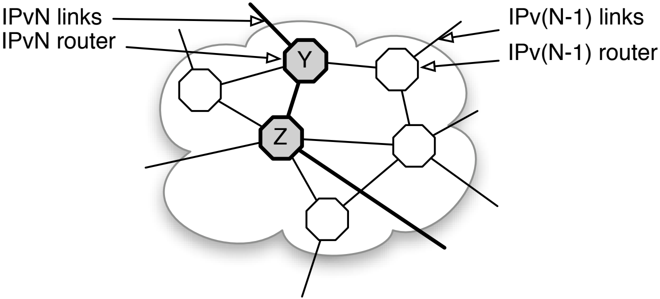
1. Locate IPvN router
2. Move packets to IPvN router
3. Get IPvN address

Network

1. Topology construction
2. Addressing
3. Routing

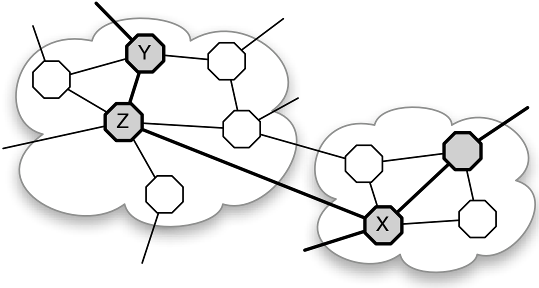
Intra-Domain Topology Construction

- IPv(N-1) routing protocols
- Every router has complete knowledge
- Easy to locate IPvN routers



Inter-Domain Topology Construction

- Inter-domain tunnels based on peering policies
- Use Anycast to bootstrap
- Prevention of partitions important
    - Check for connection to *default* provider



Open Problems

Problems on our way to IPvN:

Client-Side

1. Locate IPvN router
2. Move packets to IPvN router
3. Get IPvN address

Network

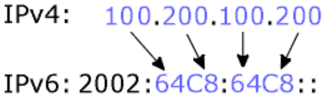
1. Topology construction
2. Addressing
3. Routing

Addressing

- Addressing
  - Format or structure of address
  - Address allocation
  - Advertising into routing fabric
- Today's Internet (IPv4 and IPv6)
  - Address allocation and advertising by local access provider
- How to get IPvN-address if access-provider does not support IPvN?

Addressing

- Possible solutions:
  - Request address from IPvN router (like DHCP)
  - Self-addressing by hosts
- Self-addressing in IPv6
  - Well-known suffix 2002: and embedded IPv4 address



- How to advertise and route such addresses?

Open Problems

Problems on our way to IPvN:

Client-Side

1. Locate IPvN router
2. Move packets to IPvN router
3. Get IPvN address

Network

1. Topology construction
2. Addressing
3. Routing

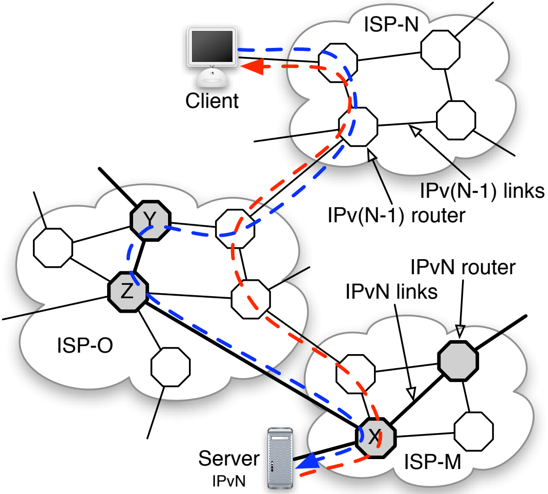
Routing

- Between routers
  - Native IPvN routing. No problem here...
- Between endhosts
  - Ingress router easily to reach (IP Anycast)
  - Egress also easy if destination is in IPvN enabled domain
  - What if destination is not in IPvN enabled domain?

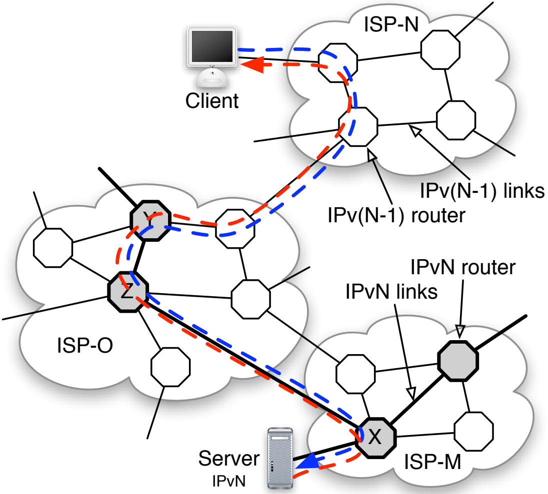
Routing to non-IPvN Domains

- Let router advertise temporary IPvN address
  - Let client register itself at ingress router
  - Simple but departure from existing norms
  - Many non-aggregatable routes
- Use IPv(N-1) routing
  - IPv(N-1) address contained in temporary IPvN address
  - Leave IPvN network and use IPv(N-1) routing
  - Simple, but fails to fully exploit IPvN deployment
- Let IPvN routers advertise *on-behalf-of* IPv(N-1) domains
  - IPvN router advertises some IPv(N-1) prefixes
  - Packet leaves vN-Bone *near* destination.

Routing Examples: IPv(N-1) Routing



Routing Examples: *on-behalf-of* Routing



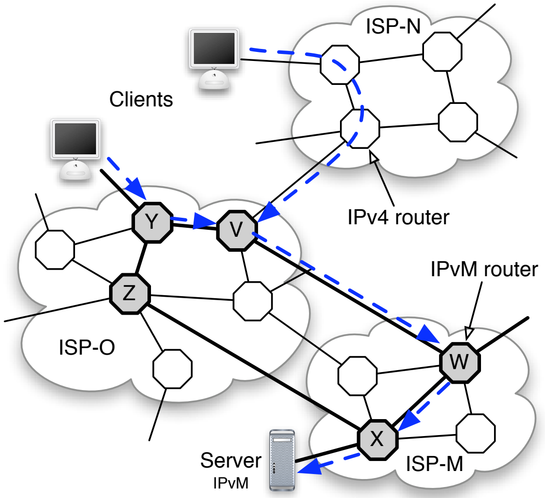
Source-Specific Multicast

- Deploy *Source Specific Multicast* (SSM)
- Provides one-to-many packet delivery
- Multicast group defined by (S,G)
  - S: Unicast address of source
  - G: Multicast group address
- Simple interface for clients
  - `subscribe(S,G)`
  - `unsubscribe(S,G)`

How it Works

1. Use IP Anycast to locate IPvM router
2. Send `subscribe(S,G)` to ingress router
    - Encapsulated in IPv4 packet if needed
3. Router adds entry to multicast forwarding table
4. Router sends `subscribe(S,G)` to next router if required

SSM Example

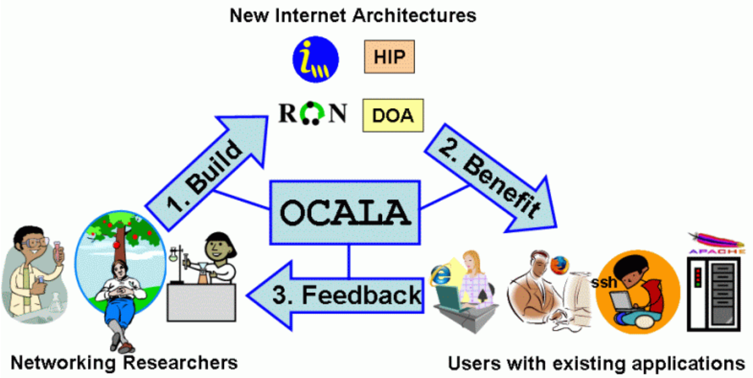

ISP-N
Clients
IPv4 router
Y
V
IPvM router
Z
ISP-O
W
X
Server
IPvM
ISP-M

Outline

Introduction

- Overlays provide new features without changing the Internet
  - Resilient Overlay Network (RON)
  - Internet Indirection Infrastructure (i3)
  - ...
- No widespread deployment
  - Users unwilling to shift to new application programs
  - No interoperability between different overlays

OCALA



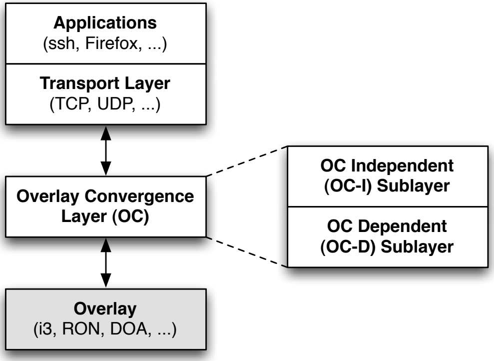
Source: `http://ocala.cs.berkeley.edu/`

Goals of OCALA

- Enable legacy applications to work over overlays
  - All applications which use IP
  - No changes at application needed
  - Users choose the best overlay for a particular application
- Enable hosts in different networks to talk to each other
  - Interoperability between hosts in different overlays
  - Interoperability between overlay hosts and *pure* IP hosts
- Factoring out common functionality
  - Concentrate on architecture; not on supporting legacy applications
  - Factor out common functionality

Architecture

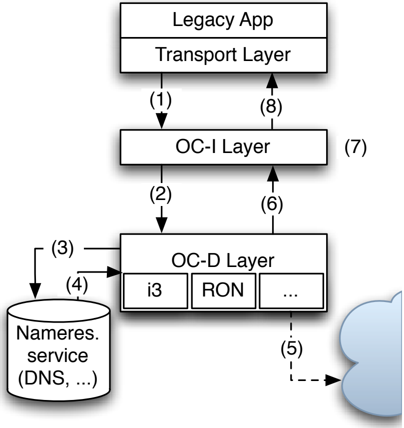
- Add new layer below Transport Layer



Expressing which Overlay to Use

- DNS-like names to identify machines (or services)
  - Supported by most legacy applications (but not all!)
  - Needs at least a configuration change in application
- Append a new part after top-level-domain
  `overlayspecific.overlayname`
  - `ucb.i3`: connect to host ucb over i3
  - `ucb` interpreted by overlay-specific OC-D
  - `i3` overlay to use

Connection Setup in OCALA



1. $DNSreq(foo.ov)$
2. $setup(foo.ov)$
3. $resolve(foo.ov)$
4. ID_B
5. *overlay specific setup*
6. $tunnel = td_{AB}$
7. $OCIsetup(pd_{AB})$
8. $DNSresp(handle = IP_{AB})$

Implementation

- As user-level proxy
- Uses *tun* device to capture packets
- Implemented for Mac OS X, Linux and Windows XP
- about 40k SLOC of C++
- OC-D modules
    - Dynamic loadable libraries
    - Simple 5 function call interface
    - i3 and RON-modules written internally
    - Many more modules written by others
- GUI for configuring OCALA

Outline

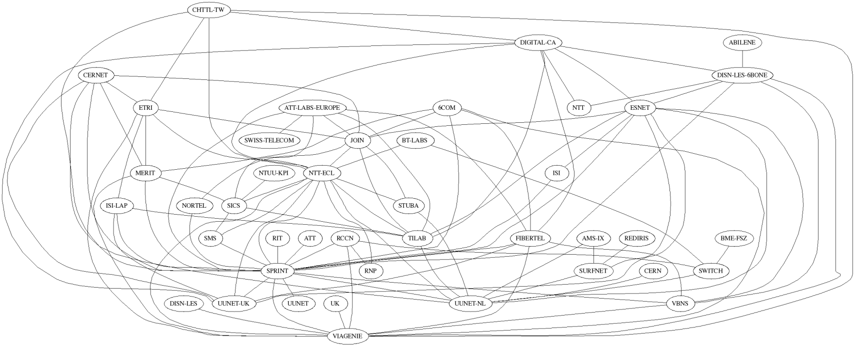
Requirements to Evolve to IPvN

- IPvN Hosts
  - Must be able to create temporary addresses
    - Has to contain IPv(N-1) address
- IPvN routers
  - Should be able to advertise IPv(N-1) routing information
  - Have to participate in IPv(N-1) unicast and anycast
  - Perform IPv(N-1) forwarding
  - Participate in vN-Bone construction
  - Perform IPvN forwarding *(of course...)*

Current State of IPv6

- Routing to ingress router by IP Anycast
  - Operational at `192.88.99.1`, RFC 3068
  - Transparently used by some home-routers
- Temporary IPv6 address containing IPv4 address
  - Standardized in RFC 3056
  - Implemented in current operating systems
- v6-Bone
  - Operational. See `http://go6.net/ipv6-6bone/`

v6-Bone



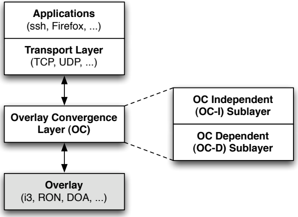
The 6Bone pTLAs and their tunnels. adamo@dblab.ece.ntua.gr. Fri Jun 9 07:30:26 EEST 2006

Evolvable Internet: My Opinion

- Good introduction to IPv6 deployment
- Summary of many other papers (60 papers referenced!)
- All ideas pretty obvious. No surprises...

OCALA: Summary

- User-level proxy: Simple to deploy
- Ready-to-use
  - Simplify implementation of new overlay-module
  - Real users, real applications
- Does not work with packet rewriting



OCALA: My Opinion

- *Just add another layer*
- Helps to simplify implementation of new overlays
- Is's a hack
  - Misuse of DNS hostname
  - Bad implementation (uses *tun* device)
  - *Library preloading* with external configuration would be a much cleaner solution
- Only useable in testing environments

Discussion

Topics:

- Evolution to IPvN
  - IP Anycast
  - Addressing
  - Routing in vN-Bone
  - IPvM (example)
- Evolution to IPv6
- OCALA

Further Reading

- Towards an evolvable internet architecture
  S. Ratnasamy, S. Shenker S. McCanne
  In Proceedings of the 2005 Conference on Applications, Technologies, Architectures, and Protocols For Computer Communications (Philadelphia, USA, August 22 - 26, 2005). SIGCOMM '05. ACM Press, New York, NY, 313-324.

- OCALA: An Architecture for Supporting Legacy Applications over Overlays.
  Dilip Joseph, Jayanthkumar Kannan, Ayumu Kubota, Karthik Lakshminarayanan, Ion Stoica, Klaus Wehrle
  3rd USENIX/ACM Symposium on Networked Systems Design and Implementation (NSDI '06) San Jose, CA, May 2006