Revisiting Routing Control Platforms with the Eyes and Muscles of Software-Defined Networking

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Agenda

• Research in scope and contribution
• RouteFlow Control Platform
  - Multi-controller architecture
  - Proof of concept implementation: Single node abstract eBGP router
• Use Cases
• Challenges
• Conclusions and Future Work
Research in scope and contribution

  - In operation at AT&T, considered a differentiator for "dynamic connectivity management".

- Research Question:
  - Re-examine the concept of RCP with the visibility (i.e., network-wide, multi-layer, flow and topology maps, full RIBs) and direct control capabilities (i.e., actual FIB installation, rich matching and instruction set) of the SDN abstraction set and the specifics of the OpenFlow choice.

- RouteFlow glues virtualized IP routing stacks with OpenFlow.

- RouteFlow acts as a new indirection layer for
  - routing protocol messages (e.g. BGP session terminates in servers)
  - RIB-(to-FIB)-to-OpenFlow transformations
Software Defined IP Routing

High cost
Specialized config.
Closed source
Slow innovation

Controller
Open interface
OpenFlow Switches

Low cost (commodity)
Multi-vendor modularity
Open source
Rapid innovation

Source: McKeown
RouteFlow

OSPF / RIP / BGP
Topologia Virtual

Servidor RouteFlow

Controlador

Rede Legada

Switch Programável

Infraestrutura Física

Switch Programável

Switch Programável

BGP

Roteador Legado
Controller-Centric Hybrid Networking

- A migration path to roll out OpenFlow technology
- Not a revolution, but an evolution of current iBGP RRs to essentially eBGP Route Controllers
  - "BGP-free edge": A cost-effective simplified edge for SW-driven innovations
Design

Key Features

- Modular architecture
  - RF-Proxy
  - RF-Server
  - RF-Client

- Database layer
  - JSON-based IPC
  - Resilient core state
  - Programmer-friendly

- Multi-Controller support
  - NOX, POX, (Ryu)
  - Floodlight, Trema (planned)
Modes of operation

- From logical routers (akin VRFs) to single node abstractions over flexible virtual networks.
- New design choices on the distribution of the control nodes.

<table>
<thead>
<tr>
<th>Logical Split Router (1:1)</th>
<th>Router Multiplexation (1:n)</th>
<th>Router Aggregation (m:1 or m:n)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Virtual Network Provider (Network Slices)</td>
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<tr>
<td>Infrastructure Provider (Physical Substrate)</td>
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</table>
Aggregated BGP routing service

- Single node abstraction of a domain-wide eBGP router
  - Think modern multi-chasis routing architectures with external route processors and OpenFlow switches acting as line cards
- Aggregation logic defined in the RF-Server
- NOX, MongoDB, LXC
Routing-centric use cases under research

- Engineered path selection
  - Think Google WAN, performance-based routing, etc.
- Optimal best path reflection
  - Per ingress/customer [draft-ietf-idr-bgp-optimal-route-reflection-01]
- Path protection with prefix independent convergence
  - Hierarchical FIBs w/ OF 1.X Tables + LFA route-precomputation
- Security
  - Data plane blackholes and middlebox injections,
  - Secure Inter-domain routing ideas (crypto intense S*-BGP, etc..)
- Simplifying customer multi-homing
  - Easy to set and control cost/performance/policy-based routing
- IPv6 migration
  - Flow matching for service termination in v4-v6 migration solutions
Challenges

- **Centralized BGP**
  - Shown to scale well in modern CPU architectures
  - Centralized does not mean not distributed (but removal from edge)

- **Small OpenFlow table sizes**
  - Transient limitation?
  - Expose existing FIB data structures as an IP lookup OF table?
  - Smart RIB&FIB reduction (e.g., simple [draft-ietf-grow-simple-va-04])
  - HW/SW flow offloading

- **Limited OpenFlow processing in datapath**
  - Transient / Un-optimized implementations

- **High availability**
  - Previous ideas from distributed RCPs
  - Database-centric designs
  - Development in-progress of “BGP SHIM” for transparent eBGP redundancy
Conclusions

• RouteFlow is
  - a simple yet powerful (adaptable, inexpensive) router design
  - a platform for real IP routing protocol experimentation
  - a tool for OpenFlow adoption via controller-centric hybrid networking

• Many open research questions and future work
  - OF 1.X, MPLS, OAM, GUI, configuration mgm, etc.

• Opportunity for a community-driven development of competitive, deployable, open routing control solutions
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Thank you!

Questions?
Live DEMO

• Access:
  - http://go.cpqd.com.br/7API-demo

• Indiana University GUI demo:
  - http://goo.gl/T3Tqe
4 Virtual routers
10 Gig and 1 Gig connections
2 BGP connections to external networks
Remote Controller
New User Interface
Compare interfaces over the last 30 years

“PC” user interfaces

Network user interfaces

Demystifying Configuration Challenges and Tradoffs in Network Based ISP Services (Benson, Akella, Shaikh SIGCOMM 2011)

Source: Chris Small (Indiana)
RouteFlow User Interface

- How to make network administration:
  - Simpler to implement
  - More robust and consistent
  - Easier to manage

- Automation and Abstraction
- Can you build very different interfaces with SDN backends?
  E.g., type: http://netkarma.testlab.grnec.iu.edu/rf/ or... http://goo.gl/T3Tqe

Source: Chris Small (Indiana)
RouteFlow Platform research topics

- High availability
- Integration of OF v1.1, v1.2 and v1.3
- LDP / MPLS support towards open-source LSR
- Realizing the northbound SDN abstractions
  - Specification / Configuration
  - Network Information Base
  - Knowledge Information Base
- Troubleshooting, testing, debugging, ...
- ...

\[ L2 \quad LV \quad AC \]
Advancing the RouteFlow GUI...
Promises
Collaborations and community developments

- Web-based UI & Internet 2 HW pilot [C. Small, Indiana] ✔
- Aggregated BGP Routing Service [C. Corrêa, Unirio] ✔
- SNMP plugin [J. Stringer, Google] ✔
- Optimal BGP best path reflection [R. Raszuk, NTT-MCL] 🙄
- OpenFlow v1.1 and v1.2 [w/ Ericsson] 🙄
- Open Label Switched Router [OSRF; Google] 🙄
- Multi-path, Fast-ReRoute, BGP-Sec, IPv6, ... [YOU?] ?
... building a community

Visits: 12,000+ (5,000+ Unique)
From over 1,100 cities of 90+ countries all over the globe!

http://go.cpqd.com.br/routeflow/

368 days since Project Launch
Conclusions

• RouteFlow is
  - a simple yet powerful (adaptable, inexpensive) router design
  - a platform for real routing protocol experimentation
  - a tool for OpenFlow adoption via controller-centric hybrid networking

• Many open research questions
• Experimental research facilities are critical for validation
• Opportunity for a community-driven development of competitive, deployable, open routing control solutions
Benefícios e impactos

- **Inovação tecnológica** em soluções de redes e serviços para os proprietários de infra-estrutura, os provedores de serviços e a comunidade de pesquisa.
- **Oportunidade para que empresas nacionais** possam competir e inovar na área de aplicações para gerenciamento e controle de redes de pacotes.
- **Novos modelos de negócio** que promovem redução de CAPEX e OPEX por meio de novos serviços (ex. alocação dinâmica de fatias/recursos da rede), reaproveitamento de ativos e automatização dos processos operacionais.
- **Diminuição do tempo ao mercado** na implementação de funcionalidades e soluções de redes integradas e customizadas à demanda do cliente.
- **Simplificação e barateamento** dos equipamentos pela diminuição dos requisitos mínimos de SW embarcado e pilhas de protocolos proprietárias.
- **Consolidação dos planos de controle e gerência** de infra-estruturas de rede, facilitando a convergência ampla e a migração para novos padrões e tecnologias de rede de transporte.
## SDN Converged Network Services

<table>
<thead>
<tr>
<th></th>
<th>Rigid Legacy Transport Network</th>
<th>Open Flow-Enabled Software Defined Network</th>
<th>Application or Destination-Driven Traffic Optimization</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Control Session Plane</strong></td>
<td>![CS]</td>
<td>![CS]</td>
<td>![CS]</td>
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<tr>
<td><strong>Name Resolution</strong></td>
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<tr>
<td><strong>Virtualized Data Plane</strong></td>
<td>![OF] ![OF]</td>
<td>![OF] ![OF]</td>
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<tr>
<td><strong>Transport Plane</strong></td>
<td>![App] ![App]</td>
<td>![App] ![App]</td>
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</table>
Rede Convergente Definida por Software (RCDS)

Source: NEC, adapted
“Modern” OF/SDN architecture

Business Requirements and Use Cases:
Search, Social Networks, Cloud Computing, Web, Finance, etc.

Applications built using Application Frameworks:
Hadoop, OpenMPI, Memcached, Dryad, Globus, etc.

Control Logic

SDN Components
- Abstract Network Service Model
- Global Network View (Graph)
- Forwarding and Device State Model

Application Programs

Device Capabilities

DIR/HAL

Physical Hardware

Global Management Abstraction
(Network Hypervisor)

Network View Abstraction
(Network Operating System)

Forwarding Interface Abstraction (DIR)
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- Troubleshooting, testing, debugging, ...
- ...

L2  L3  AC  L
Control Plane Distribution Options

- Vertically integrated (classic Router/Switch Model)
- Decoupled (original OpenFlow model)
- Hybrid (evolving model in ONF)

**Logically Centralized ("servers")**

**Fully distributed ("on box")**

Data Path jointly controlled by standard on-box control plane and centralized off-box controller

Legend:
- Data plane
- Control plane function

Slide courtesy Frank Brockners
Inform network of desired behavior

Inform application of data intrinsically in the network

Management Plane

Control Plane

Data Plane

Network Element

OF/OF++, Hybrid Switch

Agent

Config
Routing Extensions
Tunnels
Topology
Cross Connect
Routes
Classifiers
QoS
Analytics