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Software Defined Networking (SDN) for ISP Networks

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Agenda

- Introduction
- ISP Networks
- Software Defined Networking
- Introduction to RouteFlow
- Behavior of RouteFlow
- Conclusion

Introduction

- Evaluation of SDN for ISPs
- Focus is on datacenter networks
- Fewer efforts for ISP networks
- RouteFlow used as a SDN solution
- Test cases for characterization

ISP Networks

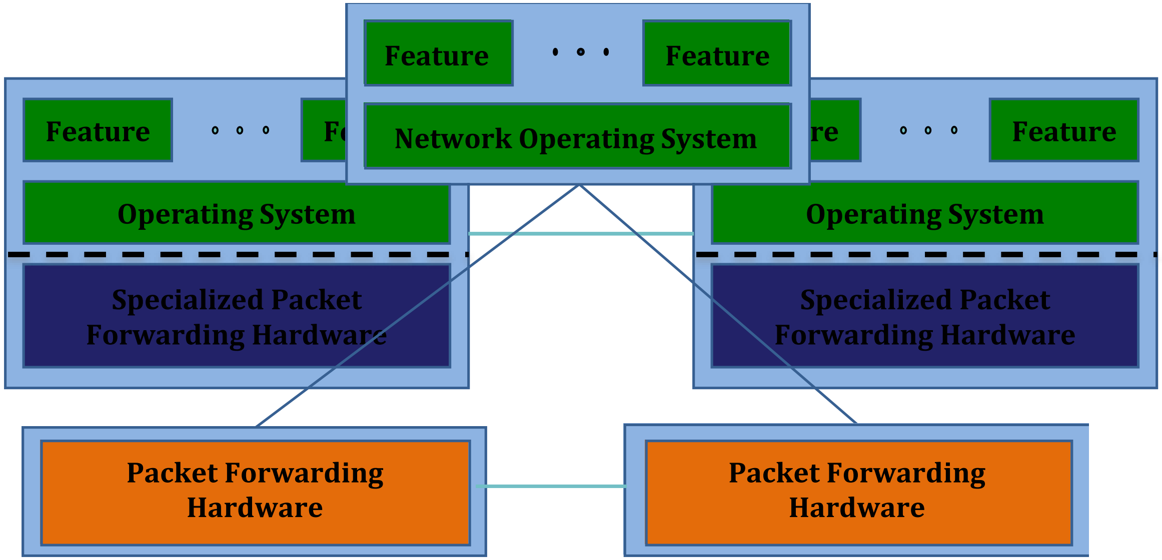
- ISPs provide network based services.
  - Internet access, VPN, VPLS etc.
- ISPs implement internal functions.
  - Routing, traffic engineering, monitoring, failure recovery, billing etc.
- Interacts with customers and other ISPs
- Core-edge arrangement
- Geographically distributed network
- Vertically integrated devices

Challenges for ISPs

- Demand for swift service deployment
- Dependence on vendor development lifecycle
- Slow and manual device configurations
- Difficulty in customization for diverse customers

Software Defined Networking (SDN)

- A new concept proposed by Open Networking Foundation (ONF)
  - Separation of the control and the data planes
  - Centralized controller with global network view
  - Programmable control of network



SDN Components

- Physical or virtual switches/datapaths

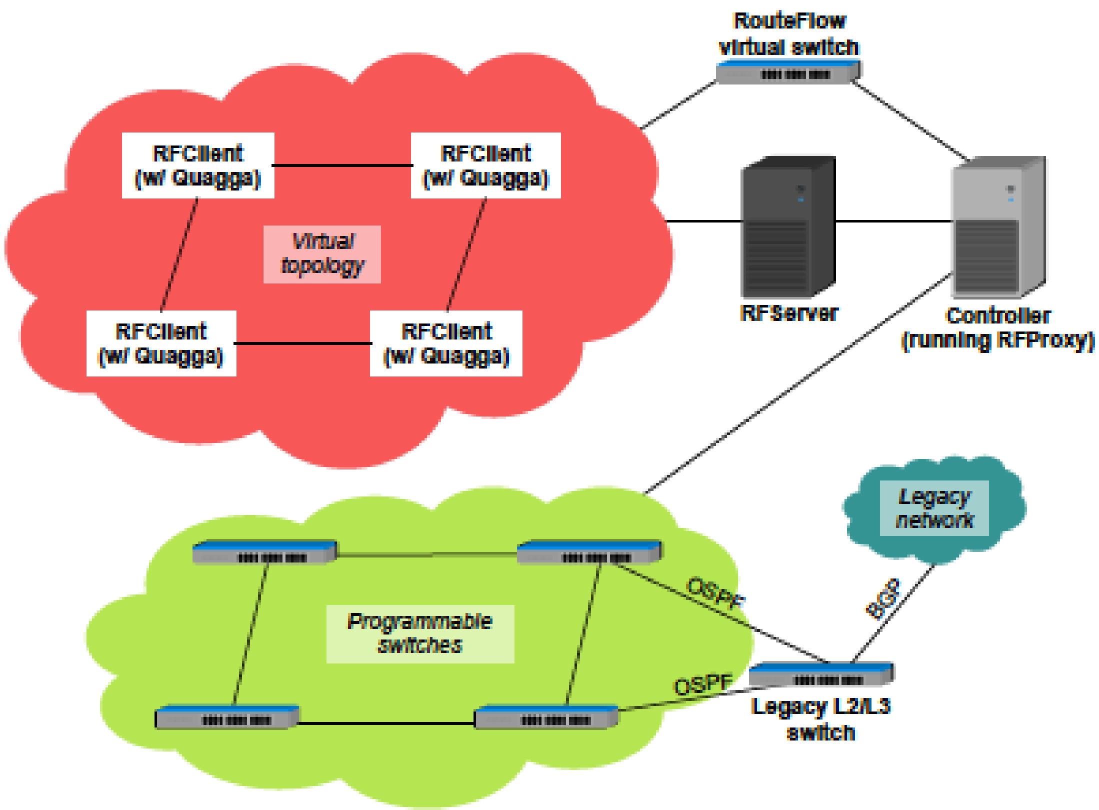
- OpenFlow protocol
  - Messages, flow tables, match fields, actions, counters

- Network Operating System(NOS)
  - Control processes & network view

- Network Applications
  - VPN, VPLS, BWoD, managed routers, MPLS tunnel creation, traffic engineering etc.

RouteFlow

- Enables legacy routing in OpenFlow networks.
- Utilizes distributed virtual control plane.



- Enables transparent operation with non OpenFlow networks.

RouteFlow Configuration

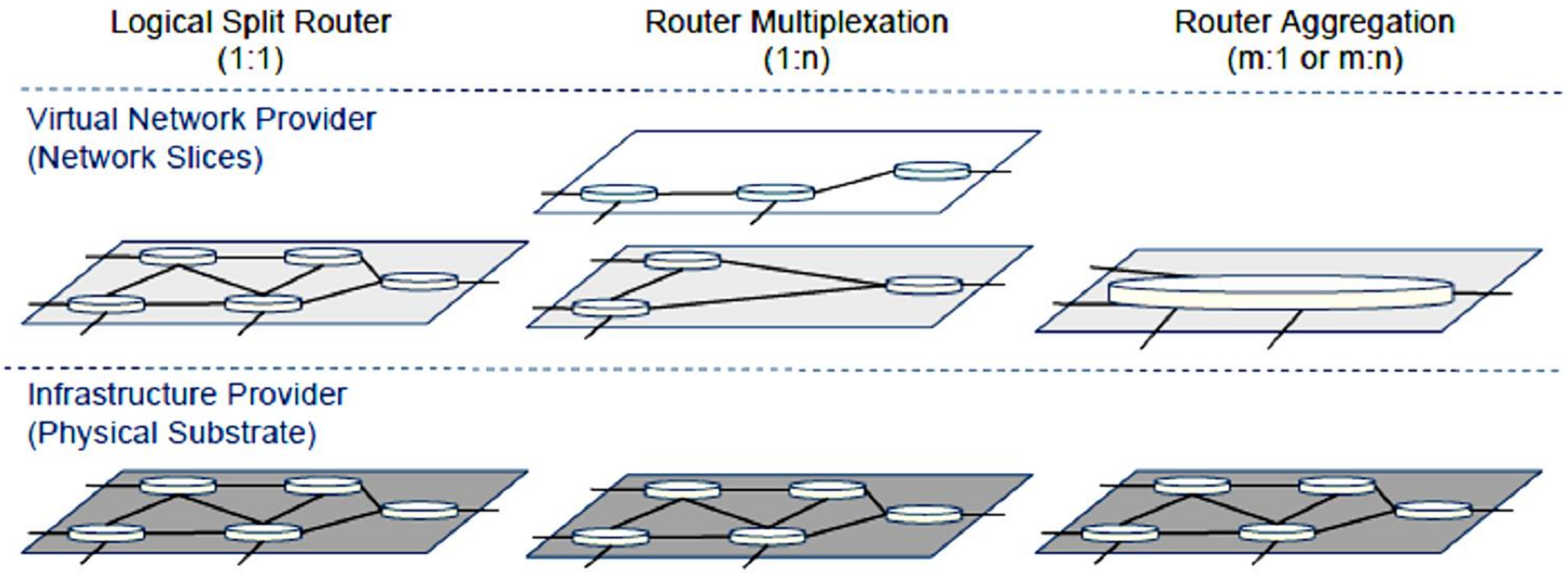
- Static and manual configuration

- Runtime changes in network are not supported

- Two step configuration process
  - Router virtual machine (VM) creation
  - Router virtual machines to OpenFlow switch mappings

RouteFlow Operation

- Multiple mapping modes
  - Logical split (1:1)
  - Router multiplexation (1:n)
  - Router aggregation (m:1)



RouteFlow Flow Table Installation

- Types of flows
  - Fixed Flows (FF)
  - Variable Flows (VF)
- Total Flows (TF) = FF + VF
- VF depends on
  - Number of ports (NP)
  - Directly (DC) & indirectly connected (IC) network destinations
- VF = (NP - 1) x (DC + IC)

Flow Type	**Fixed Flows (FF)**	**Variable Flows (VF)**
Installation	Proactive	Proactive & reactive
Priority	32800	Depends on prefix length
Number	10	variable
Packet Types	BGP, OSPF, ICMP, ARP etc.	IPv4

Relation between Routing & Flow Tables

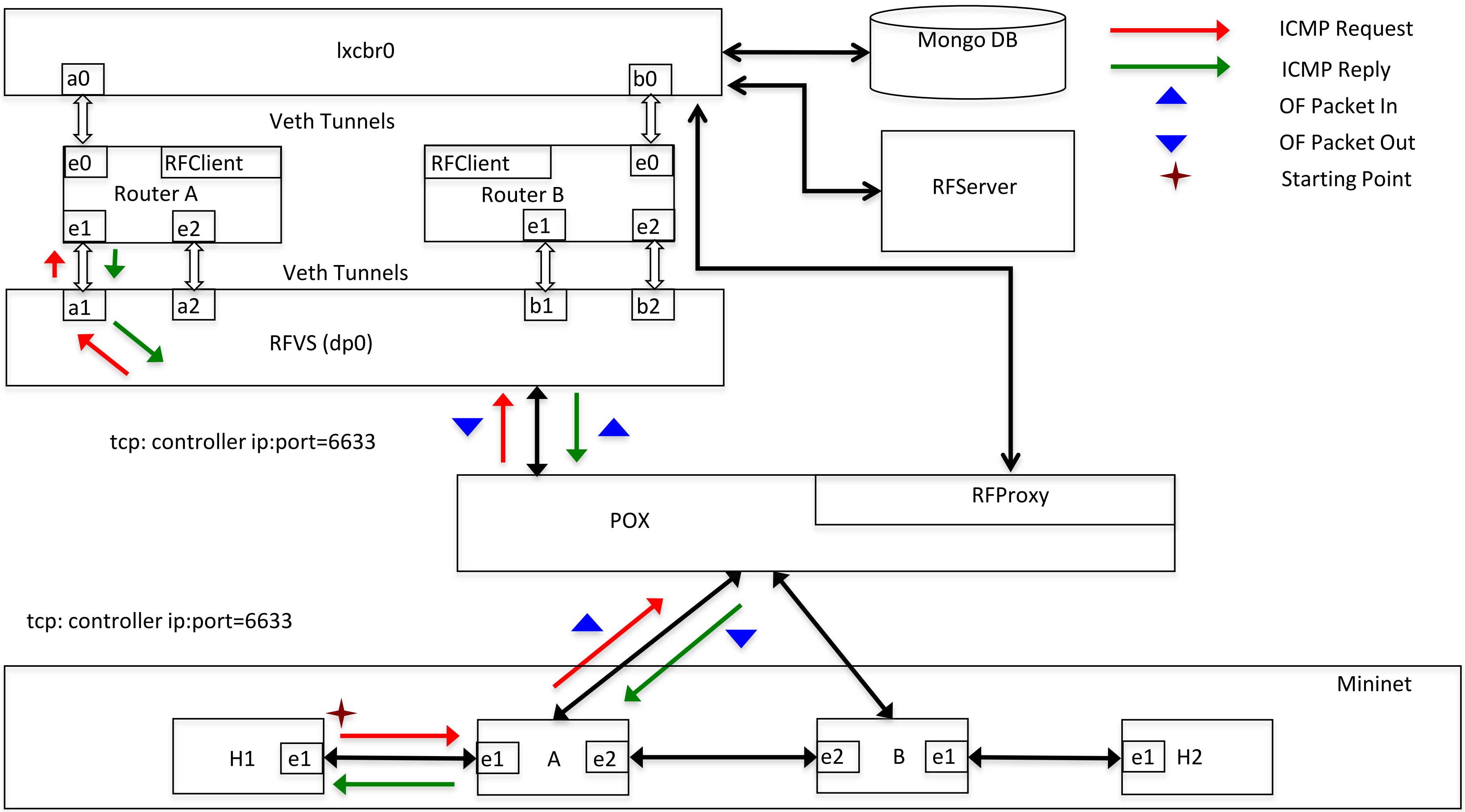
- One to many relation between routing and flow table entries
- Each routing table entry cause (NP-1) flow table entries
- Total BGP prefixes = 0.5 million
- OpenFlow table size required ~ 5 million for a 10 port switch
- Wildcard Input port match field or use FIBIUM like approach

RouteFlow Behavior

- Topology independent test cases
  - Control traffic handling
  - Data traffic handling
  - Failure handling
  - RouteFlow specific

Control Traffic Handling in RouteFlow

- ARP packet flow

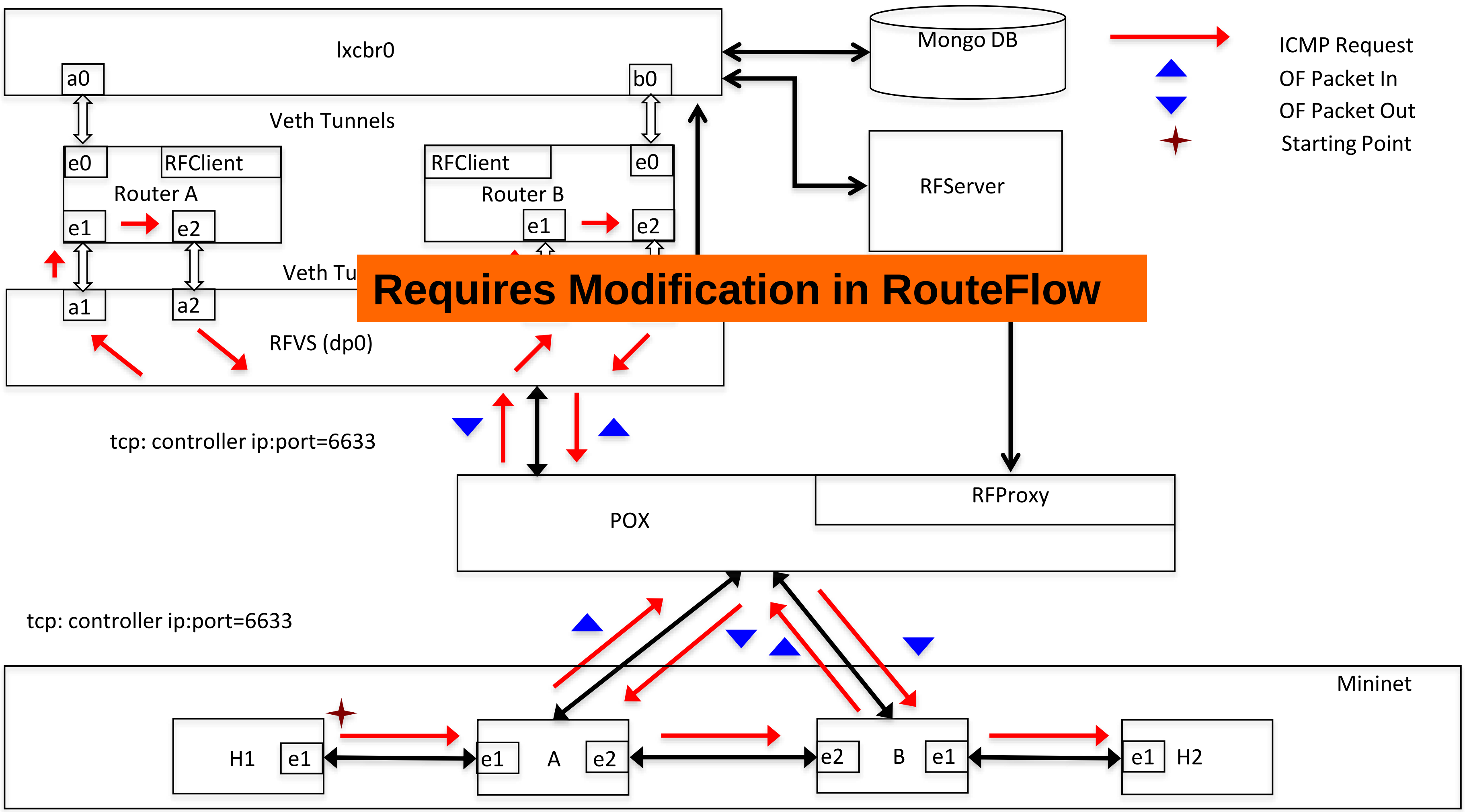


ARP Packet Flow

- No ARP processing in OF switches
- Reactive flow installation for the host
- Unicast ARP queries during running IP flows

Control Traffic Handling in RouteFlow

- High priority ICMP, BGP etc. flow table entries



Analysis

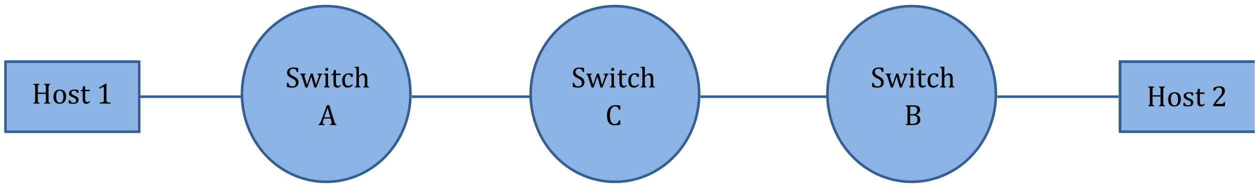
- Control packets sent to routers at each hop
- Fine for OSPF, RIP, ARP packets but adds extra delay for ICMP, BGP packets
- Adds extra traffic on RFVS & OF Controller link
- Decrease the priority for ICMP, BGP control flows
- Increase flow table lookup delays inside switch

Analysis…(2)

- Avoid unicast ARP packets between transit routers
- ICMP packets for specific router sent to controller
- Similar modification is useful for BGP packets

Traceroute in RouteFlow

- Tool for route and transit delay discovery



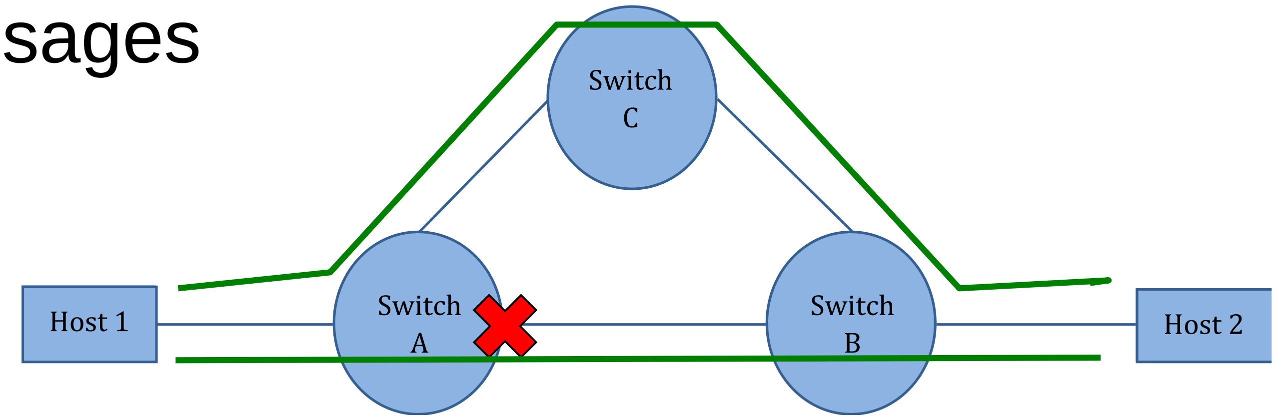
- ICMP & UDP probe packets

Requires newer OpenFlow version

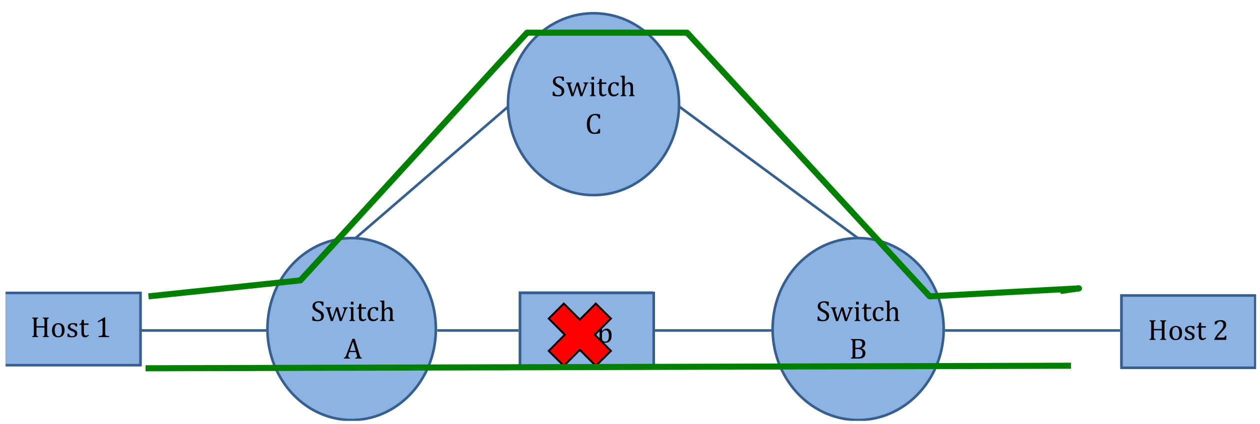
- ICMP probe yields two different results
  - High priority flow >>> 4 hops
  - Low priority flow >>> 1 hop
  - No TTL decrement in OpenFlow 1.0
- UDP probe detects only 1 hop
- Legacy networks connected via RouteFlow network
- Number of hops remain unknown

Port & Link Failure in RouteFlow

- Port failure cause port status modification messages



- Link failure is simulated to avoid status change messages



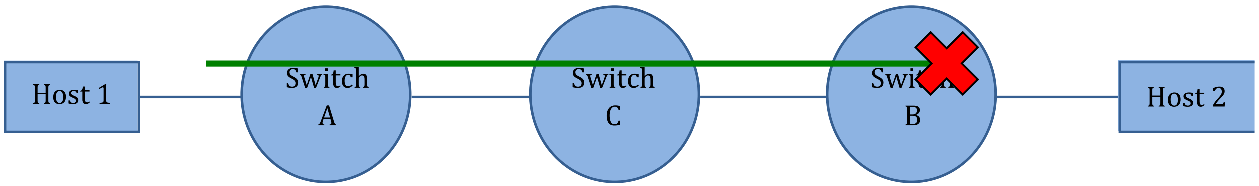
Port & Link Failure...(2)

- No response to status modification messages
- Relies on OSPF dead interval for recovery
- Slow recovery process approx. 10sec for 4 sec OSPF dead interval
- MPLS FRR ~ 50 ms recovery time

Requires Modification in RouteFlow

UDP/TCP Packet Flow

- Similar forwarding response



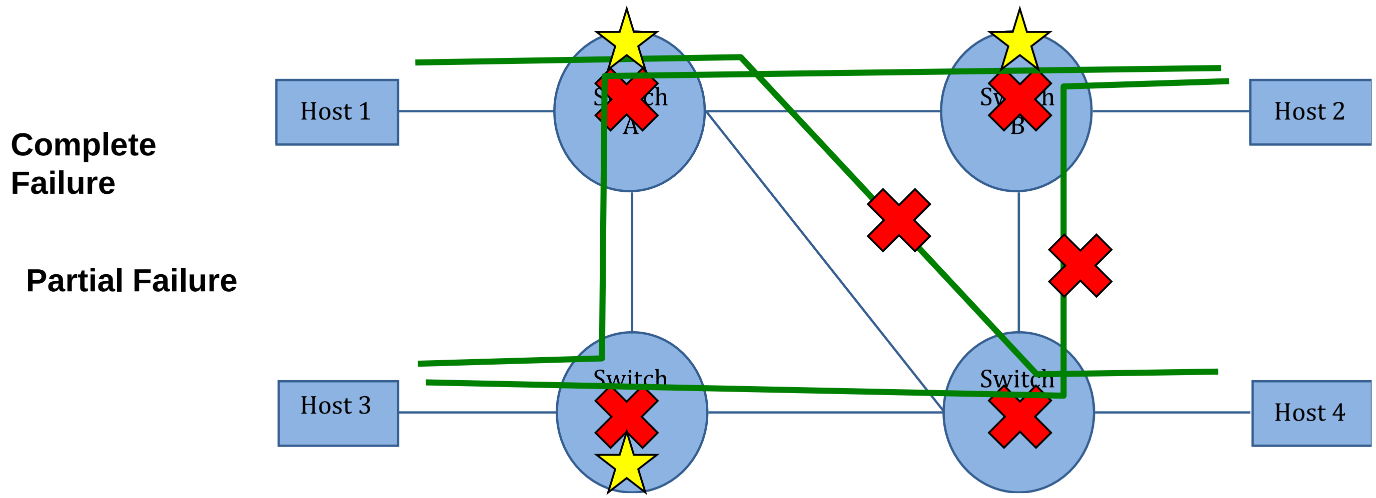
- Both UDP/TCP P gress switch B

RouteFlow Problem

- No flow entry for Host 2
- No ICMP error report to source Host 1
- Require a generic IPv4 flow entry in edge switches

Link Failure between Controller & Switches

- SDN/OF specific failure



- Two scenarios tested
  - Link failure with complete network
  - Link failure with few switches
- UDP, TCP and ICMP flows used
- Switches retained flow tables for complete failure
- Switches with link to controller received flow modifications

Link Failure between Controller & Switches…(2)

- Running flow in both scenarios stopped after some random time
- No backup controller in OF 1.0
- Main cause of fl[obscured]uccessful ARP queries
- Impossible to start new flows using affected switches
- Flow recovery in second scenario if alternative path available

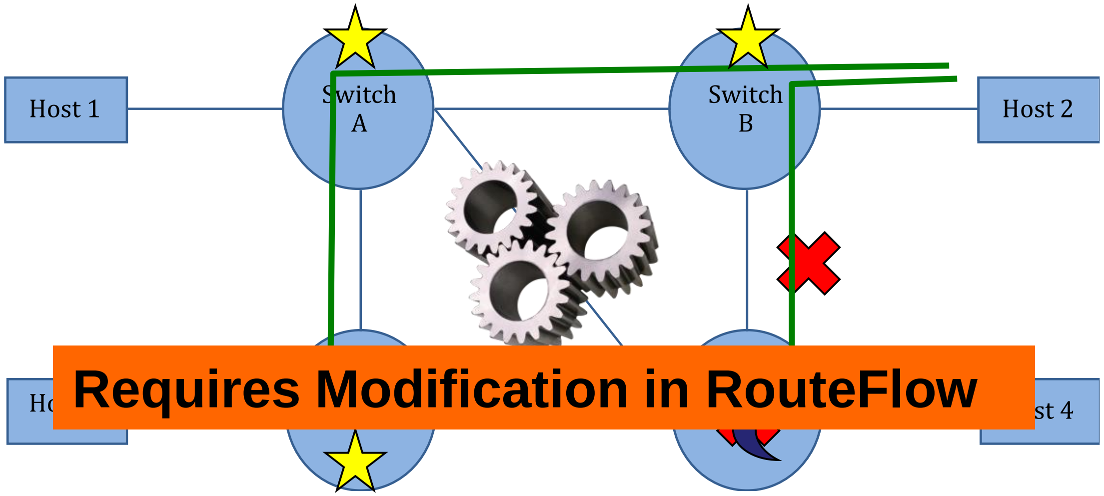
SDN & OpenFlow Problem

Router VM State Modification

- Specific to RouteFlow

VM freezes

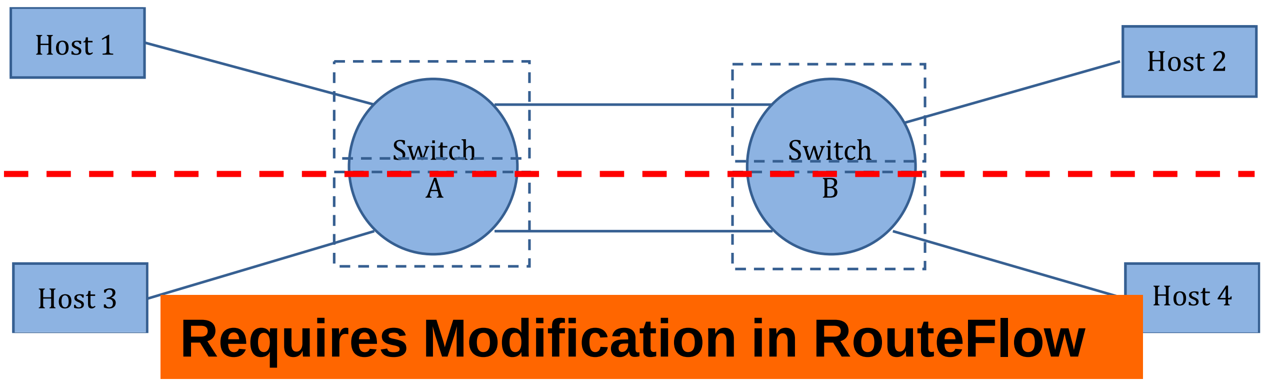
VM fails



- Unexpected failure or planned state modification
- Recover from planned state modification
- Unable to recover from VM failures
- Manual effort required to recover from VM failure

Router Multiplexation Mode

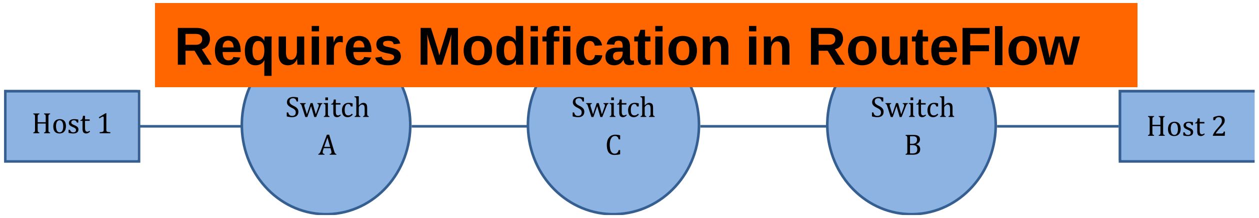
- Logically isolated network segments



- Isolation not achieved in OF network
- Flows for all ingress ports
- Require modification in RouteFlow
- Somewhat similar to virtual routing & forwarding (VRF)

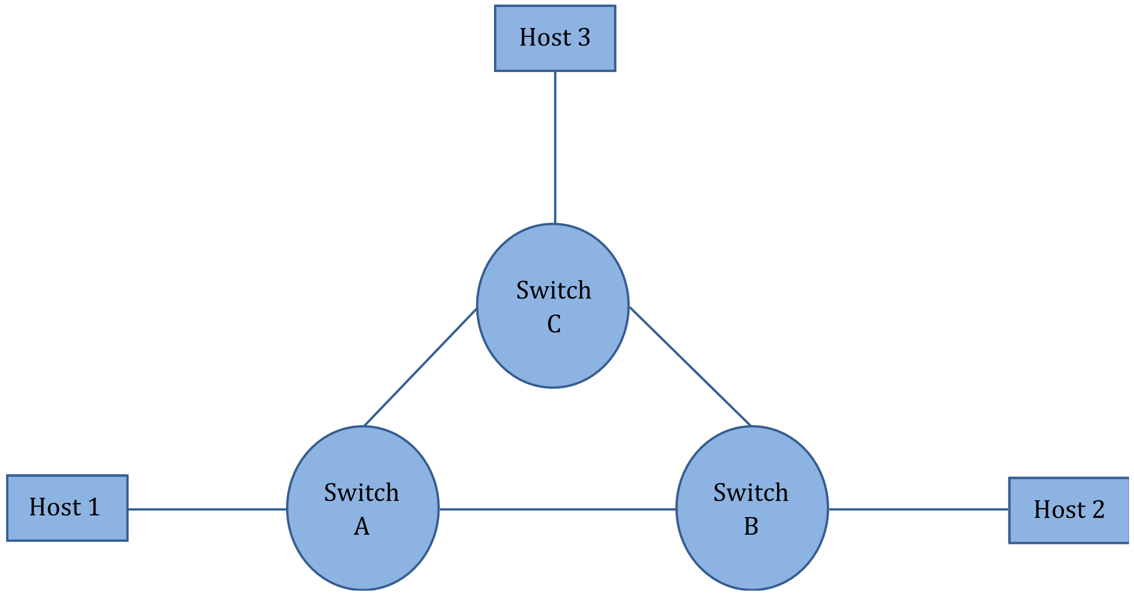
Router Aggregation

- Single router for multiple switches
- Linear and full mesh topologies
- Requires configuration of inter switch links



- No flow entries for switch C except fixed flows
- Switch A and B have flow entries for directly connected host
- Linear topology do not utilize ISL for data packets

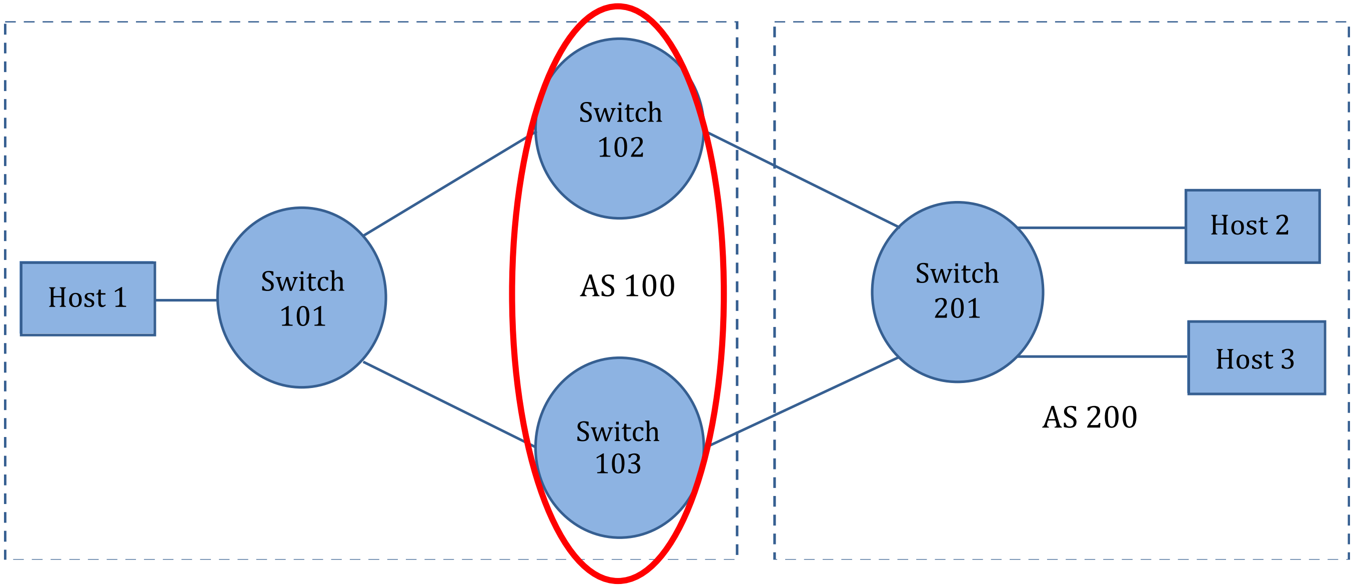
Router Aggregation…(2)



- All ISLs are used for data packets
- All switches have host specific flow entries for all hosts
- Requires full mesh topology for proper aggregation
- Useful for isolation between intra and inter domain routing

BGP Router Aggregation

- EBGP speakers aggregated for a domain



- Routers in AS100 for switch 102 & 103
- No IBGP session required between switch 102 &103
- Easy to manage single router

Miscellaneous Test cases

- DHCP server in RouteFlow routers

- Interfacing with customer routers

- Some interesting future scenarios
  - Multipath routing
  - Multicast routing
  - MPLS switching
  - QoS related tests

Conclusion

- RouteFlow as a SDN solution
  - Separation of the control and data plane
  - Centralized controller
  - Distributed routing
  - No abstraction for network applications

- Other SDN solutions
  - OPEN : MPLS TE, VPN
  - Mutilflow : Multicast routing
  - Inter AS routing component
  - ONIX : Distributed controller paltform

Conclusion…(2)

- RouteFlow is not a very good SDN solution
- Require changes in RouteFlow implementation
- Integration with other SDN solutions

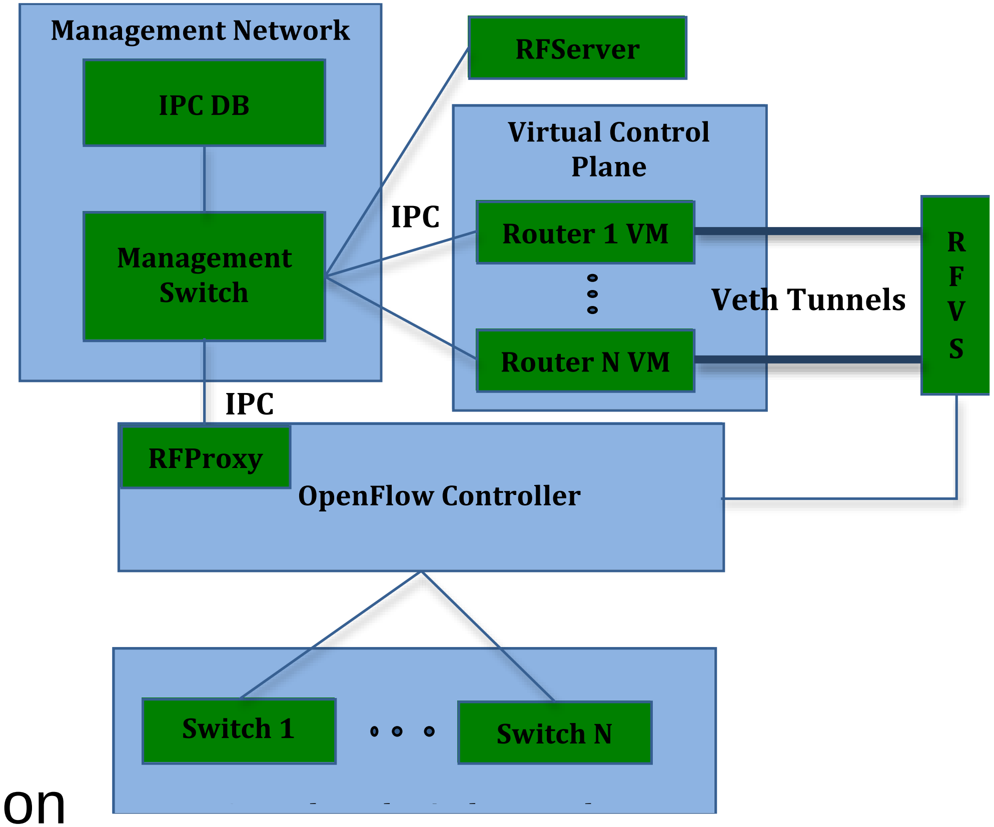
Future Work

- Isolation between Inter & intra domain routing
- Centralized routing for intra domain destinations
- Integration with other SDN solutions
- Provision of APIs for network applications

Questions

RouteFlow Components

- RFServer
- RFClient
- RFProxy
- RFProtocol
- RouteFlow virtual switch (RFVS)
- Management Switch
- Inter-process communication (IPC) Database



RouteFlow Operation

- Management switch & IPC database is initialized
- Router VMs & OpenFlow controller is started
- RFServer with configured mappings is started
- RFVS is connected to OF controller and router VMs
- OpenFlow switches are added to the network

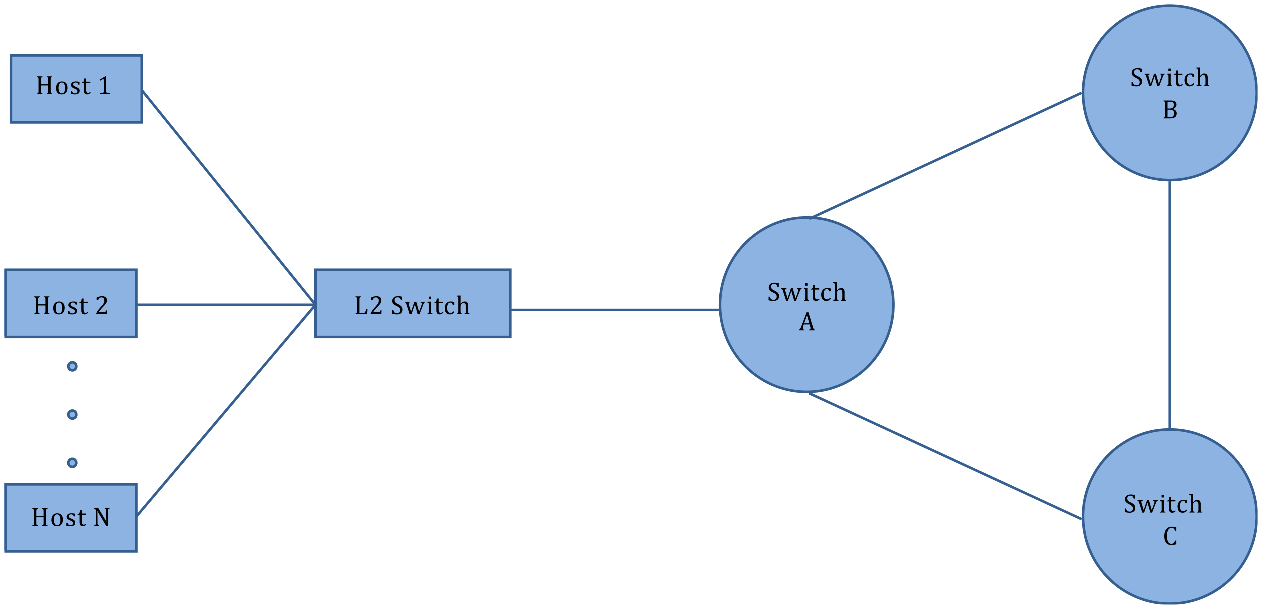
RouteFlow Operation

- Routing tables are built

- Proactive and reactive flow table entries are installed in switches

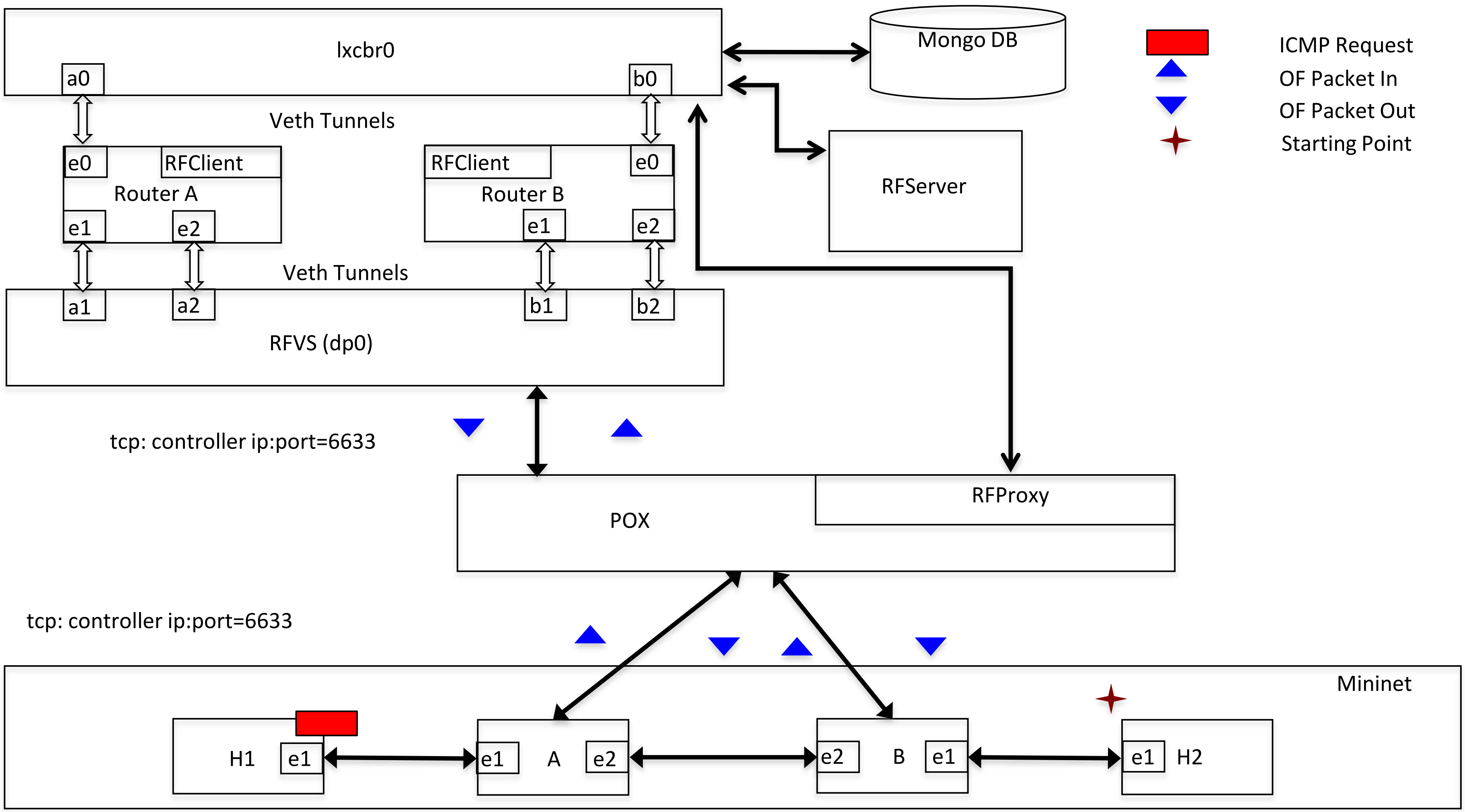
RouteFlow Flow Table Installation…(2)

- Directly and indirectly connected network destinations for A.



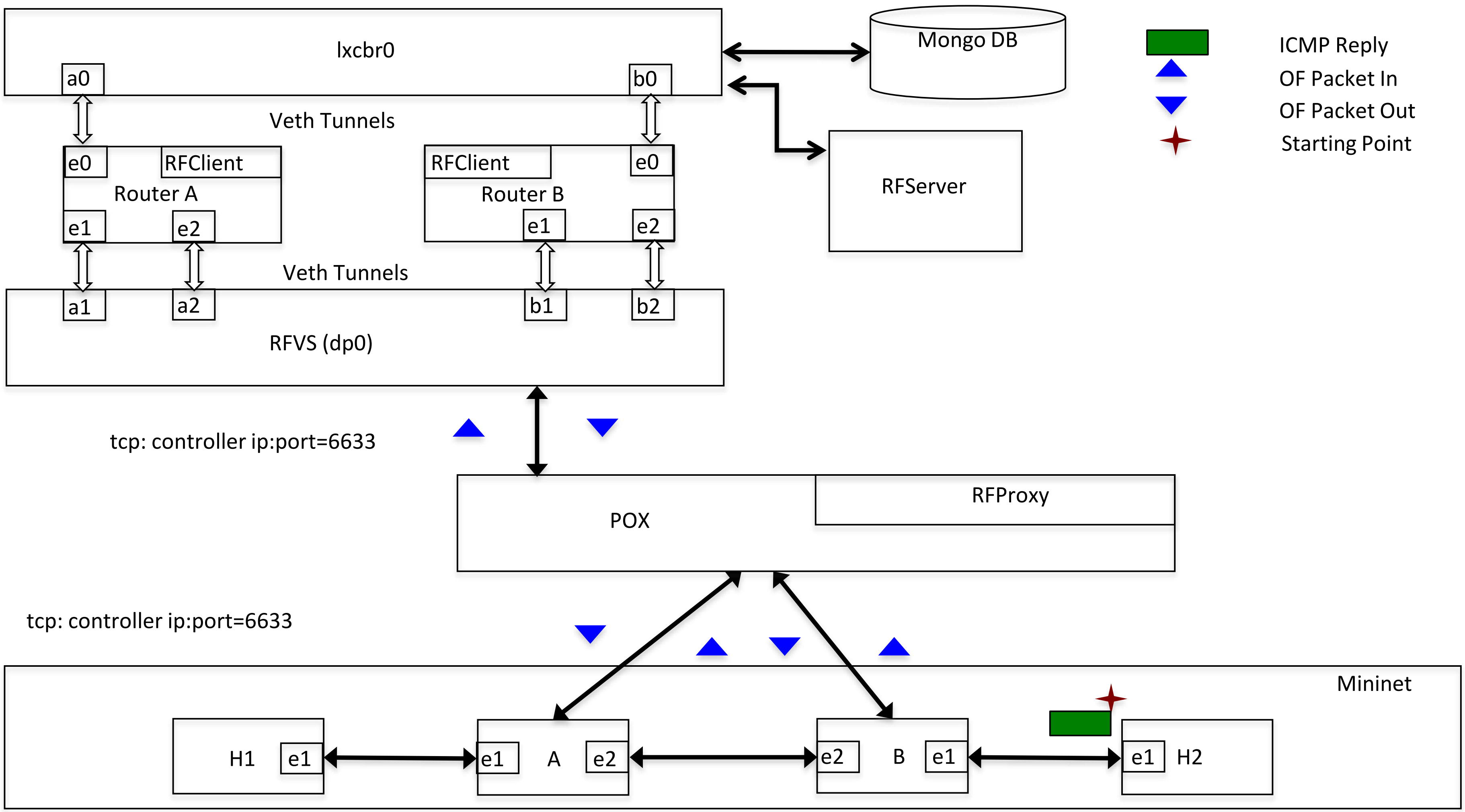
- Directly connected (DC) destinations for A = N + 2
- Indirectly connected (IC) subnets for A = 1
- VF = (NP - 1) x (DC + IC)
- IC flows are subnet specific & DC flows are network address specific

- High priority flow table entries



Control Traffic Handling in RouteFlow

- High priority flow table entries



Network Architecture

- The design and framework of a network, including the characteristics of individual hardware, software, and transmission system components and how they interact in order to ensure the reliable transfer of information. Prior to the development of such architectures, interoperability between the various systems of a single manufacturer was unusual, and it certainly did not exist between the products of multiple manufacturers. IBM's Systems Network Architecture (SNA) and the Digital Equipment Corporation's (DEC's) Digital Network Architecture (DNA), aka DECnet, corrected these shortcomings within the IBM and DEC domains, but they still did not interoperate. Truly open systems architectures still remain in the distant future, although great strides have been made in this regard through the Open Systems Interconnection (OSI) model fostered by the International Organization for Standardization (ISO). Network architectures tend to be layered, which serves to enhance their development and management. While they primarily address issues of data communications, they also include some data processing activities at the upper layers. These upper layers address application software processes, presentation format, and the establishment of user sessions. Each independent layer, or level, of a network architecture addresses different functions and responsibilities. The layers work together, as a whole, to maximize the performance of the process. See also ISO, OSI Reference Model, and SNA

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