Seamless Network-Wide Migrations

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Human factors are responsible for 50 to 80% of network device outages.

— Juniper Networks, 2008
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— Juniper Networks, 2008

Large (resp. medium) businesses lose an average of 3.6% (resp. 1%) in annual revenue due to network downtime.

— Infonetics Research, 2004 – 2006
The progressive modification of the configuration of a running network without loosing any IP packets
Migrating the network can provide immediate benefits

Network migration can improve the

- manageability
- performance
- stability
- security

of the entire network
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- performance
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- security

introduce (remove) a hierarchy
support different features
improve route manipulation

of the entire network
Migrating the network can provide immediate benefits.

Network migrations can improve the:

- manageability
- performance
- stability
- security

reduce control-plane load
reduce routing-table size
reduce convergence time

of the entire network
Migrating the network can provide immediate benefits

Network migrations can improve the

- manageability
- performance
- **stability**
- security

of the entire network

- isolate parts of the network
- reduce the churn
Migrating the network can provide immediate benefits.

Network migrations can improve the

- manageability
- performance
- stability
- security

of the entire network

use stable code base
prevent potential attacks
Migrating the network is operationally complex

Reconfigure a running network while respecting Service Level Agreement

Make highly distributed changes on all the routers, in a coordinated manner

Face potential routing anomalies as non-migrated routers interact with migrated ones
Seamless Network-Wide Migrations

1. IGP migrations
   Ordering matters

2. BGP migrations
   Ongoing work

3. How can we help?
   Manage complexity
Seamless Network-Wide Migrations

1. IGP migrations
   Ordering matters

2. BGP migrations
   Ongoing work

How can we help?
Manage complexity
Problem

Replace the IGP configuration of a running network, router-by-router, without causing any anomalies

Sub-problem 1

Current Practice

Run the two IGP configurations in parallel

Replace the IGP configuration of a running network, router-by-router, without causing any anomalies
Migrating the IGP usually requires running two routing planes

Abstract model of a router

Control-plane

Initial IGP

Data-plane

Initial Forwarding paths

At first, the initial IGP dictates the forwarding paths being used
Migrating the IGP usually requires running two routing planes.

Abstract model of a router:

- **Control-plane**
  - Initial IGP
  - Final IGP

- **Data-plane**
  - Initial Forwarding paths

Then, the final IGP is introduced without changing the forwarding.
Migrating the IGP usually requires running two routing planes.

Abstract model of a router

Control-plane
- Initial IGP
- Final IGP

Data-plane
- Final Forwarding paths

After having converged, the final IGP is used by flipping the preference.
Migrating the IGP usually requires running two routing planes.

Abstract model of a router

Control-plane

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Data-plane

Final Forwarding paths

After having converged, the final IGP is used by flipping the preference.
Migrating the IGP usually requires running two routing planes

Abstract model of a router

Control-plane

Data-plane

Final IGP

The initial IGP is removed as it is not used anymore

Final Forwarding paths
Sub-problem 1

Replace the IGP configuration of a running network, router-by-router, without causing any anomalies.
Sub-problem 2 Replace the IGP configuration of a running network, router-by-router, without causing any anomalies
Migrating the IGP can create *migration loops*

Up to 90 *migration loops* can arise during an IGP migration.
Sub-problem 2   Replace the IGP configuration of a running network, router-by-router, without causing any anomalies
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Contributions  Seamless IGP migration is possible as long as the reconfiguration process follows a strict ordering
Contributions
Seamless IGP migration is possible as long as the reconfiguration process follows a strict ordering which one?
Reconfiguring the IGP might change the forwarding paths being used

In a flat IGP, routers forward traffic according to the shortest-path towards the destination.

In a flat IGP, R2 reaches R1 via R4
Reconfiguring the IGP might change the forwarding paths being used

In a hierarchical IGP, routers prefer paths contained within a single zone over the ones crossing several zones

In a hierarchical IGP, R2 reaches R1 directly
Whenever the forwarding paths change, forwarding loops can be created.
Forwarding paths towards R1

initial paths

R1  10  R3
100 1
R2  10  R4

flat IS-IS

intermediate paths

R1  10  R3
100 1
R2  10  R4

R1  10
100 1
R2  10
R3
R4

R1  10
100 1
R2  10
R4

final paths

R1  10
100 1
R2  10
R3
R4

hierarchical OSPF

Forwarding paths towards R1
First, we migrate R3

Forwarding paths towards R1

initial paths

flat IS-IS

intermediate paths

final paths

hierarchical OSPF
First, we migrate R3
Then, we migrate R4

Forwarding paths towards R1

initial paths  

flat IS-IS

intermediate paths  

hierarchical OSPF

final paths
Then, we migrate R4

Forwarding paths towards R1

- **Initial paths**
  - Flat IS-IS

- **Intermediate paths**
  - Hierarchical OSPF

- **Final paths**
  - Hierarchical OSPF
Whenever the forwarding paths change, forwarding loops can be created.

A loop is created if R4 is migrated before R2.

Forwarding paths towards R1:

- **Initial paths** (flat IS-IS):
  - R1 → R3
  - R3 → R4
  - R4 → R2

- **Intermediate paths** (hierarchical OSPF):
  - R1 → R3
  - R3 → R4
  - R4 → R2

- **Final paths** (hierarchical OSPF):
  - R1 → R3
  - R3 → R4
  - R4 → R2
Migrations have to be performed following a precise ordering

No loop arises if R2 is migrated before R4

Forwarding paths towards R1

**initial paths**

- R1 to R3
- R3 to R4
- R4 to R2

**intermediate paths**

- R1 to R3 (green)
- R3 to R4
- R4 to R2

**final paths**

- R1 to R3 (green)
- R3 to R4
- R4 to R2

- flat IS-IS
- hierarchical OSPF
Migrations have to be performed following a precise ordering.

No loop arises if R2 is migrated before R4.

Forwarding paths towards R1:

- **Initial paths** for flat IS-IS:
  - R1 to R3: 10
  - R3 to R4: 100
  - R4 to R2: 1
  - R2 to R1: 10

- **Intermediate paths** for hierarchical OSPF:
  - R1 to R3: 10
  - R3 to R4: 100
  - R4 to R2: 1
  - R2 to R1: 10

- **Final paths** for hierarchical OSPF:
  - R1 to R3: 10
  - R3 to R4: 100
  - R4 to R2: 1
  - R2 to R1: 10
Migrations have to be performed following a precise ordering

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Forwarding paths towards R1
Although hard in theory, finding an ordering is possible in practice

Implementation of two ordering algorithms
1. correct, complete, but slow
2. correct, not-complete, but fast

Complete support of the
- introduction (removal) of an IGP hierarchy
- introduction (removal) of route summarization
- modifications of link weights
For all the tested networks, we have been able to find an ordering Up to 20% of the routers might be involved in an ordering.
Our techniques can also deal with links and nodes failures during the migration.

Failures can change the computed ordering as they modify the underlying IGP topology.

Solutions

- Precompute failover orderings
- Compute a new ordering when a failure is detected
We implemented a provisioning system which automates the process

Network in which IGP 1 is replaced by IGP 2
First, the *Ordering Component* computes the ordering (if any)

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Order: [R1, R2, R3, R4]

Network in which IGP 1 is replaced by IGP 2
Second, the *IGP Monitor* builds a dynamic view of the IGP and assesses its stability.

Network in which IGP 1 is replaced by IGP 2
Third, the Configuration Manager introduces the final configuration (not yet used) on all the routers.

Network in which IGP 1 is replaced by IGP 2
Fourth, the final IGP’s completeness and stability are verified by the *IGP Monitor*

Network in which IGP 1 is replaced by IGP 2
Fifth, the *Configuration Manager* reconfigures each router - according to the ordering — so that it uses the final IGP.

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Network in which IGP 1 is replaced by IGP 2
Sixth, the IGP migration is over. The *Configuration Manager* removes the initial IGP configuration from each router.

Network in which IGP 1 is replaced by IGP 2.
Let’s reconfigure an existing network from a *flat* IGP ... 

GEANT  
European research network  
36 routers  
53 links
Let’s reconfigure an existing network from a flat IGP to a hierarchical IGP

GEANT
European research network
36 routers
53 links

Backbone zone
South-west zone
South-east zone
North-east zone
Lossless reconfiguration is possible, by following the precomputed ordering.

Average results (50 repetitions) computed on 700+ pings per step from every router to 5 problematic destinations.

Traffic gets lost during more than 80% of the process.

No loss occurs with proper ordering.
Seamless Network-Wide Migrations

IGP migrations
Ordering matters

BGP migrations
Ongoing work

How can we help?
Manage complexity
BGP reconfiguration scenarios are numerous.

Scenarios

**iBGP**

- Full-mesh to route-reflection
- Route-reflection to full-mesh
- Add, (re-)move sessions

**eBGP**

- Add, (re-)move sessions
- Modify in(out)bound policies
BGP reconfiguration scenarios are numerous ... and problematic

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Preliminary evaluations confirm that problems may arise even when following the best current practices.
As for the IGP, reconfiguring BGP can create problems
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In a full-mesh, every router knows 2 paths to reach the destination.
As for the IGP, reconfiguring BGP can create problems.

Both R1 and R3 forwards traffic to R4.
As for the IGP, reconfiguring BGP can create problems.

R3 is reconfigured first by adding a client session towards R2.
As for the IGP, reconfiguring BGP can create problems

R3 loses the visibility of R4’s paths when the initial sessions are removed
As for the IGP, reconfiguring BGP can create problems.

A forwarding loop appears since R3 and R4 use each other to reach P.
Adding iBGP sessions locally can worsen the visibility globally.
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The same prefix is learned on R4, R5 and R6.
Adding iBGP sessions locally can worsen the visibility globally.

Due to route-reflection, RR1 is not aware that R5 is an egress.
Adding iBGP sessions locally can worsen the visibility globally

Adding an iBGP session between R5 and RR1 solves the problem ... but worsen RR2’s visibility
Adding iBGP sessions locally can worsen the visibility globally.

RR1 does not propagate to RR2 paths learned on peer sessions.
Adding iBGP sessions locally can worsen the visibility globally

Worse! If R4 loses its path, RR2 cannot reach P anymore
Reconfiguring BGP relying only on the protocol is quite challenging.

Checking if adding (removing) an iBGP session will trigger:

- forwarding loops
- routing instabilities
- visibility issues
- traffic shifts

is computationally intractable.
Leveraging other technologies helps in achieving seamless BGP reconfiguration

Use the BGP/MPLS VPNs machinery

- Deploy the different configurations in different VRFs
- Migrate by switching the VRF used to forward traffic
Leveraging other technologies helps in achieving seamless BGP reconfiguration

Use the BGP/MPLS VPNs machinery
- Deploy the different configurations in different VRFs
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Extend BGP graceful restart to the entire network
- Disconnect the RIB and the FIB before the migration
- Reconnect them together after the migration
Leveraging other technologies helps in achieving seamless BGP reconfiguration

Use the BGP/MPLS VPNs machinery
- Deploy the different configurations in different VRFs
- Migrate by switching the VRF used to forward traffic

Extend BGP graceful restart to the entire network
- Disconnect the RIB and the FIB before the migration
- Reconnect them together after the migration

A lot of research challenges still remain ...
Seamless Network-Wide Migrations

IGP migrations
Ordering matters

BGP migrations
Ongoing work

How can we help?
Manage complexity
By using our techniques, we can help you achieve lossless migrations

Based on the initial and the final configurations, we can

**IGP**
Compute the operational ordering you should follow in order to not lose any packets

**BGP**
Evaluate the damages of the reconfiguration and work on ad-hoc solutions by modeling the network behavior

Please, come and talk to me if you are interested
Seamless Network-Wide Migrations

- IGP migrations
  - Ordering matters
- BGP migrations
  - Ongoing work
- How can we help?
  - Manage complexity
Don’t fear network reconfiguration, adapt the network to its environment

Seamless reconfigurations are possible but they require careful planning

Our techniques provide theoretical guarantees that every reconfiguration step is safe

Add flexibility to your network management seamlessly move to the current best configuration
Seamless Network-wide Migrations
towards more agile networking

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