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Root Causes for iBGP Routing Anomalies

Correctness of the iBGP Routing Root Causes for iBGP Anomalies Improvements for the Real Life

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Correctness of the iBGP Routing

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Maintainability Scalability Reliability

What do you expect from a routing protocol?

Extensibility Flexibility Correctness Efficiency

*bility Usability

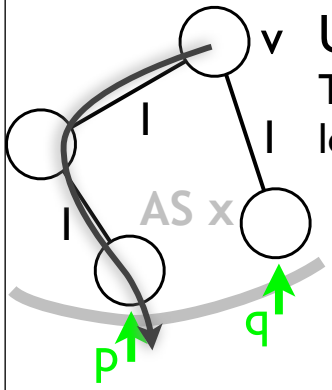
Matches specific requirements Performant Behavior

Correctness Problems in the iBGP Routing: iBGP Anomalies

Basic correctness properties of routing protocols: Expressiveness, Global Consistency, and Robustness

Expressiveness Problems

The routing decision is cost-suboptimal.



Unnecessary Costs

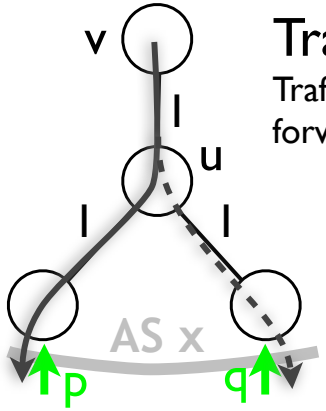
Traffic is forwarded via an unnecessarily long or expensive path.

Violations of Agreements

Traffic is forwarded via an exit point that specifies a backup path.

Global Consistency Problems

Routers make local routing decisions that conflict with each other.



Traffic Deflection

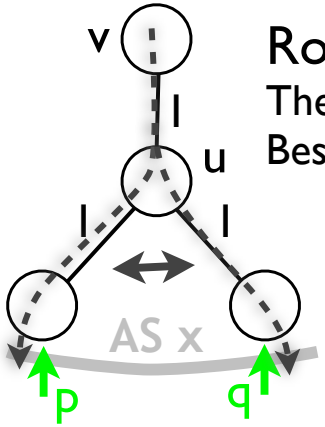
Traffic is taken away from the intended forwarding route.

Loops

Several inconsistent routing decisions form cycles.

Robustness Problems

The routing processes do not enter a predictable final state.



Route Oscillation

The routing processes never converge. Best paths change endlessly.

Non-determinism

Even if all edge conditions are known, the final routing is not predictable.

Correctness Problems in the iBGP Routing: State of Affairs

Even if correctness problems are well-known and well-studied, they still appear in production systems.

Current State

IBGP anomalies are still an important issue.

The problems are known

The problems and their consequences are known.
Protocol designers should be aware of the problem.

The same mistakes are made again!

Protocols are still not validated. New iBGP schemes cause the same correctness problems.

Motivation and Goals

What seems reasonable at this point?

Understanding iBGP Anomalies

We want to identify the root causes for the problems.
Avoiding them eliminates iBGP anomalies.

Basis for Improvements

We want to provide the basis for protocol designers to ensure and verify correctness.

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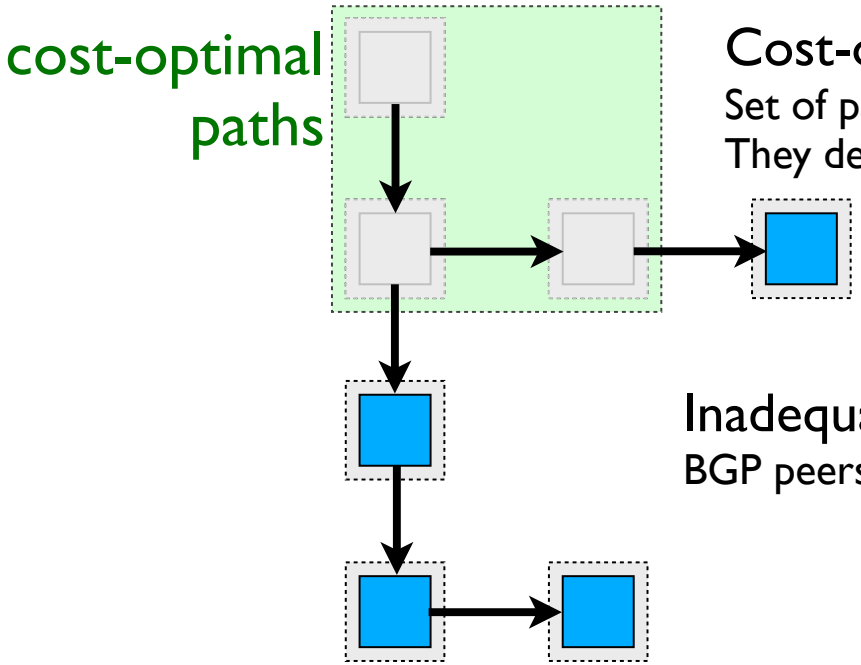
Expressiveness Problems: Unknown Cost-optimal Paths (1)

Cost-suboptimal routing decisions may be induced due to a lack of information on all cost-optimal paths.

Unknown Cost-optimal Paths

If no cost-optimal path is known, traffic cannot be forwarded via a cost-optimal path.



Cost-optimal Paths

Set of paths that minimize the forwarding costs. They depend on the receivers point of view.

Inadequate Announcements

BGP peers may not provide any cost-optimal path.

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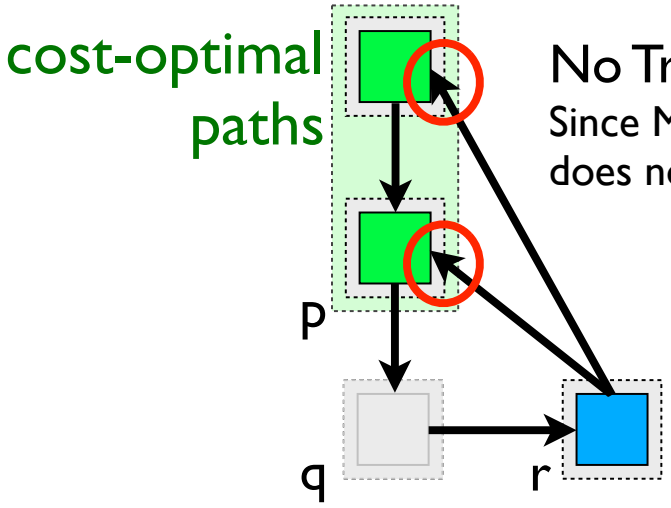
Expressiveness Problems: Path Maskings (2)

Cost-suboptimal routing decisions may be induced due to cost-suboptimal paths that mask cost-optimal ones.

Maskings of Cost-optimal Paths

Cost-optimal paths may be masked by cost-suboptimal ones, if particular routing information is unknown.



No Transitive Ordering Relation

Since MEDs are only compared in a peer-AS group, BGP does not define a transitive ordering relation.

Path Maskings

If important paths are unknown, known cost-optimal paths may be beaten by worse paths.

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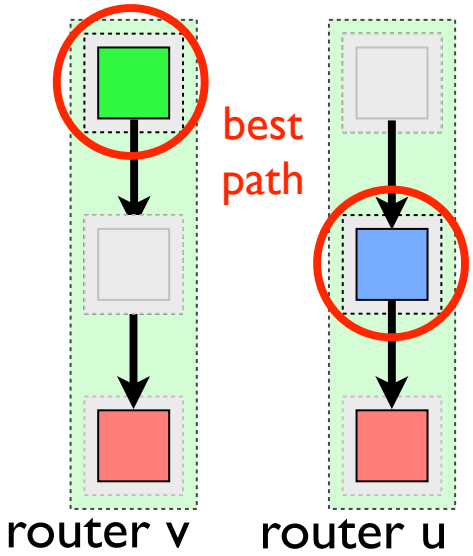
Global Consistency Problems: Lack of Relevant Information (3)

If routers on a future forwarding route do not know equivalent paths, consistent routing decisions cannot be made.

Lack of Relevant Routing Information

Routers cannot come to equivalent routing decisions if their information bases differ significantly.



Known Paths on a Route

Generally, routers on an intended forwarding route may know different cost-optimal paths.

Dissenting Knowledge

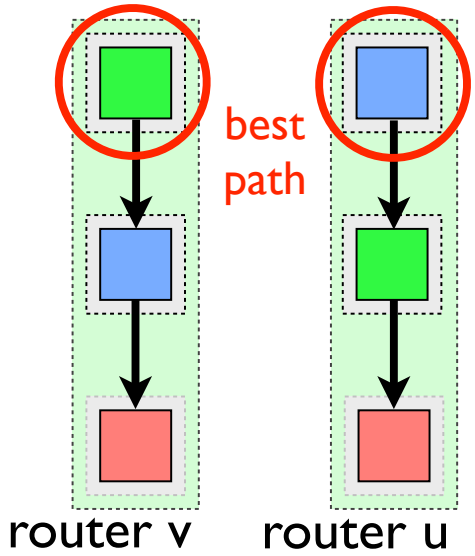
As a result, consistent routing decisions cannot be made if knowledge on relevant paths differs.

Global Consistency Problems: Dissenting Path Rankings (4)

Due to local path attributes evaluated in the best path selection process, paths may be ranked differently.

Dissenting Path Rankings

Even if the same paths are known, consistent decisions are not made if the path rankings dissent.



Non-isotonic Attributes

Not all path attributes behave isotonic: If a path is extended by a physical hop, preference may change.

Dissenting Rankings

As a result, even if the same paths are known, routers may come to dissenting routing decisions.

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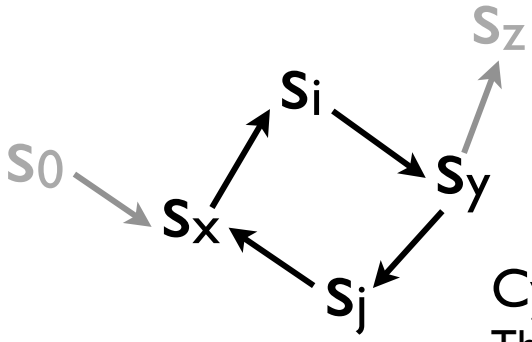
Robustness Problems: Cyclic State Transitions (5)

Considering a configuration over time, it moves from state to state until a stable state is reached. Problems appear if cycles exist.

Cyclic State Transitions

The same states in a configuration may be cyclically entered again and again.



Optimization

The routing process should lead to an incremental optimization of the routers' local routing decisions.

Cyclic Dependencies

The own best path announcement may affect another routing decision so that information important for the own routing decision is withdrawn.

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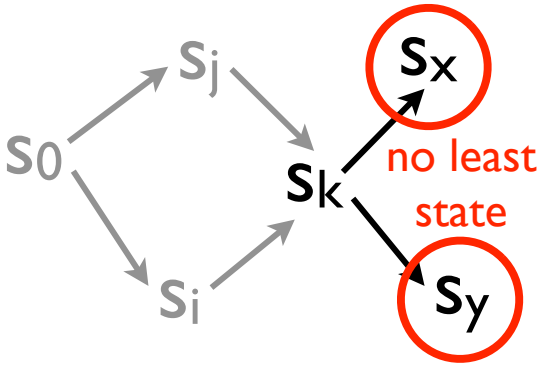
Robustness Problems: No Least State is Defined (6)

The configuration may enter several different stable states. The entered state cannot be predicted in advance.

No Least State Exists

Since BGP does not define a transitive ordering relation, states may be locally optimal.



State Transitions

Since update messages may be timed differently, a state may traverse in several different states.

Local Optimal States

Several states exist that define a local optimum. Once such a state is entered, the routing is stable.

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Improvements for the Real Life

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How does Knowledge on the Root Causes Help in Practice?

Based on the root causes for iBGP anomalies, problems can be easily identified and correctness can be proven.

Improvements for the Real World

Identify and avoid correctness problems!

Problematic Protocol Properties

Root causes help to find iBGP extension properties that cause problems.

Problematic Configurations

They help to identify configurations where problems appear.

Design Workarounds

An understanding for the root causes help operators to specify workarounds.

Verify Correctness

Root causes are a tool-set to verify the correctness of a protocol.

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Conclusion and Future Work:

Anomalies in the iBGP Routing can be traced back to six root causes. Take care of these problems and design a correct protocol!

IBGP is prone to Correctness Problems

Expressiveness, Global Consistency, and Robustness
Problems may appear.

Problems have Six Root Causes

In case of iBGP, anomalies are caused by six properties iBGP schemes come along with.

Impact on the IBGP Routing

Knowledge on the root causes helps to identify problems, design workarounds, and prove correctness.

What is the Scope of the Problem?

It seems interesting to systematically study which effects may appear in which iBGP schemes.

Development of Correct iBGP Schemes

Based on the results achieved here, inherently anomaly-free iBGP schemes for different purposes can be developed.

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Thank you! Are there any questions?

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