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Local Transit Policies and the Complexity of BGP Stability Testing

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BGP

- Border Gateway Protocol (BGP)
  - used to interconnect ISPs (Internet Service Providers) all over the world
  - policy-based protocol

BGP can be unstable

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  - used to interconnect ISPs (Internet Service Providers) all over the world
  - **policy-based protocol**

- risk of global routing anomalies [VaradhanGovindanEstrin00]

BGP can be harmful

- Border Gateway Protocol (BGP)
  - used to interconnect ISPs (Internet Service Providers) all over the world
  - **policy-based protocol**

- risk of global routing anomalies [VaradhanGovindanEstrin00]

- performance degradation [WangMaoWangGaoBush06]
- denial of service [KushmanKandulaKatabi07]

revising the original design

- autonomy + expressiveness = instability risks
  - ISPs can filter paths according to the **expressiveness** of routing configuration languages
  - ISPs can rank paths in full **autonomy**
- existing research directions
  - extend the protocol with oscillation-detection capabilities [GriffinWilfong00]
  - impose static restrictions to autonomy [GaoRexford00]

our viewpoint

assumption:

- ISPs' full autonomy must be preserved

question:

how expressive can policies be in order to allow an efficient static assessment of BGP stability?

- w.r.t. different stability problems

stability problems

given a set of BGP configurations:

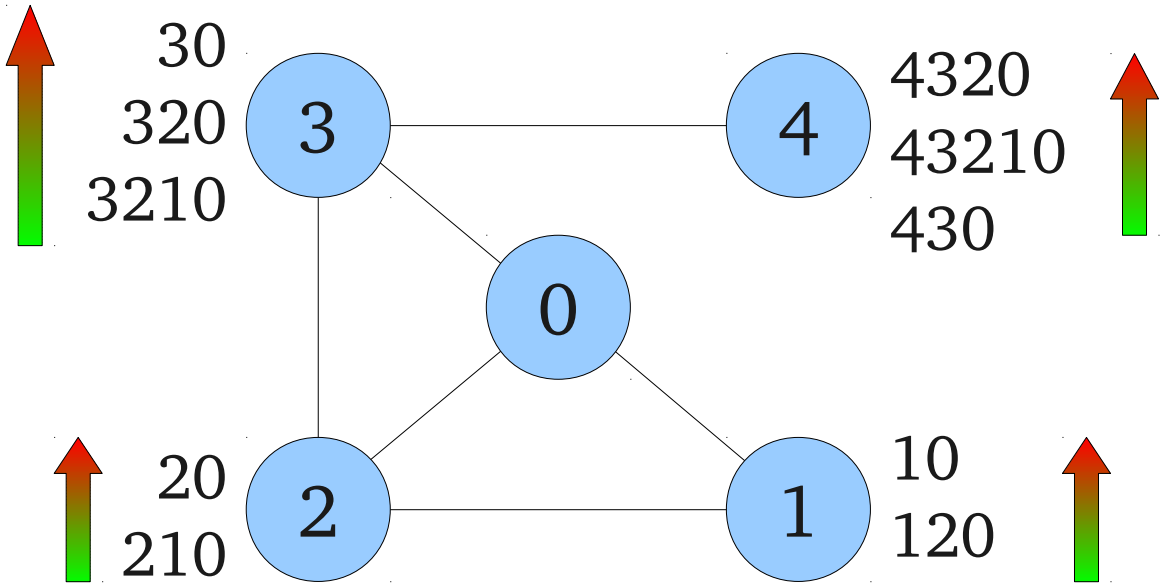
- **safety:** is routing guaranteed to converge to a stable state? [GriffinShepherdWilfong99]
- **robustness:** safety + arbitrary link failures [GriffinJaggardRamachandran03]
- **safety under filtering (SUF):** safety + arbitrary combination of routing filters [FeamsterJohariBalakrishnan07]

the Stable Path Problem model (SPP)

[GriffinShepherdWilfong02]

most used model to study the stability of BGP

- each ISP is modelled as a vertex
- BGP peerings are represented with edges
- each vertex has a list of permitted paths to reach 0
- ordered lists express rankings among paths



our contributions

- how difficult is it to find a solution to the previous stability problems?

	SPP
SAFETY	**Hard**
SUF	**Hard**
ROBUSTNESS	**Hard**

why is safety hard?

in the SPP model it is easy to define routing policies of a set of ISPs such that:

- there exist two paths such that only one of them can be selected
- routing policy contains some paths such that if they are steadily selected then every vertex is stabilized

these properties reveal the intrinsic combinatorial nature of BGP

routing policies

- is SPP suitable for an assessment of BGP stability?
- a typical BGP policy looks like this:

```
ip as-path access-list 1 deny _31358_
ip as-path access-list 1 permit .*$
```

filtering

```
route map myPolicy 10 permit
  match as-path 1
  set local-preference 120
```

ranking

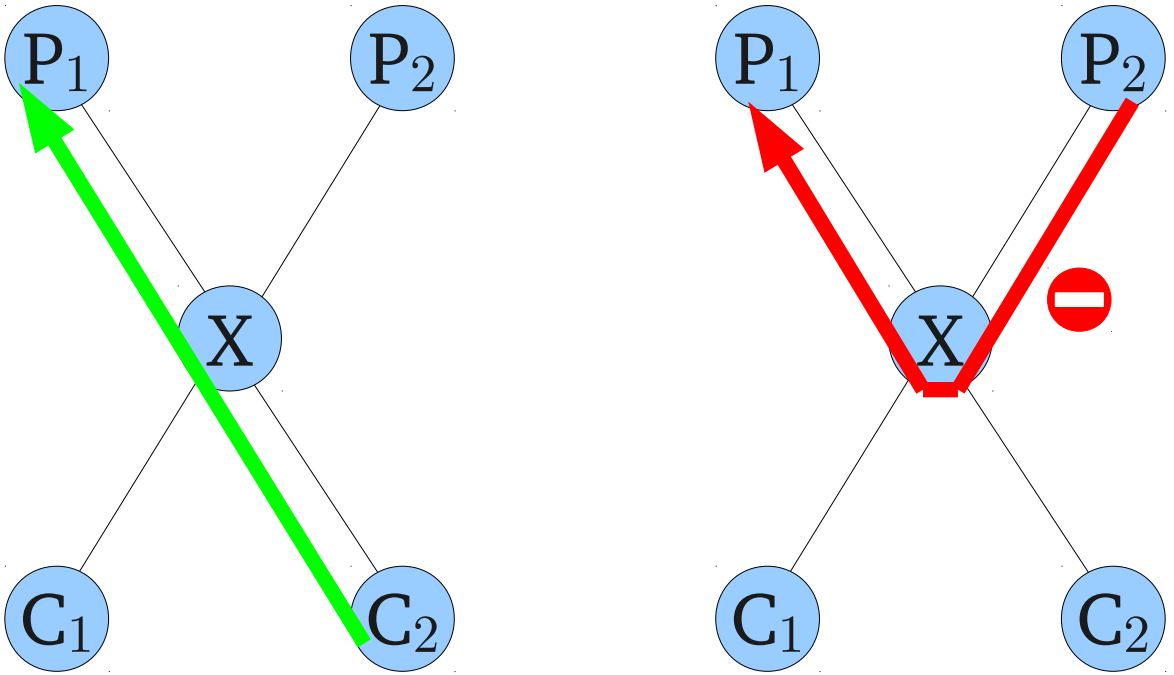
- SPP enumerates an exponential number of paths
- SPP models arbitrarily complex policies

searching for efficient checks

- Can we achieve efficient stability checks by restricting policy expressiveness?

Local Transit Policies (or 3-SPP)

- ISPs write their routing policies according to commercial agreements with their neighbors
  - for instance, an ISP does not want to forward traffic between two of its providers



our contributions

- computational complexity of stability problems:

	Local Transit	SPP
SAFETY	**Hard**	Hard
SUF	**Hard**	Hard
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our contributions

- computational complexity of stability problems:

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- checking for stability is hard even in Local Transit model
- can we efficiently check sufficient conditions for stability?

sufficient conditions for stability ...

given the configuration of a set of routers

- **no-dispute-wheel (NO-DW):** does the configuration contain a *dispute-wheel*?
  [GriffinShepherdWilfong99]
- **no-dispute-reel (NO-DR):** does the configuration contain a *dispute-reel*?
  [CittadiniDiBattistaRimondiniVissicchio09]

Both DWs and DRs are **cyclic** structures of preferences

… are also hard to be checked ☹

- computational complexity of stability problems:

	Local Transit	SPP
SAFETY	Hard	Hard
NO-DW	**Hard**	**computationally feasible (*)**
NO-DR	**Hard**	**Hard**
SUF	Hard	Hard
ROBUSTNESS	Hard	Hard

(*) [GriffinShepherdWilfong99]

breaking through the hardness barrier

- we further limit policy expressiveness
  - new model: **Local Transit Export-All**, or 2-SPP
  - ISPs can only accept or reject all paths from each neighbor
- safety can be efficiently checked in the model
  - … but the model is too much restrictive

Local Transit Export All - insights

Key lemma. Given any arbitrary vertex v, there exists a stable routing state such that v routes its traffic through its most preferred neighbor.

- two or more stable states ⇒ routing anomalies [SamiSchapiraZohar09]

- a greedy algorithm iteratively assigns stable paths to each ISP

take away: what we cannot do

- given a set of BGP configurations:
  - safety, robustness and SUF are hard to check
  - both in the SPP and in the Local Transit models
  - in the Local Transit model even NO-DW is hard to check

  ⇒ **is hard to analyze real-world policies**

take away: what we can do

- Gao-Rexford conditions can easily be checked [GaoRexford2000][CittadiniDiBattistaErlebachRimondini10]

  ⇒ **to gain computationally feasible stability-checking we lose in autonomy**

- safety can easily be checked in the Local Transit Export-All model

  ⇒ **to gain computationally feasible stability-checking we lose in expressiveness**

open problems: what is the boundary?

- finding acceptable expressiveness restrictions which allow efficient stability check is still an open problem

	Local Transit Export-All	Local Transit	SPP
SAFETY	computationally feasible	Hard	Hard
NO-DW		Hard	computationally feasible (*)
NO-DR		Hard	Hard
SUF		Hard	Hard
ROBUSTNESS		Hard	Hard

- (*) [GriffinShepherdWilfong99]

open problems: robustness

- can we achieve efficient stability-checking in the Local Transit Export-All model for robust-related problems?

	Local Transit Export-All	Local Transit	SPP
SAFETY	computationally feasible	Hard	Hard
NO-DW	**?**	Hard	computationally feasible (*)
NO-DR	**?**	Hard	Hard
SUF	**?**	Hard	Hard
ROBUSTNESS	**?**	Hard	Hard

(*) [GriffinShepherdWilfong99]

Thank you