Réseaux II - TP3
Tiny Internet Project

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1 Introduction

L'objectif de ce TP est modéliser une interconnexion de réseaux. Pour ceci vous utilisez C-BGP.

Votre modélisation impliquera la configuration complète de plusieurs routeurs appartenant à divers domaines. Cette configuration comprendra principalement les éléments suivants :

1. la topologie(physique) du réseau
2. la configuration du routage intradomaine ainsi que si nécessaire la configuration de routes statiques
3. la configuration des routeurs BGP afin d'assurer une connectivité interdomaine
4. via l'usage de filtres de routage, l'implémentation des relations de type "business" entre les domaines participants

Il vous est demandé de fournir un rapport détaillé expliquant vos choix de designs. Entres autres vous fournirez un schéma détaillant les relations business, et vous expliquerez comment les filtres permettent de respecter ces relations. Les poids IGP n'étant pas fixé sur les liens, vous expliquerez également de quelle manière vous avez choisi de les attribuer

Ce document est organisé comme suit. La section 2 décrit la topologie du *Tiny-Internet*. Par la suite la section 3 présente le fonctionnement de l'outil de modélisation. Elle détaille également pas par pas comment représenter le *Tiny-Internet* au moyen du langage de modélisation de CBGP.

2 Topology

The topology of the *Tiny-Internet* internetwork [1] is shown in Fig. 1. The topology is composed of 9 different domains. A brief description of the domains is provided in Table 1. This table lists the function of each domain as well as its ASN and the prefixes it owns. Depending on their function, all the domains do not behave equally in the topology and this has an impact on how routing information is exchanged.

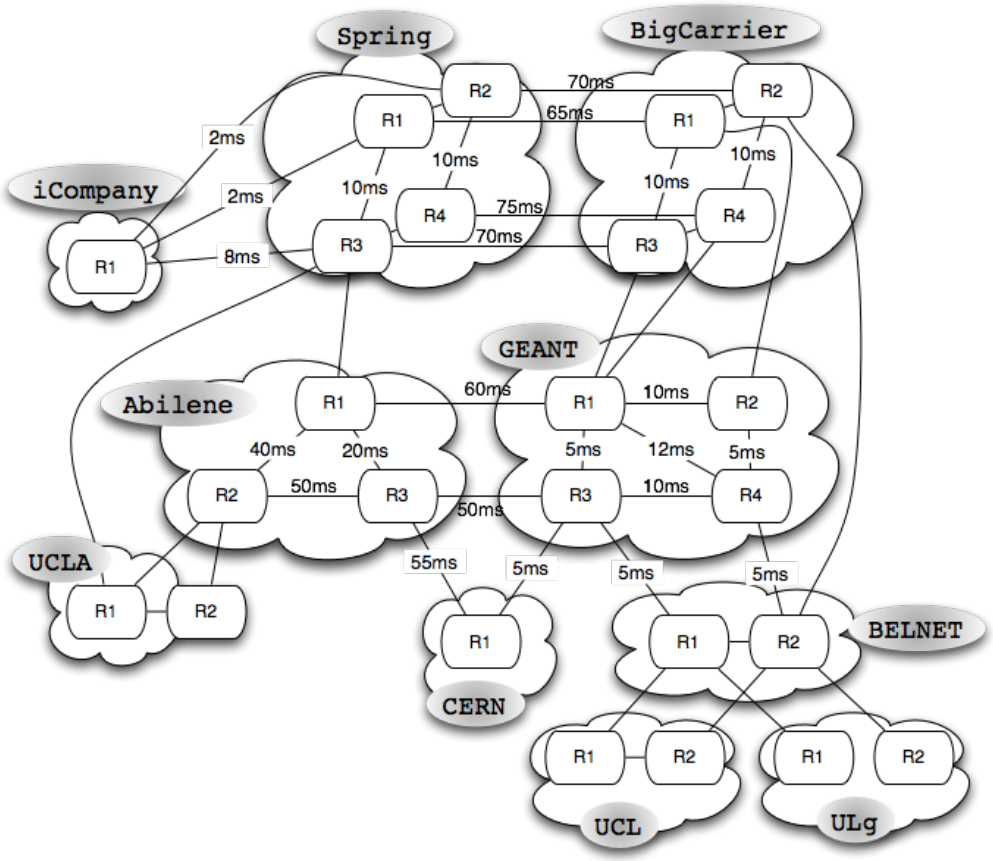

FIGURE 1 – Network topology of the *Tiny-Internet*.

First, there are commercial networks such as *BigCarrier*, *Spring* and *iCompany*. Then we have non-profit networks such as *Abilene*, *GEANT*, *BELNET*, *CERN* and university networks : *UCLA*, *UCL* and *ULg*. The commercial company *iCompany*, the university networks and *CERN* are stub networks. They only contain sources and sinks of traffic but they don't provide a transit service to other networks. To the opposite, transit is the core business of the *BigCarrier* and *Spring* networks. *Abilene*, *GEANT* and *BELNET* are special transit networks. They are government-funded networks and they only provide connectivity among non-profit networks (such as universities). We will consider for this lab session that there is one exception : *GEANT* will provide a commercial transit service to *CERN* since it has no other mean to reach the commercial Internet destinations such as *iCompany*.

One **important objective** of this lab session is the configuration of routing policies to constrain the propagation of routing information among domains in conformance with the business relationships described above. You can obtain more information on the link between business relationships and routing filters in [Gao00, GR00, CR05]. For example, your setup should prevent the *GEANT* network to advertise to *BELNET* routes received from *BigCarrier*, since *GEANT* is not allowed to provide a transit service for commodity Internet traffic to *BELNET*. Another example is the case of *CERN*. Your setup should prevent traffic from transiting through *CERN* as it is a stub network. This must remain true even in case of a link failure between *Abilene* and *GEANT*. We do not list all the business

1. The *Tiny-Internet* setup is inspired from the real Internet, however, any resemblance to existing network names is purely coincidental.

relationships between the different domains but you should be able to infer them from the above paragraph. You are invited to list in your report the business relationships and how your routing policies are defined to enforce them.

Note that in real networks, it is also important to configure routing policies in a way that eases future maintenance. One way to achieve such goal is through the use of BGP Communities. We briefly discuss BGP Communities [CTL96, CB96, BQ03] in Section 3.3.

Domain name	**ASN**	**Description**	**Prefix**
BigCarrier	1	Commercial Transit Provider	1.0.0.0/8
Spring	2	Commercial Transit Provider	2.0.0.0/8
iCompany	200	Enterprise Network	2.1/16
Abilene	11537	US Research and Education Transit Provider	3.0.0.0/24
GEANT	20965	European Research and Education Transit Provider	4.0.0.0/24
BELNET	2611	Belgian NREN	4.1.0.0/24
			1.1.0.0/24
CERN	201	European Research Institution	4.200.0.0/16
			3.200.0.0/16
UCLA	52	University Network	3.1.0.0/16
			2.2.1.0/24
UCL	65535	University Network	130.104.0.0/16
ULg	65534	University Network	139.165.0.0/16

Table 1 –

To build your network model, you will need to make several design decisions just as if you were a network operator. You are of course free to refer to network design and configuration books to learn about best operational practice. Some interesting references are provided at the end of this text [Ste99, HP00, ZB03]. Do not forget to **describe in your report the design decisions you made and why**.

An example of design decision is the assignment of IGP weights to the links. For each router in each domain, you will need to assign an IGP weight. Tuning link weights allows you to influence how the IGP selects shortest paths. You are completely free to select the IGP weights, however, be aware that there are more clever link weight assignments than others. One possibility is to select lowest delay paths. The delay along the links is provided in Fig. 1. We assume that the links without a delay explicitly shown have a 1ms delay.

Note that in this lab session, all the domain networks will be operated by a single person or group : you. However, you need to keep in mind that in the real Internet, these domains are operated autonomously by different entities. In your configuration, you need to take that into account and **maintain a clear distinction** between the configuration of each domain. For example, it is not allowed to configure all the routers of the *Tiny-Internet* in a single IGP domain.

2.1 Some questions to keep in mind

— Ensure that no traffic is allowed to transit through stub networks and more generally that business relationships are enforced with routing filters. It is especially important to enforce the valley-free property and route ranking (customer > peer > provider). See [Gao00, GR00] for more details. Ensure that no commercial traffic is allowed to transit through the research transit networks.
— Try to select lowest delay routes as much as possible...
— Validate the routing selection obtained. Does it match what you expected ? How would you automate that check ?
— Determine what will happen if the link between X and Y fails ? Are you sure the business agreements are still respected ? Example : links between *Abilene* and *GEANT*.

3 Modelling tool

In order to better understand the process of building a network model with the C-BGP simulation tool, it is useful to learn some important facts. C-BGP is aimed at computing the outcome of the routing protocols (in particular BGP) in large networks. C-BGP does not model the network at the physical or link levels. For instance, it does not care about Ethernet segments and switches. C-BGP only cares about the layer-3 adjacencies between nodes. Moreover, the model of the intradomain routing protocol in C-BGP is static. That means that the computation of the IGP routes is done in a centralised way based on the knowledge of the topology, without exchanging information between nodes (as it would happen in a real IS-IS or OSPF network).

To compute the routes in a network, C-BGP takes into account the network topology and the configuration of all the routers. C-BGP is configurable through a CISCO-like command-line interface. A summary of important C-BGP commands is provided in Section 3.2. When configuring large projects, is is often more convenient to write a script that describes the simulation setup. This setup includes several steps that need to be carried in a well-defined sequence. These parts are described in more details in the following paragraphs.

The first step consists in describing the topology shown in Fig. 1. The topology is composed of nodes (routers) and links. A node is created using the **net add node X** command while a link is added using the **net add link X Y** command. At the level of the "physical" topology, there is no distinction between domains.

The second step consists in configuring an intradomain routing protocol in each domain. For this, you need to specifiy to which domain each node belongs. In addition, you need to assign an IGP weight to each link in each domain. To create an IGP domain, you need to use the **net add domain D igp** command. Then, each node can be assigned to a domain by using the **net node X domain D** command. You can assign an IGP weight to a link by using the **net link X Y igp-weight W** command. This command assigns the weight in the direction X to Y. You can assign the same weight to both directions by using the **–bidir** option. Finally, the IGP routes are computed by running the command **net domain D compute**. In addition to IGP routing, it is possible to configure static routes. This can be done with the command **net node X route add D –oif=I W**.

The final step consists in configuring BGP routers. To create a BGP router on one existing node, use the command **bgp add router A X**. To add a BGP neighbor to a BGP router, use **bgp router X add A Y**. You need to change the state of the session with each peer in order to activate them. This is done with **bgp router X peer Y up**. Some neighbors will need routing filters to enforce the business relationships among domains. Routing filters can be configured in two directions : for incoming routes (routes received from the neighbor) and for outgoing routes (routes advertised to the neighbor). Adding an inbound route filter can be done with the command **bgp router X peer Y filter in**. The configuration of routing filters is detailled in Section 3.3.

3.1 Example

In order to help you write C-BGP scripts, this section provides a small but complete example of configuration. The example topology is shown in Fig. 2. It is composed of two domains, each containing 3 routers. In each domain, the routers are fully meshed. The links are all assigned an IGP weight value of 1. Peering links are not configured in the IGPs ; static routes are used instead.

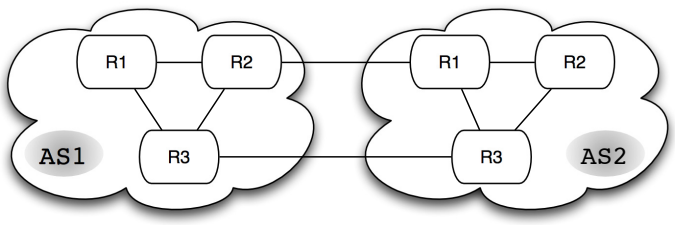

FIGURE 2 – Example topology.

To run the above script, you just copy/paste it into a file and pass it to C-BGP as follows. The output of the final **traceroute** command should appear on the console.

```
student$ cbgp -c net-cours-cbgp.cli
  1     1.0.0.2 (1.0.0.2)       icmp error (time-exceeded)
  2     2.0.0.1 (2.0.0.1)       icmp error (time-exceeded)
  3     2.0.0.2 (2.0.0.2)       reply
student$
```

3.2 Useful C-BGP commands

This section enumerates a large number of C-BGP commands that your setup will probably need. For each command, a short description is provided along with the list of parameters.

- **include F**
  Load and execute a C-BGP script from file F.
- **net add node X**
  Create a new node with IP address X.
- **net add link X Y**
  Create a new link between nodes X and Y.
- **net add domain D igp**
  Create a new IGP domain identified by D.
- **net node X domain D**
  Assign node X to domain D.
- **net link X Y igp-weight [–bidir] W**
  Assign weight W to the link X Y in the direction from X to Y. If the option –bidir is specified, the weight is assigned in both directions. Otherwise, it is assigned only in the direction from X to Y.
- **net domain D compute**
  Compute the IGP routes in domain D. Basically, that means that C-BGP will compute shortest path trees rooted at each node in domain D.
- **net node X route add D [–gw=G] [–oif=I] W**
  Add a static route towards destination prefix D in node X. An optional gateway G can be specified (a recursive lookup will be performed to find the ougoing interface to reach G). An Alternative is to mention the outgoing interface I to be used. The route is associated with a weight W.
- **net node X add iface A T**
  Add a network interface with address A and type T to node X. The type T is one of loopback (lo), router-to-router (rtr), point-to-point (ptp), point-to-multipoint (ptmp), virtual (tun).
- **net node X show rt D**
  Show the content of node X's routing table towards a given destination D. The destination can be an asterisk (*) to obtain all the routes, a prefix P to obtain all the routes that exactly match P or an address A to obtain all the routes that best-match A.
- **net node X show ifaces**
  Show the list of interfaces.
- **net node X show links**
  Show the content of node X's routing table.
- **bgp add router A X**
  Create a BGP router on node X. The router is configured as belonging to the BGP domain A.
- **bgp router X**
  Enter the context of router X.
- **bgp router X add network P**
  Originate a prefix P from router X. This will cause the advertisement of BGP routes towards this prefix to all the neighbors of this router.

— **bgp router X add peer A Y**
Add a peer Y which belongs to the BGP domain A.
— **bgp router X peer Y next-hop-self**
Configure the router to update the next-hop with its own address for routes received from peer Y.
— **bgp router X peer Y up/down**
Open/close the session with Y.
— **bgp router X show peers**
Show the list of peers of a BGP router. This command will also provide the current state of each BGP session (useful for debugging your setup).
— **bgp router X show rib P|***
Show the content of the BGP routing information base for a single destination prefix (P) or for all the destinations (*).
— **bgp router X peer Y filter in/out**
Create an input or output BGP filter for peer Y. See Section 3.3 for more details and a complete example.
— **bgp router X peer Y filter in/out add-rule**
Add a rule to a BGP filter.
— **... match P**
Define the matching predicate P for the routing filter rule. See Section 3.3.1 below for more details.
— **... action A**
Define the action A for the routing filter rule. See Section 3.3.2 below for more details.
— **net node X traceroute Y**
Traces the route from node X to the destination address Y. Note that the traceroute command requires reachability between X and Y in both directions.
— **net node X record-route Y**
Traces the route from node X to the destination address Y. It is not required that Y be able to reach X in order for the record-route command to succeed.
— **sim run**
Run the simulation of the BGP convergence.

3.3 BGP Routing filters

An important part of the simulation setup concerns the configuration of routing filters. This section explains what is a routing filter and how it is configured. Basically, a routing filter is a sequence of rules. Each rule is composed of two parts : a predicate and an action. The predicate describes to which routes the filter applies. An example of predicate is "*all routes towards prefix P*". The action part describes what must be done with the routes accepted by the predicate. There are three main actions : deny the route, accept the route or change an attribute of the route. An example of action is "*set the value of the route's local-preference to 100*".

In the following example, router 1.0.0.1 is configured to assign the local-preference 100 to all routes received from neighbor 2.0.0.1.

```
bgp router 1.0.0.1
    // ...
    peer 2.0.0.1
        filter in
            add-rule
                match any
                action "local-pref 100"
    // ...
```

A common way to configure routing filters in large networks is to rely on a special BGP route attribute named "Communities". Basically, the idea is to define classes of routes that must be treated in the same manner. For example, it is possible to define the class of all the routes received from

customer networks. Technically, to do that, all the routes received from customer networks are tagged with a community value. A community value is simply an integer number that is associated with the route. A route can be tagged with multiple communities if it belongs to different route classes.

In the following example, we assume that we have two border routers 1.0.0.1 and 1.0.0.2. Router 1.0.0.1 is connected to provider AS2 through router 2.0.0.1 while router 1.0.0.2 is connected to provider AS3 through router 3.0.0.1. We do not want to provide transit through our providers. Therefore, we need to avoid sending to one provider the routes received from the other one. We show in the example how router 1.0.0.1 is configured to tag all the routes received from 2.0.0.1 with the community 1 :1 and how router 1.0.0.2 relies on this community to avoid advertising these routes to provider 3.0.0.1.

The following sections list the filter predicates and actions supported by C-BGP. The predicates are shown in Section 3.3.1 while the actions are in Section 3.3.2.

3.3.1 Predicates

- **any**
  Match any route.
- **prefix is P**
  Match routes whose destination prefix is exactly P.
- **prefix is P**
  Match routes whose destination prefix is included in P.
- **path RE**
  Match routes whose AS-Path matches the regular expression RE.
- **community is C**
  Match routes whose Communities attribute contain the given community value.

3.3.2 Useful C-BGP Filter Actions

- **accept**
  Accept the route.
- **deny**
  Reject the route.
- **local-pref L**
  Set the route's local-pref to L.
- **metric M|internal**
  Set the route's multi-exit-discriminator to M or to the internal IGP weight.
- **as-path prepend N**
  Prepend the route's AS-Path N times.
- **community add C**
  Add the community value C to the route's Communities attribute.
- **community strip**
  Remove the content of the route's Communities attribute.

3.4 Debugging your script

What if all fails ? This section lists a few tricks you can use to pinpoint where the issue is.

Suppose you want to perform a traceroute between R1 in UCL (130.104.0.1) and R2 in BELNET (4.1.0.2). Traceroute reports that the destination host is unreachable. That means that R1 has no route that matches 4.1.0.2. This route should have been learned by R1 through BGP. The first action to take is to have a look at R1's forwarding table using the **net node 130.104.0.1 show rt *** command. Look at the result. It should confirm you haven't a route towards 4.1.0/24.

There can be multiple reasons why this route didn't make its way to R1. First possibility, the BGP session between R1 in UCL and R1 in BELNET is not in the ESTABLISHED state. You can check this with the **bgp router 130.104.0.1 show peers**. The command should list the BGP neighbors of R1

in UCL. If you can't see R1 in BELNET (4.1.0.1) it means you forgot to declare this BGP neighbor. If there is an entry with 4.1.0.1, then look at the neighbor's state. It should be ESTABLISHED. If it's not in the ESTABLISHED state, there are 3 other possibilities. First, the neighbor is in IDLE state. That means you haven't declared that the BGP session should be opened (this is done with the **peer up** command). Second, the neighbor is in ACTIVE state. That usually means that the BGP neighbor could not be reached. You need to check if there is one route to reach the BGP neighbor. Usually, it is configured as a static route towards that exact neighbor, i.e. towards 4.1.0.1/32. Third, the neighbor is in OPENWAIT state. That means the BGP neighbor can be reached, an OPEN message has been sent but no answer was received. It is likely that you forgot to run the simulation. When a router sends a message, it is put in a simulation queue. You need to tell the simulator that it must process the content of the simulation queue. This is done with the **sim run** command.

If the BGP session is correctly established, you can check if one BGP route towards 4.1.0/24 has been received. Check this with **bgp router 130.104.0.1 show rib ***. This command will list all best BGP routes. You shoud see a route towards 4.1.0/24. If it's not the case, then you can check if a route was received but was not considered by the BGP decision process. Use the command **bgp router 130.104.0.1 show adj-rib in * *** to obtain the list of received routes. If the route has been received, it is likely that the next-hop was not reachable. You can check what the BGP decision process did with this route by running **bgp router 130.104.0.1 debug dp 4.1.0/24**. If to the contrary, no route towards 4.1.0/24 was received, you need to check in the other routers why the route wasn't propagated.

First, let's have a look at the originator routers. The BELNET prefixes should be announced by at least one of the BELNET routers and preferably by both. Let's have a look at R1 in BELNET with **bgp router 4.1.0.1 show networks**. You should see the BELNET prefixes. If it's not the case, it means you probably forgot to declare the BELNET prefixes. This can be done with the **bgp router 4.1.0.1 add network 4.1.0/24**.

3.5 Keeping the history of cbgp commands

If asked politly, cbgp can store commands typed through the command-line interface in a file. For this purpose, you need to declare the CBGP_HIST_FILE variable in your shell environment. If this variable is empty, a default file name will be used for the file (.cbgp-history) and it will be created in your home directory. You can override the file name by specifiying another file name as the environment variable's value.

The default cbgp history length is limited to 500 lines. This can be overriden with another environment variable named CBGP_HIST_FILESIZE. The variable's value must be a positive integer.

4 Conclusion

A la fin de la 4eme séance de ce TP nous attendons de vous de nous remettre une archive `tiny-internet-xxx.tar.gz` où`xxx` sera remplacé par votre numéro de groupe.

Cette archive comprendra la configuration complète *Tiny-Internet* dans le langage de script de CBGP. Cette configuration peut être fournie via un ou plusieurs fichiers (par exemple un par domaine). De plus vous remettrez un rapport de maximum 6 pages reprenant vos choix et justifications de design.

Références

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