University of Minho
<u>Multiservice Networks</u> **TP Essay n.3** **Study of QoS and Traffic Control Mechanisms in IP Networks** **MEI / MERSTel / MIEI — 1st Year**

Objectives

Comparative study of traffic control mechanisms in IP networks and corresponding parameterization, using the Network Simulator NS-2.

Topology description

The network topology to be used as test platform is illustrated in Figure 1. The network topology includes six clients (from Cli1 to Cli6), two edge routers (E1 and E2), and a core router (C0). The clients' access links have a capacity of 5Mbps and a delay of 5ms.

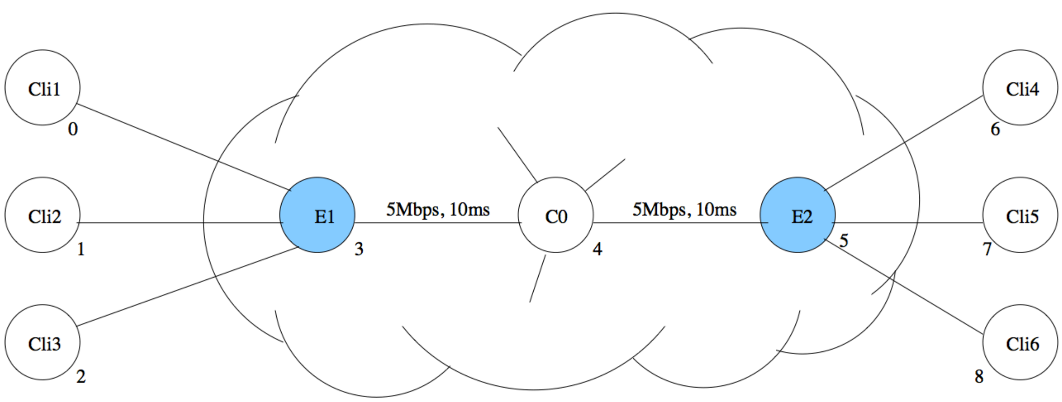

Figura 1: *ISP network topology*

The scripts *qos*.tcl* available in the UMinho e-learning platform include all TCL commands required to implement the topology described above using NS-2.

The topology is deliberately symmetric to simplify traffic analysis. In most of the cases, it will be enough to analyze flows in one way, although there is always the possibility of analyzing flows in both ways.

As the topology evinces, if all clients use the link capacity simultaneously then congestion will occur in the network backbone, and the service provider will not be able to guarantee proper traffic delivery. To minimize or solve this effect, the ISP is expected to implement traffic control mechanisms in order to promote quality of service (QoS) in the domain.

Applications / Services available

- CBR over UDP - generates Constant Bit Rate (CBR) traffic over UDP. This may correspond to the transmission of audio or video traffic at a regular/periodic rate.

  Parameters: rate (bits/sec) e packet size (Bytes);

- FTP - transfer of large files over TCP;
- HTTP - Transfer of web pages of limited size over TCP; the transfer is organized in sessions and may occur more than a page transfer per session;
- Voice over UDP - simulates a voice call over UDP; this traffic is characterized by having a constant rate, alternating between talk and silence time periods.

  Parameters: rate (bits/sec) and burst size (in seconds).

Tools and evaluation metrics

Metrics to use in the simulations:

- Loss rate (total and per flow), in packets/sec
- Bandwidth in use (total and per flow), in bits/sec

The *awk* scripts *loss.awk* and *bw.awk* allow to extract the required data from the output trace file *out.tr* (generated by ns) in order to visualize both metrics.

Please read the NS manual/tutorial [1] or other documentation (e.g., *http://nile.wpi.edu/NS/analysis.html*) to get acquainted with the ns trace format and with the way to extract data from it (e.g. using *awk* scripting).

A possible use of the scripts mentioned above is the following (in case of error try to use `gawk` [2]):

```
$ grep "^d" out.tr | awk -f loss.awk
$ xgraph loss*.gr

$ grep "^r" out.tr | awk -f bw.awk
$ xgraph bw*.gr
```

The scripts generate several files with extension *.gr*, namely: one file reporting the total results and other files reporting partial results for each identified flow. The flows are identified through the pair of values: *node.port* of the source and *node.port* of the destination, for instance, *loss.gr* and *loss_0.0_8.0.gr*.

Other important QoS metrics are one-way delay and jitter, however, they will not be matter of analysis at this stage.

Best-Effort

By default, routers handle packets based on a simple FIFO queuing system, trying to forward them in the best possible way according to the available resources (memory and CPU). This well-known model is called Best-Effort as there are no QoS guarantees on packet delivery (in terms of bounded delays, loss and/or bandwidth utilization).

Copy the script *qos0.tcl* from the course area in the e-learning system to your local working area and run the simulation. To get acquainted with the simulation scenario, consider similar clients with CBR applications, generating each one a rate of 3Mbps, for a total of six flows (0->8, 1->7, 2->6, 8->0, 7->1, 6->2).

A. Answer to the following questions:

- **A.1** Identify the links under congestion.
- **A.2** Using the scripts *loss.awk* and *bw.awk* obtain the graphs illustrating the levels of loss and bandwidth utilization along the time. Now, change the queues associated with the links under congestion from `DropTail` to `RED` and obtain the corresponding results and graphs. Comment the results properly.
- **A.3** Under congestion, what would be the outcome if one client would generate more CBR traffic than the others? Justify.

In a more realistic scenario, it would be expectable to have both UDP and TCP traffic with other characteristics (FTP, HTTP, etc.).

Using the procedures already included in the simulation script, change them in order to obtain the following scenario:

- a CBR application sending 3Mbps from client 1 to client 6, and other from client 6 to client 1;
- a FTP connection from client 2 to client 5, and other from client 4 to client 2;
- a voice connection over UDP from client 3 to client 4, and vice-versa.

B. Obtain the results and graphs that may be useful for analysis in order to answer the following questions:

- **B.1** Identify which applications are more affected by congestion? and why?

Differentiated Services

The model of differentiated services (DiffServ) relies on a specific code inserted within Type of Service (IPv4) or Traffic Class (IPv6) field of IP packet headers, marking them as consequence of a previous classification process. Each code, called Diffserv Codepoint or DSCP, allows to identify packets as belonging to a particular class of service. Without the ability of giving explicit QoS guarantees, DiffServ routers in the network treat each packet according to the class it belongs. Note that the treatment each node gives to a traffic class should be consistent with the one other routers provide within the DiffServ domain.

In a router, packets are temporarily stored in queues (physical and/or virtual queues) before packet forwarding takes place. This poses two questions:

- how to manage packets within a queue?
- how to control packet scheduling among multiple queues?

By default, the usual queuing discipline is FIFO (First In First Out), i.e., packets are queued per order of arrival, being dropped when the queue is full (commonly designated as `DropTail`). This corresponds basically to the absence of an Active Queue Management (AQM) technique in the routers configuration. Recall that AQM techniques, such as RED and RIO, aim to be proactive by discarding packets selectively before queues overflow in order to prevent congestion. For instance, RED (*Random Early Detection*) considers two thresholds in the queue over which the packets are discarded randomly with distinct (configurable) probabilities.

In presence of multiple queues, an adequate packet scheduler needs to be implemented. The network simulator NS-2 supports several traffic schedulers, namely: RR (Round Robin), WRR (Weighted Round Robin), WIRR (Weighted Interleaved Round Robin) e PRI (Priority Scheduler). Please, check the NS manual for their operational details.

Copy the script *qos1.tcl* from the e-learning platform to your personal working area.

C. Answer to the following questions:

C.1 Based on the script code and on the manual, and for the links `E1 - C0` and `C0 - E2`, identify:

- the number of existing queues and the traffic scheduler in use;
- the queuing discipline in use and the configuration of each queue;
- the amount of memory allocated to the queues;
- the queues which handle data flows;

C.2 Taking into account the simulation results/statistics, identify the queue which suffers higher packet loss. Try to justify such behavior.

C.3 Generate the graphs reflecting the packet loss and bandwidth utilization along the time. Comment the results when compared to the best-effort scenario, and explain the differences.

C.4 Assume that traffic from all clients is marked as belonging to the same class of service. Would the option for a single traffic class bring any added value to network QoS when compared with the best-effort scenario?

C.5 Suppose that the service provider intends to implement the following policy:

- To assure a 30% of capacity to clients with identical characteristics (the full capacity may be used if available).
- Traffic exceeding the negotiated rate must be downgraded, i.e., forwarded with lower priority.

The students are expected to propose and justify a concrete solution to implement this policy, using appropriate traffic control mechanisms available within NS2. Include illustrative simulation results, and discuss the pros and cons of the proposed solution from the service provider perspective.

References

[1] NS-2 Tutorial, http://www.isi.edu/nsnam/ns/tutorial/ or http://www.isi.edu/nsnam/ns/doc/ns_doc.pdf

[2] GNU Awk, http://rudix.org/packages/gawk.html