Qualità del Servizio nei Sistemi Geograficamente Distribuiti

Roma, 9-10 Giugno 2004

Delay Bounds For FIFO Aggregates

L. Lenzini, L. Martorini, E. Mingozzi, G. Stea

Università degli Studi di Pisa
Dipartimento di Ingegneria dell'Informazione
Via Diotisalvi, 2
56122 Pisa

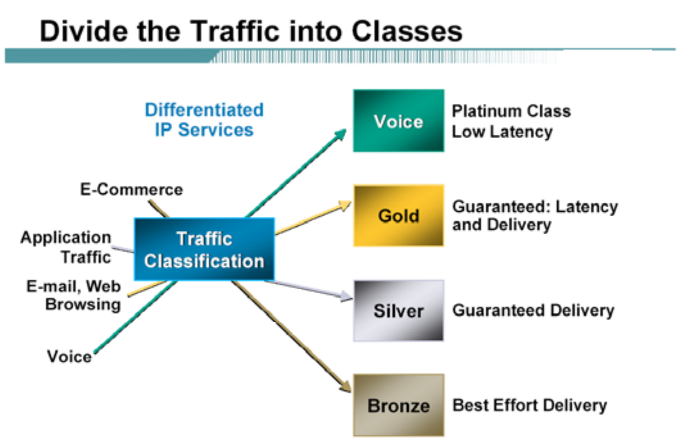
Outline

- ✓ Introduction
- ✓ Results
- ✓ Conclusions and Future Work

Aggregate Scheduling

- ✓ Aggregate scheduling as "the" solution for scaling complexity when providing QoS in Internet
- ✓ A notable example is provided by the *Differentiated Services* (*DS*) architecture

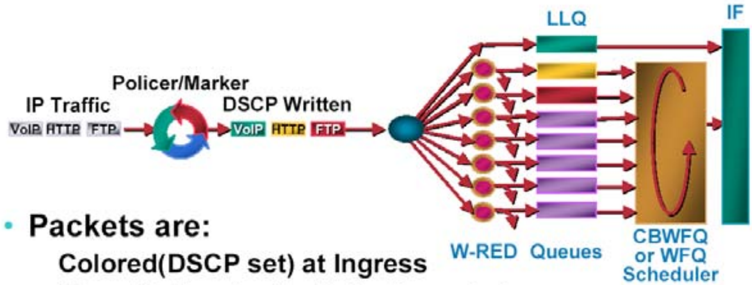
Classifier



According to DS, packets are classified at the DS domain ingress as belonging to a small number of different QoS classes, each one receiving a differentiated service within the network

Edge Router Components

Putting it All Together

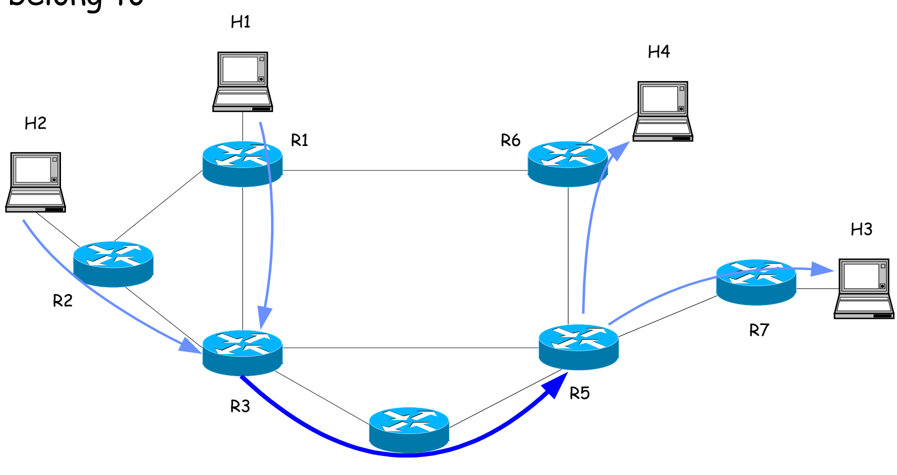


- **Packets are:**
  - Colored(DSCP set) at Ingress
  - Classified and potentially discarded by W-RED (Congestion Management)
  - Assigned to the appropriate outgoing queue
  - Scheduled for transmission by CBWFQ

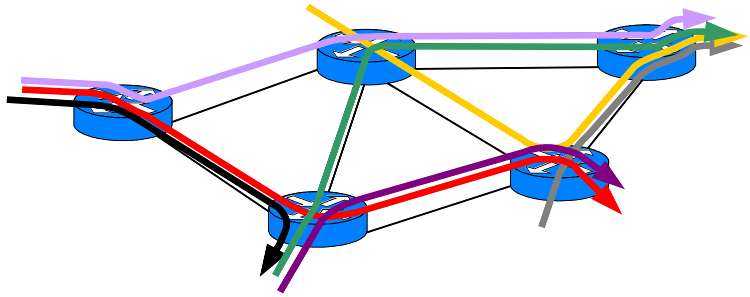
Qualità del Servizio nei Sistemi Geograficamente Distribuiti

DS Interior Components

✓ Packets are treated at core routers according to a specified per-hop behavior (PHB), independently of the flow they belong to



Objective



- ✓ Analytical derivation of delay bounds for individual flows given that capacity is statically reserved to the aggregate traffic at core routers
- ✓ The above bounds can be used as the base for call admission control at edge routers

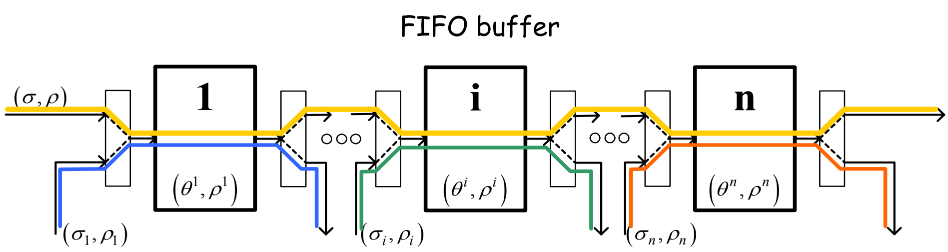
Network Calculus

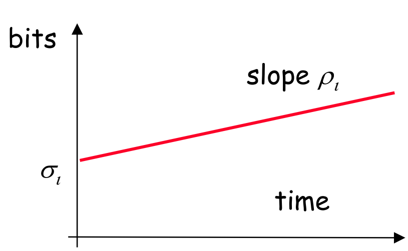
- ✓ Network Calculus is a set of tools and theories for the deterministic analysis of communication networks
- ✓ Application of min-plus algebra
- ✓ Does not supersede stochastic queueing analysis, but gives new tools for analysis of sample paths

Related Work

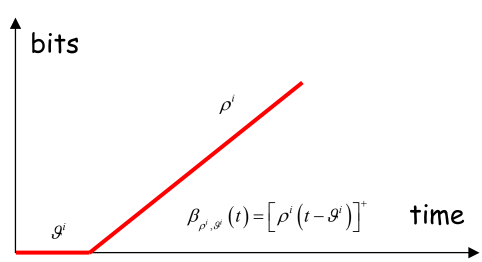
- ✓ Charny, Le Boudec [QoFIS'00]
  - Generic network configuration
  - It holds for small utilization factors: $\nu < 1/(H-1)$
  - Inversely proportional to $1-\nu(H-1)$
- ✓ Fidler [QoS-IP'03]
  - Tandem network, any interference pattern allowed

Case Study 1





Leaky Bucket Arrival Curve



Rate-latency service curve

The result

✓ **Definition**. A subset of all nodes as follows

$$I(l) \triangleq \{ i : (\rho^i - \rho_i) \le (\rho^l - \rho_l) \}$$

❖ **Theorem**. The delay bound is as follows

$$\sum_i \frac{\rho^i - \rho_i}{\rho^i} \le 1 \implies h_{\text{lub}} = \sum_i \theta^i + \sum_i \frac{\sigma_i}{\rho^i} + \sum_i \frac{\sigma}{\rho^i}$$

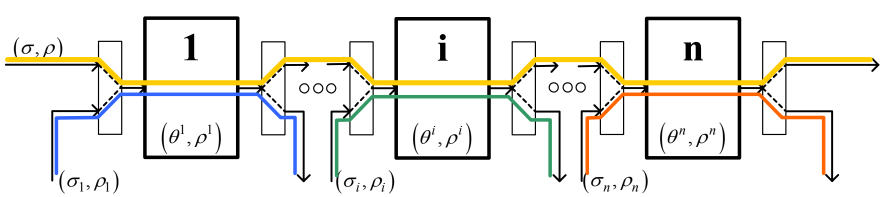
$$\sum_i \frac{\rho^i - \rho_i}{\rho^i} > 1 \implies h_{\text{lub}} = \sum_i \theta^i + \sum_i \frac{\sigma_i}{\rho^i} + \left[\sum_{i \in I(k)} \frac{\sigma}{\rho^i} - \frac{\sigma}{\rho^k - \rho_k} \left(\sum_{i \in I(k)} \frac{\rho^i - \rho_i}{\rho^i} - 1 \right) \right]$$

where node k is such that

$\sum_{i \in I(k)} \frac{\rho^i - \rho_i}{\rho^i} > 1$ and $\sum_{i \in I(l) \subset I(k)} \frac{\rho^i - \rho_i}{\rho^i} \le 1$ for any other l

Qualità del Servizio nei Sistemi Geograficamente Distribuiti

A Special Case



✓ Assume that $\rho^i = \rho + \rho_i$

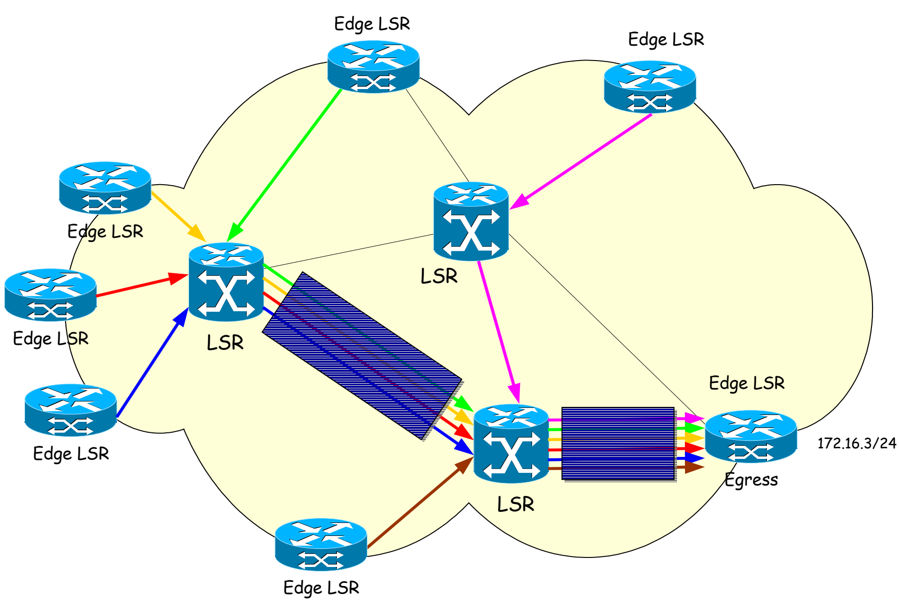
✓ According to the Theorem, the bound is

$$h_{\text{lub}} = \sum_i \theta^i + \sum_i \frac{\sigma_i}{\rho^i} + \left(\frac{\sigma}{\rho} \right) \wedge \left(\sum_i \frac{\sigma}{\rho^i} \right)$$

Reference

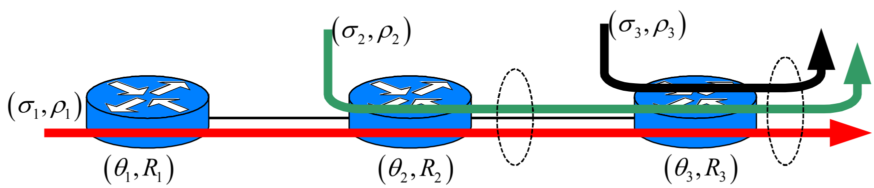
- ✓ L. Lenzini, E. Mingozzi, G. Stea, "Delay Bounds for FIFO Aggregates: a Case Study", Proceedings of the 4th COST263 International Workshop on Quality of Future Internet Services (QoFIS'03), Stockholm, Sweden, October 1-3, 2003

Sink-Tree Aggregation



Path model for a single flow

- ✓ When computing the delay bound for a single flow (e.g., the red one), a sink-tree domain can be modeled as a sequence of nodes, in each of which *one* other flow joins the aggregate
- ✓ All flows leave at the same node, i.e. the sink-tree root

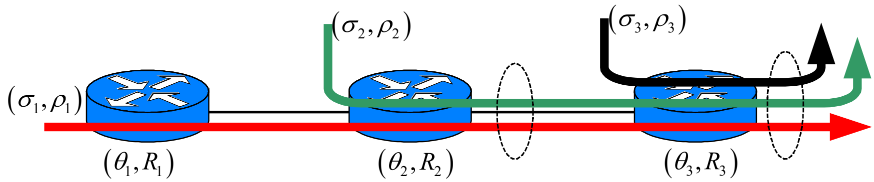


Qualità del Servizio nei Sistemi Geograficamente Distribuiti

The lowest upped delay bound

- ✓ In a 3 node sink-tree, the lowest upper delay bound for a tagged flow is:

$$V = \sum_{x=1..3} \theta_x + \frac{\sigma_3}{R_3} + \frac{\sigma_2}{\wedge\left(R_2, R_3 \cdot \frac{R_2}{R_2+\rho_3}\right)} + \frac{\sigma_1}{\wedge\left(R_1, R_3 \cdot \frac{R_1}{R_1+\rho_2+\rho_3}, R_2 \cdot \frac{R_1}{R_1+\rho_2}, R_3 \cdot \frac{R_2}{R_2+\rho_3} \cdot \frac{R_1}{R_1+\rho_2}\right)}$$



- ✓ The bound is tight

Conclusions and Future Work