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# IP QoS: The Challenge of Building Efficient Networks


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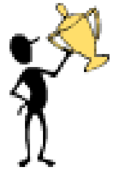
# Outline

- Introduction
- The Internet Today
- Why is IP QoS so Difficult?
- Solutions for QoS
- Internet Service Models
- Some Challenges
- Some Results

# Introduction



- **Definition**

  ***Internet Protocol Quality of Service (IP QoS)***

  **1. At a high level of abstraction**

  ***Ability to deliver network services with consistent & predictable quality (e.g., service availability, delay, delay variations/jitter, throughput, packet loss)***

  **2. At a network resource level**

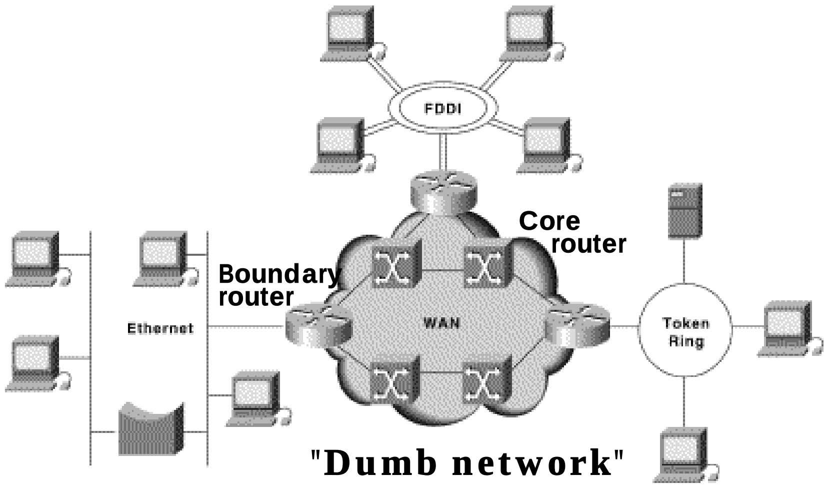
  ***Set of capabilities that a service provider uses to prioritize traffic, to control bandwidth and network latency***

- **Main point**

  **IP QoS claims for resource reservation in the network (bandwidth, buffer space, etc)**

# The Internet Today

- **Internet is characterized by**
  - ♦ Connectionless-based service
  - ♦ Network does the routing whereas the end-system does the control
  - ♦ "Soft state" or no session state in the network
  - ♦ No centralized control but end-to-end control
  - ♦ Users have complete control over applications & selection of services




**Nobody owns the Internet, and nobody can turn it off!**

# Why is IP QoS so Difficult?

- **Fundamental conflict**

**Connectionless service offerings of Internet**
**vs**
**Connection-Oriented service claims by IP QoS**

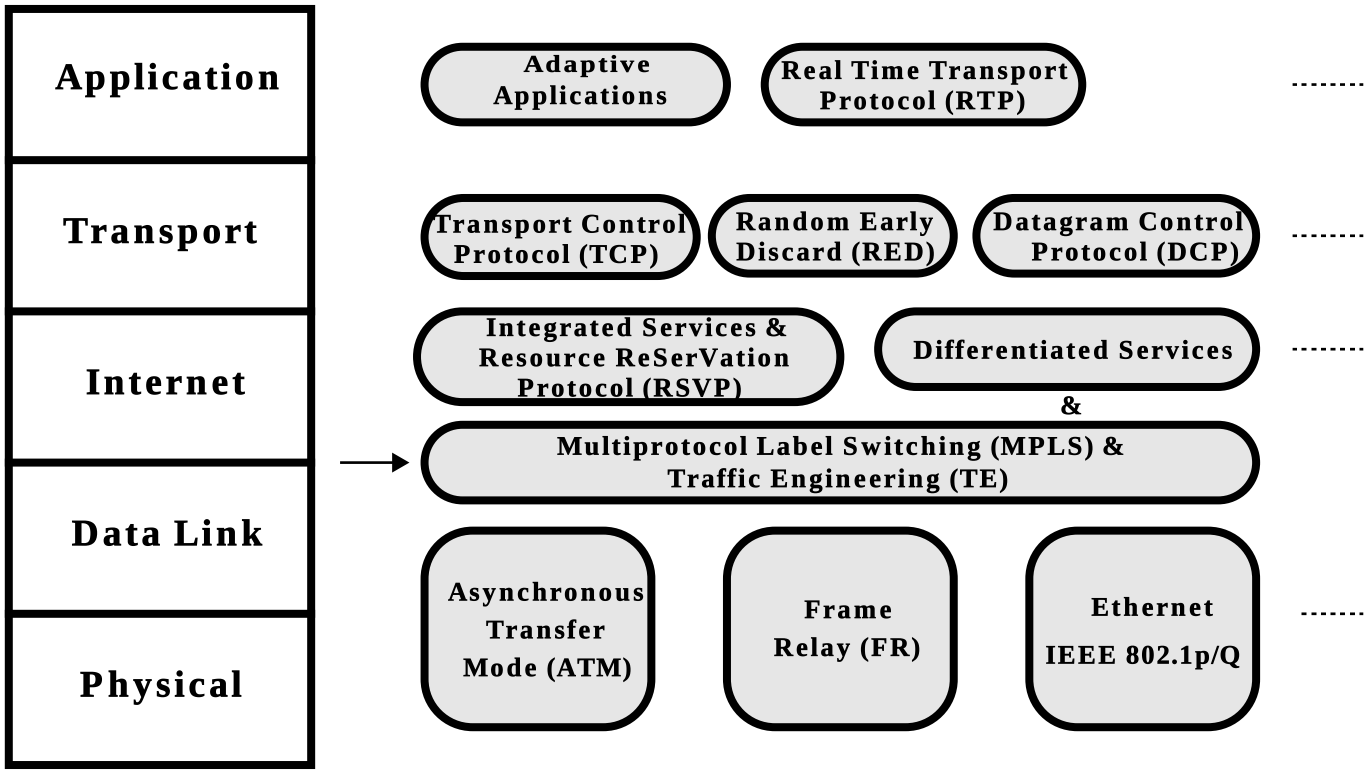
- **On top of that, the solutions must be**
  - ♦ Scalable
  - ♦ Provide for delay control
  - ♦ Provide for differentiation vs competitors
  - ♦ Low operation costs

  ……

# Solutions for QoS

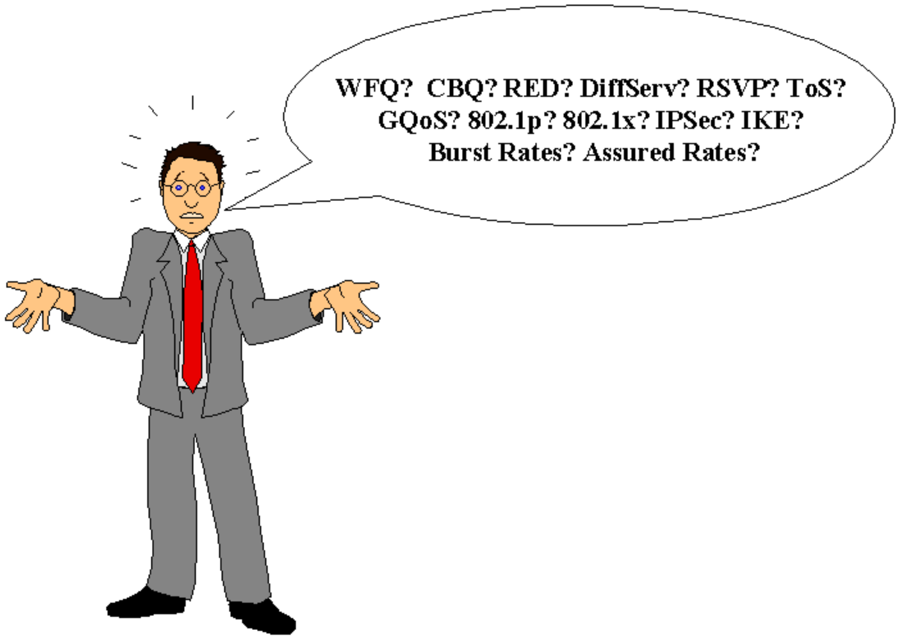
- **Main question**

**How to provide scalable, robust & manageable resource reservation?**

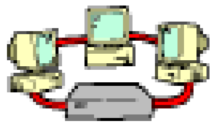


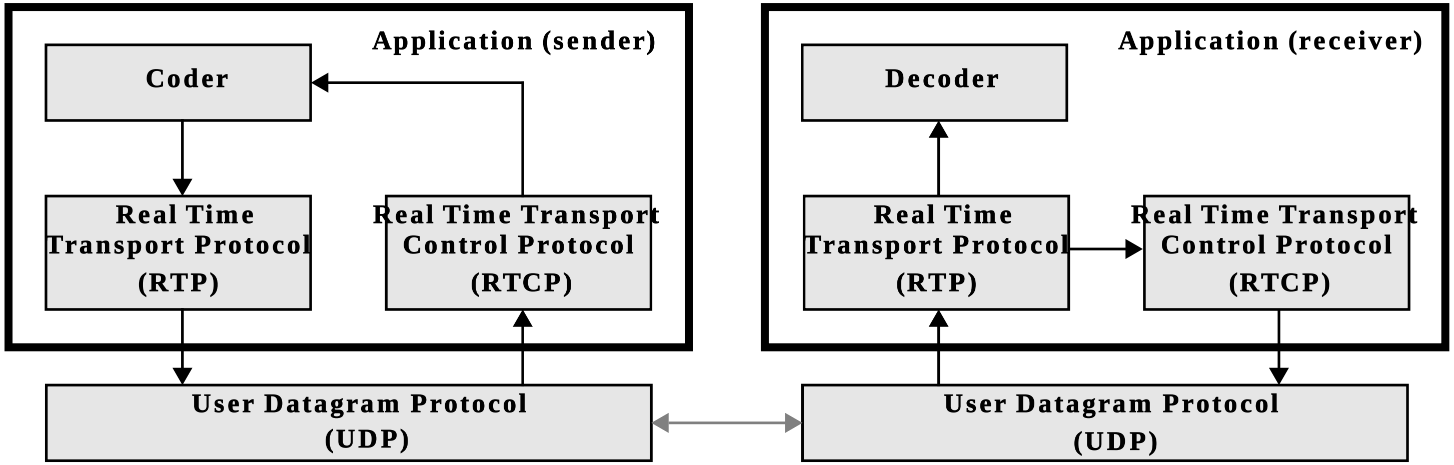
# Internet Service Models

- **Best-Effort Service Model**
- **Integrated Service Model**
- **Differentiated Service Model**
- **Hybrid Model**



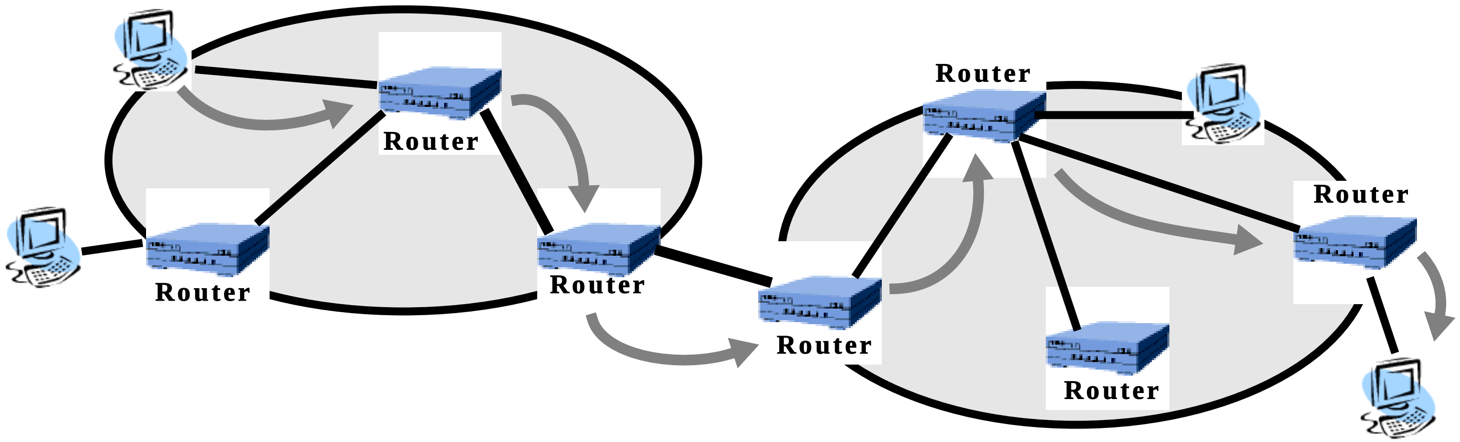
# Best-Effort Service Model





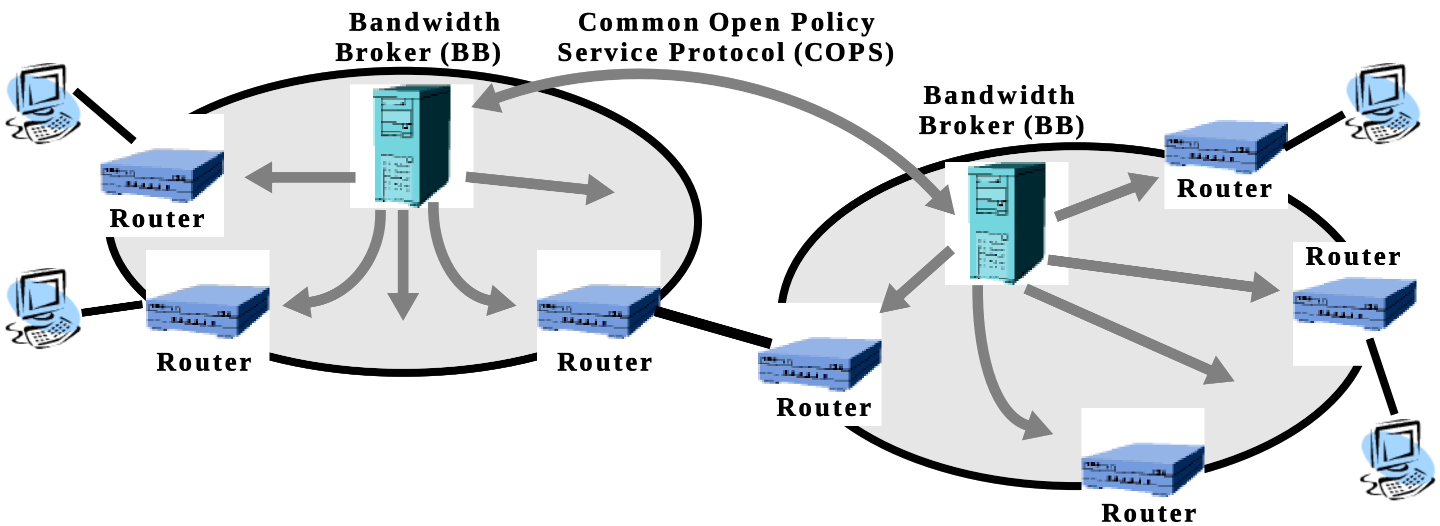

- **Adaptive applications on top of Real-Time Transport Protocol (RTP)**
- **First Input First Served (FIFO) queueing policy within routers**
- **Unpredictable QoS**

# Integrated Service Model



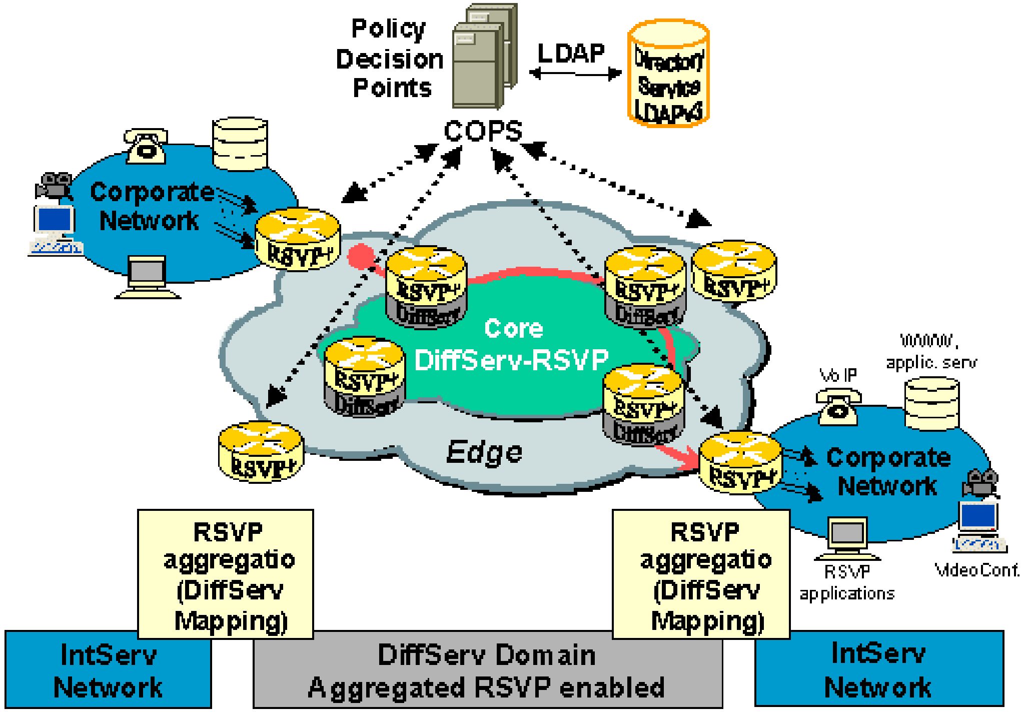

- Used together with Resource ReSerVation Protocol (RSVP)
- Per-flow service state at every hop
- Flow-based QoS guarantees
- Scalability problems!
- Incomplete accounting & billing concepts
- Complex!

# Differentiated Service Model




- Manages each cloud's resources (Bandwidth Broker)
- Focus on aggregates and NOT on individual flows
- Packets are "colored" to indicate forwarding "behavior"
- Policing at network periphery to get services
- Highly scalable!
- "Aggregated" QoS guarantees only!
- Poor on the guarantees for end-to-end applications

# Hybrid Model




- **Emerging model!**
- **Takes benefit of the strengths of IntServ and DiffServ models**
- **Still under study!**

# Some Challenges

- **Scalable solutions**
- **Reliable service levels**
- **Differentiating vs competitors**
- **Dumb vs intelligent routing**
- **Traffic self-similarity**

# Some Challenges (cont.)

- **Dumb vs Intelligent Routing**

Stone-age limitations!

**Today, routers are**

- Simple, unreliable & dumb
- Can't scale
- Can't balance load themselves
- Manual traffic engineering
- Bandwidth over-provisioning has been viewed as solution
- Based on assumptions not challenged in more than 30 years!

**Conclusions**

- No longer possible to run networks profitably with traditional routers
- Networks have become unnecessary complex as equipment is unnecessary dumb

# Some Challenges (cont.)

- **Traffic Self-Similarity**

**Extreme complexity of Internet traffic, showing fractal & multi-fractal properties**

- ♦ Self-similarity
- ♦ Long-Range Dependence (LRD)
- ♦ Slowly decaying variance
- ♦ Heavy-tailed distributions


**Origins**

- ♦ Large variability in file sizes at the application level
- ♦ Traffic aggregation (statistical multiplexing)
- ♦ TCP behavior, it acts as a bearer to Long-Range Dependence

**Serious consequences on traffic control & performance**

- ♦ New mathematical tools are needed for performance evaluation (e.g., multi-fractal traffic models, theory of large deviations)

# Some Results

- **Performance Model**

**Client-server simulation framework**

- ♦ Client & server nodes connected by an Internet cloud (Frame Relay)

**Applications of type WWW, email & FTP are considered**

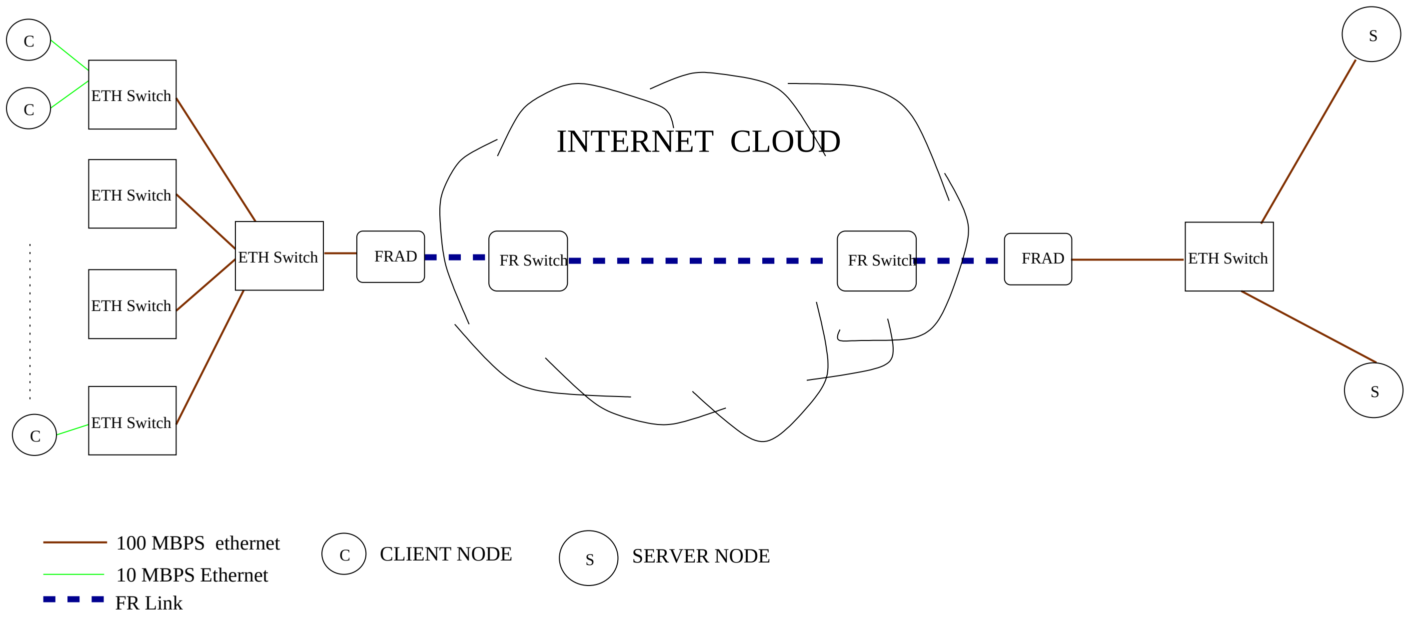
**OPNET simulation environment was used**

**Real Internet traffic flows were used in the model**

**Focus on end-to-end delay performance (while maintaining packet losses within specified limits)**

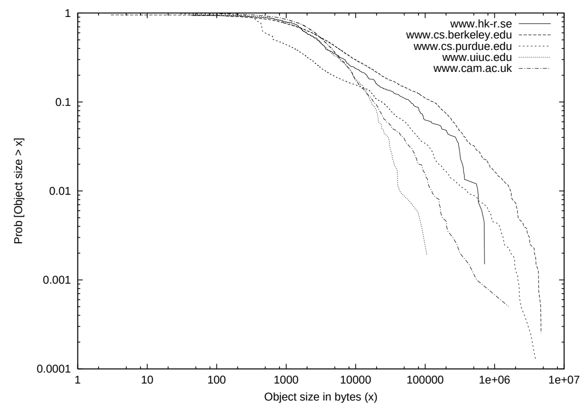
- ♦ Link level
- ♦ Application level

# Simulation Model

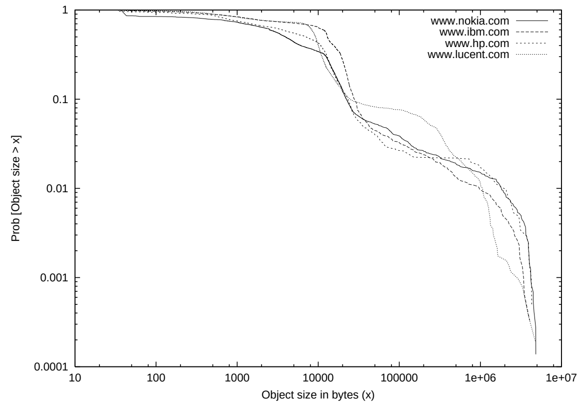



# Application Properties

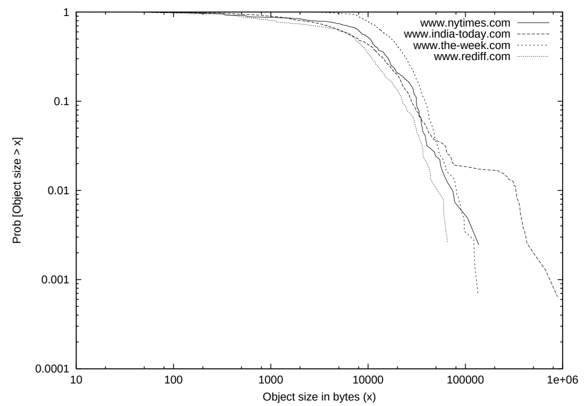
- **Distributional properties of WWW (server side)**



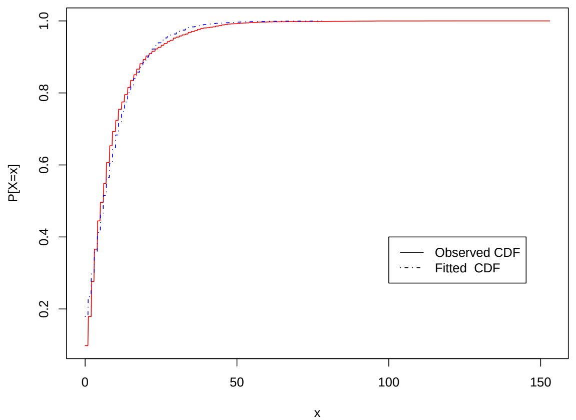

**Universities**
**(mixture of Lognormal & Pareto distributions)**




**Commercial (it.com)**
**(mixture of Uniform & Pareto distributions)**




**Entertainment (media.com)**
**(mixture of Lognormal & Pareto distributions)**

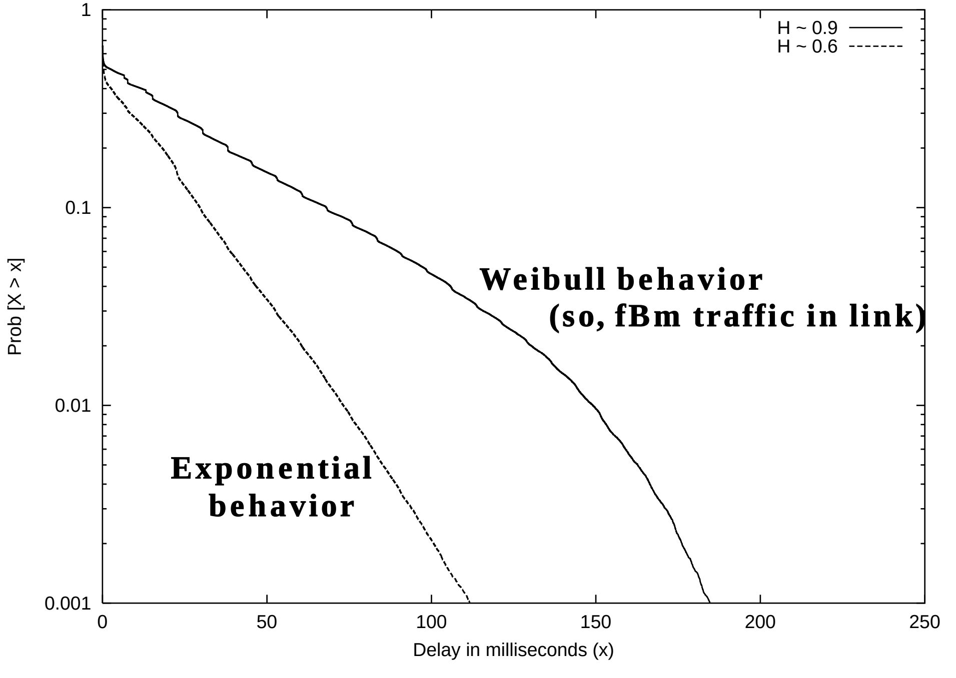



**WWW document structure**
**(negative binomial distribution for the number of embedded documents)**

# Packet Level Delay Performance

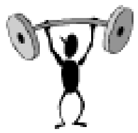
- **Effect of Long-Range Dependence (LRD) on end-to-end delay**

**(High utilization in link; min TCP window size; no Frame Relay control)**



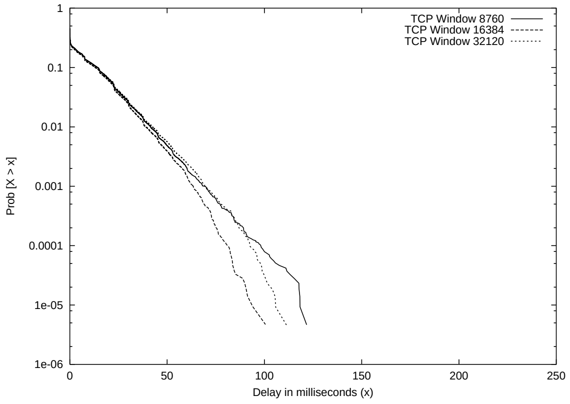

**Profound impact of LRD!**

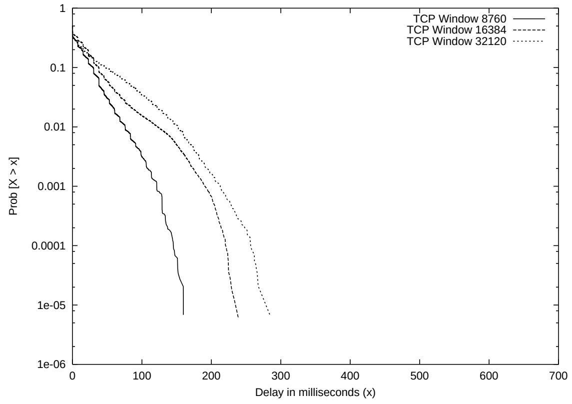
# Packet Level Delay Performance (cont.)



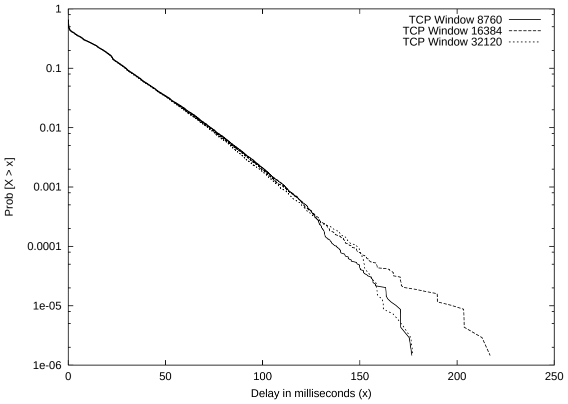
- **Effect of TCP window size (no Frame Relay control)**

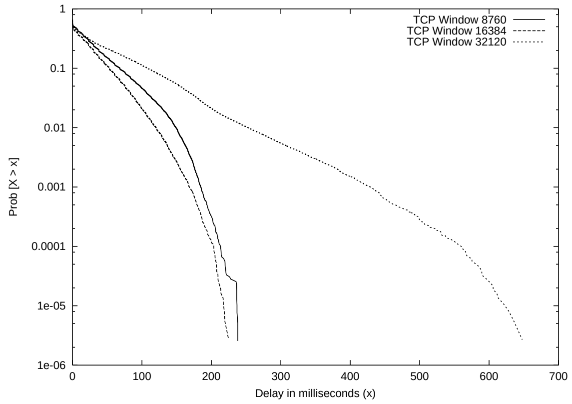
**Low utilization levels**




**High utilization levels**



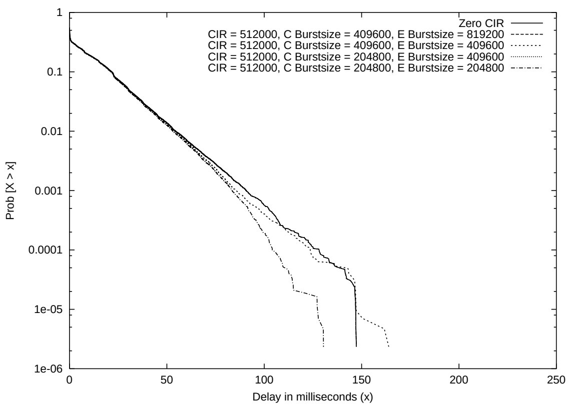



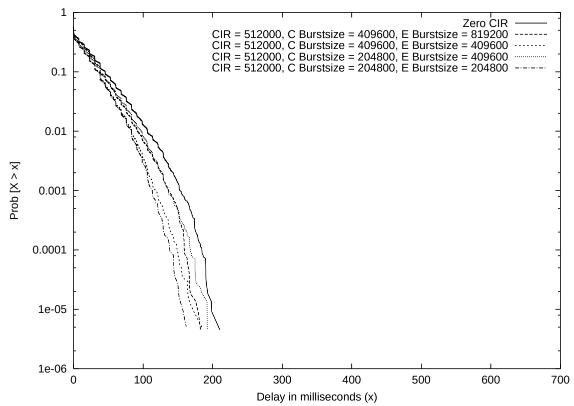

**Short-Range Dependence (SRD) traffic** | **Long-Range Dependence (LRD) traffic**

# Packet Level Delay Performance (cont.)

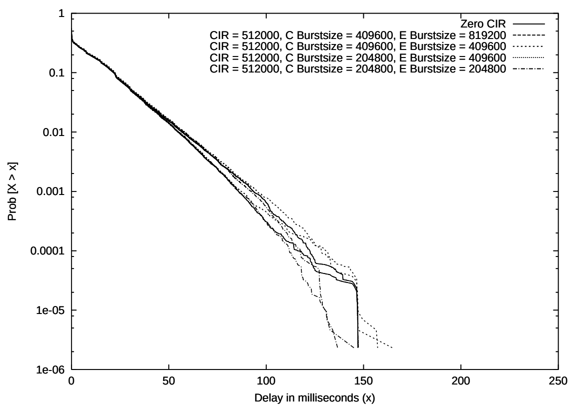
- **Effect of Frame Relay (FR) controls**

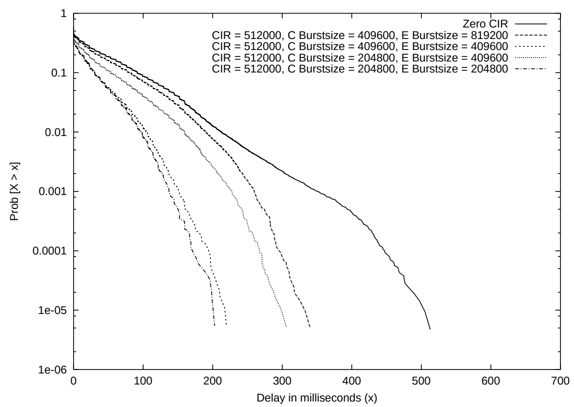
**"Minimum" TCP window size**



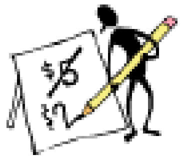

**"Maximum" TCP window size**



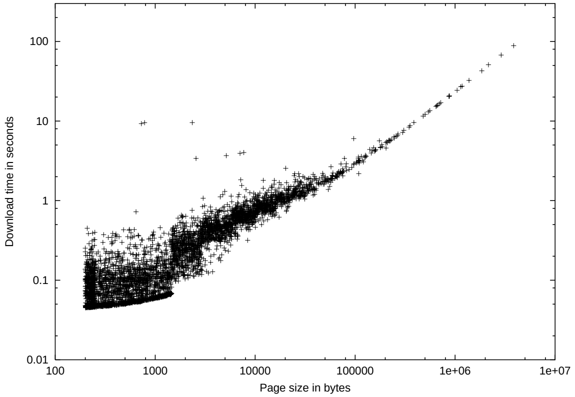

**Short-Range Dependence (SRD) traffic** | **Long-Range Dependence (LRD) traffic**

# Application Level Delay Performance

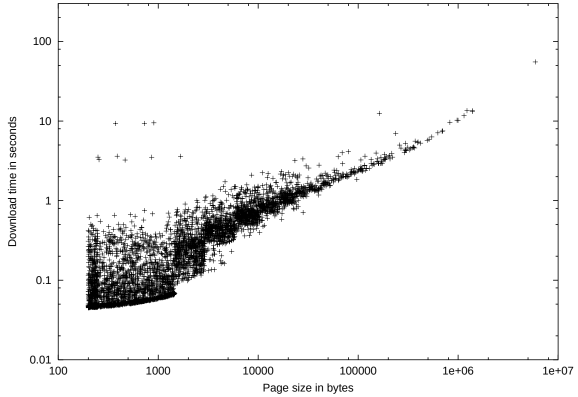


- **End-user delay performance for WWW service**

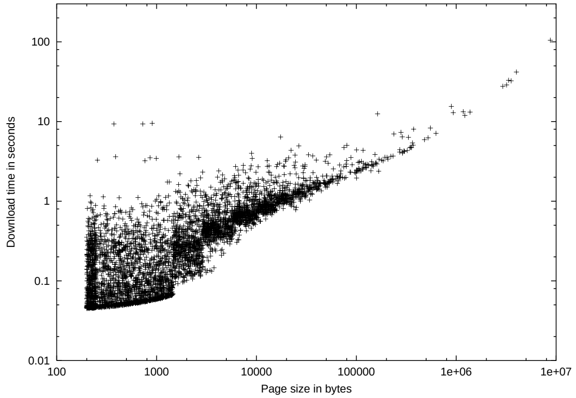
**"Minimum" TCP window size**



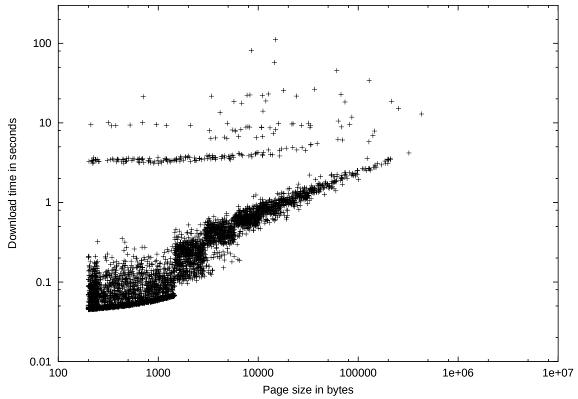

**Soft FR control & larger burstiness accepted**




**"Maximum" TCP window size**




**Tight FR control & small burstiness accepted**




**No Frame Relay control; high utilization**

**Frame Relay control; high utilization**

# Conclusions

- Today's networks are ill builded to take service providers into the future
- Strong need for development of new technologies & protocols for IP QoS
- The new Internet is expected to provide scalability, delay control, load balancing & multi-services
- Research case-study has shown limitations of the actual Internet model
- Focus was laid on Internet resource engineering only

**Thank You!**