

Utility and Quality-of-Service Models for the Dissemination of WWW Resources

Marios D. Dikaiakos

Department of Computer Science
University of Cyprus
mdd@ucy.ac.cy

Athena Stassopoulou

Department of Computer Science
Intercollege, Cyprus
athena@intercol.edu

*Workshop on Web Measurement, Metrics and Mathematical Models
9th International WWW Conference, Amsterdam, May 2000*

Overview

- Web-Content Dissemination via Satellite.
- Motivation.
- Basic Definitions and Modeling.
- Service Configuration through QoS guarantees.
- Conclusions and Future Work.

Web-content Dissemination via SAT

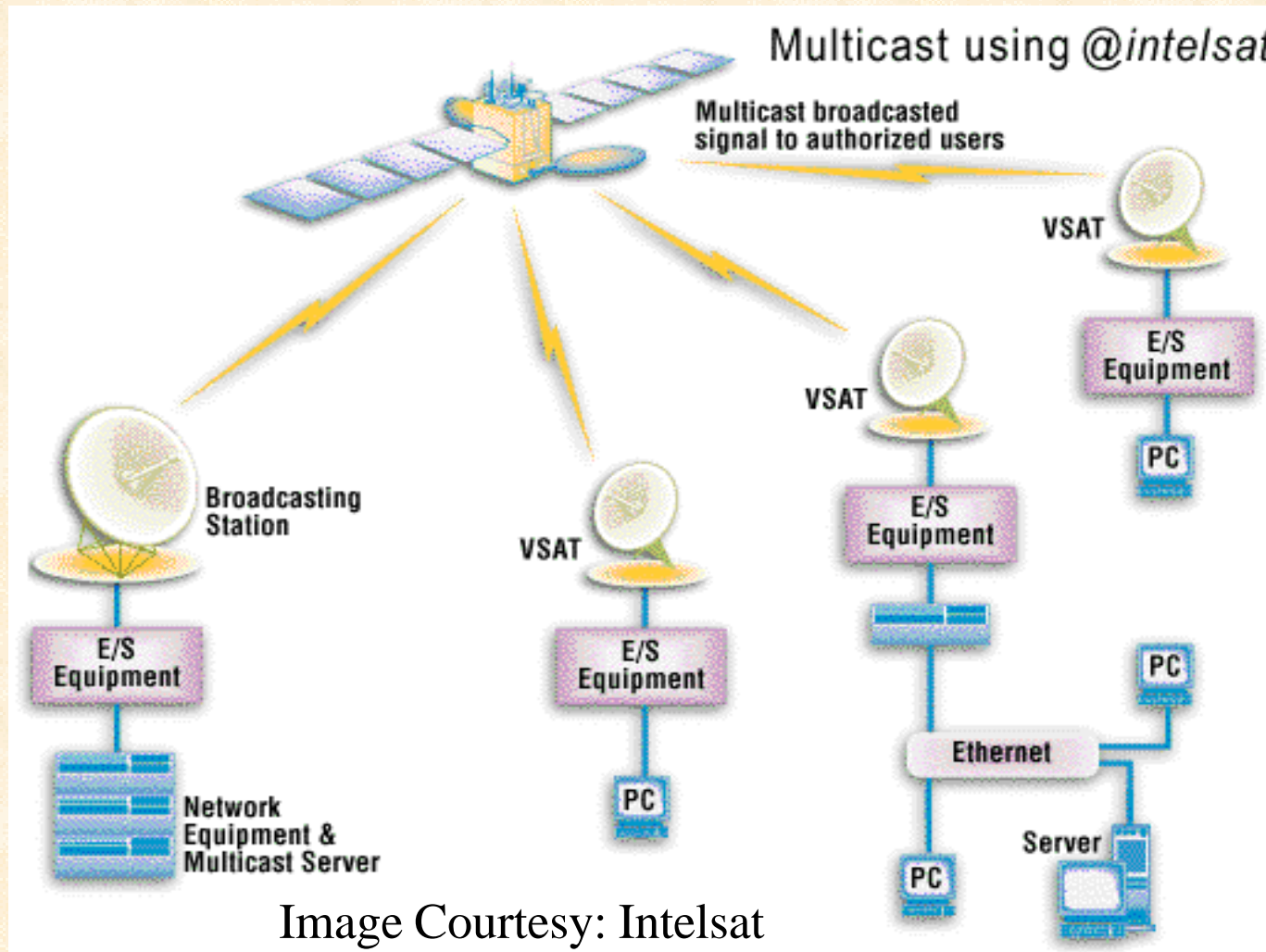


Image Courtesy: Intelsat

**Satellite
Caching**

Motivation

- Selection of the multicast content to achieve client satisfaction.
- Basic Assumptions:
 - Multicasting Web-content with a simple, periodic schedule.
 - Multicast operator collects regularly information about the "interests" of its clients.
 - Multicast operator selects content based on client profiles.
 - Mechanism for prefetching content via alternative path.

A Prefetching Mechanism

- Effectiveness of prefetching for each client determined by:
 - "Adequate" coverage of its interests.
 - An improved hit-ratio for its Web-caching hierarchy.
 - A relief for its (overloaded) terrestrial connections.
 - Price paid for the service.
- Depends on:
 - Selection of content for dissemination.
 - Perception and Formulation of Client Utility.
 - Charging schemes applied by multicast operator.
 - Negotiation framework between operator and clients.

A Modeling Problem

- To select content for dissemination, we need a theoretical framework to:
 - Model *Client Interests*.
 - *Define* of the dissemination service.
 - Formulate the *Utility* derived by each client.
 - Formulate the *Quality of Service* provided.
 - Express relevant *Pricing Schemes*.
 - Articulate a service *Analysis Framework*.

Simple Definitions

- **URL profile** : a description of client interests

$$A_i = \{a_{i,j} \mid j = 1, \dots, n_i\}, \quad i = 1, \dots, M$$

- **Multicast profile**: a definition of the diss. Service

$$A = \{a_k \mid k = 1, \dots, N\}$$

- Characteristics:

$$A \subseteq \bigcup_{i=1}^M A_i \quad A_i \cap A \neq \emptyset, \quad \forall i \in \{1, \dots, M\}$$

- Constraints: $\|A\| \ll \left\| \bigcup_{i=1}^M A_i \right\|$

Simple Definitions (ctd)

- **Similarity Metrics:** between service and profiles

- *Resemblance:*

$$res(A, B) = \frac{\|A \cap B\|}{\|A \cup B\|}$$

- *Coverage:*

$$cov(A, B) = \frac{\|A \cap B\|}{\|A\|}$$

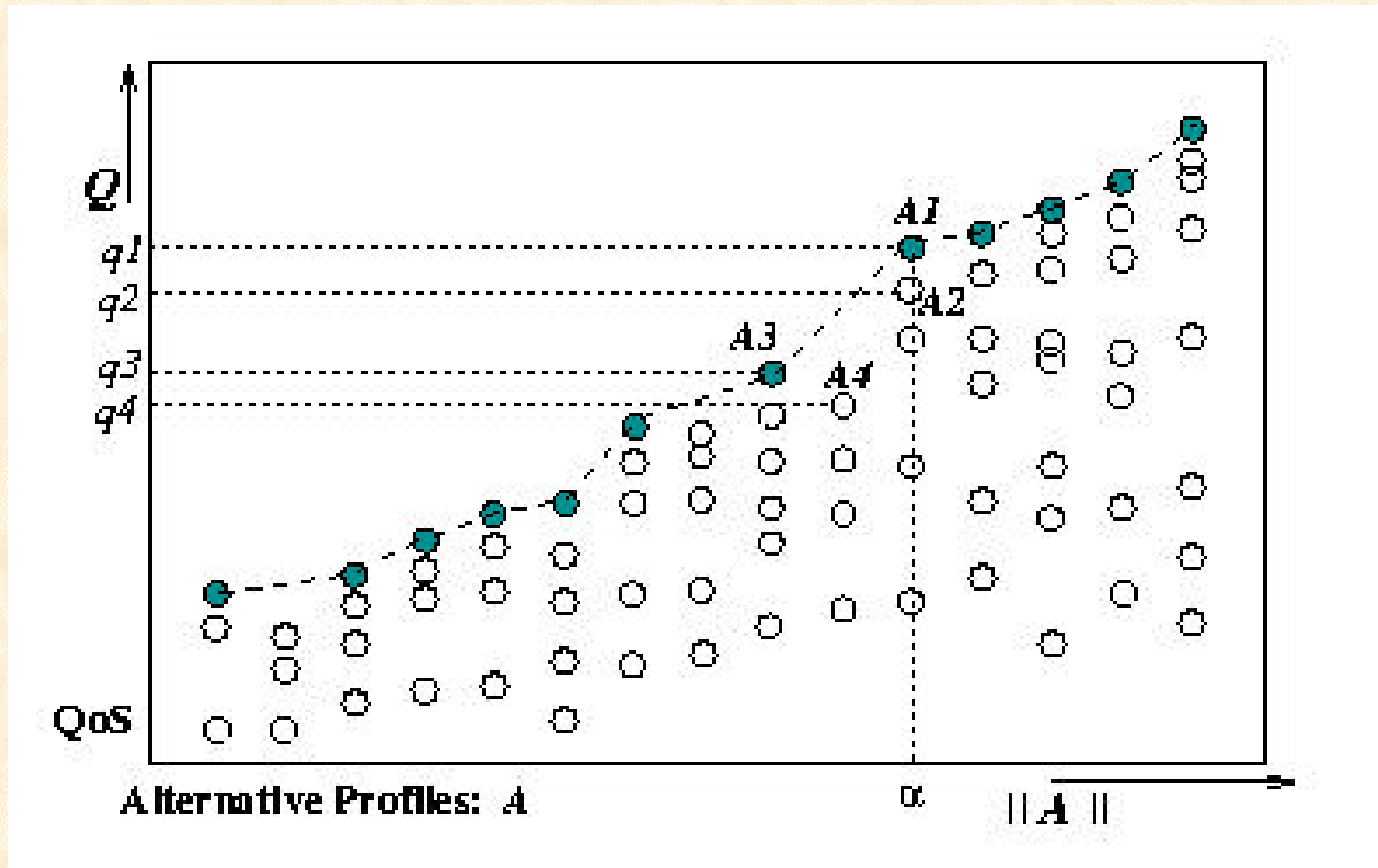
Pricing and QoS Models

- **Subscription-based Pricing:** clients pay the multicast-operator a fixed, monthly subscription fee covering leased satellite equipment and the periodic data feed.
- **Usage-based Pricing:** clients pay the multicast-operator a fixed, monthly subscription fee covering leased satellite equipment, and a monthly fee proportional to the amount of bytes received from the satellite.
- **Quality of Service:**
$$Q(t, A_i, A) = \begin{cases} res(A_i, A) & \text{where } t \equiv \text{Usage-based pricing} \\ cov(A_i, A) & \text{where } t \equiv \text{subscription-based pricing} \end{cases}$$

Negotiating Web-Multicasting Services

- For a given set of client profiles, the multicast operator can generate various alternative multicast profiles providing various Qualities of Service, at different prices.
- Ideally, each client would choose among the set of available multicast profiles, seeking to maximize its own QoS and minimize its charge.
- In this setting, a clients would be willing to consider for purchase only *Candidate Profiles*, *i.e.*, profiles with QoS-values monotonically increasing with respect to price.

"Candidate" Profiles



The QoS Guarantee

- It is not feasible to run an automated negotiation for selecting a candidate profile for multicasting.
- Client considerations can be incorporated in a **service contract**:
The multicast operator pledges to multicast a candidate profile that will provide all clients with a minimum guaranteed QoS value.
 - We call this value the **QoS-guarantee** or **Quality factor**.
 - The multicast operator also seeks to minimize the size of the multicast profile, in order to minimize its cost.

Service Configuration through QoS Guarantees

- Theorem: Given a service configuration established upon QoS-guarantees, the service-cost for the multicast operator is less under Subscription-based pricing, than under Usage-based pricing.
- Problem: Web-content selection under the QoS-guarantee service configuration and for subscription-based pricing is defined as follows:

For a multicast operator with M clients, find a multicast profile A with minimum cardinality, such that:

$$\text{cov}(A_i, A) \geq q$$

for all clients i .

Computing the Multicast Profile

- Web-content Selection is NP-Complete (reduction through *Hitting Set*).
- Polynomial Approximation Algorithm: $O(MN^2)$
- Experimentation shows that, for our approximation algorithm, the *quality factor* determines the *compression rate* achieved by the multicast operator at the computation of the multicast profile.
- Furthermore, that the *quality factor* provides the multicast operator with a good estimate of **worst-case service-costs**.

Conclusions & Future Work

- Introduced a modeling framework for satellite caching that enables us to:
 - Define formally Utility and QoS.
 - Explore and compare different pricing schemes.
 - Propose a service-configuration framework.
 - Specify and resolve the problem of Web-content selection according to our service-configuration framework.
- Extend our analysis and explore other pricing schemes.
- Investigate more efficient algorithms for content-selection.