Charging Middleware for Mobile Computing

Burkhard Stiller
ETH Zürich, Swiss Federal Institute of Technology,
Computer Engineering and Networks Laboratory, TIK, Zürich, Switzerland
E-Mail: stiller@tik.ee.ethz.ch

- Introduction, Resource Valuation, and Network
- Pricing Models
- The Feasibility Problem and CPS
- Conclusions and Future Work

Observed Changes

- Traffic characteristics:
  - Best-effort and guaranteed Services.
  - Reliable and time-sensitive.
- Traffic control:
  - (Soft) state information.
  - Exclusive usage.
- Service integrated networks:
  - Experiences in ATM.
  - How about packet-based networks?
  - How about ubiquitous communications?
- Solution possibilities:
  - Reducing QoS or pricing of differentiated services.
Resources, Service Quality, and Valuation

- Simple text-based e-mail: app. 500 Byte
  - User's valuation: almost zero cost.
- Real-time stock quote: app. 500 Byte
  - User's valuation: difficult to determine (?)
- IP phone call (1 min): app. 12 kByte (16 kbit/s)
  - User's valuation (depending on quality, distance, time-of-day): between almost zero cost and 3,- US$.
- Greeting card e-mail: app. 500 kByte

Is there any clear relation between resources, service quality, and user's valuations of services?

Terminology and Functional Components

- Accounting
- Metering
- Pricing
- Charge Calculation
- Billing

Overall: “Charging”
Generic Architecture of an Access Nodes

- Fairness is based on willingness-to-pay.

Peculiarities of Internet Charging

- Technical feasibility and economic viability.
- Recent charging focussed on feasibility only ...

Combined effects of economic, perceived, technical factors.
Flat Fees

- **Fixed fees for IP access**, independent of:
  - Bandwidth utilization, Quality-of-Service, or congestion.
  - Transmitted information or users' valuation.

- **Advantages:**
  - Simplicity for user and provider, minimal effort.
  - Reduced risk and a simple financial budget.

- **Drawbacks:**
  - Appearance of unintended congestion.
  - No incentives for resource usage.
  - Assignment of bandwidth by time, not by price.
  - Bandwidth assignment based on patience, not (social) valuation.
### Overprovisioning

- Provisioning of "sufficient" bandwidth.
  - Possible due to small/decreasing cost.
  - Regional cost differences.
  - Still, decreasing cost.

- **Advantage:**
  - Larger bandwidth for the same amount of money.

- **Drawback:**
  - There is no natural limit for bandwidth usage.
  - Cost are not limited by an upper boundary.
  - No traffic control in place, lack of sufficient real-time support.

### Usage-based Charging

- Charging depending "on usage".
  - Requires resource allocation mechanisms for managing distinguished resources.
  - Measurement and accounting infrastructure required.

- **Advantages:**
  - Allows for service differentiation based on valuation.
  - Supports the goal of network efficiency and economic efficiency (Pareto efficiency), congestion avoidance.

- **Drawbacks:**
  - Measurement and accounting for each activity, resource.
  - Difficult projection of financial budgets.
  - User reaction on price-QoS ratio unknown.
Relevant Time-scales

Extended Management Time-scales:
- **Atomic**: communication-relevant (Feedback and Monitoring)
- **Short-term**: application-relevant (Intervention and Control)
- **Medium-term**: session-oriented (Service Provisioning)
- **Long-term**: contract-specific (Business and Strategy)

Time-scale “Trilemma” of Internet Pricing

- **Requirements**
  - Customer
  - Provider (economic)
- **Roles**
  - Price Model
  - Provider (technical)
- **Goals**
  - Flat Fees
  - Feedback
  - Accounting
- **Mechanisms**
  - Price Model

**Time**
- ms s min h d wk m y

**Measurements**
- Technical Accounting
- Economic Efficiency
- Transparency, Predictability

**Customer (Re-)Action**
- Time

**Contracts**
- ms s min h d wk m y

© 2001 Burkhard Stiller, ETH Zürich
ETH Designed and Investigated Price Models

- **Integrated Services (IntServ) approach:**
  - **Volume-based price model:**
    - \( \text{Price}(A, t) = \text{Basic\_price}_{SC(A)} \times \text{Volume}(A) \times \text{Duration}(A) \times \text{Traffic\_factor}_{A}(t) \)
  - **Delta Auction:**
    - Incremental Vickrey auction for IP data streams.
    - Minimized signaling, uses reservations.
  - **Connection Holder is Preferred Scheme (CHiPS):**
    - Avoids synchronization effects between providers.

- **Differentiated Services (DiffServ) approach:**
  - **Cumulus Pricing Scheme (CPS):**
    - Long-term, dynamic and traffic-dependent, estimated flat fees with contracted or financial re-negotiation.

Tariffs with a Delayed Reaction

- Tariff with original input parameters of time-scale 1 is transformed by two subsequent tariffs \( \tau_{12} \) and \( \tau_{23} \) to yield an immediate charge (“cumulus points”).
Cumulus Pricing Scheme (CPS)

- ISP offers price function on resource \( x \): \( p(x) = \frac{\lambda}{x^{1/2}} \).
- Customer states resource requirement \( x \) over period \( t \).

**Cumulus Point (CP) Rule** ⇒ Thresholds.
**Reaction Rule** ⇒ Accumulation.

(Economic feedback signals.)

CPS Reaction – Long Time-scale

- A policy-driven price management:
  - Extra payment.
  - Additional contract.
  - Different contracts.
Formal Definition of CPS

- Monthly over/underutilization with respect to resource statement $x$:
  \[ \Delta_i = \Delta(t_i) \]
  i.e.,
  \[ \Delta_i = \int_{t_{i-1}}^{t_i} (V(t) - x) \, dt = \int_{t_{i-1}}^{t_i} V(t) \, dt - x(t_i - t_{i-1}) \]
  - $t_i$ describes end of measurement period $i$.
  - $\theta_{c_i}$ defines thresholds for CP assignments.

- CPs assigned: $0 \leq \theta_{c_i} - \Delta_i < \theta_{c_i+1}$ or $\theta_{c_{i-1}} < \Delta_i \leq \theta_{c_i} \leq 0$

- Reaction threshold: $\Theta$ imbalanced contract: $|\Gamma_n| \geq \Theta$

CPS Simulation

- Real-life scenario:
  - Use sampled data from the lab's LAN.
  - 5 s interval samples from router's MIB.
  - Contains aggregated best-effort IP traffic.

- A.o., questions of interest:
  - Optimizing accounting effort by sampling, what's CPS' stability based on the sampling interval length?

Example:

TIK LAN

ETH Backbone
CPS Stability: Different Sampling Intervals

- CP assignments of real-world network traffic:

  For correct traffic estimation $x$. For 10% underestimation of $x$.

CPS Characteristics

- CPS shows key characteristics of:
  - Handling of user and provider requirements.
  - Addresses rare resources, e.g., frequencies, airtime.
  - Roles re-visited:
    - Customer: Flat-fee like.
    - Provider (economic): Feedback signals (Cumulus Points).
    - Provider (technical): Sampled accounting possible.

- CPS solves the “Trilemma“ (feasibility problem):
  - Technical feasibility of an ISP pricing scheme is more stringent than user preferences or economic efficiency, but it requires a viable balance.

  Prototype implementation: CPS under DiffServ.
Conclusions

- Extension of Internet model with pricing and charging mechanisms feasible.
  - Architecture and functional components.
  - Pricing useful for "high", differentiated QoS levels.
- CPS scheme: long-term, dynamic with traffic estimation and re-negotiation.
  - CPS charges traffic aggregates, commonly used in ubiquitous communications (no per-packet distinction, but service differentiation possible, e.g., based on DiffServ).
- Charging provides an excellent policy
  - to tackle congestion (increased service quality) and
  - to provide cost recovery/revenue for service providers.

Thank you for your attention.

Many thanks to P. Flury, J. Gerke, Hasan, H. Ma, P. Kurtansky, J. Pandey, and P. Reichl as well as to the M3I project.

M3I: http://www.m3i.org or http://www.tik.ee.ethz.ch/~m3i