Charging Middleware for Mobile Computing

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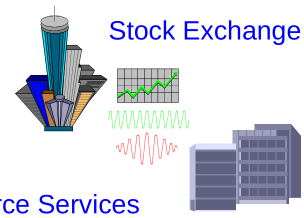
- Introduction, Resource Valuation, and Network
- Pricing Models
- The Feasibility Problem and CPS
- Conclusions and Future Work

Observed Changes

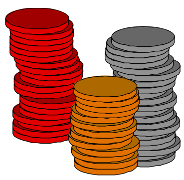
- Traffic characteristics:
  - Best-effort and guaranteed Services.
  - Reliable and time-sensitive.
- Traffic control:
  - (Soft) state information.
  - Exclusive usage.
- Service integrated networks:
  - Experiences in ATM.
  - How about packet-based networks?
  - How about ubiquitous communications?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

Stock Exchange



E-Commerce Services

Broker



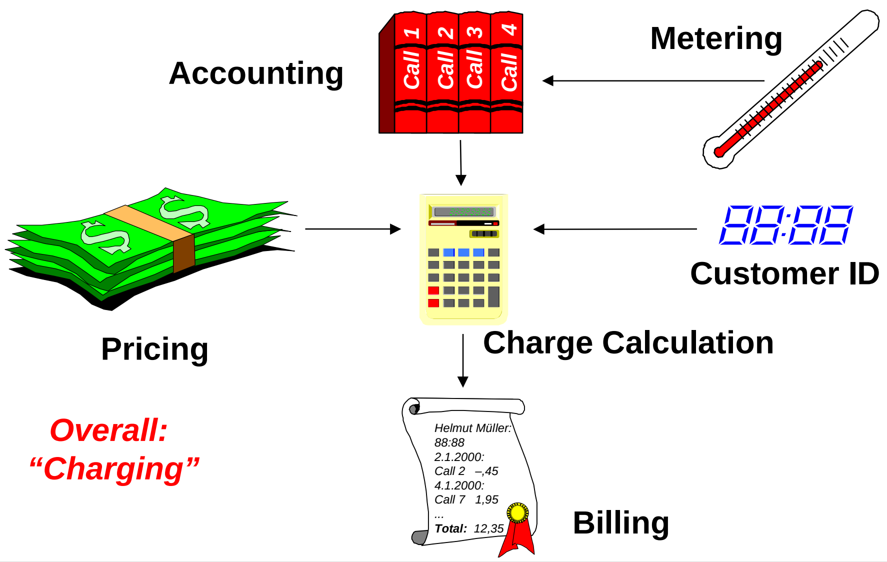
Different Prices for Services

Resources, Service Quality, and Valuation

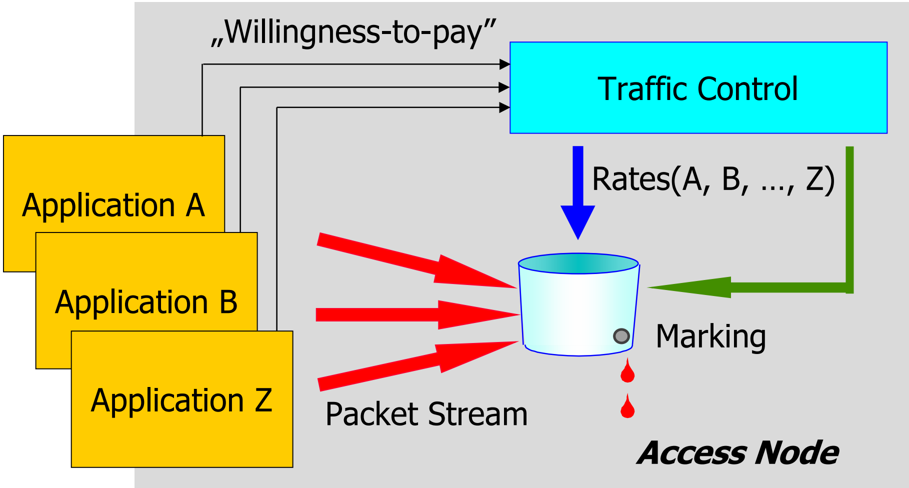
- Simple text-based e-mail: app. 500 Byte
  - User's valuation: almost zero cost.
- Real-time stock quote: app. 500 Byte
  - User's valuation: difficult to determine (?)
- IP phone call (1 min): app. 12 kByte (16 kbit/s)
  - User's valuation (depending on quality, distance, time-of-day): between almost zero cost and 3,- US$.
- Greeting card e-mail: app. 500 kByte
  - User's valuation: Postage of app. -,50 US$.

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

Terminology and Functional Components



Generic Architecture of an Access Nodes



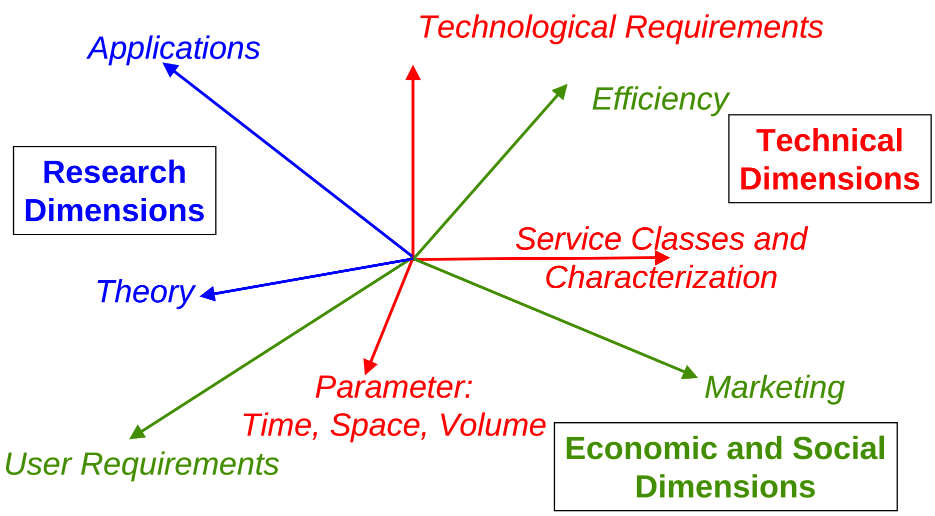
- Fairness is based on willingness-to-pay.

Peculiarities of Internet Charging

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

Combined effects of economic, perceived, technical factors.

Pricing Classification Scheme



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.

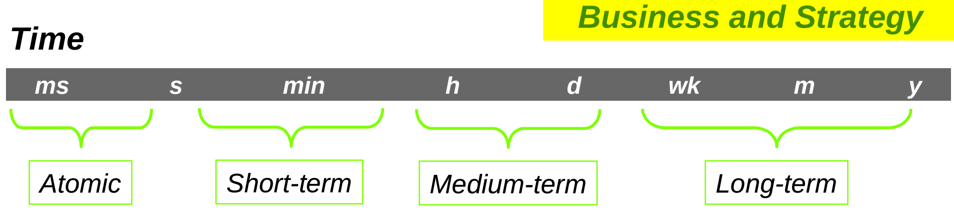
Usage-based Charging

- 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.

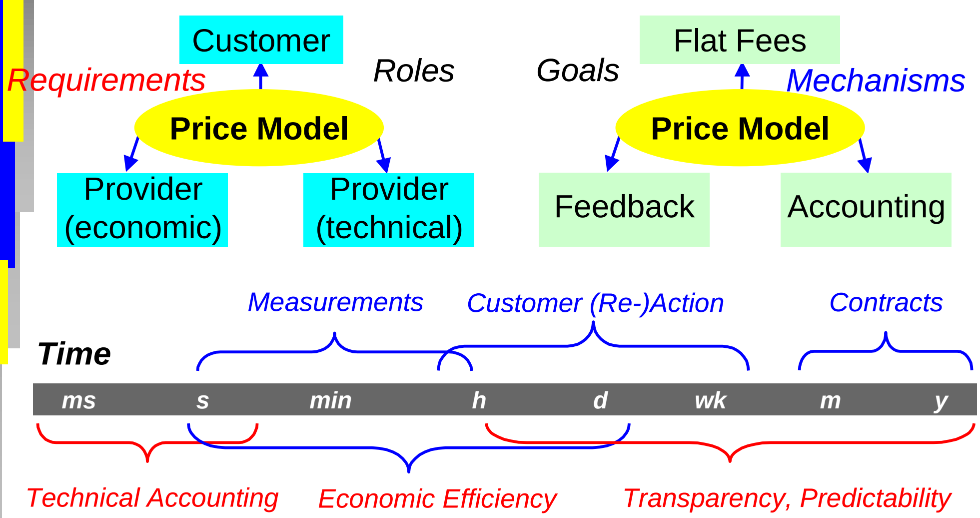
Relevant Time-scales

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



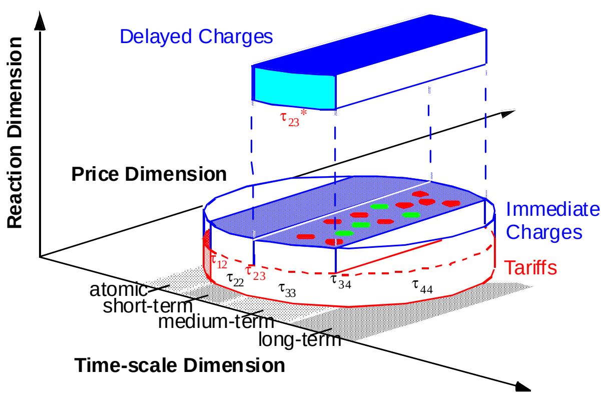
ETH Designed and Investigated Price Models

- Integrated Services (IntServ) approach:
  - Volume-based price model:
    - Price(A, t) = $\text{Basic\_price}_{SC(A)}$ * Volume(A) * Duration(A) * $\text{Traffic\_factor}_{(A)}$ (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.

A Application
DK Service Class
t time

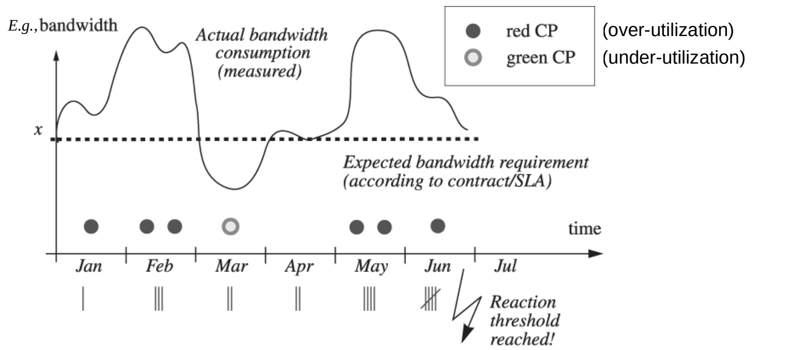
Tariffs with a Delayed Reaction

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



Cumulus Pricing Scheme (CPS)

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

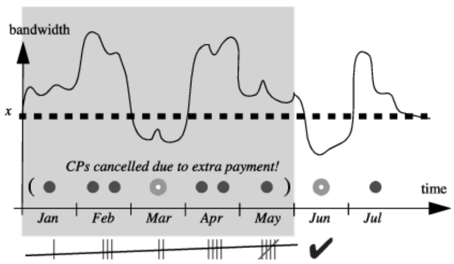


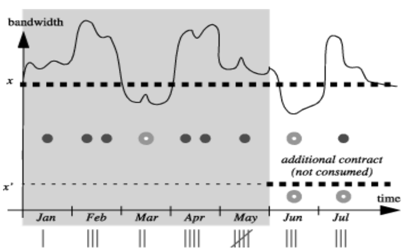
- Cumulus Point (CP) Rule ⇒ Thresholds.
- Reaction Rule ⇒ Accumulation.

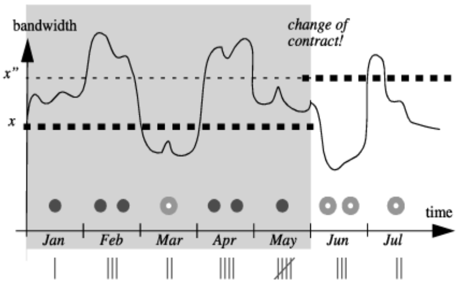
} Economic feedback signals.

CPS Reaction – Long Time-scale

- A policy-driven price management:
  - Extra payment.
  - Additional contract.
  - Different contracts.







Formal Definition of CPS

- Monthly over/underutilization $\Delta_i = \Delta(t_i)$ with respect to resource statement x:

  i.e., $$\Delta_i = \int_{t_{i-1}}^{t_i} (V(t) - x)\,dt = \int_{t_{i-1}}^{t_i} V(t)\,dt - x(t_i - t_{i-1})$$

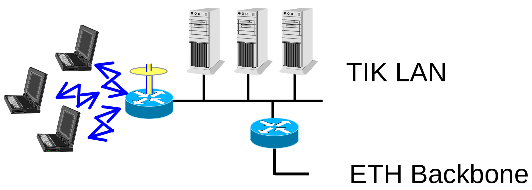
  – t_i describes end of measurement period i.
  – θ_{c_i} defines thresholds for CP assignments.

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

- Reaction threshold: Θ imbalanced contract: $|\Gamma_n| \ge \Theta$

CPS Simulation

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



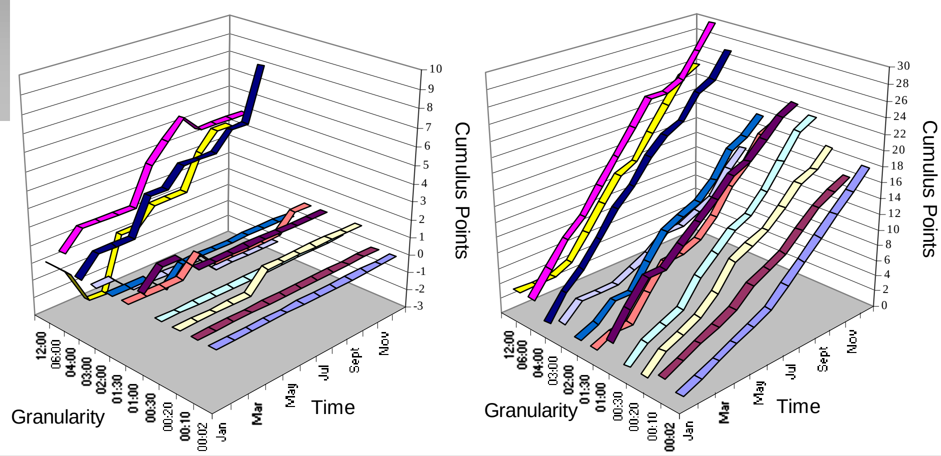
Example:

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

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.

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

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