Pricing and Security of Residential Broadband Access

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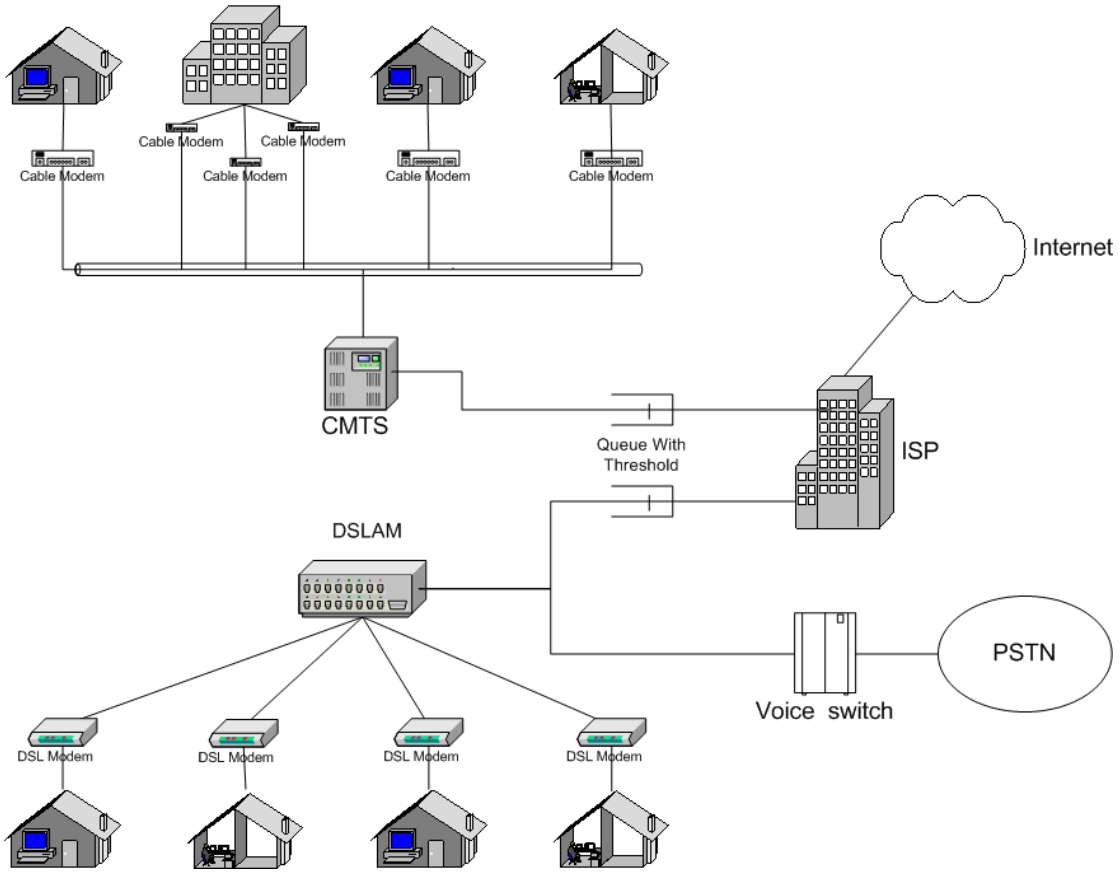
Outline

- Growth in residential broadband access
- Challenges faced by broadband access providers
  - Cost recovery from value-added services
  - Implications of broadband growth for cyber security
- First-hop authentication and packet marking
- A feasible pricing mechanism
- Authentication and authorization Issues

Growth in residential broadband access

- Wired residential broadband access encompasses DSL (telephone companies) and cable.
- All of Comcast's growth is due to broadband internet access.
- What is fueling residential broadband demand?
  - Tolerable incremental cost over a separate phone line (for dial-up access) with dramatic performance improvement in general.
  - Facilitation of "value-added" services such as VoIP, gaming, interactive and high-quality on-demand video.
- Visions of >100Mbps access via cable in near term.
- Goal of penetration from 22% of homes today to > 70%.

Wired residential broadband access



Cost recovery issues

- Expansion of residential broadband access infrastructure is very expensive.
- Probably individual subscription rates will not increase.
- DSL is bandwidth limited: phone companies need new technologies to reach >100 Mbps/user.
  - This, necessitates cost recovery from 3rd party vendors of valued-added services.
- Cost recovery: IP telephony (VoIP)
  - Consider a call between a cable modem IP phone and a plain-old telephone.
    - The VoIP user subscribes to (pays) a 3rd party provider, e.g., Vonage.
  - VoIP provider:
    - Pays telephone companies for circuits to telephone end-systems but
    - Does not currently pay cable/DSL providers for access to IP phones.
  - OK in short term: allows cable companies to “compete” with telephone companies for telephony market (even if they are not getting any revenue).

Implications of broadband growth for cyber security

- Nation's end-systems are vulnerable to attack by viruses, worms, etc.
- Increasing access rates to >100 Mbps may exacerbate large-scale worm or DDoS attacks.
  - Imagine a DDoS attack involving bots with dial-up access vs 100 Mbps access.
- US Government cyber security policy today
  - Recent DMCA and anti-SPAM legislation indicate a shift in US govt towards greater regulation of the Internet.
  - Comments on "*National Strategy to Secure Cyberspace*" policy:

    "Policy makers should consider legislative responses to the failure of existing incentives to cause the market to respond adequately to the security challenge" [NAS-panel, 2003].
  - Government policy may mandate simultaneous "securing" of broadband access together with its expansion.

User versus packet priorities

- Two possible responses to cost-recovery and cyber security challenges are to assign:
  - User priorities: one is either a priority or non-priority user.
  - Packet priorities: each user will potentially have both a priority and non-priority flow.

- Prioritization is introduced to have premium services which will provide better:
  - Availability/reliability.
  - Service quality in terms of packet latency and loss.

Packet priorities: Why?

- User priorities:
  - Allow for simple flat-rate billing (two tier), but
  - need end-user authentication and
  - packets not requiring premium quality-of-service will be given priority treatment.
- Packet priorities:
  - Give "right" incentives for priority marking.
  - Do not completely block a user when there is congestion in access network queues.
- Basic assumption: During high demand contention will largely be at packet level (3rd layer) rather than at data-link level (2nd).

Packet marking: How?

- Unused 2-bit TOS field in IPv4 packet header.
- IETF RFC 3168 suggests using those as notification for congestion at end-nodes.
- Propose end-users employ a TOS bit to indicate packet priority.
- A priority mark could:
  - Indicate participation in a value-add (premium) service or
  - Denote a packet that is part of a more reliable service.
- Marks would have no meaning beyond the 1st PoP of the access provider, i.e., only first-hop packet marking.

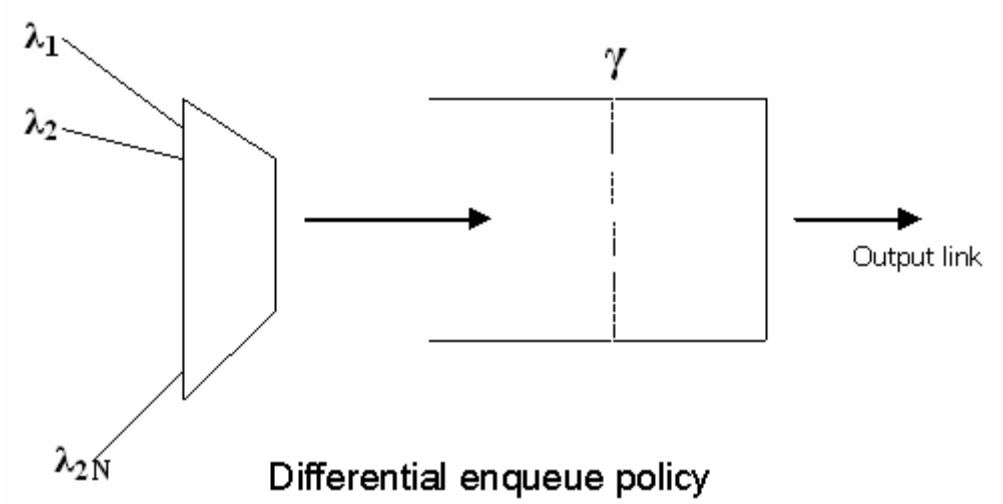
Packet marking: Billing

- Non-priority flow is billed at a flat rate.
- Usage-based pricing on priority flow.
- Need to inform each user of the current “priority spot prices.”
- Need to authenticate the priority flow of each user.
- Access provider can then do cost recovery from user and/or possibly from third-party vendor of value-added services.

Pricing of priority packets

- 1st PoP router handles two priorities of packets (two flows).
- Consider packet memories feeding output links.
- Suppose they use differential enqueue policy based on a threshold (T) rule: when averaged queue backlog exceeds T, drop all non-priority packets.
- Dynamics of such a queue for a fixed usage-price for priority service was previously studied by us.
- Basic assumption on relative significance of L3 congestion (at this queue) versus L2 congestion (between this queue and end-users).
- End-users perceive congestion and elevate certain packets to priority status which is analogous to bidding in a Vickrey auction.
- Can add dynamic “tatonnement” pricing mechanism based on averaged queue backlog (demand).
- Billing accomplished by 1st PoP router and current “spot” prices communicated back to end-users.

Pricing of priority packets



End-user dynamics

- N users each potentially with a low and high priority flow (2N flows and, effectively, 2N users).
- At i^{th} iteration, n^{th} user sets λ_n to:

  $$\lambda_{n,j+1} = G(y_n, \theta_n(\underline{\lambda}_j), \lambda_{n,j})$$

  where y_n is demand and θ_n is QoS.
- Under MIMD, assuming θ_n increases with λ_n:

  $$G(y, \theta, \lambda) = \lambda\theta/y.$$
- When equilibrium queue backlog q<T, continuous-time version of these dynamics were shown to have Lyapunov function:

  $$L(\underline{\lambda}) = \Sigma_n (y_n \lambda_n - I_n \lambda_n^2).$$
- Other differential enqueue/dequeue mechanisms possible that can, e.g., guarantee best-effort traffic is not starved of bandwidth.

Authentication and Authorization Issues

- Security benefits of priority-flow authentication:
  - Cyber attacks are often anonymously launched (at least initially).
  - Such malicious activity will hopefully be restricted to the non-priority flow category.
  - Thus, access of premium flows to the Internet may not be compromised during a cyber attack (assuming that premium flows are preferentially treated at the PoP and, perhaps, elsewhere).
  - So, authentication may improve the reliability of access of premium packets.

Securing priority flows from unauthorized access

- In a dedicated line network access systems (DSL, ISDN):
  - Services are tightly coupled with customer phone number.
  - Impersonation is impossible without physical wire- tapping and traffic injection.
- In a cable modem system:
  - The Data-Over-Cable Service Interface Specifications (DOCSIS) – a dominant US standard – includes Baseline Privacy Plus Interface Specification (BPI+)*.
  - BPI+ provides users with data privacy across the cable network and service protection for Multiple System Operators (MSOs).

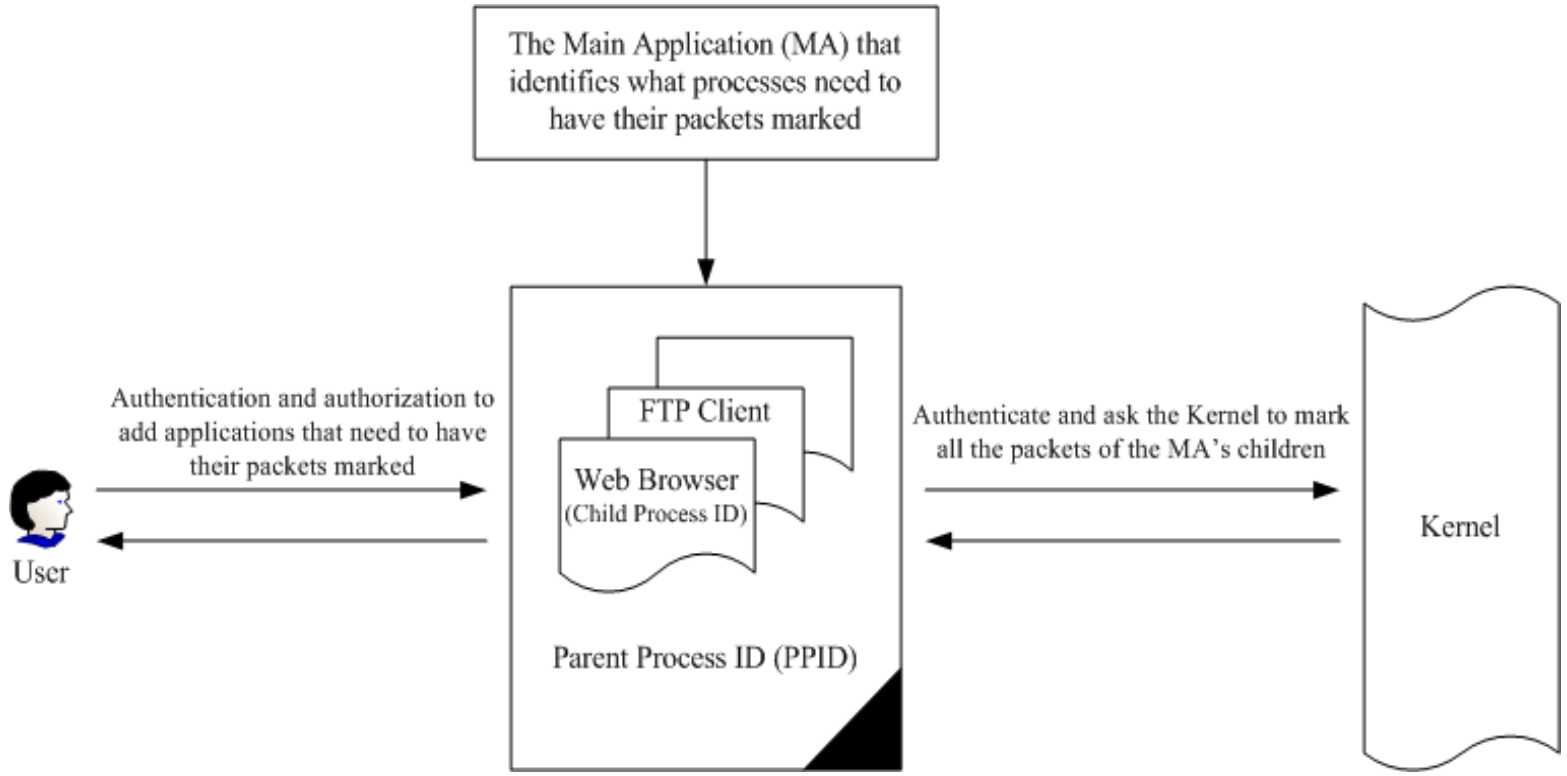
*BPI+ specification describes the MAC-layer security services between cable modems and their CMTS.

Authentication issues (cont)

- Cable Modem: An Issue
  - Problem: Spoofing IP address of the service provider's TFTP server to reconfigure cable modem to illegally increase end-user's bandwidth.
  - Solution: Prohibit a cable modem from registering if there is no matching TFTP traffic through the CMTS preceding the registration attempt.

- Securing priority flow services from malware (worm, trojan, etc.)
  - Include a kernel patch to disable raw sockets.
  - Include a patch to authorize special applications exclusive access to certain fields in IP header.

Authentication Issues (cont)



A security mechanism to protect per-packet pricing services from malware

Summary

- Proposed a mechanism for dual-priority access to residential broadband internet access networks.
- Usage-based and flat-rate pricing for priority service was explored.
- Primary focus was: usage-based pricing as it has
  - Advantages in terms of user incentives.
  - But significantly greater security challenges.

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