Improve Overall Home Network QoS with Credit-based Home Access Point (CHAP)

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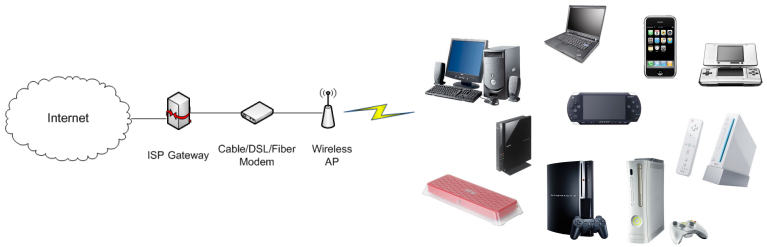
Motivation

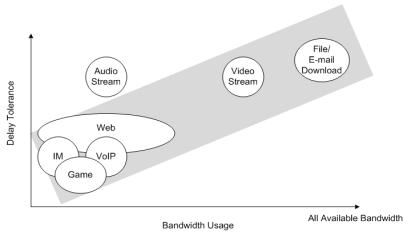
- IEEE 802.11 WLANs widely deployed in both residential, commercial and academic environments
- Wide range of devices connected over IEEE 802.11
- Wide range of QoS requirements from different devices and applications

Typical Home Network Topology and Devices/Activities of Interest

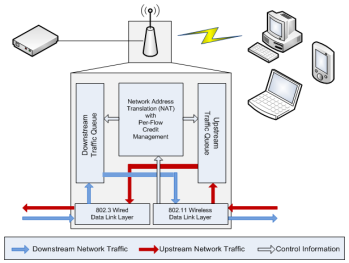


Activities
Instant Messaging
Video Games
VoIP
Web Browsing
Web Browsing (AJAX)
Audio Streaming
Video Streaming
E-mail download
File download (FTP/HTTP/etc)
File download (P2P)

Delay Tolerance vs. Bandwidth Usage



Block Diagram of CHAP



CHAP Algorithm

Downstream Traffic

dequeue()

1. Find k such that $\alpha_k = \max[\alpha_i, \ldots, \alpha_n]$ and $k \in$ set of backlogged flows
2. If $\alpha_k \le 0$ then
3. $\alpha_i = \frac{\alpha_i}{2} + I \quad \forall i \in$ active flows
4. dequeue p from flow k
5. $\alpha_k = \alpha_k - \text{cost}$

enqueue(p)

1. add p to the end of the queue

Upstream Traffic

dequeue()

1. dequeue p from the front of the queue

enqueue(p)

1. add p to the end of the queue
2. find k such that p belongs to flow k
3. $\alpha_k = \alpha_k - \text{estimated cost}$

Delay Analysis

Application of delay analysis model of Probabilitistic Priority Discipline

$\overline{T_i}$: E[sojourn time for class i packets]
$\overline{W_i}$: E[waiting time in queue for class i packets]
$\overline{N_i}$: E[number of packets waiting in queue i]
$\overline{W_o}$: E[residual service time]
$\rho_i : \lambda_i s_i$
$\rho : \sum_{i=1}^{n} \rho_i$
$\tilde{i}$: class other than class i
q_i : probability that class i queue is nonempty
ω_i : probability that the head packet from class i is served when class $\tilde{i}$ is nonempty

Variables needed for calculation

$$\omega_1 = \rho_1, \quad \omega_2 = 1 - \rho_1, \quad \text{and} \quad \omega_1 + \omega_2 = 1 \qquad \beta_i = (1 - q_i) + \omega_i q_i$$

$$q_1 = \frac{[1 + \omega_1\rho_1 - \omega_2\rho_2] - \sqrt{(1 + \omega_1\rho_1 - \omega_2\rho_2)^2 - 4\omega_1\rho_1}}{2\omega_1}$$

$$q_2 = \frac{[1 + \omega_2\rho_2 - \omega_1\rho_1] - \sqrt{(1 + \omega_2\rho_2 - \omega_1\rho_1)^2 - 4\omega_2\rho_2}}{2\omega_2}$$

Average queuing delay experienced by class i packets $$\overline{W_i} = \frac{\overline{W_0} + s_{\tilde{i}} \frac{1-\beta_{\tilde{i}}}{\beta_{\tilde{i}}}}{1 - \rho_i - \lambda_{\tilde{i}} s_{\tilde{i}} \frac{1-\beta_{\tilde{i}}}{\beta_{\tilde{i}}}}$$

Probabilities p_i are calculated based on each flow's credit range

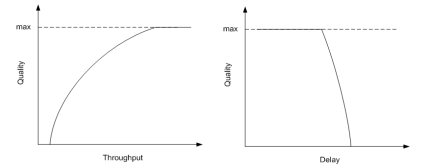
$$p_i = \begin{cases} \frac{\alpha_i^k - \alpha_{i+1}^k}{\Delta\alpha_i} \\ + \sum_{w=1}^{m-2} \int_0^{\alpha_{i+w}^k - \alpha_{i+w+1}^k} \frac{\Delta\alpha_{i+w} - x}{\prod_{y=0}^{w} \Delta\alpha_{i+y}} \prod_{z=1}^{w-1} \left(\Delta\alpha_{i+z} - x - \left(\alpha_{i+z}^k - \alpha_{i+w}^k\right)\right) dx \\ + \int_0^{\alpha_{i+m-1}^k - \alpha_i^l} \frac{\Delta\alpha_{i+m-1} - x}{\prod_{y=0}^{m-1} \Delta\alpha_{i+y}} \prod_{z=1}^{m-2} \left(\Delta\alpha_{i+z} - x - \left(\alpha_{i+z}^k - \alpha_{i+m-1}^k\right)\right) dx \end{cases}$$

Credit Analysis

i : Flow index
C : Total outgoing rate (pkt/s)
R_i : Outgoing rate of flow i (pkt/s)
α_i : Credit of flow i (s)
α_i^h : Upper bound of α_i (s)
α_i^l : Lower bound of α_i (s)
θ_i : Change in α_i over 1 second
I : Increment (s)

Range of Credit of Flow i: $$2I - 2\frac{r_i}{r_k} I \le \alpha_i \le 2I - \frac{r_i}{r_k} I$$

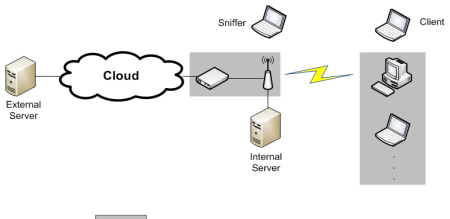
QoS Metric based on Throughput and Delay



$$Q_t(T) = \begin{cases} 0 & , \quad T \le T_{min} \\ -\frac{1}{\log\frac{T_{min}}{T_{max}}} \times \log T + \frac{\log T_{min}}{\log\frac{T_{min}}{T_{max}}} & , \quad T_{min} < T \le T_{max} \\ 1 & , \quad T > T_{max} \end{cases}$$

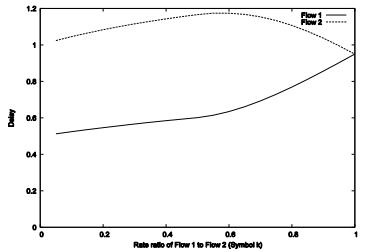
$$Q_t(d) = \begin{cases} 1 & , \quad d \le d_{min} \\ -\frac{1}{(d_{max} - d_{min})^2} \times (d - d_{min})^2 + 1 & , \quad d_{min} < d \le d_{max} \\ 0 & , \quad d > d_{max} \end{cases}$$

Home Network Measurement Setup



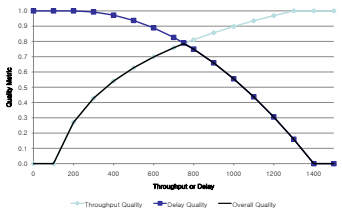
Equipment already resent at home

Delay from the Analytical Model



Generalized QoS Metric

$$Q(T,d) = \min(Q_t(T), Q_d(d))$$



Home Network Measurement Experiment

- Find good and bad locations for the client laptop
- The set of tests run over 48 hours from Tue. morning till Thu. morning
- Each set takes 10 minutes at the most
- The tests to both servers are run every 30 min. with 15 min. apart.

Application	Duration
UDP Ping	2 per second all session long
WRAPI	Query all session long
VoIP	40 seconds
Game (FPS)	40 seconds
Streaming Video (single)	2 minutes
Streaming Video (multiple)	2 minutes
Downstream Speed Test	40 seconds
Upstream Speed Test	40 seconds