A Filtered-based Flow Control Scheme

Chia-Feng Lee(李佳峰)

Department of Communication Engineering
National Chiao-Tung University
HsinChu, Taiwan, R.O.C.

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Outline

- Introduction: General Background
- Notations and Problem Definitions
- Main Results: Properties of Filtering
- Simulation Models
- Simulation Results and Remarks
- Conclusions

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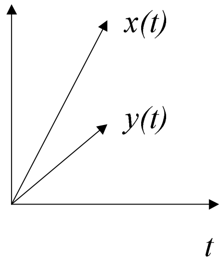
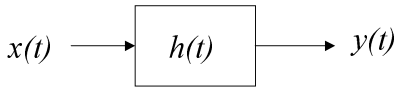
General background : filtering

- In 1998, Chang introduced the notation of "filter" to network.

x(t): accumulated arrival

y(t): accumulated departure





$$y(t) = x(t) * h(t) = \min_{0 \le s \le t} \{x(s) + h(t-s)\}$$

(min,+) : '+' is replaced by 'min' ;

'$*$' is replaced by '+'

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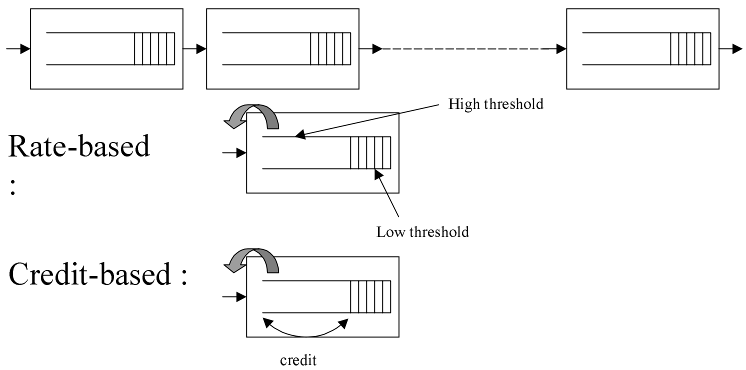
General background : flow control



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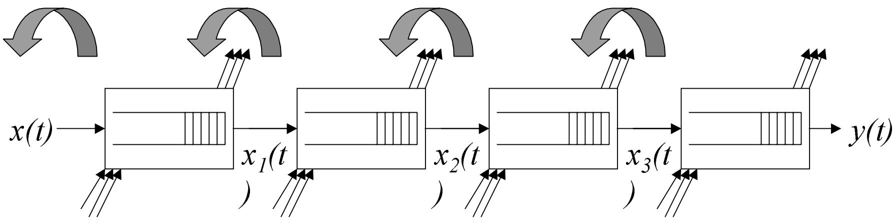
Notation and problem definitions



• Fixed length buffer of size 200

• Aggregated arrivals from other inputs perform like bursty Poisson

• Two cases will be considered: with/without knowledge of information on the degree of congestionness of subsequent network nodes.

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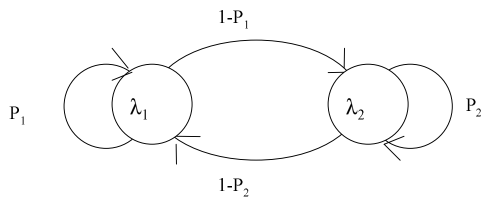
Notation and problem definitions

Bursty Poisson



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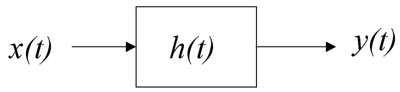
Main results



Given *x(t)* and *y(t),*

how to determine *h(t)*?

$$y(t) = x(t) * h(t)$$

$$Y(w) = X(w) + H(w)$$

$$F(w) = \sum_{t=0}^{\infty} f(t)\phi_1(w,t) \Leftrightarrow f(t) = \sum_{w} F(w)\phi_2(w,t)$$

Lemma 1: Transformation does not exist.

Key idea: By direct substitution .

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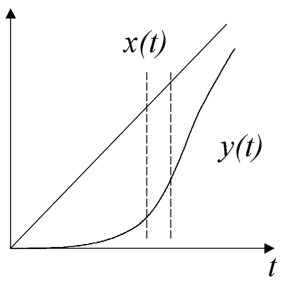
Main results

- **Observation** : Assume that *x(t)* is CBR. If for some *t,* the slop of *y(t)* is greater than that of *x(t)*, there does not exist *h(t)* satisfying *y(t)=h(t)*x(t)*.



Key idea: By direct substitution.

Remark: *h(t)* does not necessarily exist for every *x(t)* and *y(t)*.

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Main results

We distinguish into four cases:

- (unique) If $(\forall t \ge k > 0)\ y(t) - y(t-k) < x(k)$, then *h(t)* exists and is unique. Moreover, *h(t)* is equal to *y(t)* for every t.
- (infinite) If $(\forall t \ge k > 0)\ y(t) - y(t-k) < x(k)$,for all $0 \le t \ne \hat{t}$, but $y(\hat{t}) - y(\hat{t} - \hat{k}) = x(\hat{k})$,for some $0 < \hat{k} \le \hat{t}$,then *h(t)* exist,and has infinite number of solutions.
- (none) If $(\forall t \ge k > 0)\ y(t) - y(t-k) > x(k)$, for all $0 \le t \ne \hat{t}$, but $y(\hat{t}) - y(\hat{t} - \hat{k}) > x(\hat{k})$, for some $0 < \hat{k} \le \hat{t}$,then *h(t)* does not exist, provided that $\hat{t} > 1$.

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Simulation Models

- Accumulated arrival *x(t)* and accumulated departure *y(t)* can be measured
- *h(t)* satisfying *y(t)=x(t)*h(t)* may not exist.
- To find $\hat{h}(t)$ such that $\| \hat{y}(t) - y(t) \|$ is minimized, where $\hat{y}(t) = x(t) * \hat{h}(t)$.
- Restrict $\hat{h}(t)$ to be first-order. Represent it by *ct+d.*

x(t) → $\hat{h}(t) = \arg\min_{h(t)} \| h(t) * x(t) - y(t) \|$ → $\hat{y}(t)$

- Criterion: $\| \hat{y}(t) - y(t) \| = \sum_{t=0}^{n-1} | \hat{y}(t) - y(t) |$

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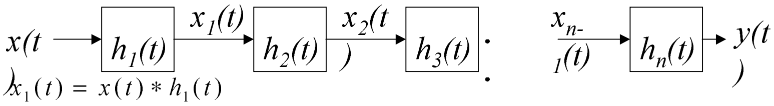
Simulation Models



$$x_1(t) = x(t) * h_1(t)$$

$$x_2(t) = x_1(t) * h_2(t) = x(t) * h_1(t) * h_2(t)$$

•

•

$$y(t) = x_{n-1}(t) * h_n(t) = x(t) * h_1(t) * h_2(t) * \cdots * h_n(t)$$

$$= x(t) * h(t)$$

$$\Rightarrow h(t) = h_1(t) * h_2(t) * \cdots * h_n(t)$$

- If $h_k(t)$ can be represented by $c_k \cdot t + d_k$, then $h(t) \approx \min\{c_1, c_2, \cdots c_n\} \cdot t + d_1 + d_2 + \cdots + d_n$.

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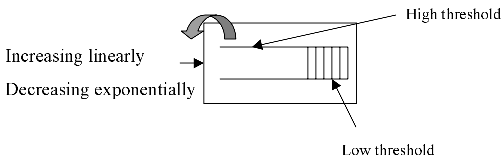
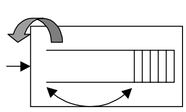
Simulations Models

Regulation methods

•Rate-based flow control:



•Credit-based flow control:



Credit=(buffer length available) *

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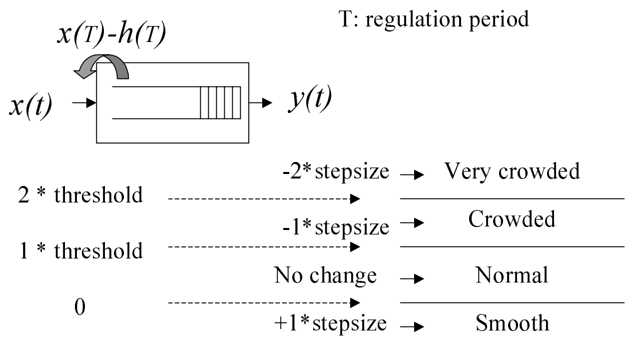
Simulation Models

•Filter-based flow control:



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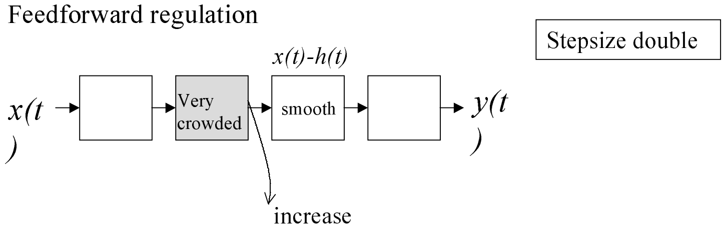
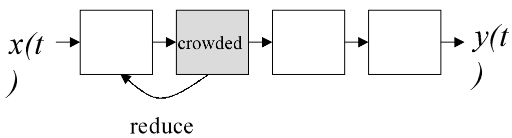
- Filter-based flow control(cont.)
  - Feedforward regulation



  - Feedback regulation



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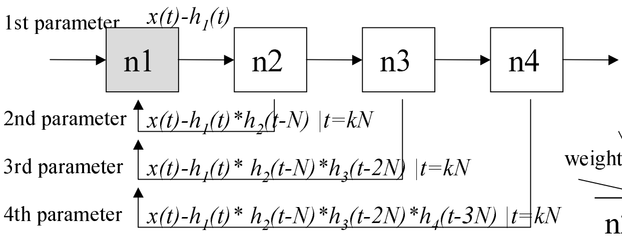
- Filter-based flow control(cont.)
  - History information and reliability of coefficients

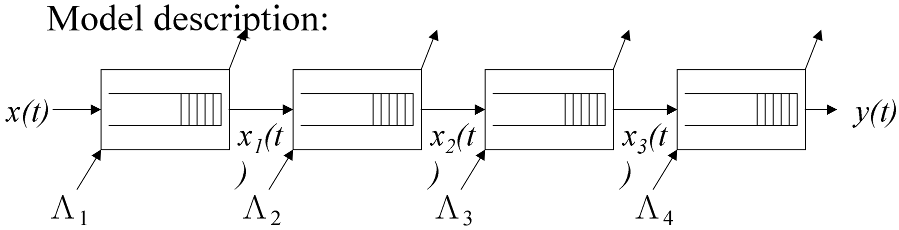


weights	1st para	2nd para	3rd para	4th para
n2	N/A	0.5	0.3	0.2
n3	N/A	N/A	0.6	0.4
n4	N/A	N/A	N/A	1

weights	1st para	2nd para	3rd para	4th para
n1	0.5	0.25	0.15	0.1

Simulation Models

Model description:



- Mean rate of Λ_1, Λ_2, Λ_3 and Λ_4 is 45, where Λ_1, Λ_2, Λ_3 and Λ_4 are bursty Poissons.
- Bufferlength = 200.
- Initial rate of $x(t)$ is 5, $0.5 \leqq x(t) \leqq 10$.

Simulation Results and Remarks

Divide the simulation process into two steps:

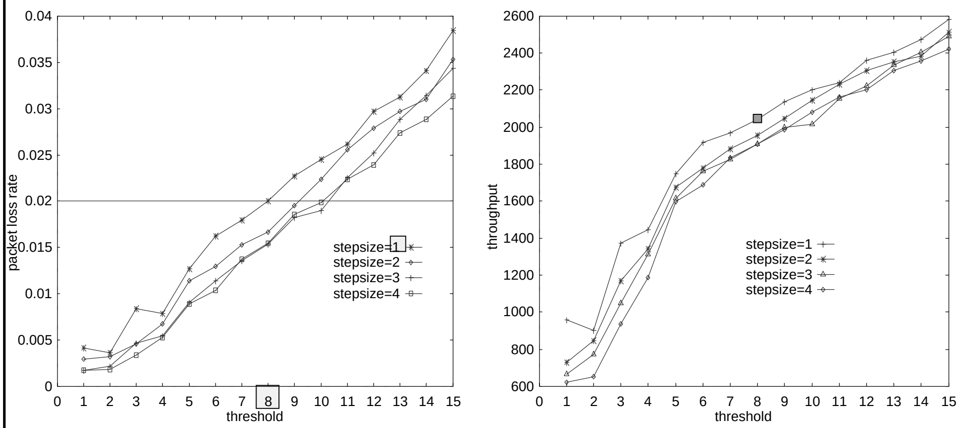
- Step 1 : Find the best threshold and stepsize that yield the largest throughput under packet loss rate $\leq$ 2%.
- Step 2 : under the threshold and stepsize obtained, simulate the performance of the three flow control schemes.

Simulation Results and Remarks

Step 1 : What is threshold and stepsize in each scheme?

- Filter-based: one threshold and one stepsize
- Rate-based: two thresholds (high threshold and low threshold) and two stepsizes (increasing ratio and decreasing ratio).
- Credit-based: only one stepsize(coefficient *a*).

Performance of filter-based flow control



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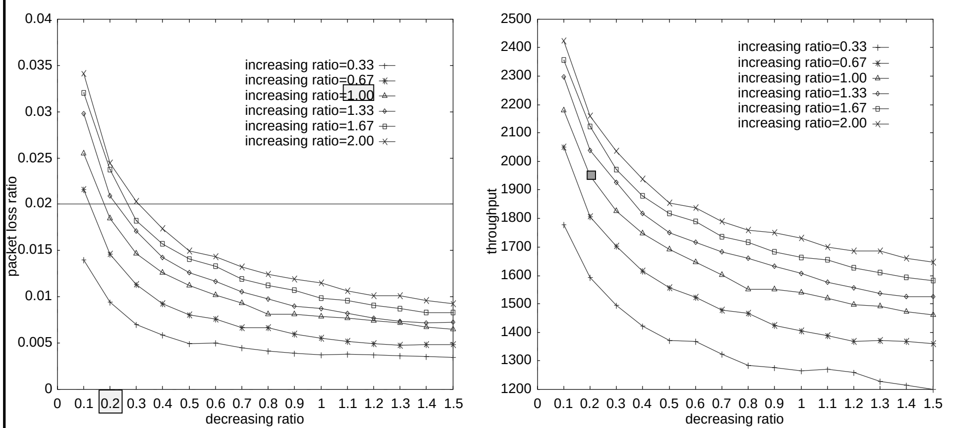
Performance of filter-based flow control

--Fixed threshold



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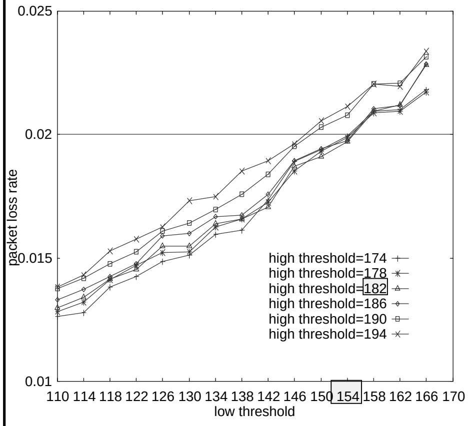
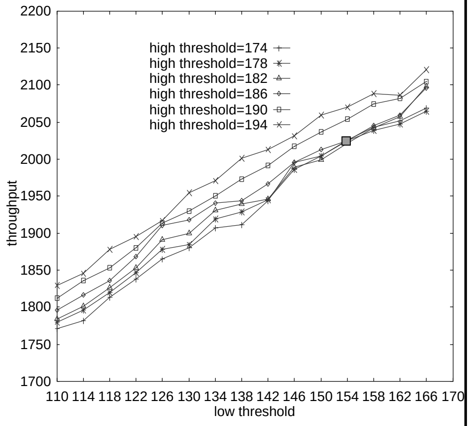
Performance of filter-based flow control

--Fixed stepsize





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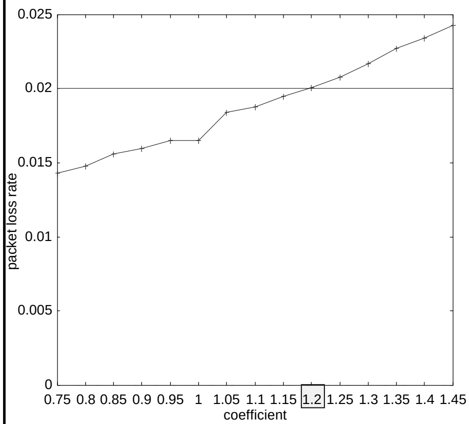
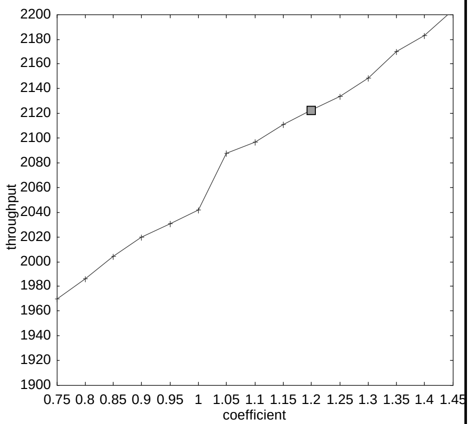
Credit-based performance :





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Simulation results and remarks

Step2:

- Fix (bursty period)/(regulation period) to 2, observe the performance under variable mean rate of exotic traffic.
- Fix mean rate of exotic traffic to 45, observe the performance at different (bursty period)/(regulation period).

Performance

Packet loss rate

Throughput

Variance of throughput

Fixed (bursty period)/(regulation period)=2

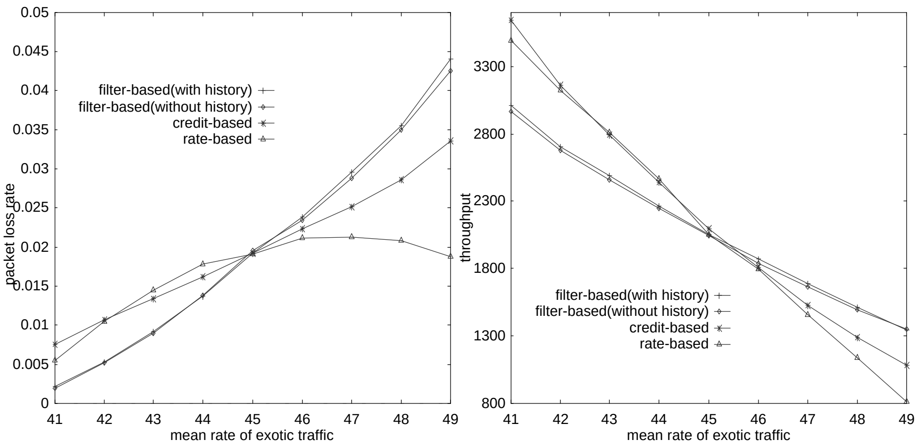
*** \ $	41	42	43	44	45	46	47	48	49
filter-based_w/h	0.0022	0.0053	0.0092	0.0137	0.0192	0.0238	0.0296	0.0355	0.0441
filter-based_wo/h	0.0019	0.0052	0.0089	0.0138	0.0195	0.0234	0.0288	0.0350	0.0425
credit-based	0.0076	0.0107	0.0134	0.0162	0.0192	0.0223	0.0252	0.0286	0.0336
rate-based	0.0055	0.0105	0.0145	0.0178	0.0191	0.0212	0.0213	0.0208	0.0188

** \ $	41	42	43	44	45	46	47	48	49
filter-based-w/h	3013.55	2703.64	2490.06	2264.63	2050.77	1870.48	1690.16	1511.86	1388.99
filter-based-wo/h	2963.84	2681.05	2460.71	2246.22	2048.20	1842.63	1660.73	1492.13	1351.23
credit-based	3644.73	3159.04	2787.61	2439.21	2095.67	1809.44	1525.28	1285.76	1080.21
rate-based	3489.73	3119.98	2811.49	2462.99	2050.98	1797.25	1455.66	1139.19	813.87

* \ $	41	42	43	44	45	46	47	48	49
filter-based-w/h	37861.2	38821.6	47811.5	49172.7	42973.8	31281.5	24675.5	20344.8	13265.1
filter-based-wo/h	28414.0	39245.5	53561.6	49000.4	49755.4	33328.6	27023.7	17340.0	11567.4
credit-based	92151.3	80391.8	102513.1	118296.1	154958.1	99737.1	71449.5	49837.2	24953.7
rate-based	17135.7	46935.3	70189.4	113257.4	149774.3	100647.1	89205.0	60394.5	47763.7

***: packet loss rate **:throughput

*:variance of the throughput $:mean rate of exotic traffic


0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.005
0
packet loss rate
filter-based(with history)
filter-based(without history)
credit-based
rate-based
41 42 43 44 45 46 47 48 49
mean rate of exotic traffic
3300
2800
2300
1800
1300
800
throughput
filter-based(with history)
filter-based(without history)
credit-based
rate-based
41 42 43 44 45 46 47 48 49
mean rate of exotic traffic

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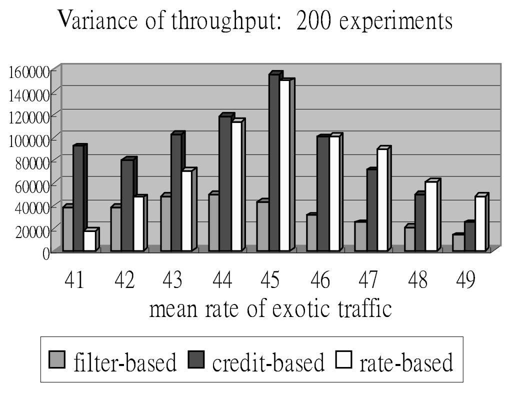
Variance of throughput: 200 experiments
160000
140000
120000
100000
80000
60000
40000
20000
0
41 42 43 44 45 46 47 48 49
mean rate of exotic traffic
filter-based
credit-based
rate-based

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Fixed mean rate of exotic traffic=45

*** \ $	0.5	1	2	4
filter-based	0.0208	0.0204	0.0192	0.0212
credit-based	0.0208	0.0206	0.0192	0.0212
rate-based	0.0205	0.0204	0.0191	0.0215

** \ $	0.5	1	2	4
filter-based	2374.86	2369.87	2050.77	1730.94
credit-based	2328.67	2353.39	2095.67	1739.98
rate-based	2377.72	2377.76	2050.98	1741.66

* \ $	0.5	1	2	4
filter-based	17912.6	19643.8	42973.8	71594.4
credit-based	25724.9	20626.3	154958.1	189603.4
rate-based	54914.8	65945.3	149774.3	232888.6

***: packet loss rate **:throughput *:variance of the throughput
$: (bursty Poisson)/(regulation period)

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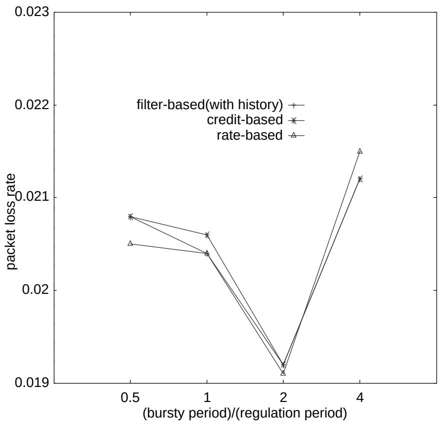

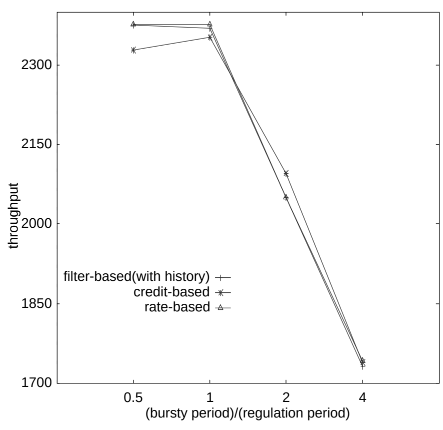

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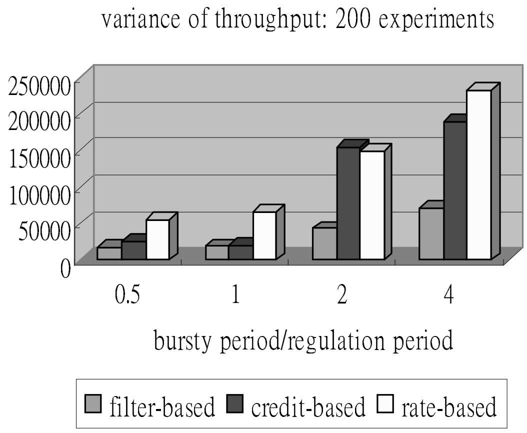

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Simulation results and remarks

Situation of more network nodes:

---set (bursty Poisson period)/(regulation period) to 1

---set mean rate of exotic traffic to 45

eight network nodes	packet loss rate	throughput
filter-based	0.0143	2243.89
rate-based	0.0141	2169.51
credit-based	0.0145	1997.40
twelve network nodes	packet loss rate	throughput
filter-based	0.0122	2127.24
rate-based	0.0122	2084.53
credit-based	0.0124	1848.28

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Conclusions

- Variance of throughput perform very well at every mean rate of exotic traffic and every bursty period/regulation period.
- When the network nodes increase, it can perform better than rate-based and credit-based.
- Future work:
  - Have different steps and thresholds at every node.
  - Have crowd-vary steps and thresholds.

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