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On Modeling of Fluctuations in Quasi-Static Approach Describing the Temporal Evolution of Retry Traffic

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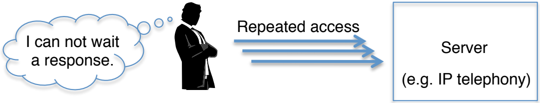
Background

- Significant problems with the Internet include node failure due to congestion or overload.
- One of the key factors behind overload is the generation of retry traffic.
- We consider user impatience which is one of the cause of retry traffic.

Retry traffic due to user impatience

- Users who can not endure their waiting time before starting the service might generate duplicate service requests.



Background (2)

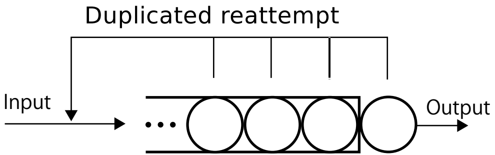
- An evaluation method that can accurately model retry traffic is important.
- In previous work, we proposed the quasi-static approach that replicates the temporal evolution of these traffic.
  - We separate a timescale of the transitions of user and system behavior in the approach.
  - The quasi-static approach can evaluate an high-speed system in which we can not use simulation approach.

The aim of this study

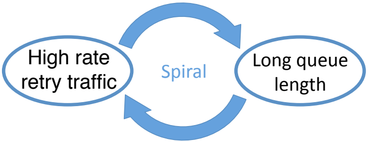
In this study, we confirm the validity of the quasi-static approach by comparing the traditional Monte-Carlo simulations.

Quasi-static retry traffic model

- We focus on one of the simplest model as an example: M/M/1 with retry traffic.
- The rate of the retry traffic is depend on the queue length.



- Long queue length bring high rate retry traffic, high rate retry traffic bring more long queue.

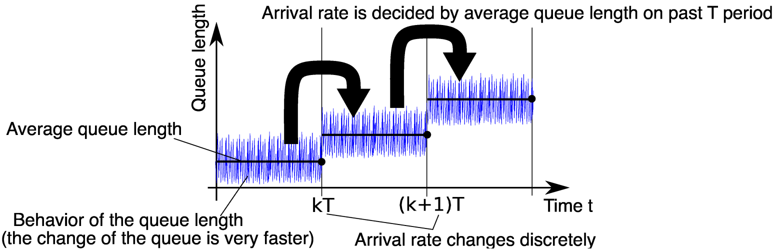


Quasi-static retry traffic model (2)

- We modeled the behavior of retry traffic as the quasi-static retry traffic model.

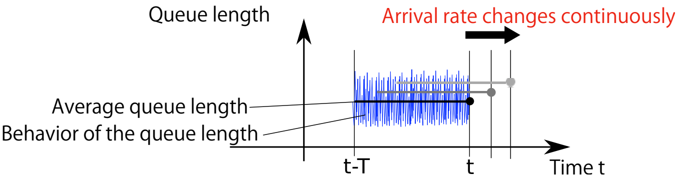
Character of quasi-static retry traffic model

- The change of the queue is very faster compared with the user responses (We can separate the timescales).
- The change of the traffic rate is proportional to average queue length on past T period.

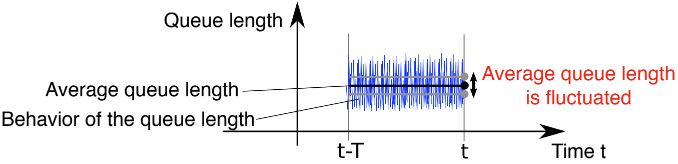


Quasi-static approach

- In actual system, the traffic changes not discretely but continuously.



- On finite speed system, an average queue length contains stochastic fluctuations.
- On infinite high speed system, the fluctuation is 0.



Quasi-static approach (2)

- By considering the continuity and fluctuation, we describe the traffic behavior as the following Langevin equation:

$$\underbrace{\frac{\mathrm{d}}{\mathrm{d}t}X(t) = F(X(t))}_{\text{Behavior of the infinite high speed system}} + \underbrace{\sqrt{D(X(t))}\,\xi(t)}_{\text{Stochastic fluctuation}}$$

$X(t)$: Number of arrivals in past T period

$\xi(t)$: White Gaussian noise

Average behavior : $F(X) = \lambda_0 - \frac{X}{T} + \varepsilon\frac{X/(\mu T)}{1 - X/(\mu T)}$

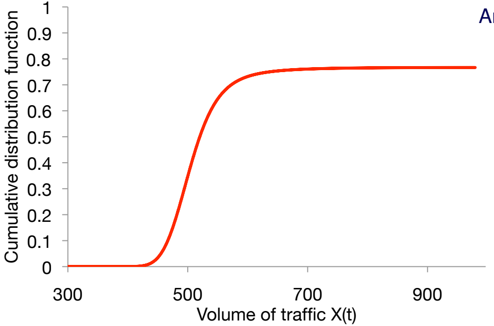
Magnitude of the fluctuation : $D(X) = \lambda_0 + \varepsilon\frac{X(t)/(\mu T)}{1 - X(t)/(\mu T)}$

Quasi-static approach (3)

- It is well known that the Langevin equation is equivalent to the Fokker-Planck equation as shown by

$$\frac{\partial}{\partial t}p(x,t) = -\frac{\partial}{\partial x}F(x)p(x,t) + \frac{1}{2}\frac{\partial^2}{\partial x^2}D(x)p(x,t)$$

- We can calculate the pdf $p(x,t)$ of $X(t)$, and can get the distribution.



Arrival rate without retry λ_0: 300

Service rate μ: 1000

Intensity of retry traffic ε: 200

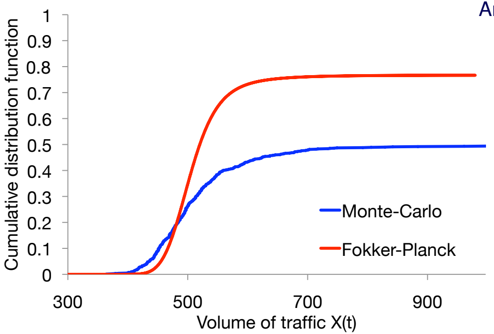
Users' response time T: 1 s

Simulation period t: 50 s

Verification of the quasi-static approach

- To confirm the validity of our approach, we compare the result with that of Monte-Carlo simulations.

$$F(X) = \lambda_0 - \frac{X(t)}{T} + \varepsilon \frac{X(t)/(\mu T)}{1 - X(t)/(\mu T)}, \qquad D(X) = \lambda_0 + \varepsilon \frac{X(t)/(\mu T)}{1 - X(t)/(\mu T)}$$



Arrival rate without retry λ_0
300

Service rate μ
1000

Intensity of retry traffic ε
200

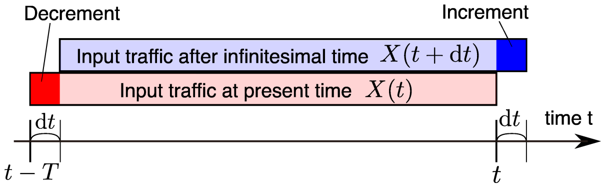
Users' response time T
1 s

Simulation period t
50 s

- The distributions that are computed by the Monte-Carlo and our approach are not corresponding.

Verification of the quasi-static approach (2)

- We reconsider $F(X(t))$ and $D(X(t))$.
  - $X(t)$ is a number of arrivals in past T period.
  - Infinitesimal change $\mathrm{d}X(t)/\mathrm{d}t$ is a random variables.
  - $F(X(t))$ and $D(X(t))$ indicate mean and variance of $\mathrm{d}X(t)/\mathrm{d}t$.
- $\mathrm{d}X(t)/\mathrm{d}t$ is composed of increment and decrement of $X(t)$.



- Mean and variance of each element are as follows.

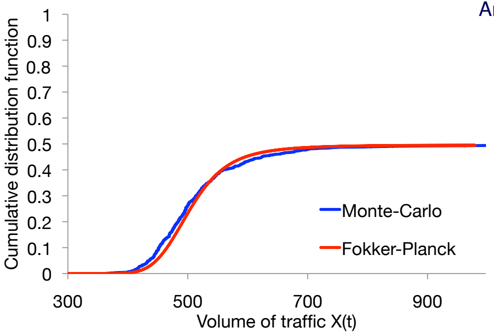
Mean of increment : λ_0 Mean of decrement : $-X/T$

Variance of increment : λ_0 Variance of decrement : X/T

Verification of the quasi-static approach (3)

- We modified $F(X(t))$ and $D(X(t))$, and recalculate the distribution of the traffic.

$$F(X) = \lambda_0 - \frac{X(t)}{T} + \varepsilon \frac{X(t)/(\mu T)}{1 - X(t)/(\mu T)}, \qquad D(X) = \lambda_0 + \frac{X(t)}{T} + \varepsilon \frac{X(t)/(\mu T)}{1 - X(t)/(\mu T)}$$



Arrival rate without retry λ_0
300

Service rate μ
1000

Intensity of retry traffic ε
200

Users' response time T
1 s

Simulation period t
50 s

- We can confirm that the quasi-static approach yields result similar to that of the Monte-Carlo simulation.

Conclusion

In this study, we verified the validity of quasi-static approach that describes the behavior of input traffic including retry traffic.

- We computed the temporal evolution of input traffic on a M/M/1 based system with retry traffic by using the quasi-static approach.
- We were able to confirm that the results are corresponding to that of Monte-Carlo simulations.
- Therefore, we confirmed that the quasi-static approach can appropriately evaluate a system with retry traffic.

Thank you very much for your kind attention.

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