Detecting Distributed Denial-of-Service Attacks by analyzing TCP SYN packets statistically

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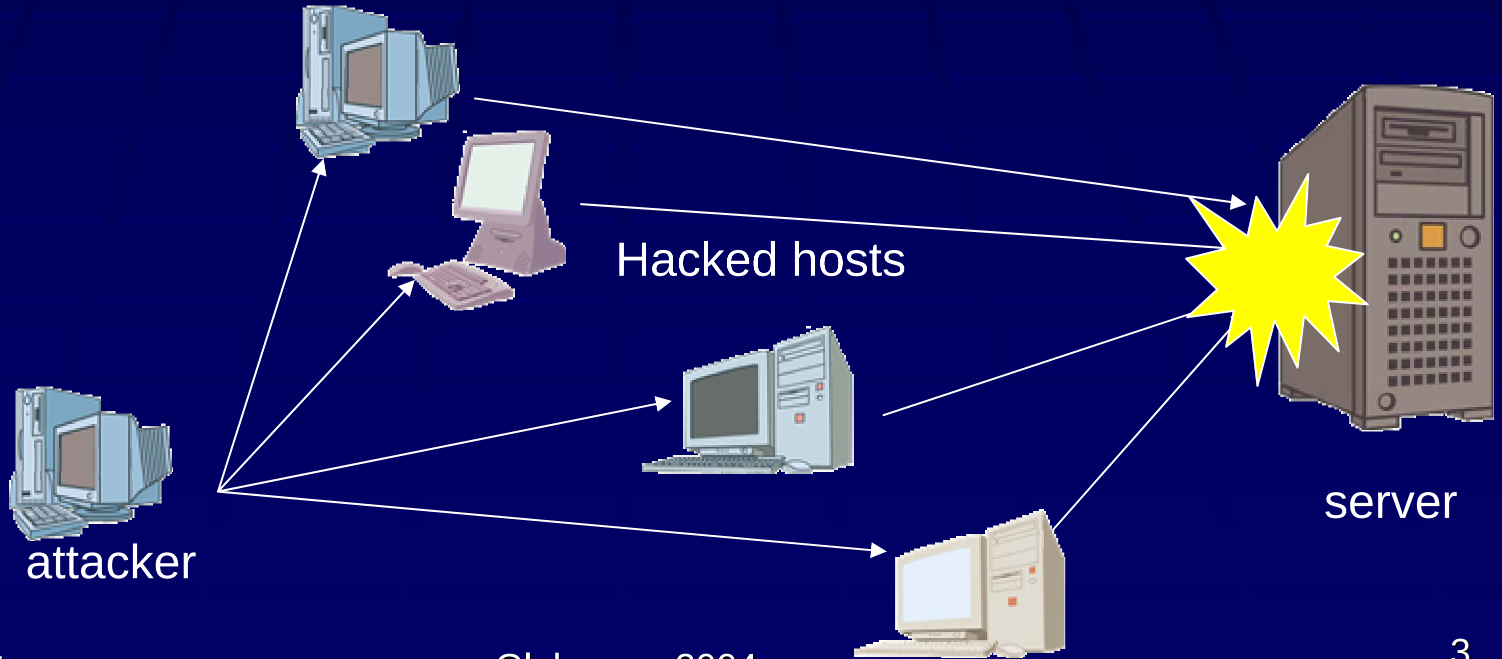
Contents

- What is DDoS
- How to analyze packet
- Traffic modeling
- Method to detect SYN Flood attacks
- Evaluation
- Summary

What is DDoS?

- An attacker hacks remote hosts and installs attack tools
- The hosts attack the same server



What is DDoS?

- The number of attacks is increasing
- The number of attack nodes is very large and attack nodes are highly distributed
- The most are SYN Flood Attacks
  - Because SYN flood can put servers into denial-of-service state easily
  - More than 90% of DoS Attacks [1]

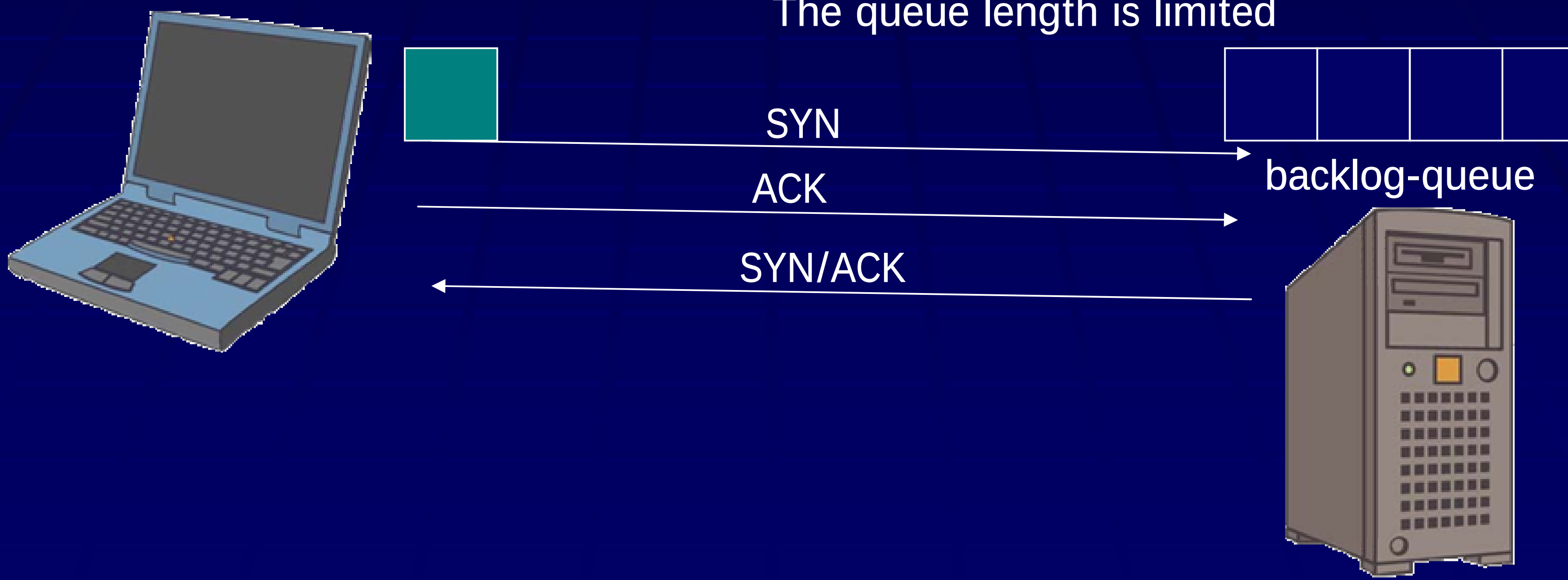
[1] D. Moore, G.M. Voelker, and S. Savage, “Inferring internet Denial-of-Service activity,” Proceedings of the 2001 USENIX Security Symposium, pp.9–22, August 2001.

What is SYN Flood?

- Normal 3-way handshake

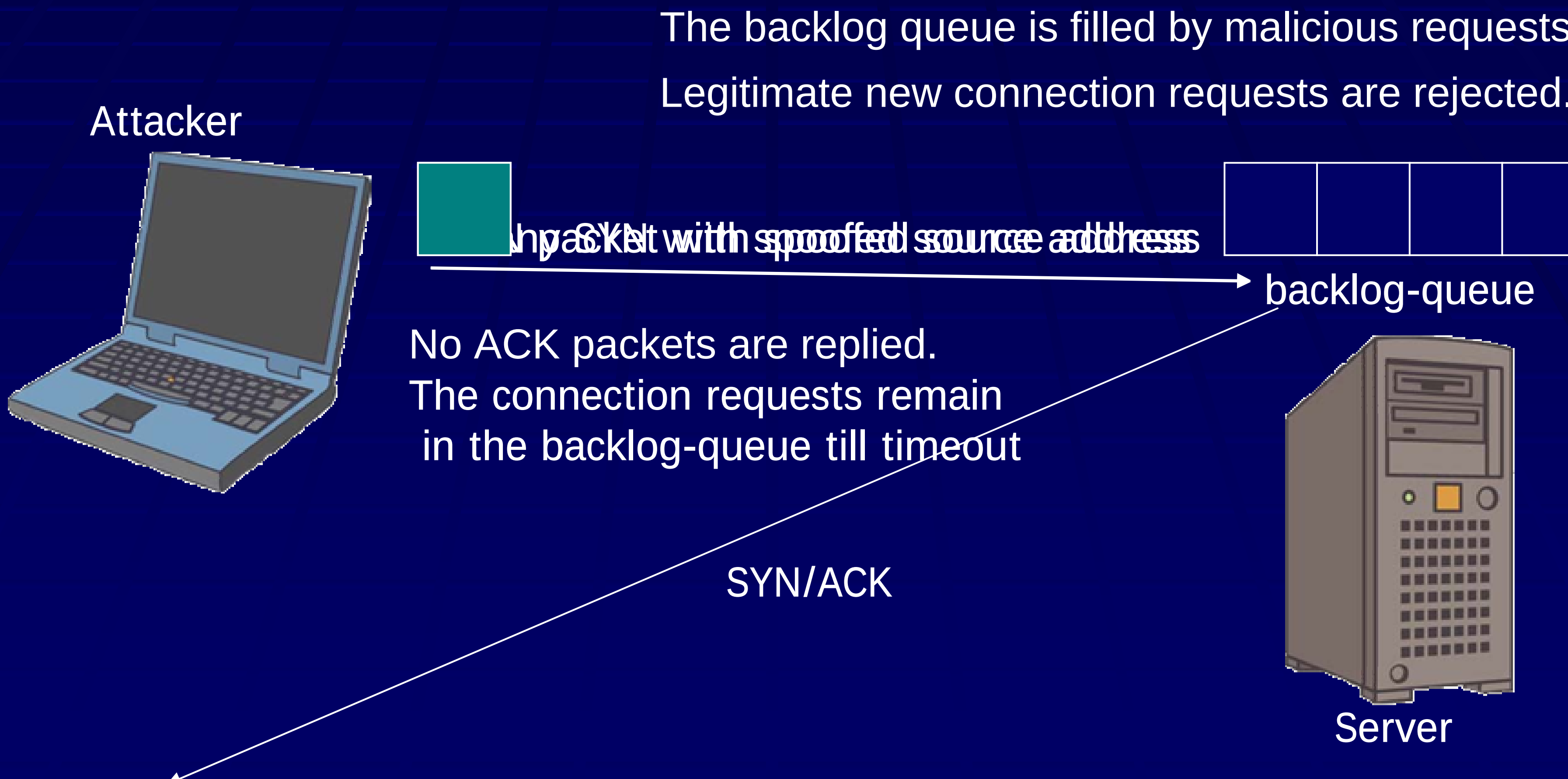
The in-progress connection requests are held in the backlog-queue

The queue length is limited



What is SYN Flood?

- Mechanism of SYN Flood



Detection of SYN Flood

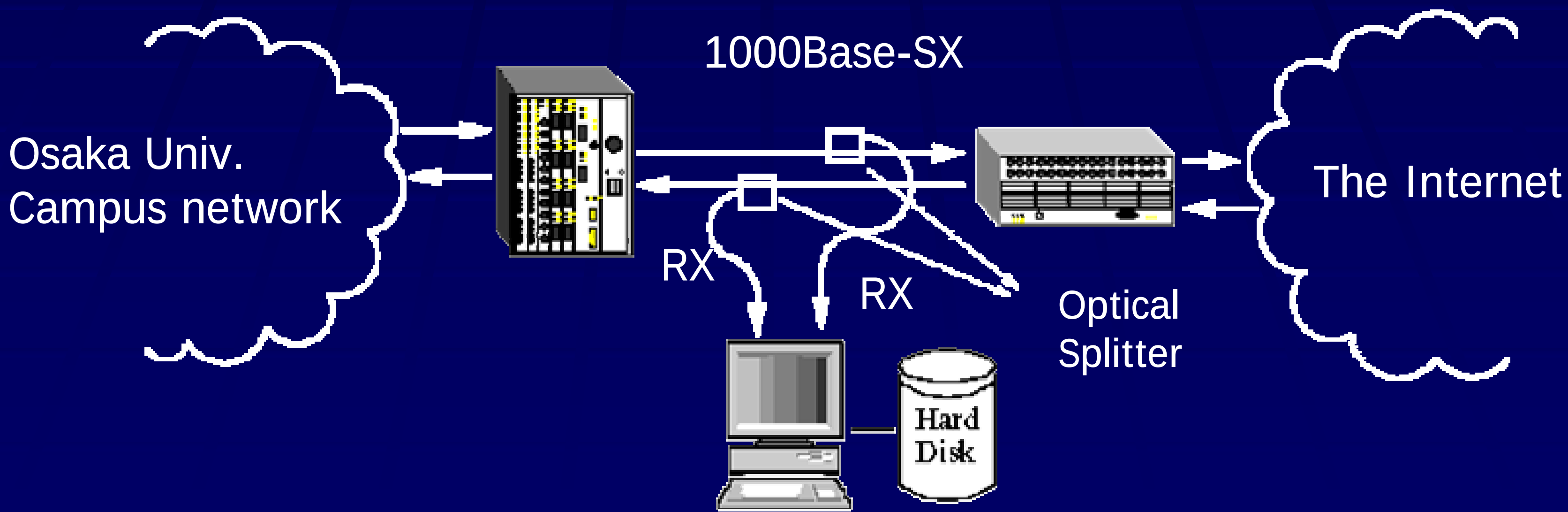
- Problem
  - The server cannot distinguish whether the receiving SYN packet is legitimate or malicious
- Existing methods
  - Detection by the mismatch of bi-directional packets
  - Detection by the mismatch between SYN and FIN
- Remaining Issues
  - Existing methods require long time to detect attacks
  - Existing methods may mistake high-rate normal traffic as attacks

The goal of our study

- Objective
  - Detecting attacks more accurately and faster
    - By using the statistical difference between normal and malicious traffic
- What we have done
  - Monitoring packets
  - Classification packets
  - Analyzing packets and modeling normal traffic
  - Making new mechanism to detect attacks using the model

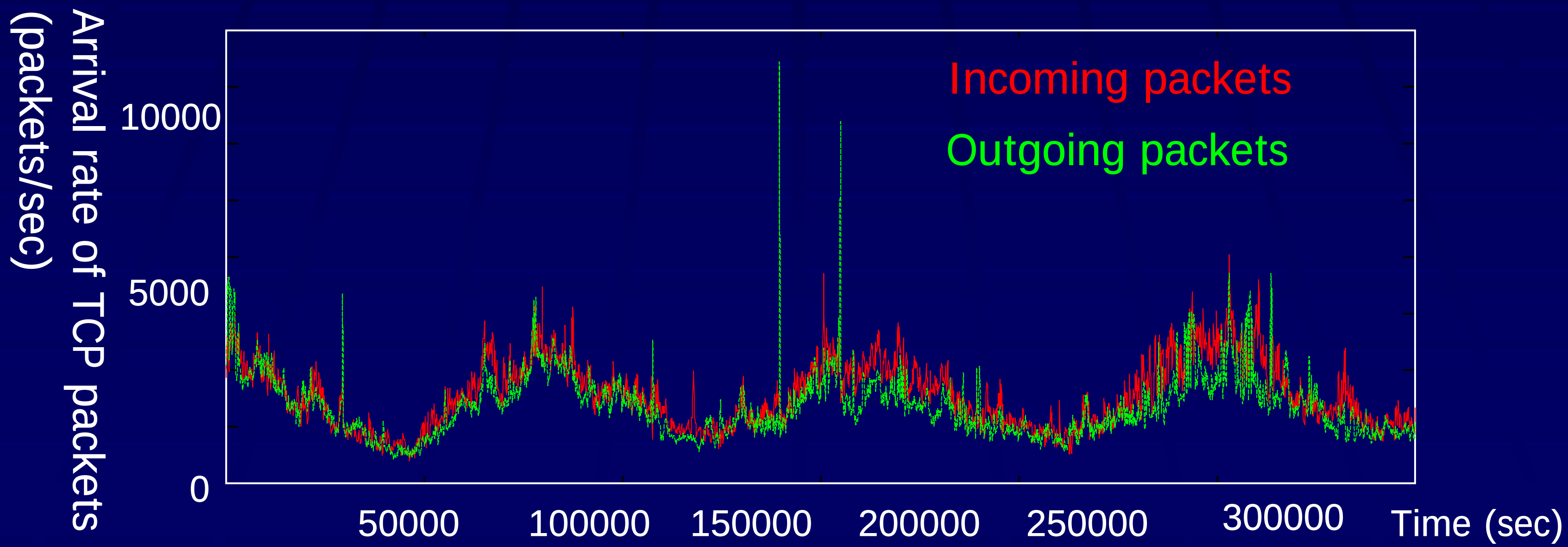
How to monitor the traffic

- We monitored packets at the gateway of Osaka University
- We analyzed the monitored packets.



The captured traffic

- 5days traffic from March 20, 2003 17:55
  - The number of TCP packets :1.9 billion
  - The number of SYN packets : 21 million

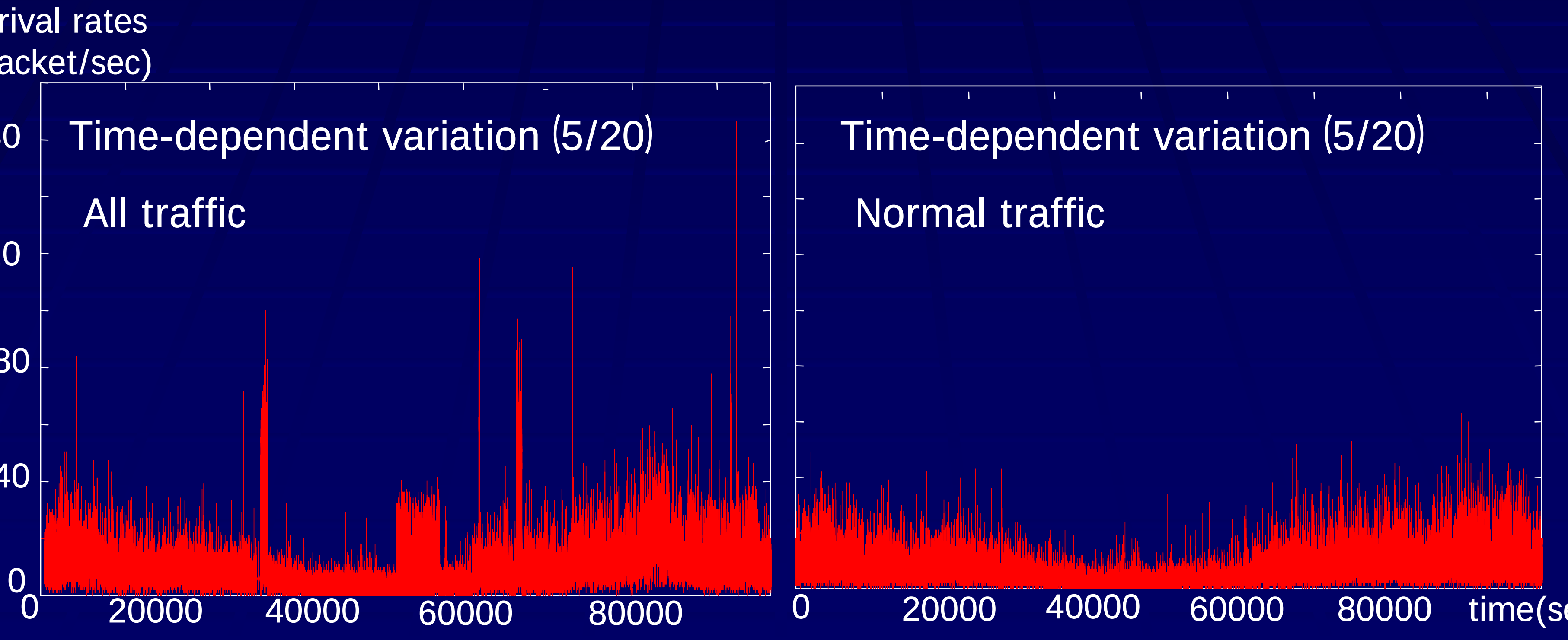


Classification of flows

- We classified monitored packets into flow
  - Flow : a series of packets which have the same (src IP, src port, dest IP, dest port) field
- We classified the flows into groups
  - Normal traffic (**85.1**% of monitored traffic)
    - The flows which complete 3-way handshake
  - Incomplete traffic (**14.9**% of monitored)
    - The flows which do not complete 3-way handshake

Arrival rates of SYN packets

- Points where arrival rate rises sharply are due to incomplete traffic
- Arrival rate of the normal traffic changes over time



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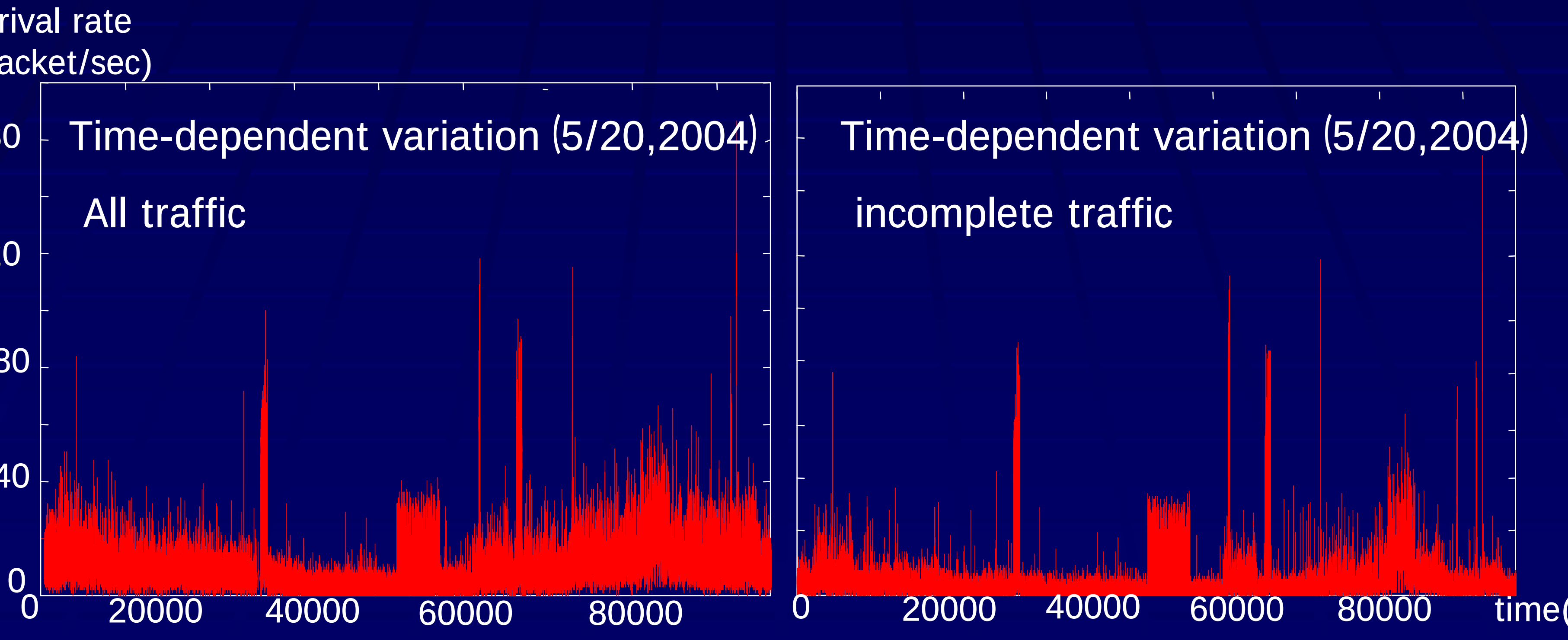


Model of SYN arrival rate

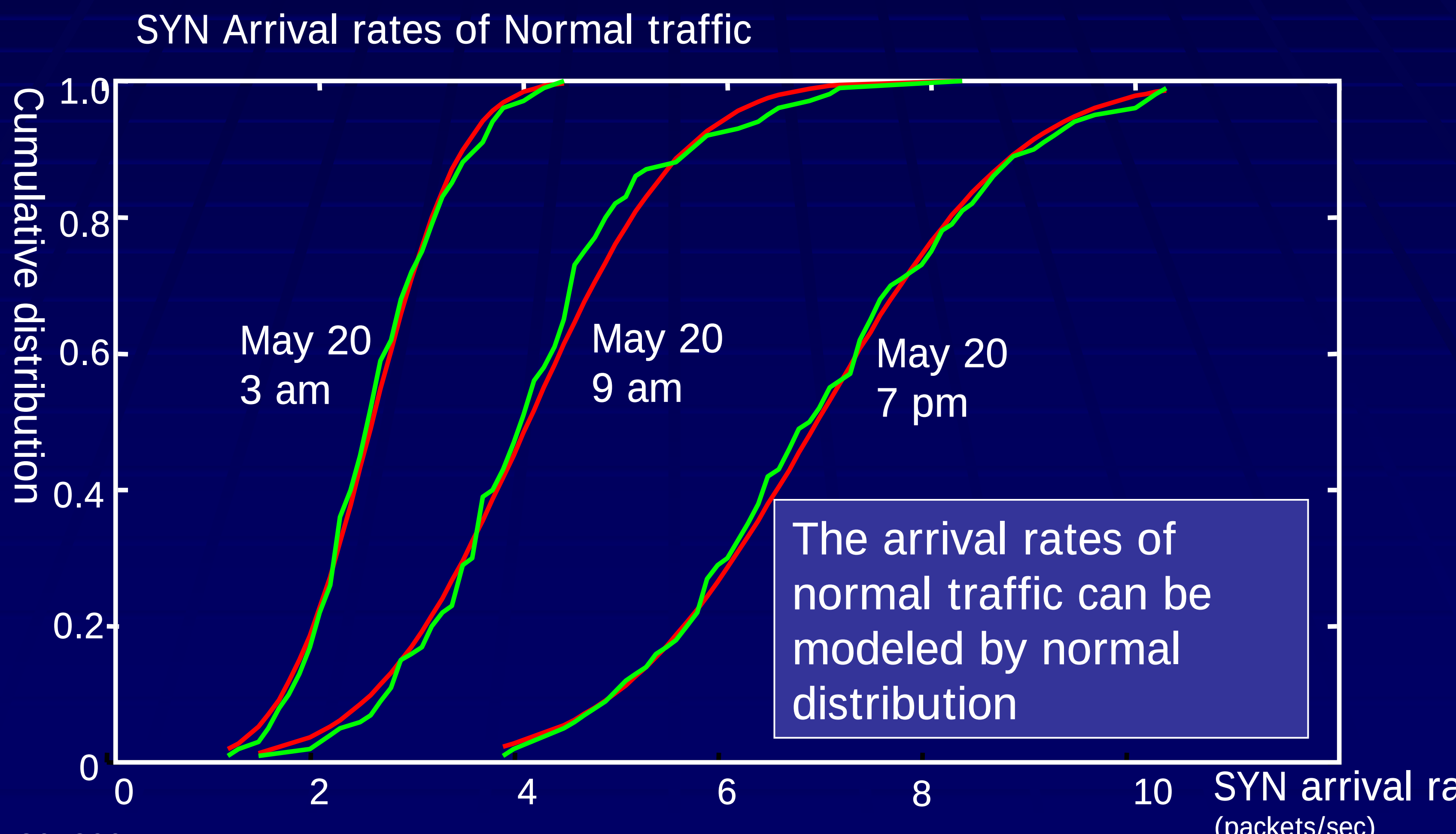
- Arrival rate of normal traffic changes moderately
- We fit the arrival rate to a normal distribution
  - The normal distribution with the mean ς and the variance σ is

$$F(x) = \int_{-\infty}^{x} \frac{1}{\sqrt{2\pi\sigma}} \exp[\frac{-(y-\varsigma)^2}{2\sigma^2}]dy$$

  - The arrival rate are positive value, and we only use the nonnegative part of the F(x)

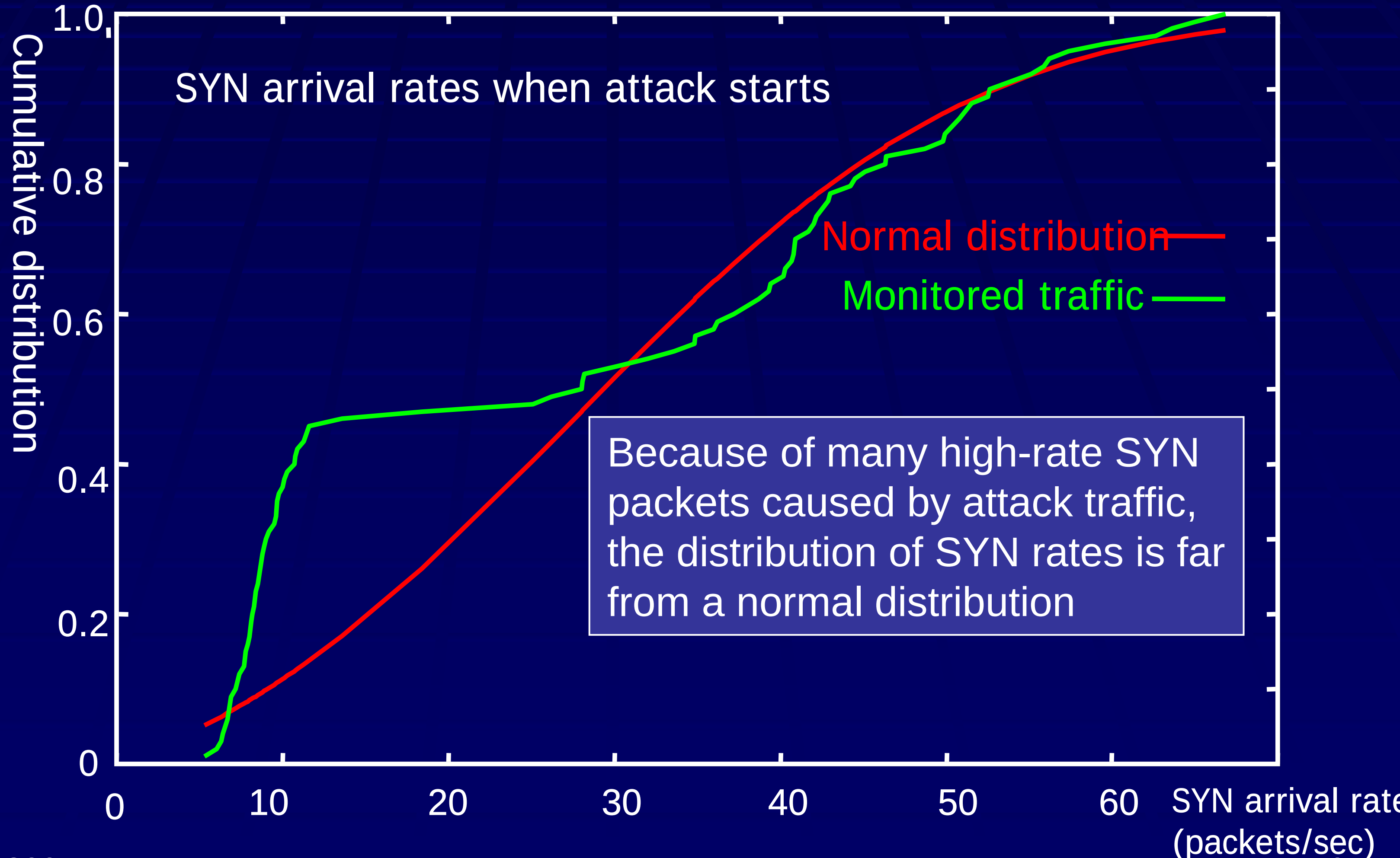
$$G(x) = \frac{F(x) - F(0)}{1 - F(0)}$$

Distributions of SYN arrival rates



The arrival rates of normal traffic can be modeled by normal distribution

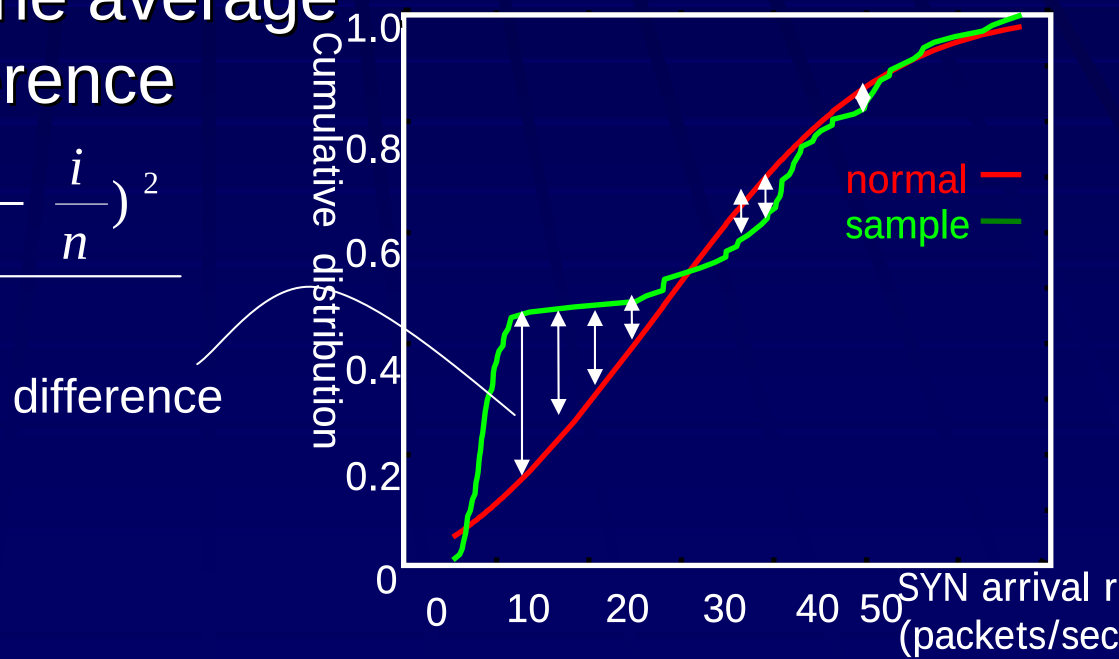
Distributions of SYN arrival rates



How to detect attacks

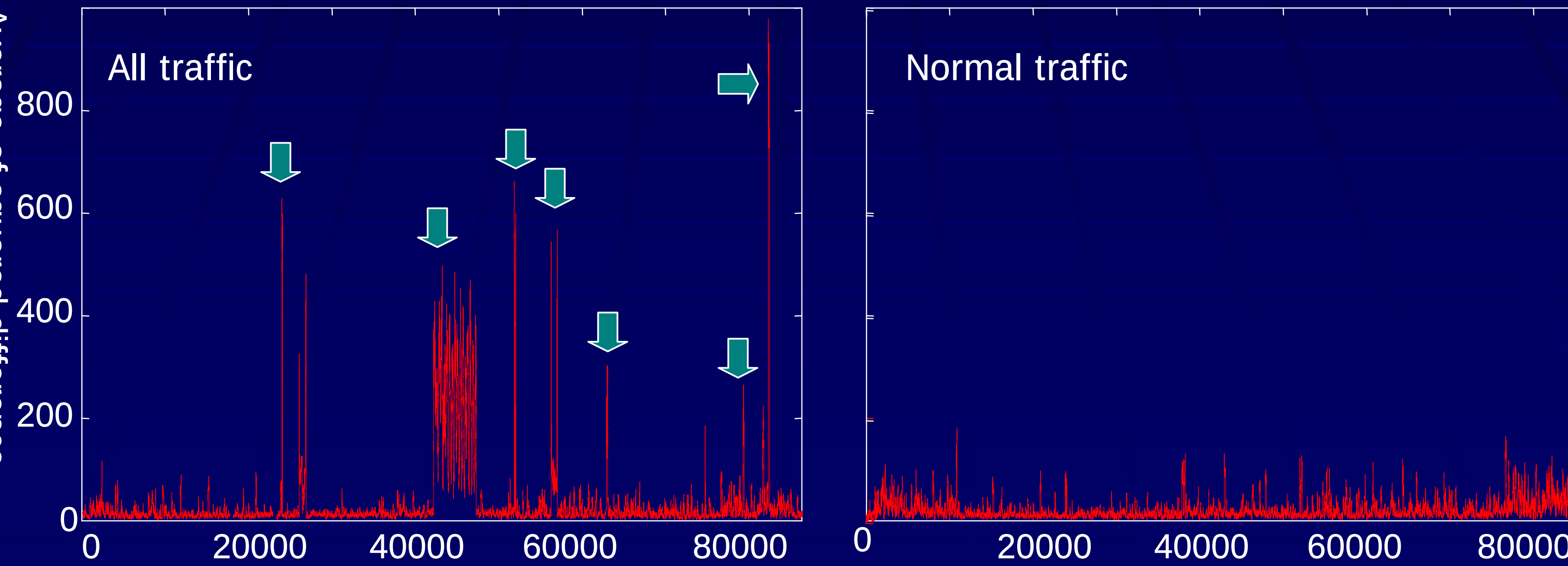
- Attacks can be identified by observing the difference between SYN arrival rates and a normal distribution
  - By calculating the average of squared difference

$$D = \frac{\sum_{i=0}^{n} \left(G(r_i) - \frac{i}{n} \right)^2}{n}$$



Average of squared difference

- The averages of squared difference for the normal traffic are small regardless of time.
- The averages of squared difference for all traffic rise rapidly at several points.



How to evaluate our method

- We wrote a program for our detecting method
- Two sample data for the trace-driven simulation
  - Monitored traffic
    - To confirm our method can detect monitored attacks
  - Traffic injected attack traffic
    - To know how small attacks can be detected

Definition of attacks

- Attacks which must be detected
  - Attacks which can put servers into denial-service state
  - Points where more than 1024 SYN packets are sent within 180 second
  - There are 10 attacks in our monitored traffic

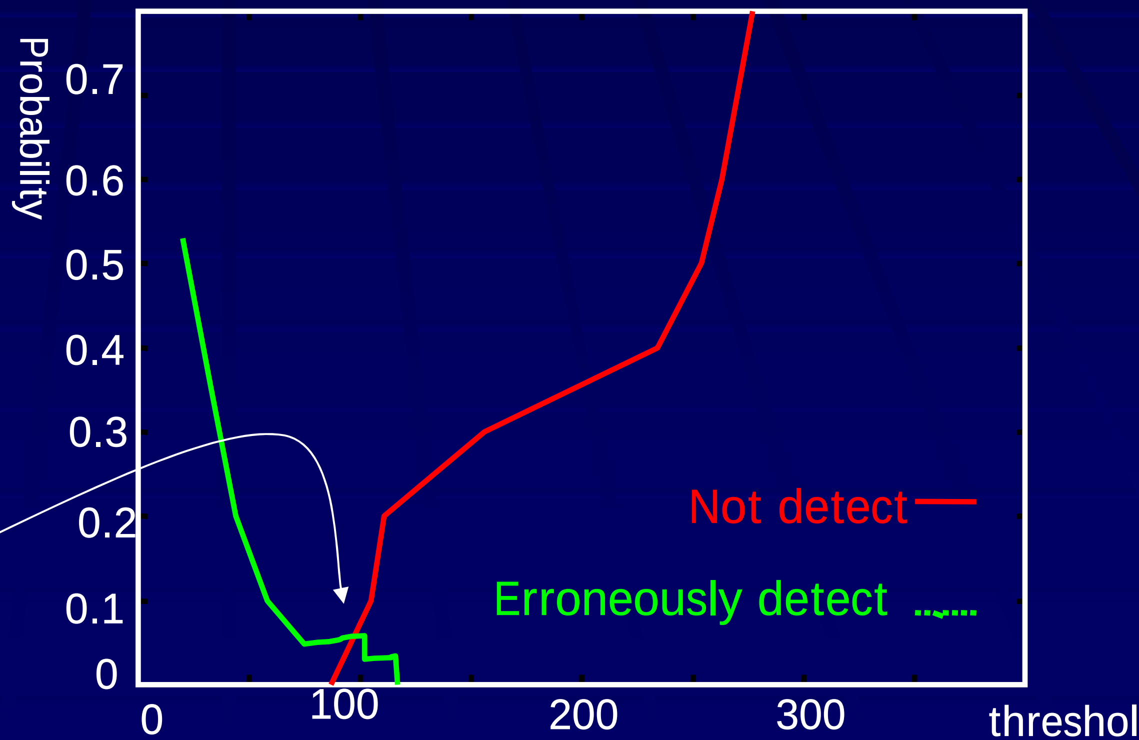
- $\text{Probability of not detecting attacks} = \dfrac{\text{number of attacks that cannot detect}}{\text{number of attacks satisfying the definitio}}$

- $\text{Probability of erronous detection} = \dfrac{\text{number of points erroneously detected as attack}}{\text{number of points detected as attacks}}$

Simulation of monitored traffic

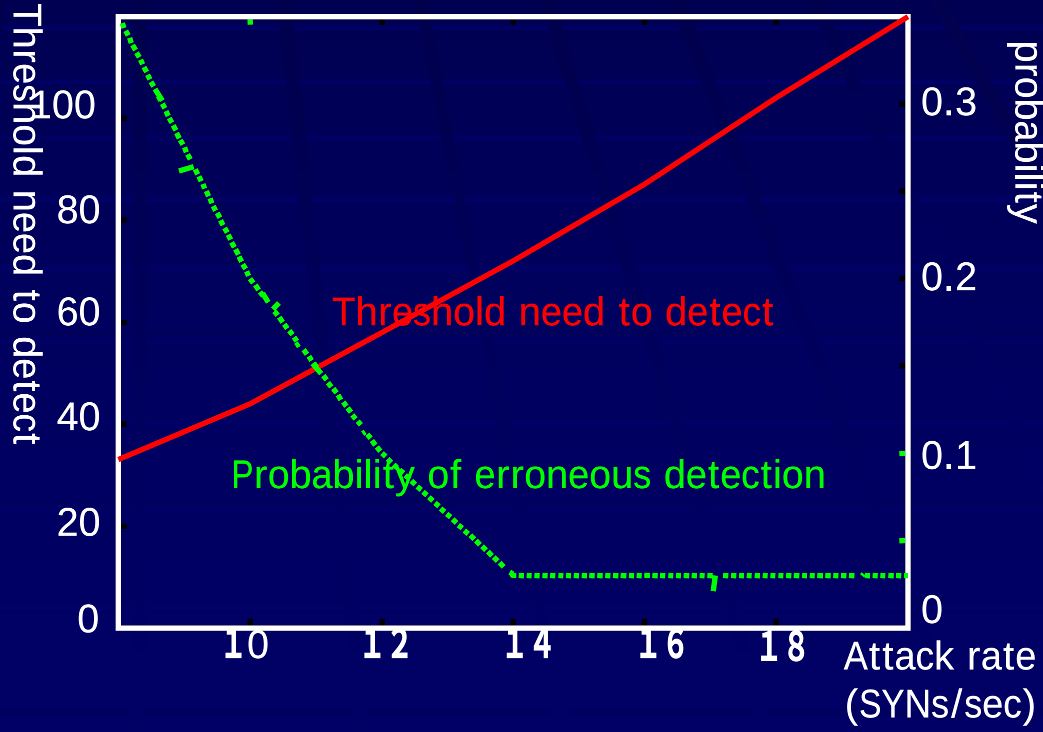
- Smaller threshold, more erroneous detection
- Most attacks can be detected without erroneous detection

There are only two erroneous Detection caused by a single client sending 20 SYNs/sec



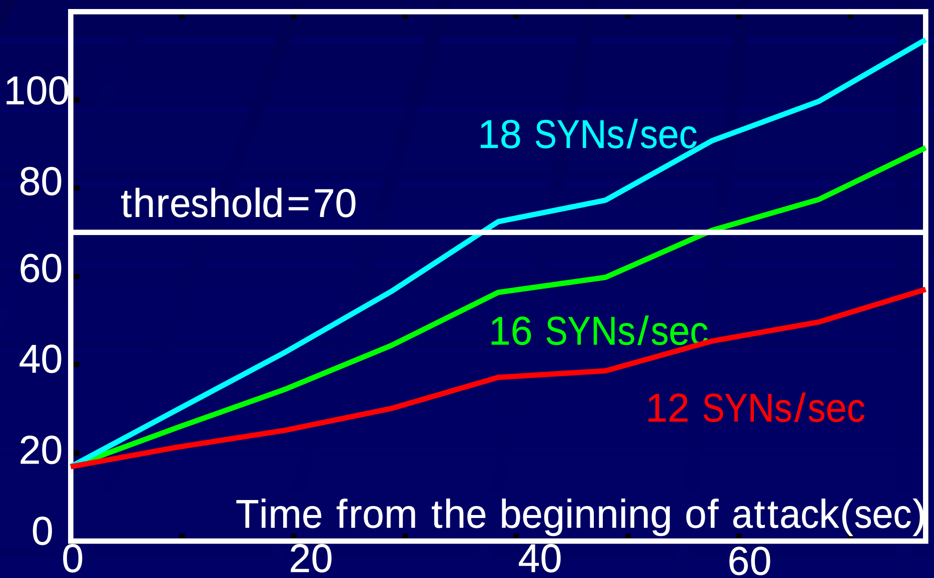
Detectable attack rate

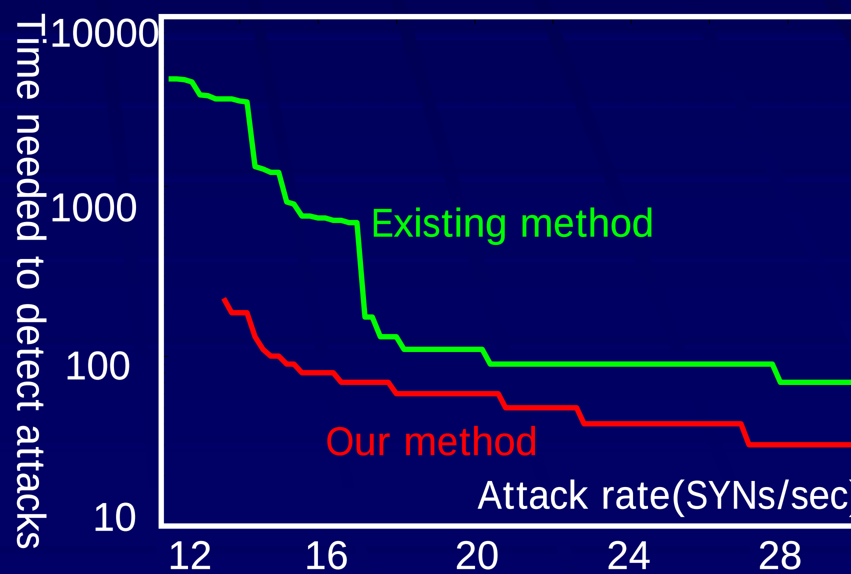
- We injected low-rate attack into the traced traffic
- Attacks whose rates are more than 14 SYNs/sec can be detected without erroneous detection



Time to detect attacks

- Averages of squared difference increase gradually after the beginning of attacks
- Our proposed method can detect faster.
  - One of reasons is because our method adopts a parametric approach.





Summary and future work

- Summary
  - We monitored and analyzed packets at the gateway of Osaka University
  - We fit the arrival rate of SYN packets to a normal distribution
  - We can detect attacks by the difference between arrival rates of SYN packets and a normal distribution
- Future work
  - Setting the parameters
  - Modeling other types of traffic

Thank you