A Queuing Formulation of Intrusion Detection with Active and Passive Responses

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Introduction

- Traditional IDS response tends to be passive – “passive response”
- Secondary investigation required because IDS is still imperfect
- Secondary investigation may not occur instantaneously
- These days, IDS can be set up to respond to events automatically – “active response”

Introduction

- Active response – dropping connection, reconfiguring networking devices (firewalls, routers), additional intelligence mining (honeypots)
- We only consider terminating connection

Introduction

- In the intrusion detection process, IDS configuration decision and the alarm investigation decision are related
- Alarm investigation resource would affect the delays in response in both active and passive response
- If multiple alarm types involved, which alarm to investigate is an issue

Research Goals

- Finding the corresponding configuration and investigation decision for the active and passive response approach
- Determine the “switching” policy on intrusion response

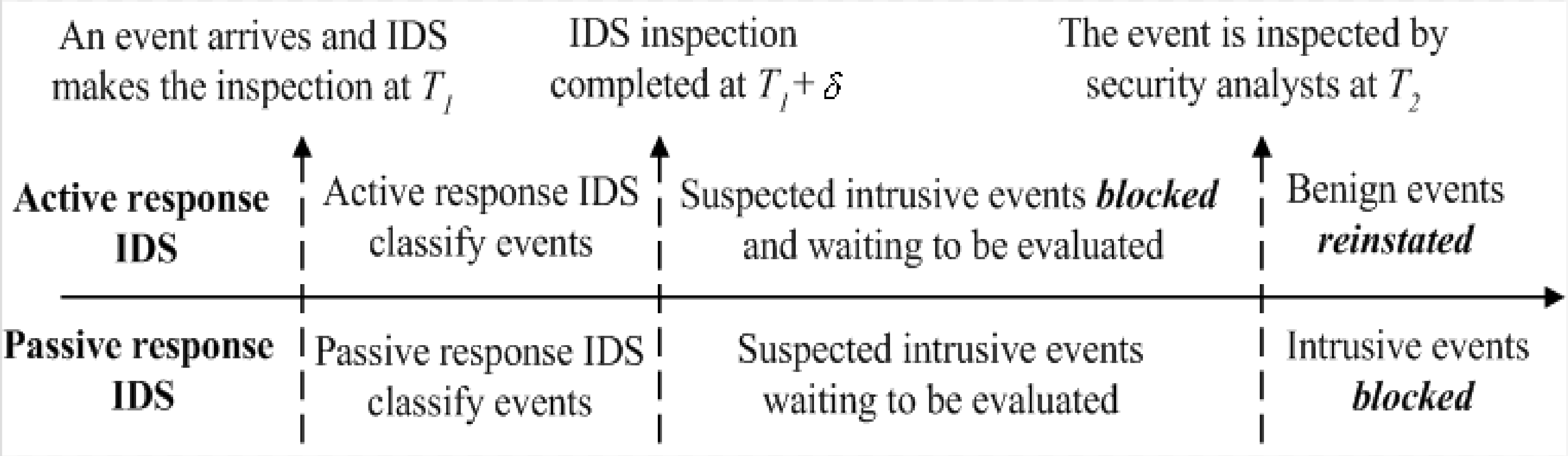
Problem Description

- Passive response
  - potential damage cost - resulting from alarmed events not investigated immediately
  - low false alarm costs since alarmed events are not disrupted

Problem Description

- Active response
  - It could prevent attack damage because the events are terminated immediately
  - higher false alarm costs contingent on the performance of the IDS

Problem Description



- Active response: false alarm cost is related to delay
- Passive response: damage cost is related to delay

Problem Description

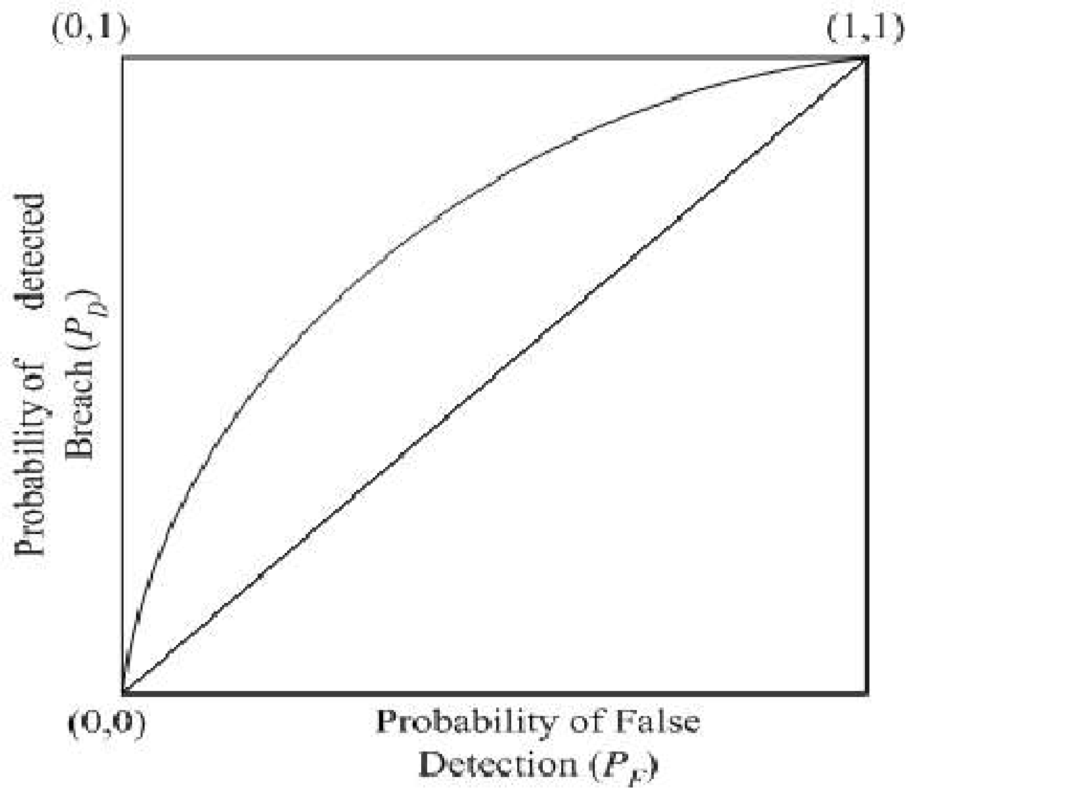
- Undetected, or non-alarmed intrusive events are assumed to be the same for the two response approach

- Given the parameter values, the decisions involved with the active and passive response approaches are different

IDS Quality: ROC curve

- A representation of IDS quality – detection rates ($\Omega(P_F)$) and false alarm rate (P_F)
- IDS quality can be determined experimentally – MIT Lincoln Lab (Lippman et al 2000a 200b), Columbia IDS group (Lee and Stolfo, 2000), etc

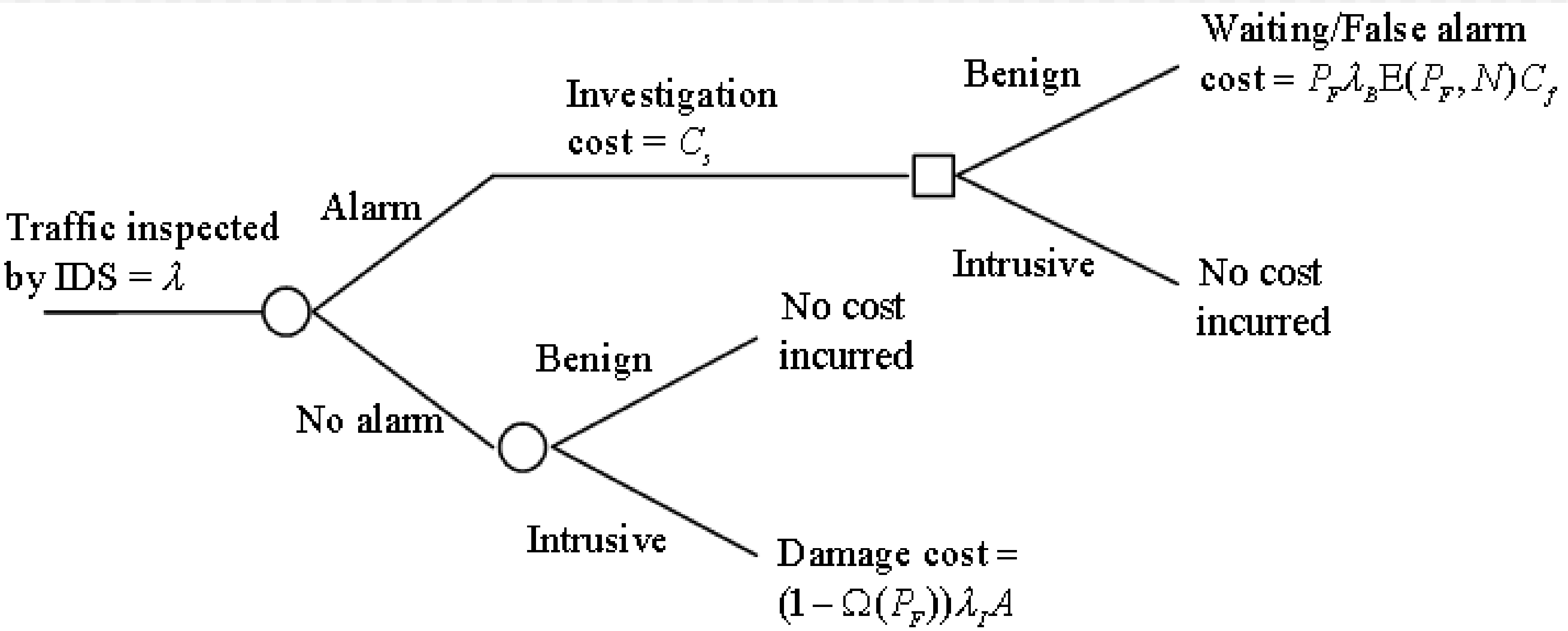
IDS Quality: ROC curve



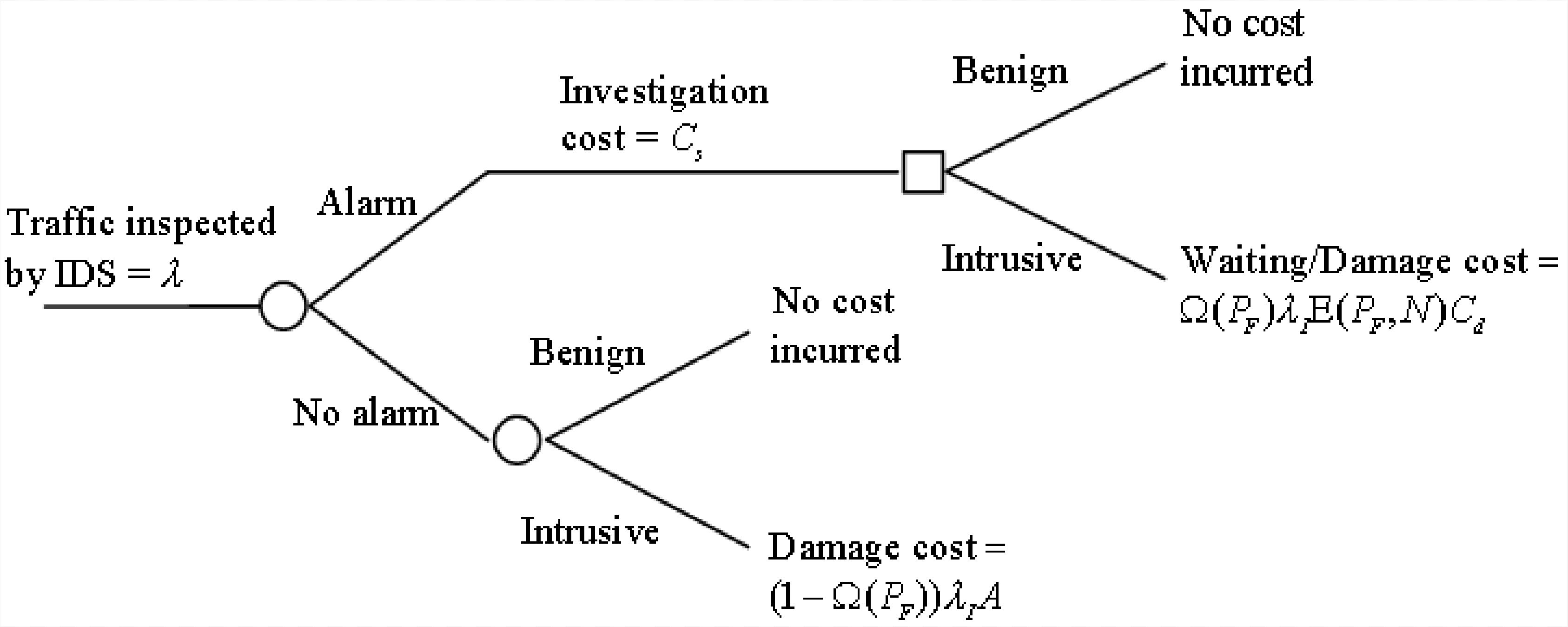
A Queuing Model of Intrusion Detection

- Benign and intrusive event arrivals – Independent Poisson process with rate λ_B and λ_I
- N – number of investigator
- μ - investigation rate
- $E(W(P_F, N)) = 1/\{N\mu - P_F\lambda_B - \Omega(P_F)\lambda_I\}$

A Queuing Model of Intrusion Detection: Active Response



A Queuing Model of Intrusion Detection: Passive Response



A Queuing Model of Intrusion Detection

Active Response

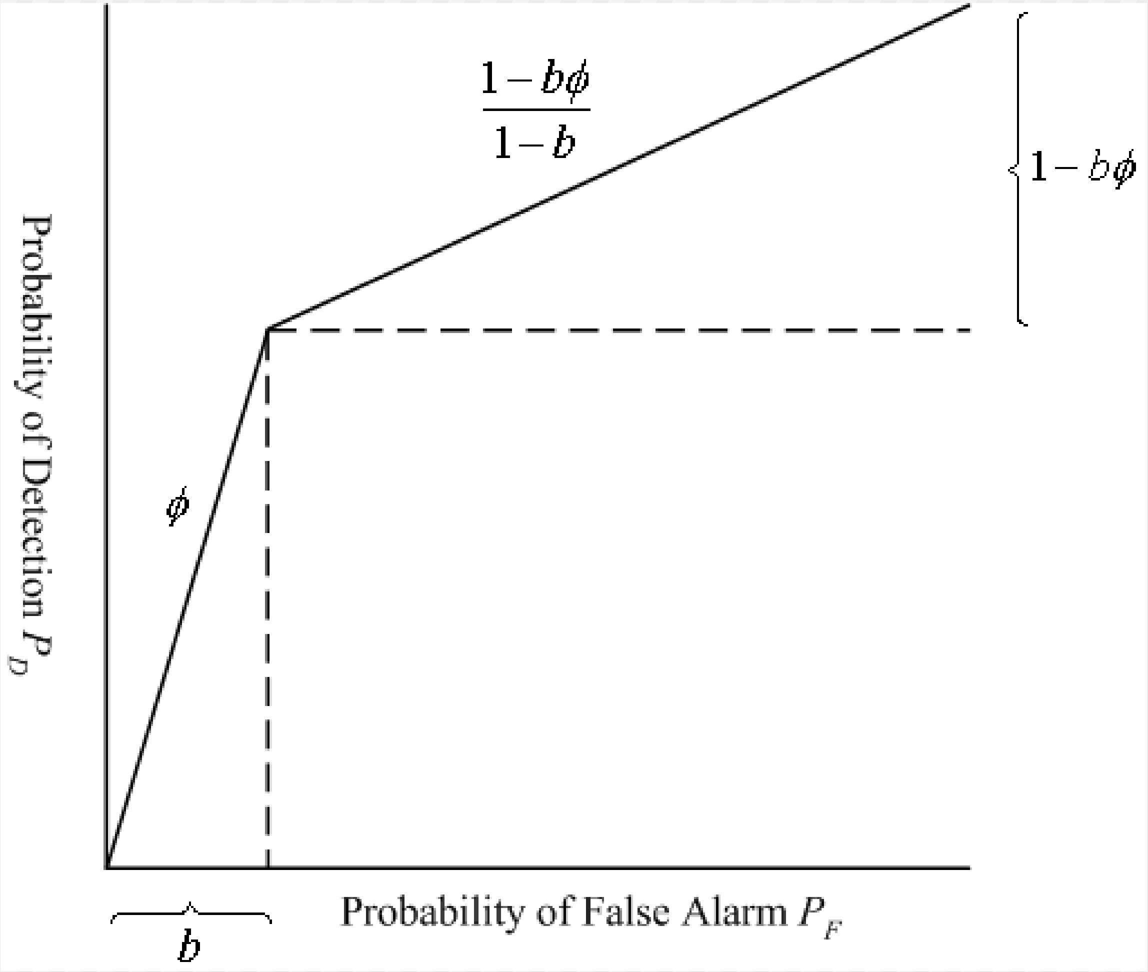
$$\min_{\substack{0 \le P_F \le 1 \\ N \ge 0}} P_F \lambda_B E(W(P_F, N)) C_f + (1 - \Omega(P_F)) \lambda_I A + N C_s$$

Passive Response

$$\min_{\substack{0 \le P_F \le 1 \\ N \ge 0}} \Omega(P_F) \lambda_I E(W(P_F, N)) C_d + (1 - \Omega(P_F)) \lambda_I A + N C_s$$

- We rewrite the N in terms of slack service rate S
  - $S = \mu N - P_F \lambda_B - \Omega(P_F) \lambda_I$

Linear Piecewise ROC



Optimal Configuration and Investigation

$$\Omega_P(P_F) = \begin{cases} \phi P_F & \text{if } P_F \leq b \\ b\phi + \frac{(1-b\phi)}{(1-b)}(P_F - b) & \text{if } P_F \geq b \end{cases}$$

$$S_A^*(P_F) = \left(\frac{\mu\lambda_B C_f}{C_s}\right)^{1/2} (P_{A,F})^{1/2}$$

$$S_P^*(P_F) = \left(\frac{\mu\lambda_I C_d}{C_s}\right)^{1/2} [\Omega(P_{P,F})]^{1/2}$$

Hybrid Response

Active (P_F, P_D)	Passive (P_F, P_D)	$TC_A > TC_P$ Conditions
$b, b\phi$	$b, b\phi$	$\lambda_B C_f \geq \phi \lambda_I C_d$ **I**
$b, b\phi$	1,1	$(1-b\phi)\lambda_I A\mu - C_s[\lambda - \lambda_B b - \lambda_I b\phi] \geq 2\sqrt{C_s\mu}\left[\sqrt{C_d\lambda_I} - \sqrt{C_f\lambda_B b}\,\right]$ **II**
1,1	$b, b\phi$	$(1-b\phi)\lambda_I A\mu - C_s[\lambda - \lambda_B b - \lambda_I b\phi] \leq 2\sqrt{C_s\mu}\left[\sqrt{C_f\lambda_B} - \sqrt{C_d\lambda_I b\phi}\,\right]$ **III**
1,1	1,1	$\lambda_B C_f \geq \lambda_I C_d$ **IV**

Hybrid Response

Active P_F, P_D	Passive P_F, P_D	$\lambda_B C_f \leq \lambda_I C_d$	$\lambda_I C_d \leq \lambda_B C_f \leq \phi \lambda_I C_d$	$\lambda_B C_f \geq \phi \lambda_I C_d$
$b, b\phi$	$b, b\phi$	Active **I**	Active **I**	Passive **I**
$b, b\phi$	1,1	Passive	Passive **II**	Passive
1,1	$b, b\phi$	Passive **III**	Passive **III**	Passive
1,1	1,1	Active **IV**	Passive **IV**	Passive **IV**

Conclusion

- Derive optimal intrusion detection decisions with linear piecewise function
- Extend the study with other types of ROC functions
- Include multiple types of alarm