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Robust and Scalable Trust Management Model for Collaborative Intrusion Detection

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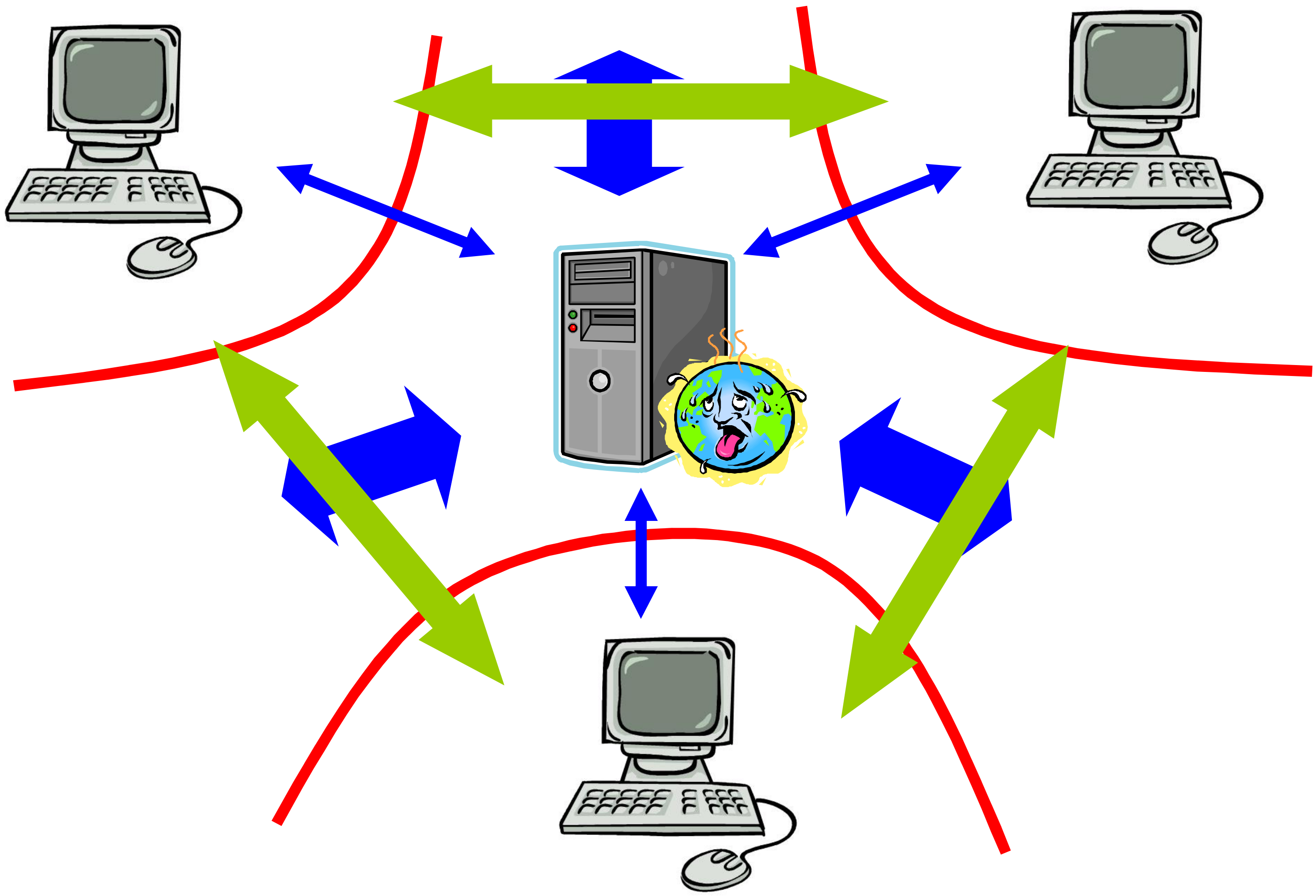
Outline

- Introduction
- Related Work
- Framework
- Trust Model
- Results
- Conclusion

Cyber Threats and Intrusion Detection Systems (IDS)

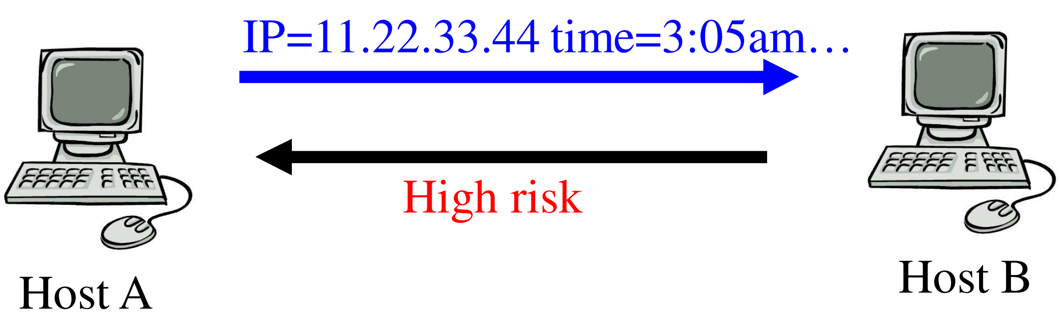
- Cyber Threats
  - Viruses, Worms, Malware, and Denial of Service attacks
- Intrusion Detection Systems
  - Firewalls, Antivirus Software, Signature-based Intrusion Detection Systems, and Anomaly-based Intrusion Detection Systems

Intrusion Detection Networks



Distributed collaboration

- Who?
  - Host-based IDSes across administrative boundaries
- How?
  - Exchange alerts and request diagnosis
- Problem?
  - Trust management



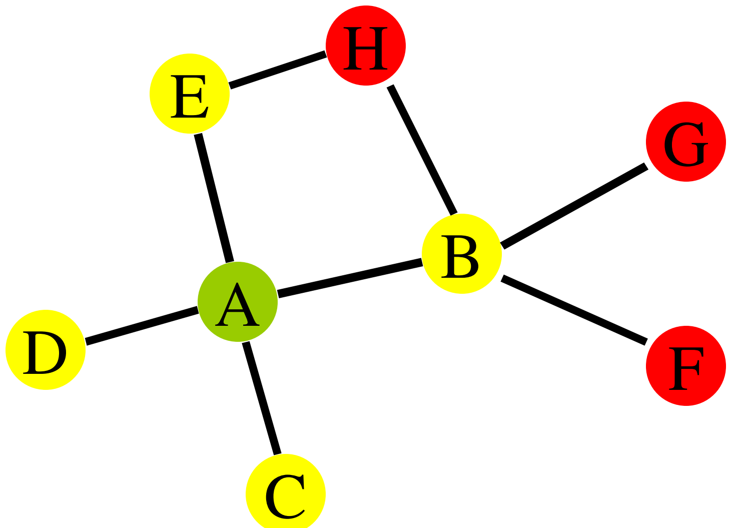
Related Work

- Duma et al. [DEXA 2006]
  - Use simple average of past experience for trust values
  - Aggregate feedback from all acquaintances
  - Suffer from various attacks
- Fung et al. [DSOM 2008]
  - Use forgetting factor to discount old experience
  - Aggregate feedback from trusted peers
  - Scalability problem

Paper Contribution

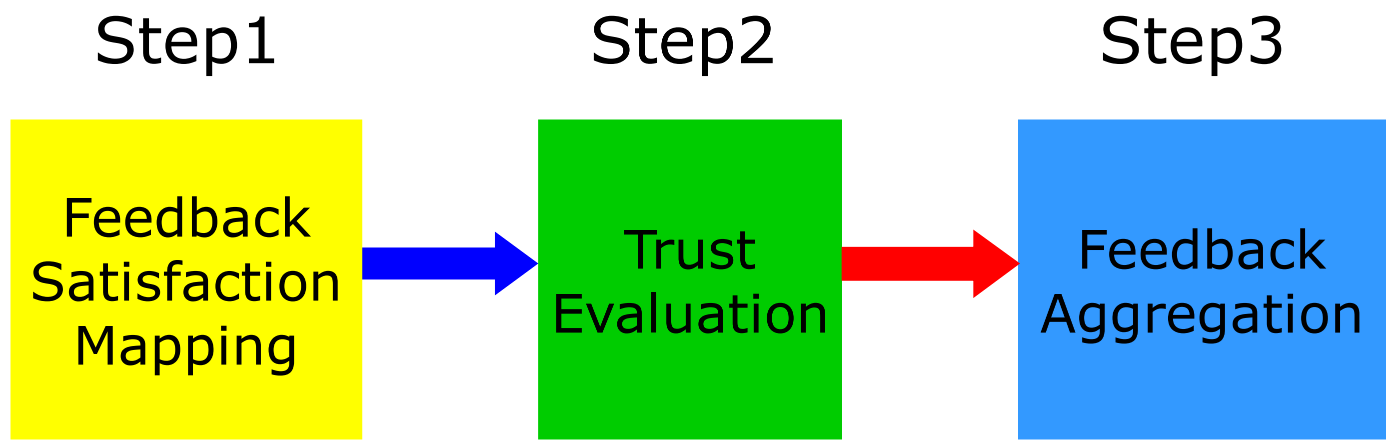
- Dirichlet-based trust management model
  - Uses Bayesian approach
  - Improved detection accuracy
  - Better robustness and scalability

Network Architecture

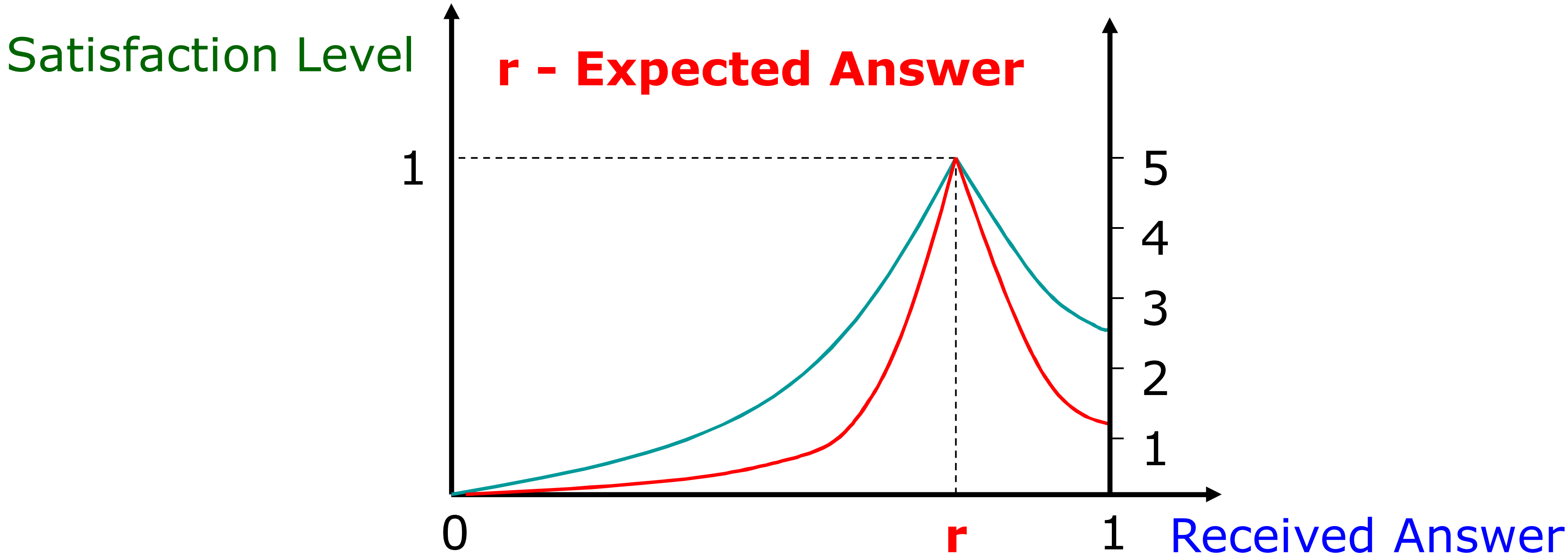


- Acquaintance (List)
- Test Message
- Real Request
- Feedback

Trust Evaluation Framework



Feedback Satisfaction Mapping



Trust Model

1. *$s_1, s_2, \ldots, s_k$* are the *k* possible satisfactions levels
2. S is the satisfaction probability vector ($p(s_1), p(s_2), \ldots, p(s_k)$)

$$f(p(s_1),\ldots,p(s_k) \mid \xi) = \boxed{Dir(\vec{p} \mid \vec{\gamma}) = \frac{\Gamma(\sum_{i=1}^{k} \gamma_i)}{\prod_{i=1}^{k} \Gamma(\gamma_i)} \prod_{i=1}^{k} p_i^{\,y_i - 1}}$$

Dirichlet model gives the density function of S

$\vec{\gamma}$ = accumulated experiences in each satisfaction level (forgetting factor)

Trust Evaluation

Trust value is the expectation of the trust variable

$$T = E[Y] = \frac{1}{\gamma_0}\sum_{i=1}^{k} w_i \gamma_i$$

$$\sigma^2[Y] = \frac{1}{\gamma_0^{\ 2} + \gamma_0^{\ 3}}\sum_{i=1}^{k} w_i \gamma_i \left(w_i(\gamma_0 - \gamma_i) - 2\sum_{j=i+1}^{k} w_j \gamma_j \right)$$

Confidence of trust estimation can be approximated as:

$$C = 1 - 4\sigma[Y]$$

Observations about Trust

- More recent experiences have higher influence on trust values than old ones
- Good experiences lead to higher trust
- Frequent experiences lead to higher confidence levels of trust estimation

Feedback Aggregation

- Now we have trust values to all acquaintances

- We use weighted average to aggregate their feedbacks
  - Only aggregate feedback from trusted acquaintances
  - Use trust value as weight

Scalability of the System

- We use an adaptive approach to reduce test message rate
  – Reduce test messages rate to highly trusted nodes and highly untrusted nodes

Simulation Setup

- Discrete event simulation
- *n* random IDSes with various expertise levels in a grid zone
- IDS model for expertise level and detection ability
- Honest and dishonest nodes

Simulation Results (1)

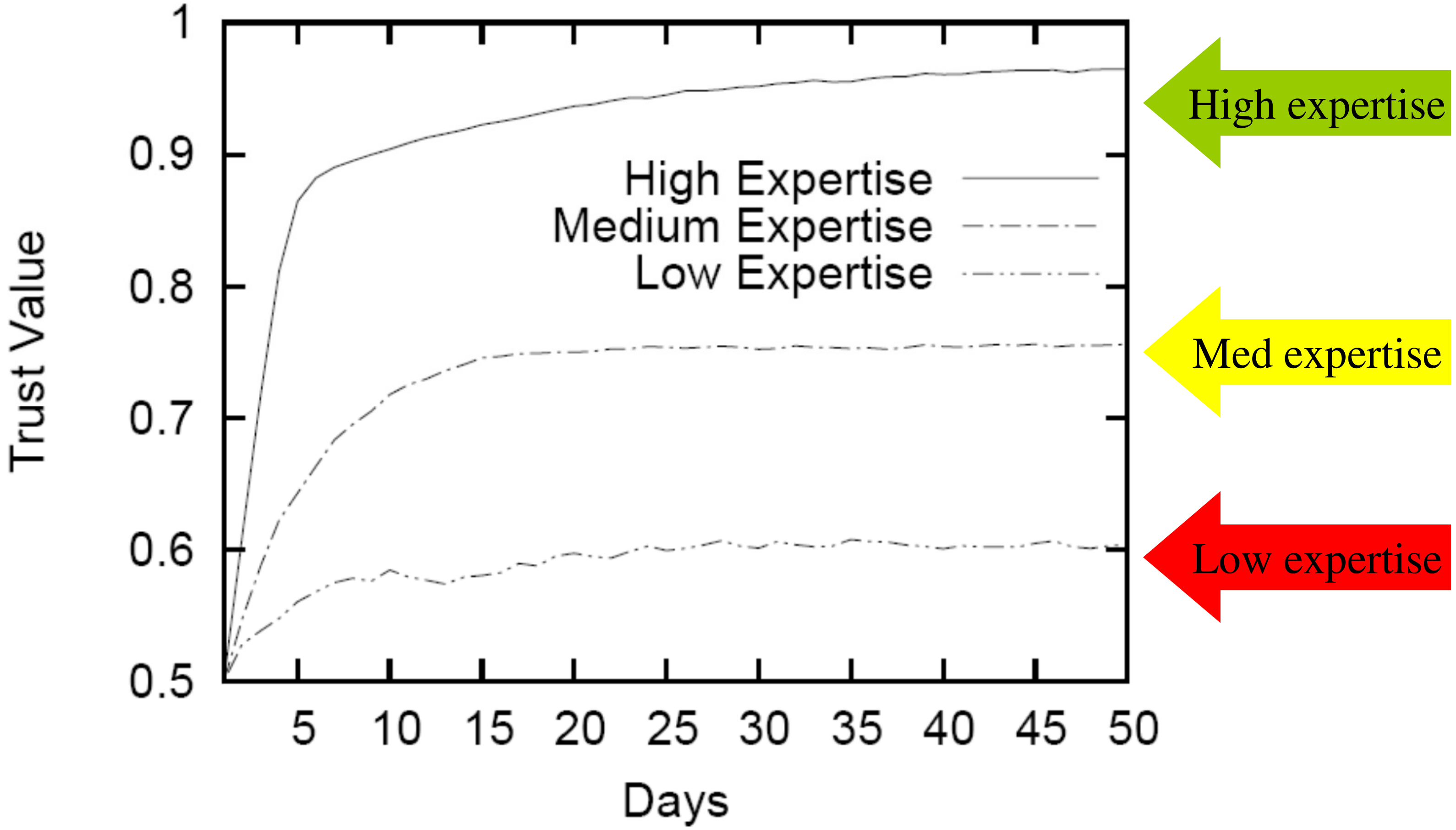


Fig 1. Trust values and expertise levels

Simulation Results (2)

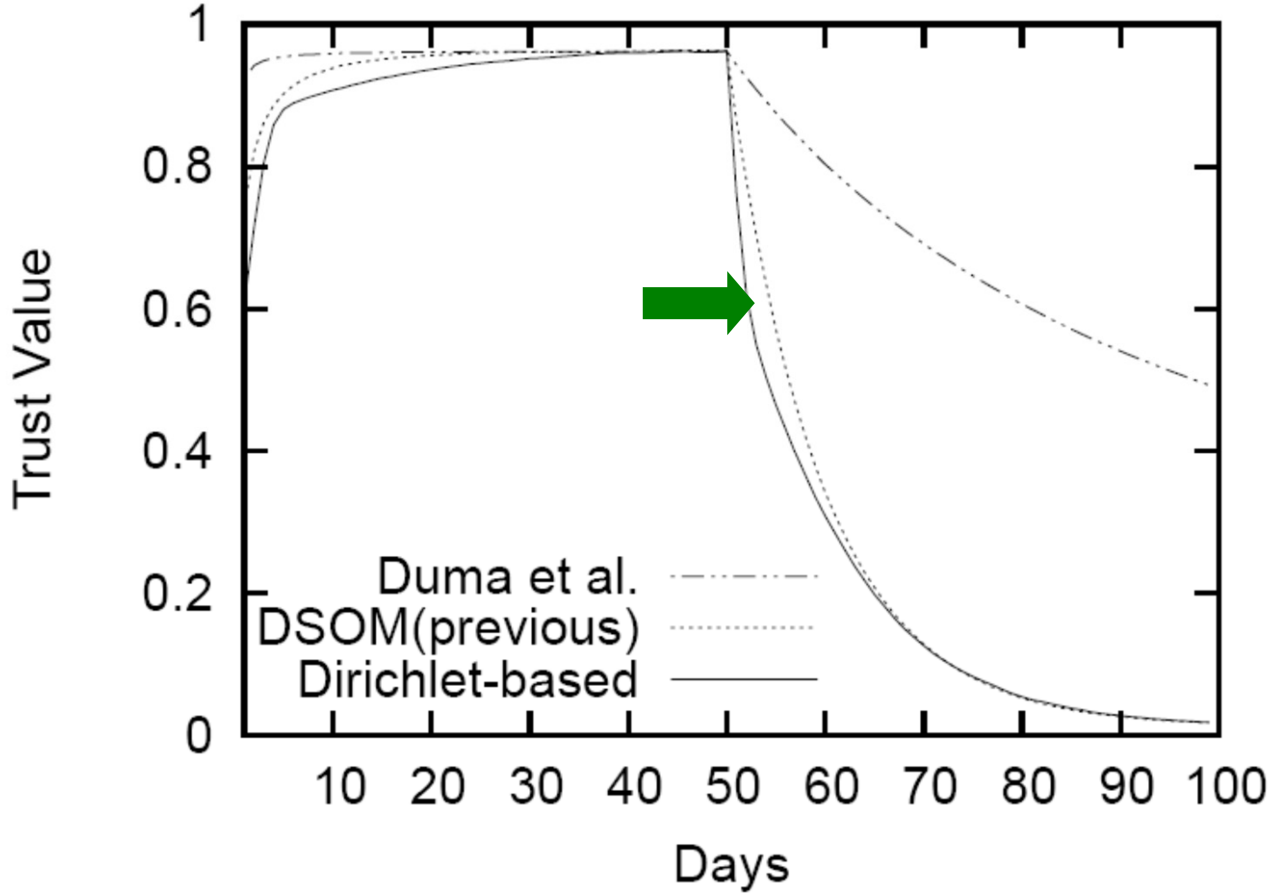


Fig 3. Trust value of malicious node under betrayal attack

Simulation Results (3)

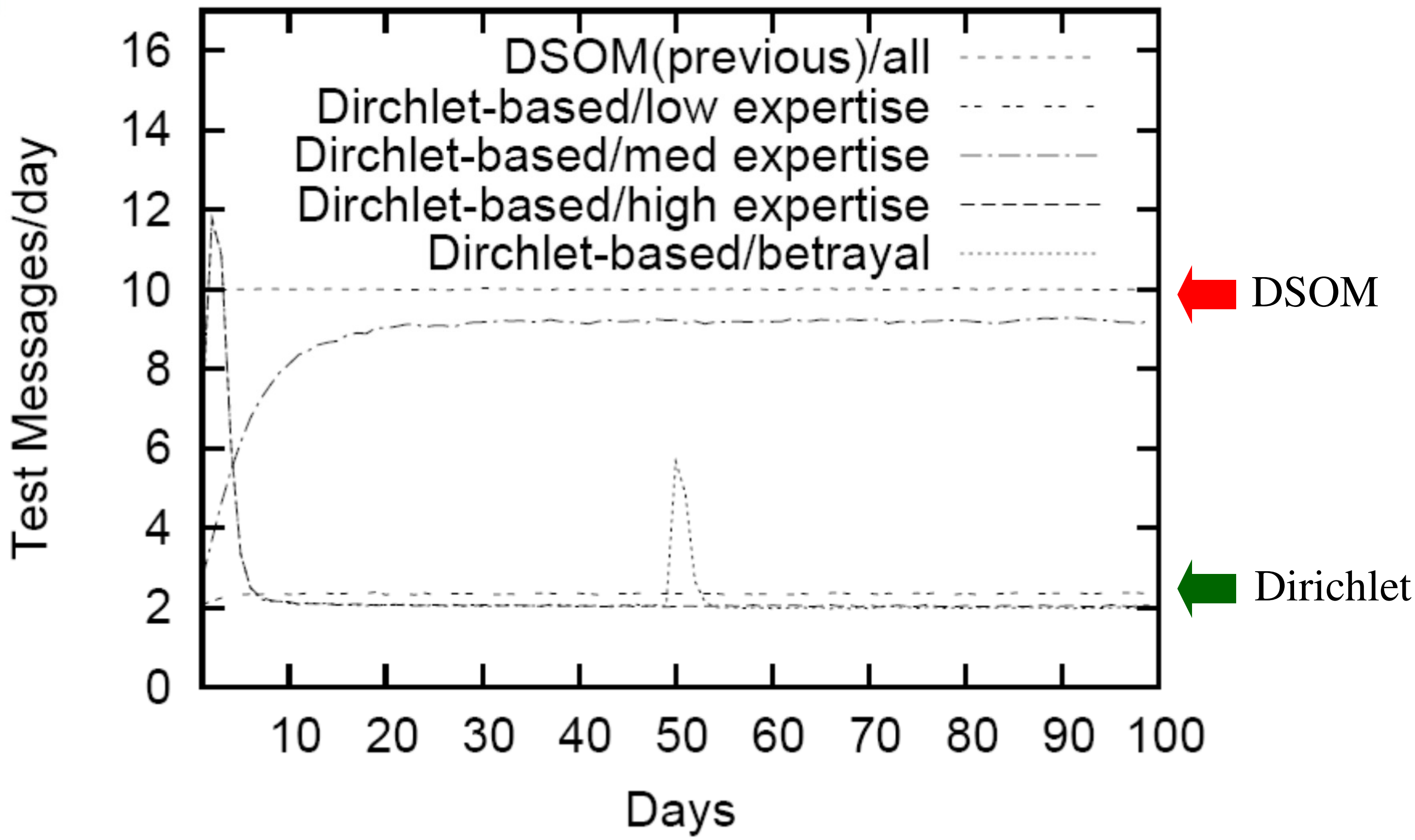


Fig 4. Test message rate under different models

Conclusion

- Proposed a trust-based IDS collaboration system
- Used the Dirichlet model to evaluate the trust values of each IDS
  – Model the confidence level of trust estimation
  – Proposed an adaptive test messages rate to reduce the communication overhead
- Improved performance, scalability, and robustness

Thank You!

Simulation Result(3)

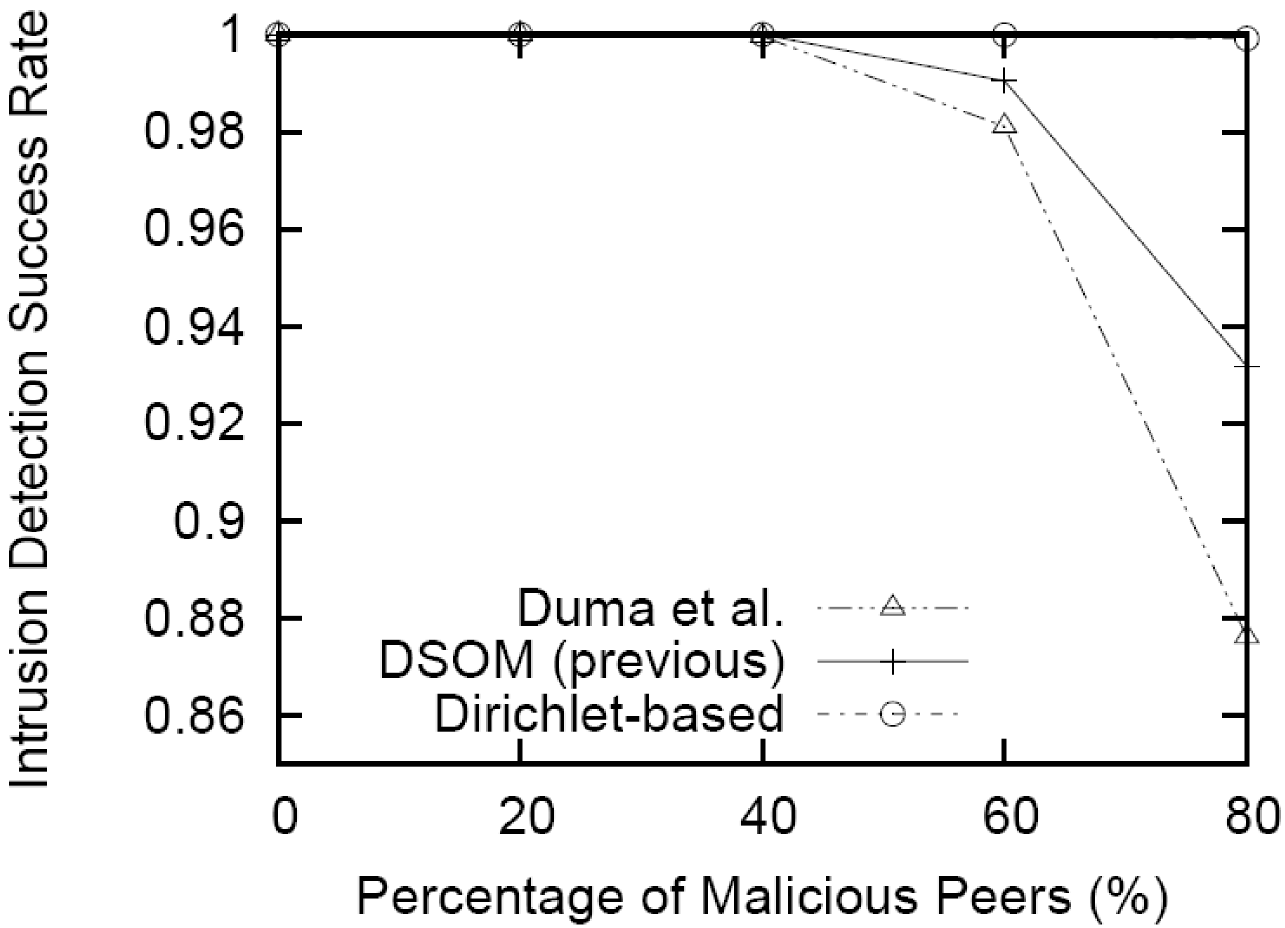


Fig 5. Detection rate under inconsistency models

Simulation Result(2)

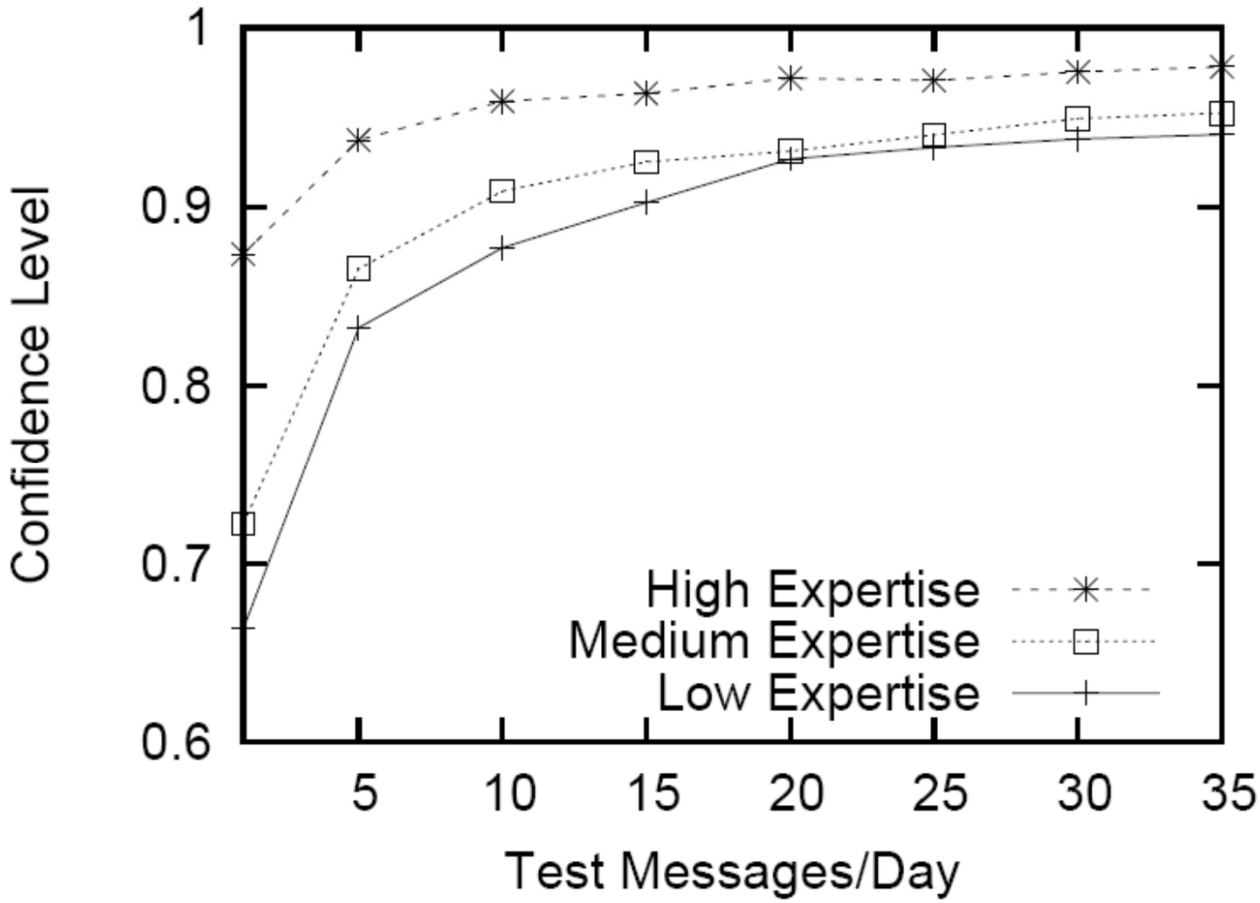
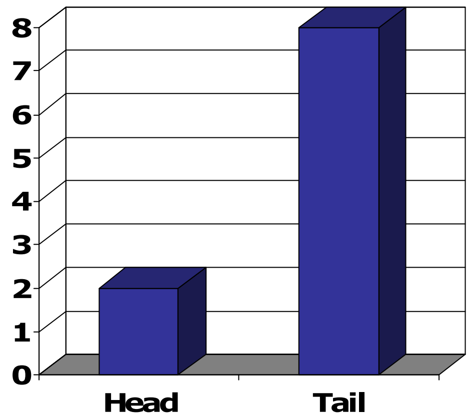
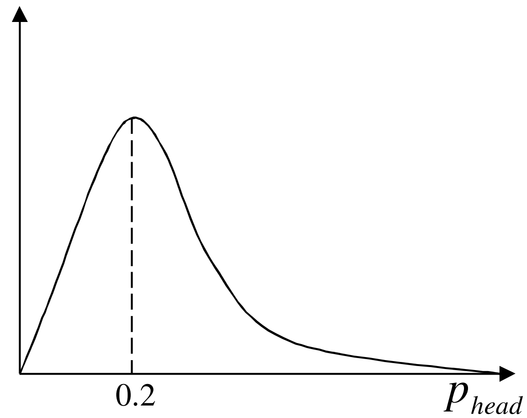


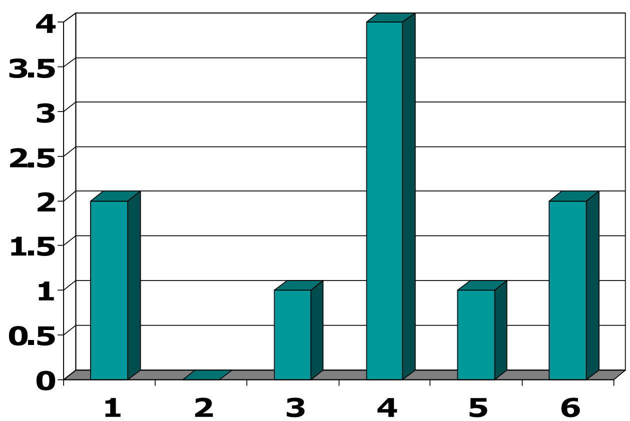
Fig 2. Confidence level and test message rate

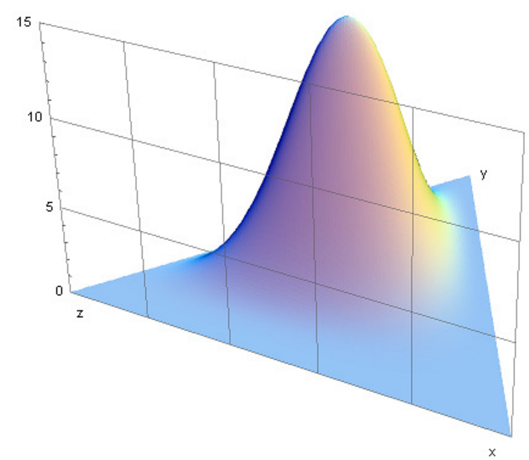
Dirichlet Distribution





$f(p_1, p_2, p_3, p_4, p_5)$





Dirichlet Distribution(con.)

A discrete random variable X has k possible outcomes. We denote the probability of each outcome to be $\{p_1, p_2, ..., p_k\}$.

We observed outcome i has appeared γ_i-1 times. Then the probability of each outcome satisfies Dirichlet probability function:

$$f(p_1,..., p_k \mid \gamma_1,...,\gamma_k) = \frac{1}{B(\gamma)} \prod_{i=1}^{k} p_i^{\alpha_i - 1}; \qquad B(\gamma) = \frac{\prod_{i=1}^{k} \Gamma(\gamma_i)}{\Gamma(\sum_{i=1}^{k} \gamma_i)}$$

Example: Toss a dice 10 times, observations on each side of the dice is{2,0,1,4,1,2}

Then the probability density function is,

$$f(p_1,...p_6 | \{3,1,2,5,2,3\}) = \frac{\Gamma(3)\Gamma(1)\Gamma(2)\Gamma(5)\Gamma(2)\Gamma(3)}{\Gamma(16)} p_1^2 p_2^0 p_3^1 p_4^5 p_5^1 p_6^2$$

Robustness of the System

- Sybil attack
- Newcomer attack
- Betrayal attack
- Collusion attack
- Inconsistency attack