Detecting Covert Communications on the Internet: Some Challenges and Solutions

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Covert Channel Definition

Any communication channel that can be exploited by a process to transfer information in a manner that violates the system security policy.

--- U.S.D.O.D. 1985, Trusted computer system evaluation criteria.

Example Internet Covert Channels

- TCP/IP Protocol
  - » Unused header fields.
  - » Encoding information in sequence numbers.
- Timing Channel
  - » Encode covert info. in the rate at which jobs are sent to a time-shared server.
  - » Measuring response times to jobs gives noisy version of message.
- Digital media (image, video…) on the web

Example Covert Messages

- Spy programs
- Company proprietary information.
- Computer virus…

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Issues in Intercepting Covert Messages on Internet (I)

- What to look for in the Internet?
- Where to look? How to identify web links that could potentially contain covert messages?
  - » Side information may be available.
  - » No side information at all.
    - random search may be futile.
    - metrics used by current web search engines may not work: e.g., popular sites.

Issues in Intercepting Covert Messages on Internet (II)

- Message carrying website may have not a public link
  - » Use http traffic request in the back bone to identify these hidden links?
- Websites are created, moved, and destroyed randomly on a daily basis
  - » Continually monitor websites of interest?
  - » How often to monitor?
- A web-page like e-bay could contain thousands of images
  - » Efficient search techniques.

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Some Approaches

- Candidate websites for investigation could be chosen as follows:
  - » External info. such as email trace, phone tapping, etc.
  - » Eliminate certain sites such as .mil, .gov…
  - » Past history.
  - » Religious cult's website?
  - » Websites of groups with radically politically opposed views?
  - » Info. from network forensic tools.

Steganography Covert Channel Requirement

- Maximize stealth
  - » Detection via steganalysis is "difficult."
  - » Perceptually transparent
- Maximize capacity
  - » Maximum embedded message length such that steganalysis detection is "difficult."
- Efficient encoding/decoding

Intercepting Steganographic Messages (I)

- Steganalysis
  - » Analyze digital data to determine presence of secret messages.
- Passive Steganalysis
  - » Steganalyst/hacker/interceptor tries to find if a secret message is present.
  - » Identify the embedding algorithm/software used.
  - » Removal of secret message is not an aim.
  - » Little or no *a priori* information available.
- Active Steganalysis
  - » Estimate the secret key, message length, etc.
  - » Estimate the secret message (grand goal!).

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Intercepting Steganographic Messages (II)

- Theoretical issues.
  - What must a steganalysis algorithm look for?
  - What are the “give aways” in current published steganography algorithms/software?
  - What is the minimum message length that can be detected?
  - What about false alarm and miss probabilities?
  - Mathematical tools from probability and statistics.
- Scalability.
  - Investigating every web site is not possible.
  - How often web sites are to be investigated?
  - Can we identify “high risk” sites in some sense?
  - Number of possible embedding algorithms could be large.
  - Message sizes could be small.

Intercepting Steganographic Messages (III)

- Is steganalysis realistic?
  - » Current approaches seem to be extreme:
    - – tuned to work for one particular embedding algorithm or use large training data set.
  - » What if the embedding algorithm is not published publicly?
  - » Need: steganalysis that works for a "class" of embedding algorithms.

Steganalysis Current Trends (I)

- Classifier/statistical learning based
  - » Train steganalysis classifiers on large training sets
  - » Use host data features.
- Pros
  - » Well understood classifier theory
  - » Works reasonably well in practice
- Cons
  - » May not work well for data that are significantly different from training set
  - » Overfitting problems
  - » How to choose training set? How large a training set? Mostly heuristics involved here.

Steganalysis Current Trends (II)

- Blind statistical system identification based
  - Use individual host data features.
  - No training set.
- Pros
  - Sound theoretical analysis possible.
  - Covert message extraction demonstrated.
- Cons
  - Stochastic non-stationarity of digital data, e.g., images.
  - New tricks needed to make it work in practice.

Optimal Web Search for Covert Message: A Mathematical Model

- Let,
  - Total number of web sites to be searched = W.
  - P(j) = Pr(website "j" contains the covert message).
  - b(j,t)=Pr(detecting covert message after spending t time units in site j | message in site j).
  - C(j,f(t))=cost of searching site j with a time/resource allocation of f(t).
  - $P(f) = \Sigma_j P(j)b(j,f(t))$ is average probability of finding covert message.
  - $C(f) = \Sigma_j C(j,f(t))$ is total cost.

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Possible Scenarios

- Case 1: $\{P(j); j=1,2,\ldots W\}$ completely known.
  - Subjectively chosen.
- Case 2: Only ordering of probabilities known, i.e., $P(1)>P(2)>\ldots>P(W)$
  - More realistic.
- Case 3: $\{P(j)\}$ completely unknown.
  - When no side info. available.

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- Web search strategy for Case 1:
  - » $P(f^*) = \max P(f)$ subject to $C(f) < T$.
- $f^*(t)$ is the optimal allocation of time to search each of the web sites.
- Suppose $b(j,t)=1-e^{-t}$, $t>0$ then, $f^*(t)$:

$$t_j = \max(0, \ln(p_j/K)); \; j=1,2,\ldots,W$$
where $K=[\Pi p_j]^{1/W} e^{-T/W}$

$$1-e^{-T/M} <= P(f^*) <= 1-T\,[\Pi p_j]^{1/W} e^{-T/W}$$

- For a desired covert message detection accuracy, bound on total required resource T can be computed.

Web Search Strategies (I)

- Let probability of detecting covert website/channel = q
- Probability of success statistically independent from one attempt to another.
- Possible search strategies:
  - » Co-ordinated strategy.
  - » Randomized strategy.

Web Search Strategies (II)

- Co-ordinated search
  - » Results of previous search results stored. That is, “memory” is built into searching.
  - » Web links previously searched, images previously investigated, etc. are stored.
  - » Avoid these links/data in future searches.
  - » Pros: Optimal strategy because of the memory.
  - » Cons: Large storage needed, cached data could become outdated…

Web Search Strategies (III)

- Randomized search
  - » No memory built.
  - » Search web sites randomly.
  - » Pros: Large storage is not needed.
  - » Cons: Does not exploit memory.

Search Relative Efficiency (I)

- N_r = no. of times a web site is searched for detecting a covert message using randomized search.
- N_c = no. of times a web site is searched for detecting a covert message using co-ordinated search.
- d_r = prob. Of detecting covert message using randomize search.
- d_c = prob. Of detecting covert message using randomize search.

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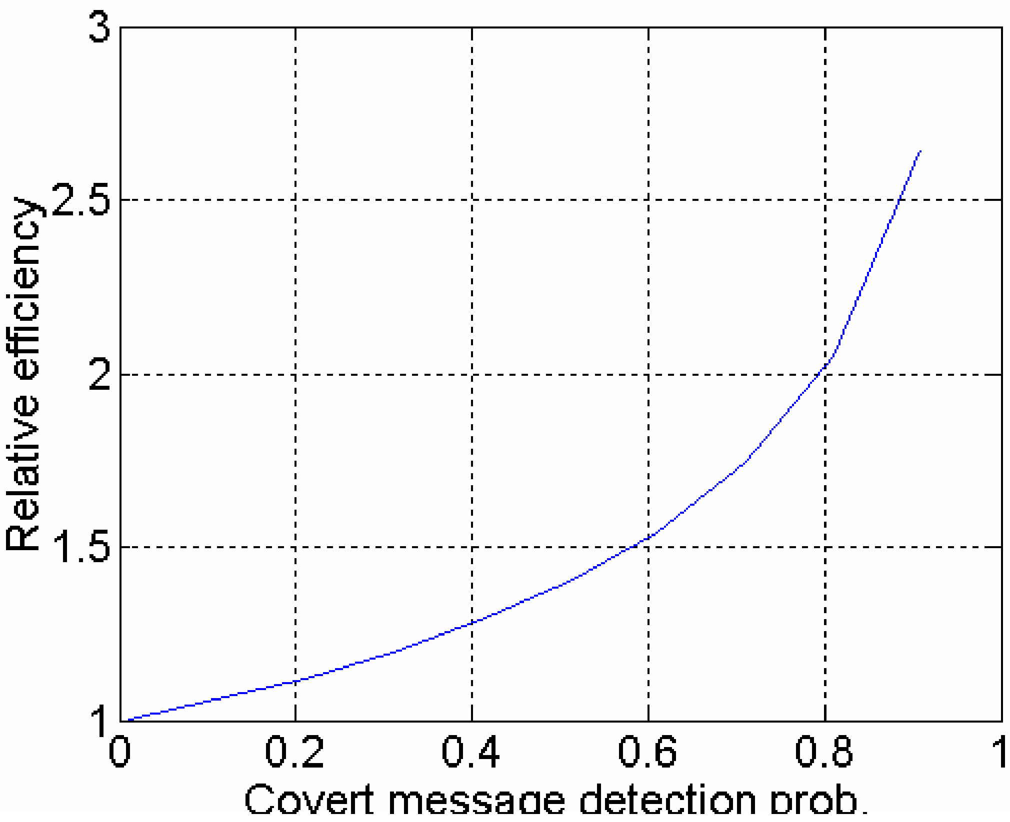
Search Relative Efficiency (II)

- If $d_r = d_c$ then, rel. eff. of the random search w.r.t. co-ord. = $-\ln(1-q)/q$.



Key Observation

- If covert message detection reliability is low, then co-ordinated and randomized searches are nearly equally efficient.

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