

PreSTA: Preventing Malicious Behavior Using Spatio-Temporal Reputation

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November 4, 2009

ONR-MURI Presentation

Report Documentation Page				Form Approved OMB No. 0704-0188	
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1. REPORT DATE 04 NOV 2009		2. REPORT TYPE		3. DATES COVERED 00-00-2009 to 00-00-2009	
4. TITLE AND SUBTITLE PreSTA: Preventing Malicious Behavior Using Spatio-Temporal Reputation				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) University of Pennsylvania,School of Engineering and Applied Science,220 South 33rd Street ,Philadelphia,PA,19104-6391				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES ONR-MURI Presentation, Nov 2009					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 23	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

PreSTA: Preventative Spatio-Temporal Aggregation

PROBLEM

SOLUTION

- Traditional punishment mechanisms (*i.e.*, blacklists) are **reactive**
- PreSTA: Detect malicious users (*i.e.*, spammers) **before** harm is done

HYPO-
THESES:

- Malicious users are **spatially** clustered (in any dimension)
- Malicious users are likely to repeat bad behaviors (**temporal**)

GIVEN:

- A historical record of those principals **known** to be bad, and the timestamp of this observation (feedback)

PRODUCE:

- An **extended** list of principals who are **thought** to be bad **now**, based on their past history, and history of those around them

TALK OUTLINE

PreSTA Running Example: Spam Detection

- Spatio-temporal properties of **spam** mail
- Basis for spatial groupings
- Calculating and combining reputations
- Classifier **performance**

Generalizing PreSTA: Additional Use-Cases for Model

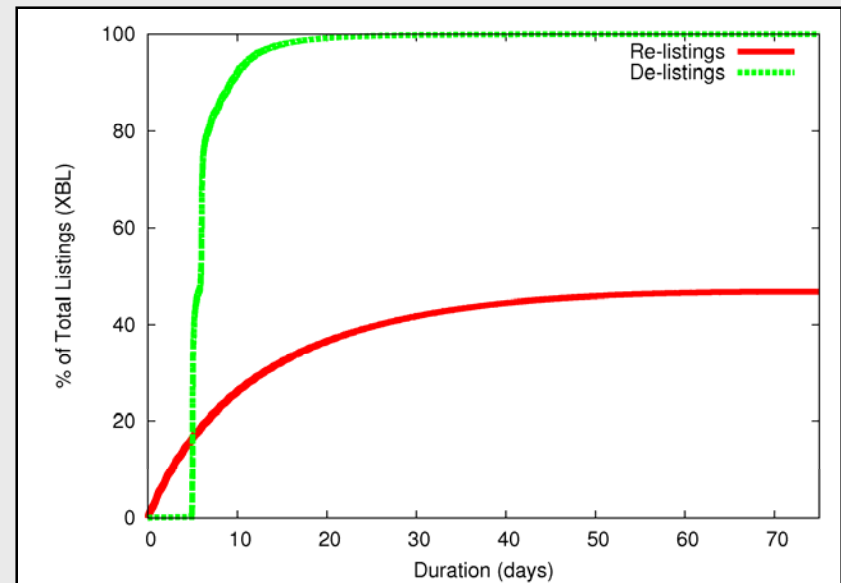
- Malicious editors on **Wikipedia**
- Applicability to the **QuanTM** model
- General PreSTA use-case criteria

Conclusions & References

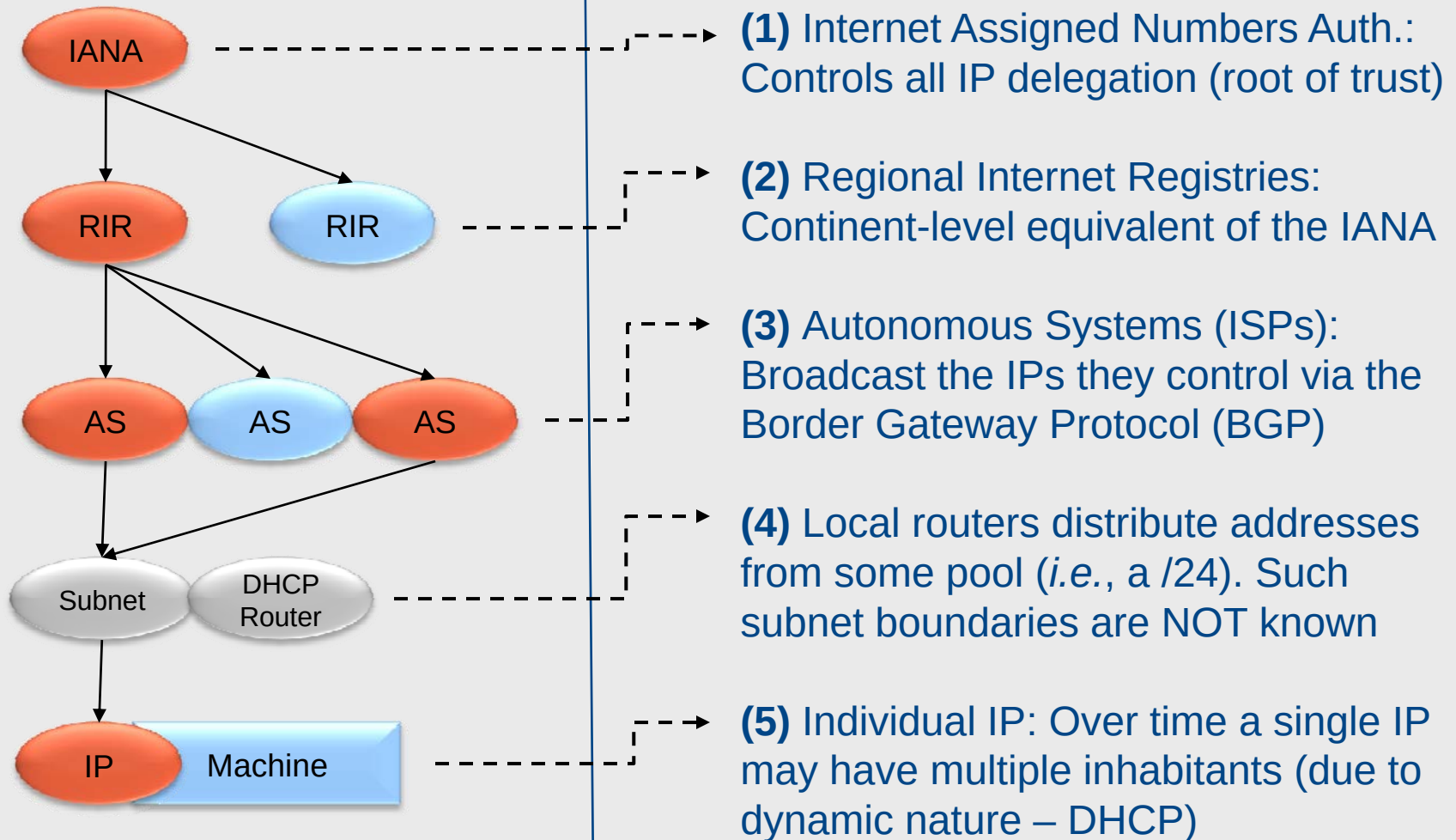
SPAM: TEMPORAL PROPERTIES

TEMPORAL: Bad Guys Repeat Bad Behaviors

- Spammers want to maximize utilization of available IP addresses, leading to **re-use**
- **Bot-nets** will compromise a machine until patched
- Blacklist entries have predictable duration (~6 days), making for trivial recycling
- Most mail servers have static IP addresses, so IP acts as a **persistent identifier** – though we later discuss DHCP considerations



IP DELEGATION HIERARCHY



SPATIAL GROUPINGS

~~IANA
/RIR~~

- The IANA and RIR granularity are too broad to be of relevant use

AS

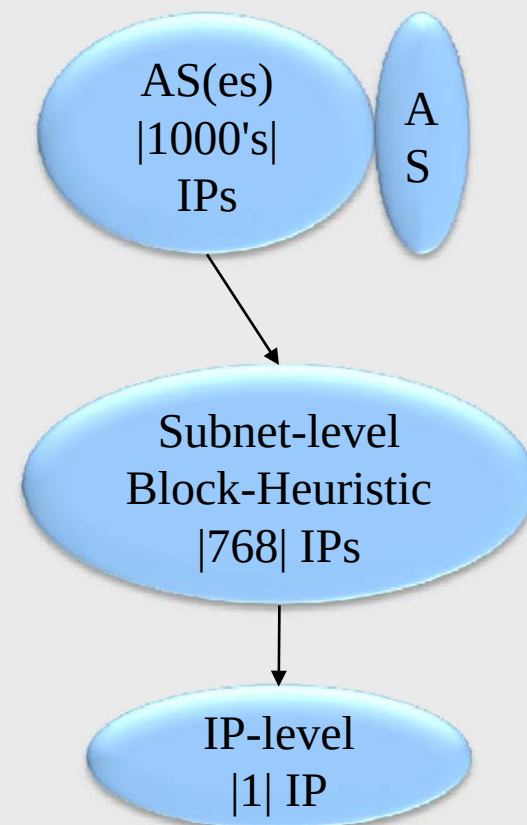
- What AS(es) are broadcasting IP?
- An IP may have 0, 1, or 2+ homes

BLOCK

- What is /24 (256 IP) membership?
- Value that block and two adjacent
- Estimation of subnet membership

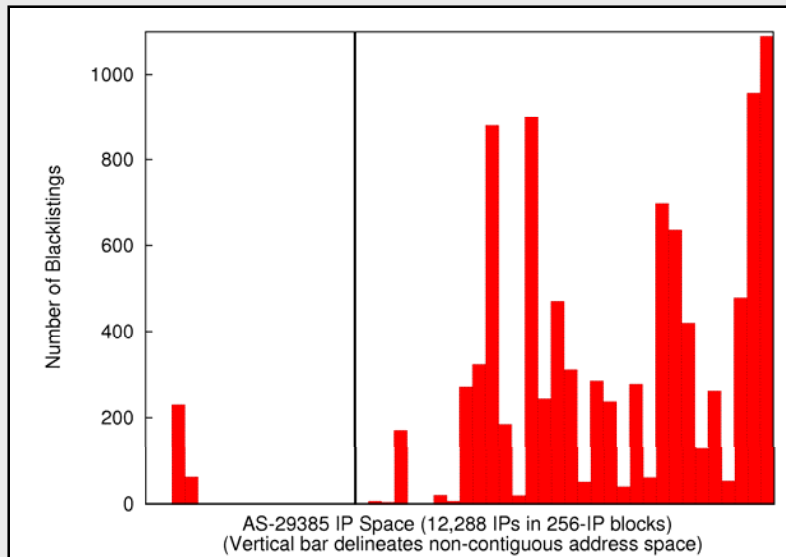
IP

- Simplest case. Little spatial value.
- Due to DHCP, may have multiple inhabitants over time, though



SPAM: SPATIAL PROPERTIES

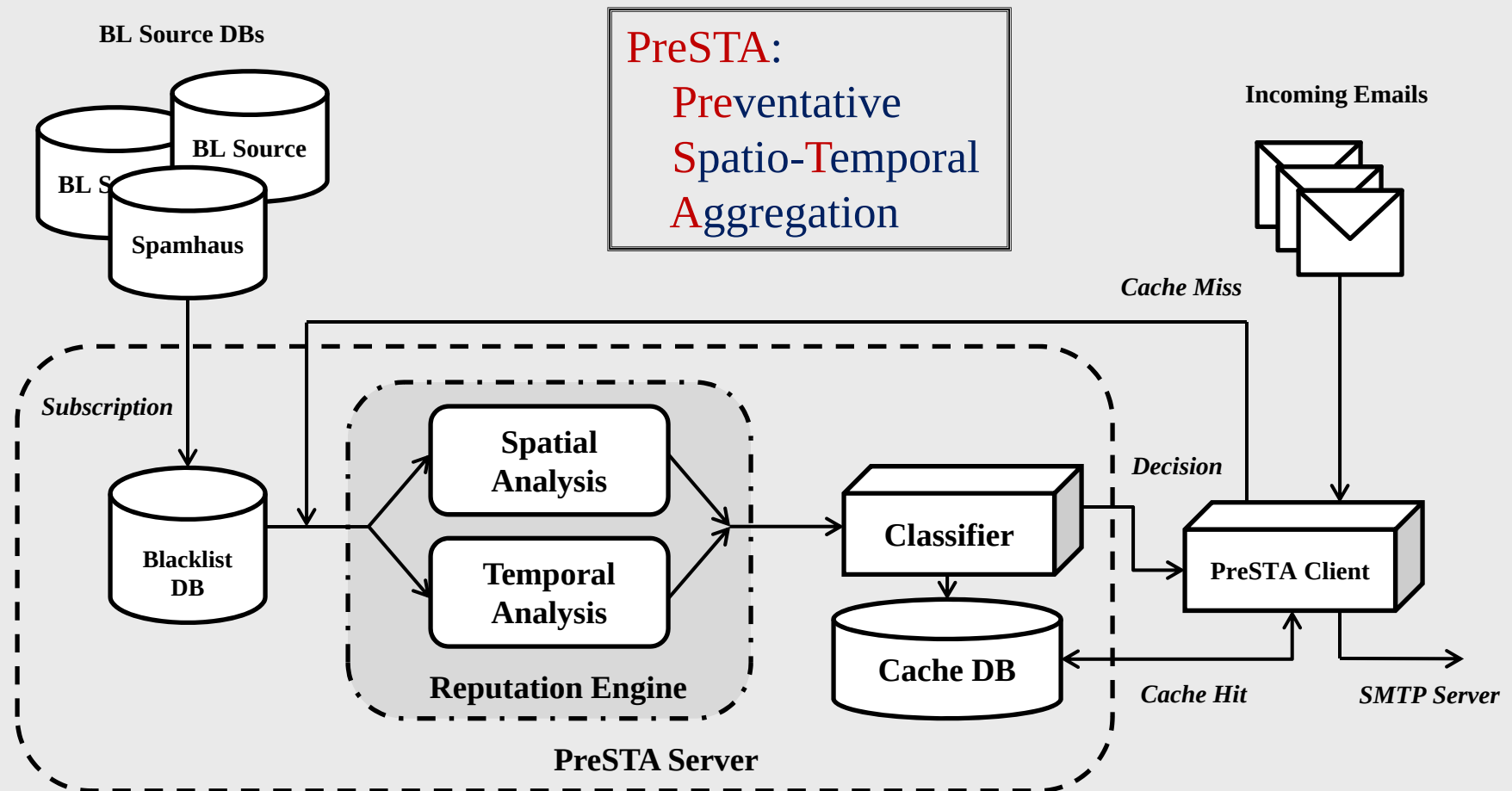
SPATIAL: Bad Guys Live in Close Proximity [3] (IP)



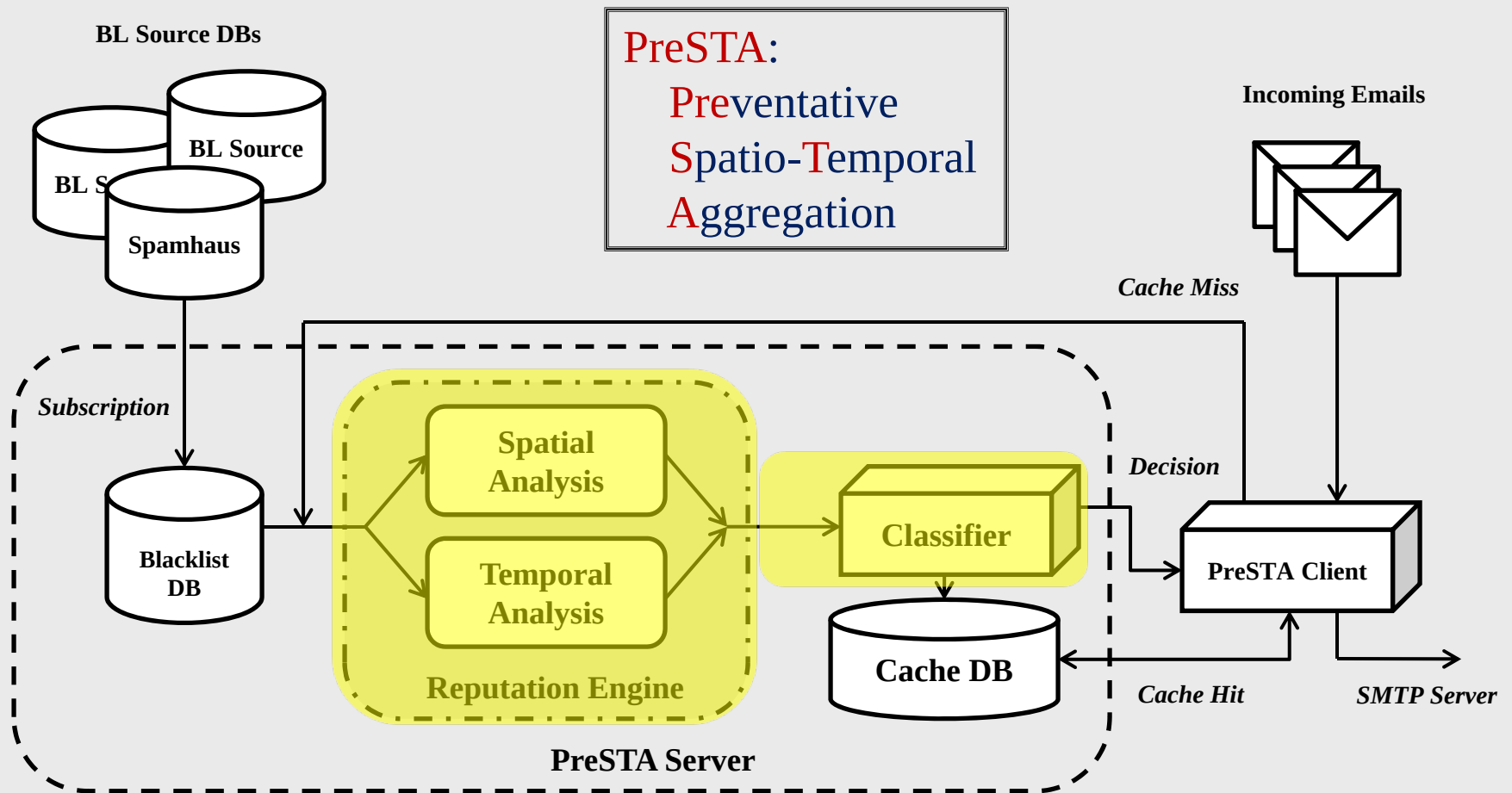
- Some ISPs/AS willing to trade **behavioral leniency** for compensation: McColo Corp. and 3FN
- Some **geographical** jurisdictions are more lenient than others (and this maps into IP space)

- As IPs become BL'ed, operations must shift to 'fresh' addresses, likely those from the same allocation (*i.e.*, subnets)

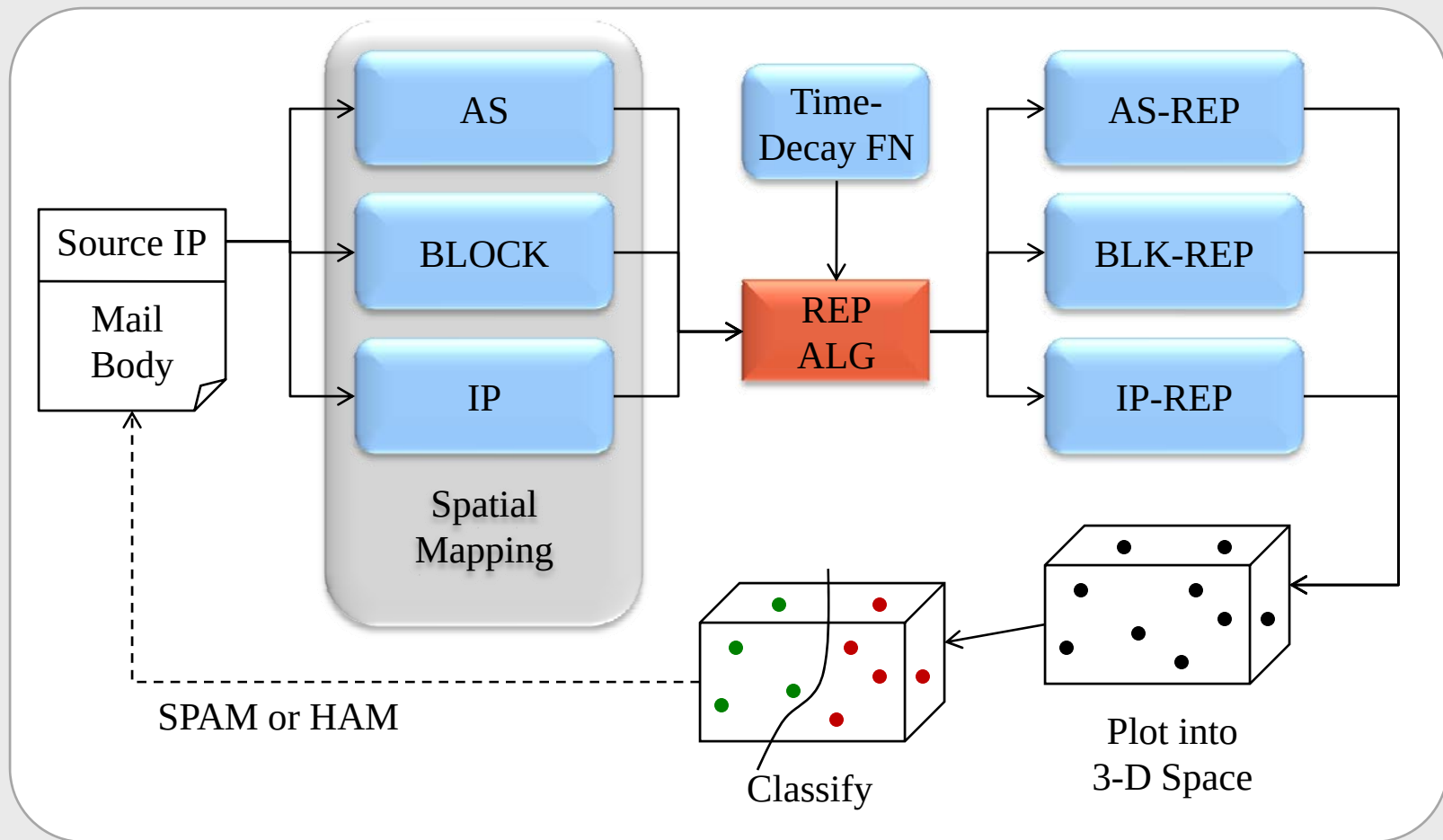
PreSTA: SPAM USAGE



PreSTA: SPAM USAGE

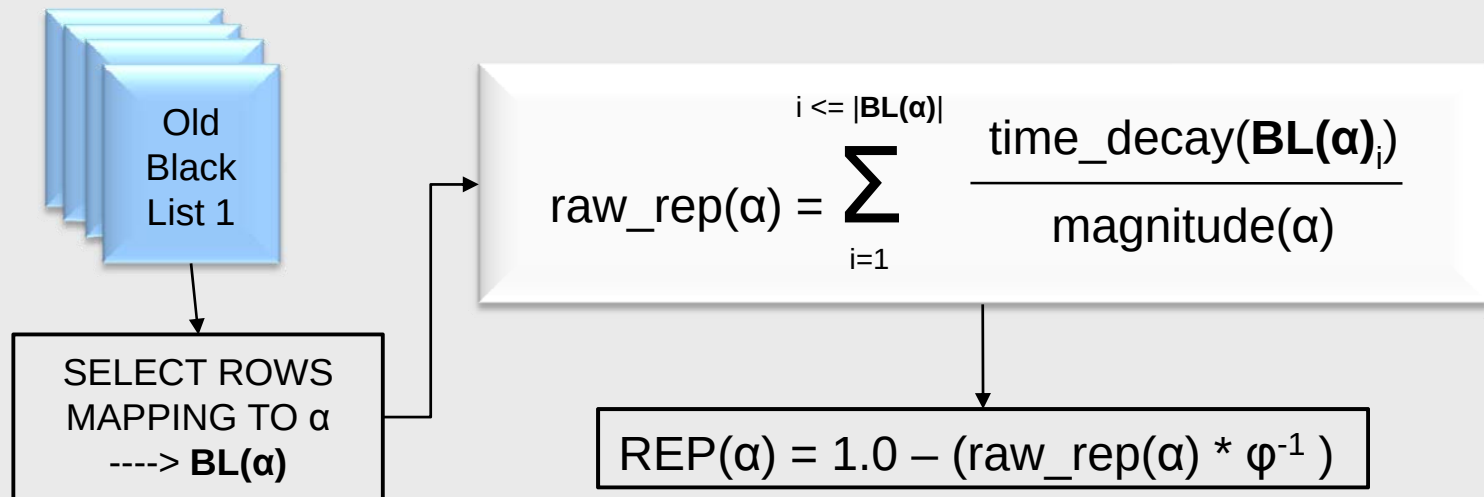


VALUATION WORKFLOW



REPUTATION ALGORITHM

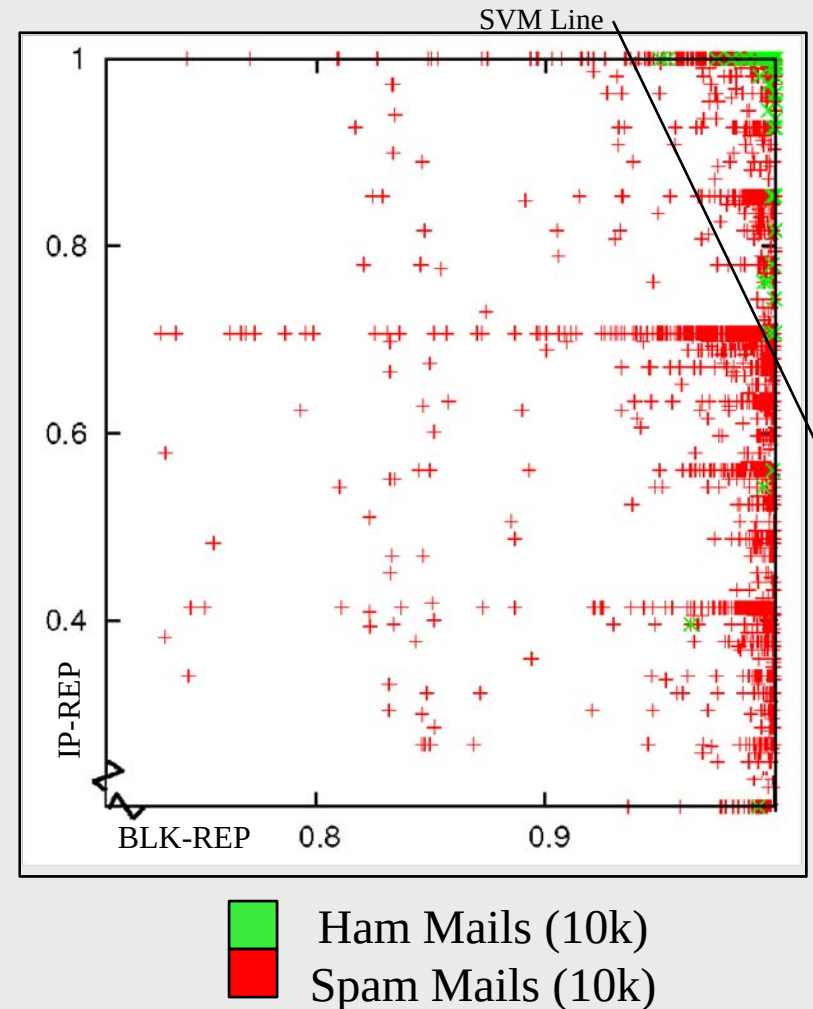
- To calculate reputation for entity α :



- $\text{time_decay}(*)$: Returns on $[0,1]$, higher weight to more recent events
- $\text{magnitude}(\alpha)$: Number of IPs in grouping α
- φ : Normalization constant putting $\text{REP}()$ on $[0,1]$

SVM LEARNING

- Combination strategies
- Support Vector Machine
 - Supervised learning
 - Train over previous email to **classify** current emails
- Draws surface (threshold) best separating points
 - Can adjust penalty weight to keep **false positives low**
 - Polynomial, RBF kernels improve on linear performance



SPAM: TESTING DATASETS

BLACKLIST

- Subscribe to **Spamhaus** provider
- Process `diff`'s between lists into DB
- Scores **86.2% detection** w/0.37% FP

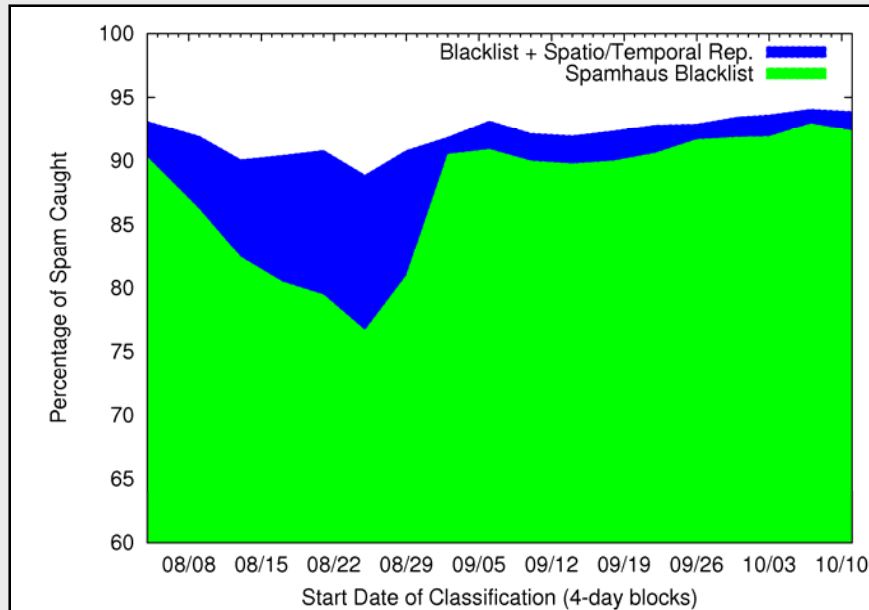
AS-MAP

- Use RouteViews data to map IP->AS

EMAIL

- 10 weeks: **15 mil. UPenn mail headers**
- Proofpoint score as definitive spam/ham tag

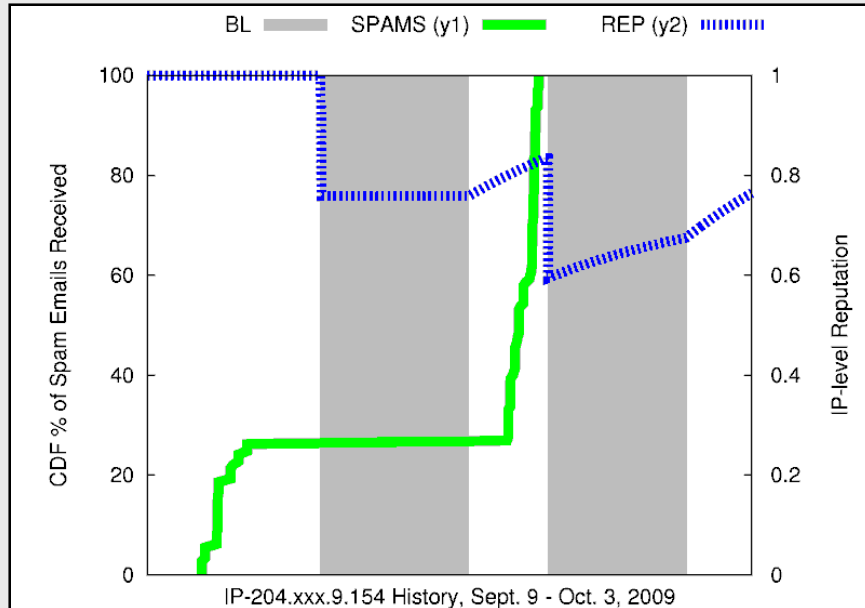
SPAM: PERFORMANCE (1)



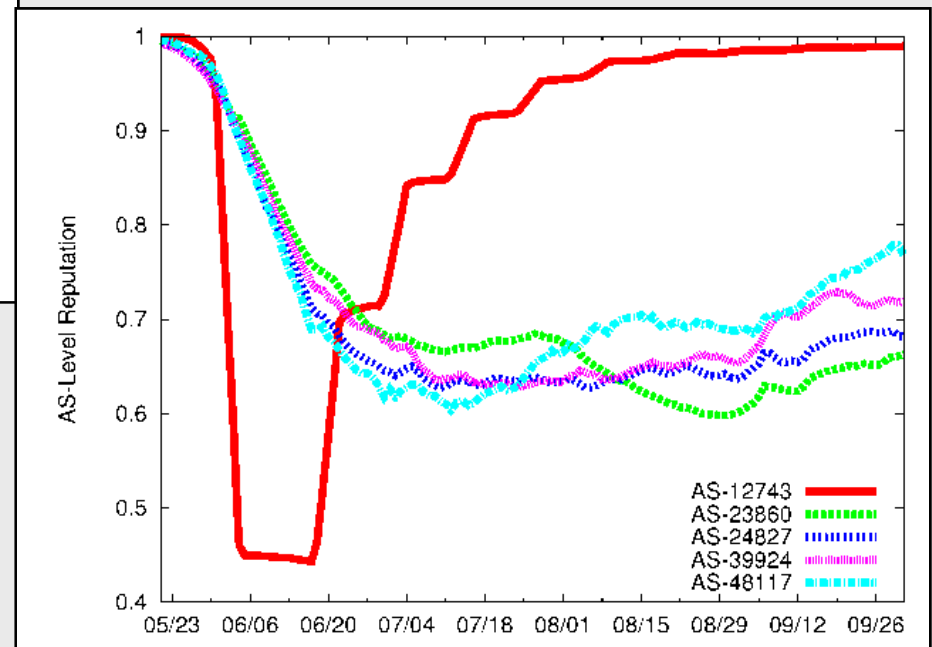
Captures up to 50% of mail not caught by traditional blacklists with the same low false-positives

- We capture between 20-50% of spam that gets past current blacklists
 - By design our FP-rate is equivalent to BLs: ~0.4%
- Total blockage remains near constant: 90%
 - Blacklists are reactive, we are predictive. We can cover its slack
 - Cat and mouse. Graph should roll over time

SPAM: PERFORMANCE (2)



< Temporal (single IP) example where our metric could mitigate spam reception



Probable botnet attack which our metric could mitigate via both temporal and spatial means >

SPAM: CONTRIBUTIONS

SNARE [3] (GA-Tech)

- Supervised learning across 13-network level features, including spatio-temporal ones
- Don't need blacklists (but **neither do we**, only known spamming IPs)

Existing 'Reputation Systems' [6]

- Exclusive use of **negative feedback**
- Existing email reputation systems [5] focus only on **sharing** classifications

DISTINGUISHING CONTRIBUTIONS

- **Formalization** of predictive spatio-temporal reputation
- Development of a **lightweight** mail filter, capable of 500k+ mails/hour

FUTURE: WIKIPEDIA

PURPOSE: Build a blacklist of user-names/IPs based on the probability they will vandalize

TEMPORAL

- Straightforward, vandals are probably **repeat offenders**
- Registered users have IDs indicating when they joined, are **new users** more likely to vandalize?

SPATIAL

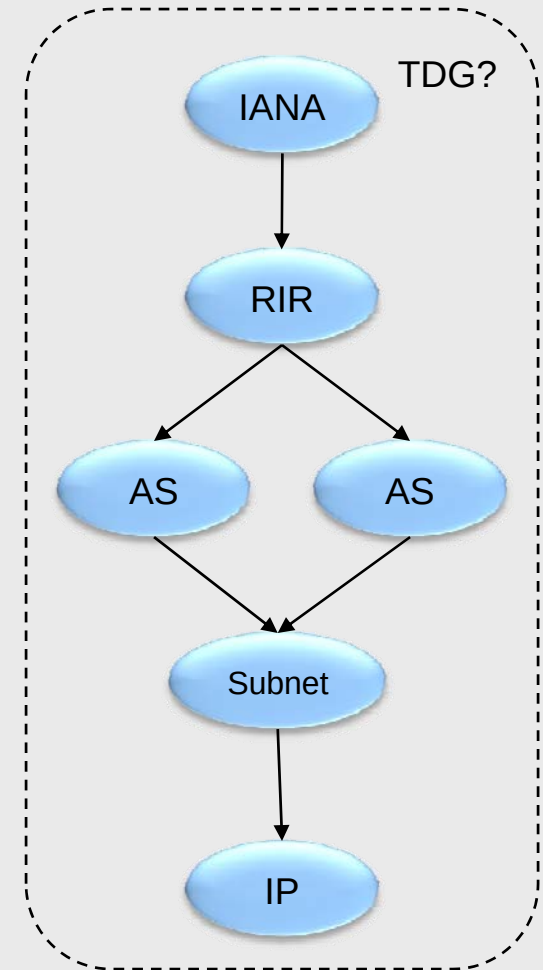
- Geographical: Based on user **location** (*i.e.*, Wash. D.C.)
- Topical: A user may vandalize one **topic** (Rush Limbaugh), while properly editing another (Barack Obama)
- Anonymous users: IP address properties

FEEDBACK

- Certain administrators have **rollback** (revert) privileges
- Comment: "Reverted edit by X to last edition by Y"

FUTURE: QUANTM [2] MODEL

- PreSTA may trivially fulfill the reputation component of qualifying **QTM** systems
 - **TDG-like** hierarchy of IP-delegation
 - Spatial groups from credential depth?
- General-use case criteria:
 - (1) There must be a grouping function to define finite sets of participants
 - (2) Observable and dynamic feedback sufficient to construct behavior history



CONCLUSIONS

Given a known set of malicious users
(and the time at which they mis-behaved)...

...additional malicious users may be identified using...

(1) **Temporal** histories of principals

(2) w.r.t the **space** in which they reside

... and such a system is useful for:

(1) Lightweight **spam**
filtering above
traditional blacklists

(2) Detecting editors
probable of vandalism
on **Wikipedia**

(3) Fulfilling the
reputation component of
any **QTM** system

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... and such a system is useful for:

(1) Lightweight **spam**
filtering vs
traditional blacklists
DONE

(2) Detecting editors
on Wikipedia
IN PROGRESS

(3) Fulfilling the
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any **QTM** system

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(and the time at which they mis-behaved)...

...additional malicious users may be identified using...

(1) **Temporal** histories of principals

(2) w.r.t the **space** in which they reside

... and such a system is useful for:

(1) Lightweight **spam**
filtering vs
traditional blacklists
DONE

(2) Detecting editors
of bad content
on Wikipedia
IN PROGRESS

(3) Enhancing the
reputation component of
any **AIW** system
**FUTURE
WORK**

REFERENCES

- [1] - West, A.G. *et al.* Preventing Malicious Behavior Using Spatio-Temporal Reputation. In submission to *EuroSys '10*.
- [2] - West, A.G. *et al.* QuanTM: A Quantitative Trust Management System. In Proceedings of *EuroSec '09*.
- [3] - Hao, S. *et al.* Detecting Spammers with SNARE: Spatio-temporal Network Level Automated Reputation Engine. In *18th USENIX Security Symposium*, August 2009.
- [4] - Ramachandran, A. *et al.* Understanding the Network-level Behavior of Spammers. In *SIGCOMM '06*.
- [5] - Alperovitch, D. *et al.* Taxonomy of Email Reputation Systems. In *Distributed Computing Systems Workshops '07*.
- [6] - Kamvar, S.D. *et al.* The EigenTrust Algorithm for Reputation Management in P2P Systems. In *12th WWW '03*.