UNIVERSITY OF FLORIDA

The Case for Less Predictable Operating System Behavior

15th Workshop on Hot Topics in Operating Systems

Ruimin Sun, Donald Porter, Daniela Oliveira,
Matt Bishop

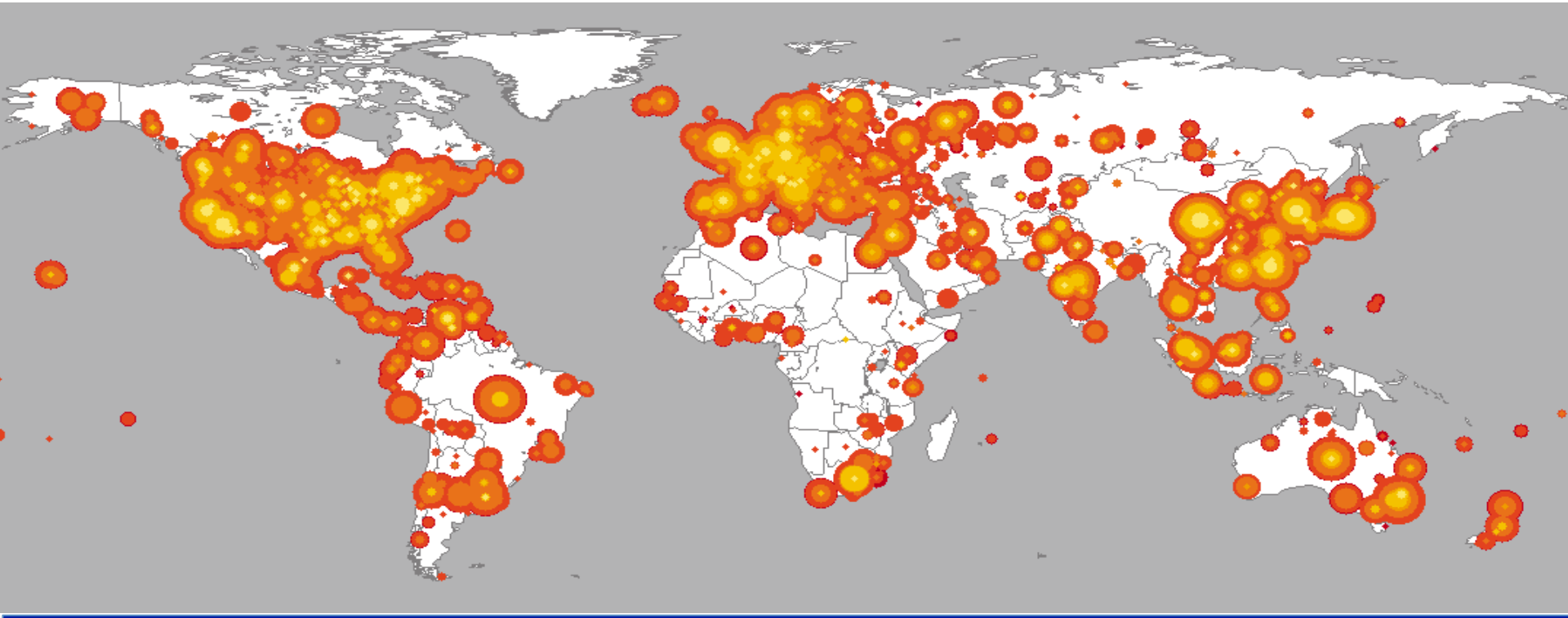
UF UNIVERSITY of FLORIDA

Stony Brook University

UCDAVIS UNIVERSITY OF CALIFORNIA

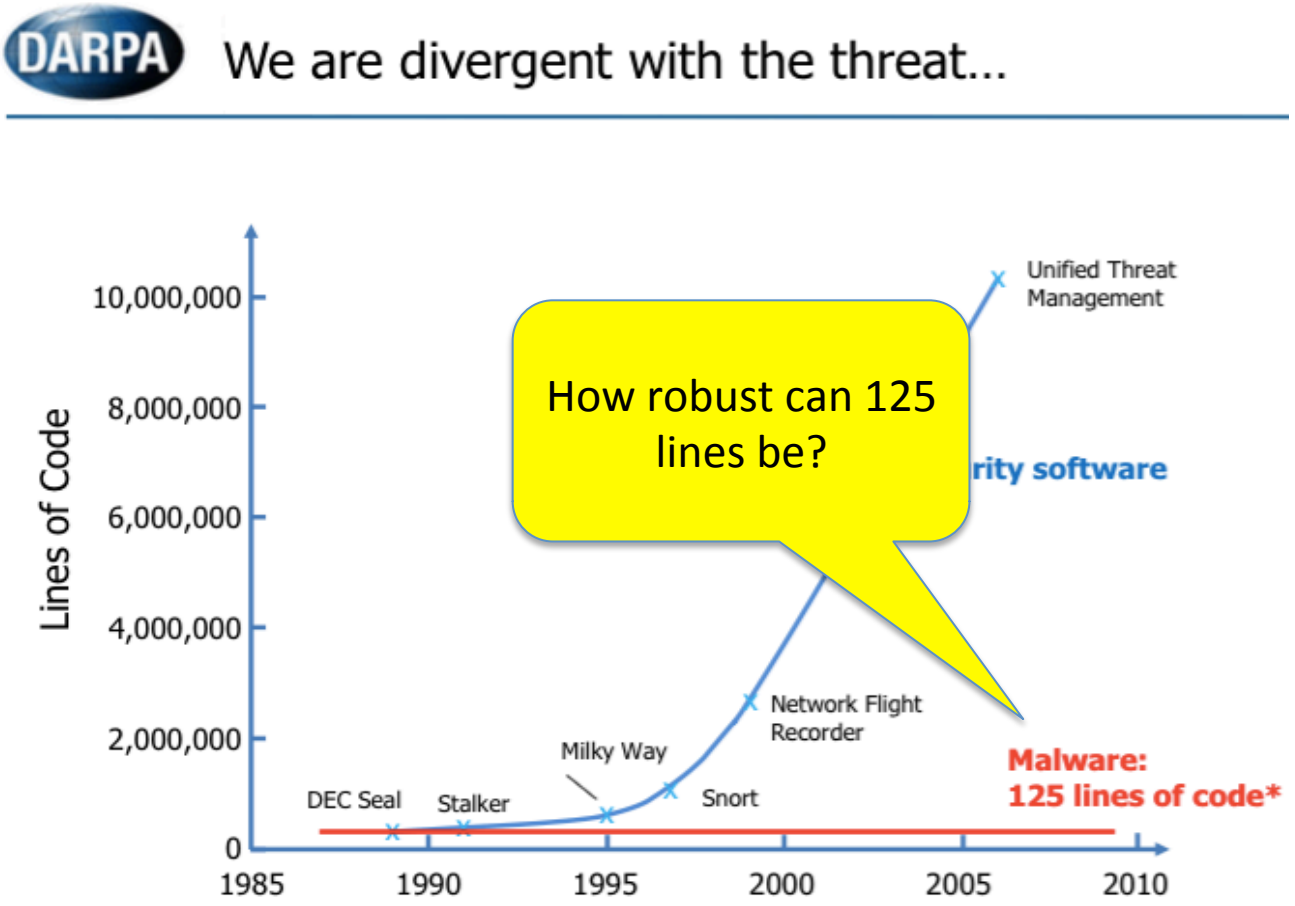
The Monoculture Problem

- Any vulnerability is automatically widespread
  - W32/Blaster infected **1.4 million** systems in **a month**.
  - Code-Red worm 2001



Malware Sizes are Small

- Lots of effort to get into a system
- Once malware on, easy to remain



Peiter "Mudge": DARPA Framework for Cyber Security 2011
Similar arguments in S. Forrest. (WEIS 2015)

We Blame Predictability

- After breaking into a system, malware almost always works as expected
  - Ex: Configuration files always in /etc

Maybe Unpredictability is the Solution?

- What if the OS behaved adversarially toward dodgy software?
  - Ex.: Doing the wrong thing for some system calls
- Robust malware would get a lot harder to write…

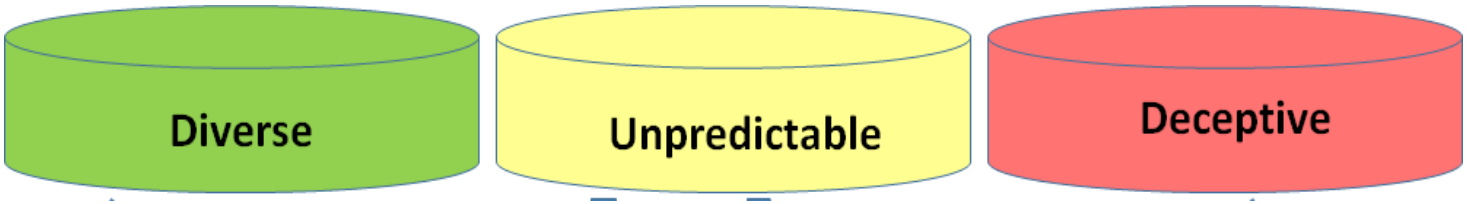
Good Software is Hard to Write

- Portable, robust software already includes a ton of error-handling code and end-to-end checks
  - E.g., lots of variation among UNIX variants
- And applications increasingly distrust the OS
  - Intel SGX, Haven, Inktag, Virtual Ghost, etc.
  - Protecting against Iago attacks amounts to even more careful system call checking

Malware should have to do at least this much work

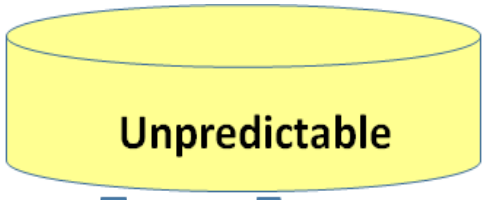
Toward An Unpredictable OS

- Our prototype: **Chameleon**
- Focus on unpredictable system call behavior
  - No bug-for-bug compatibility
  - Non-deterministic system call errors
- Applications run in one of three environments
  - Can move over time



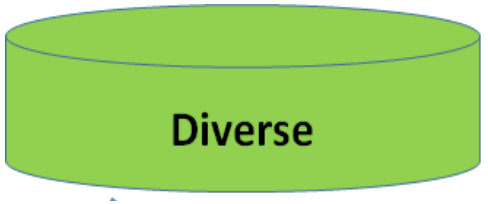
Unpredictable: Unknown Software

- Example: Downloaded game, maybe *trojan*?
- Raise engineering effort for anything to run
  - Disproportionate harm to malware?
- Approach: Perturb system calls in kernel
  - Arguments, return values, drop call altogether
- Monitor software, possibly transition to other environments



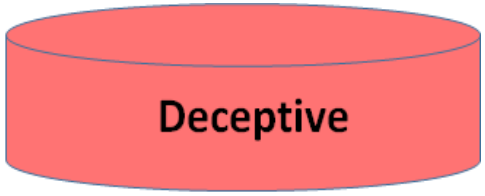
Diverse: Known-Good Software

- Fewer instances of same exploit
  - Restrict unpredictability to specification
- Trend to push functionality out of kernel
  - Easier to implement N versions of each piece
- Randomly combine *implementations* at runtime
- More in paper



Deceptive: Known Malware

- Similar to a honeypot
  - Monitor and report to CERT
- System behaves consistently, but falsely
  - E.g., bogus files, fakes actions taken as root
- More in paper



Working Scenario

Bob, 78

living in a retirement community in Florida

- not computer savvy
- clicks in links from phishing email
- installs malware engage in later DDoS attacks
- Bob never notices as malware is active after 1am.

Chameleon Scenario

Who knows?

Signed by Mozilla

Matches malware signature

Diverse

Unpredictabl

Deceptive

Looks ok

Looks malicious

Preliminary Study

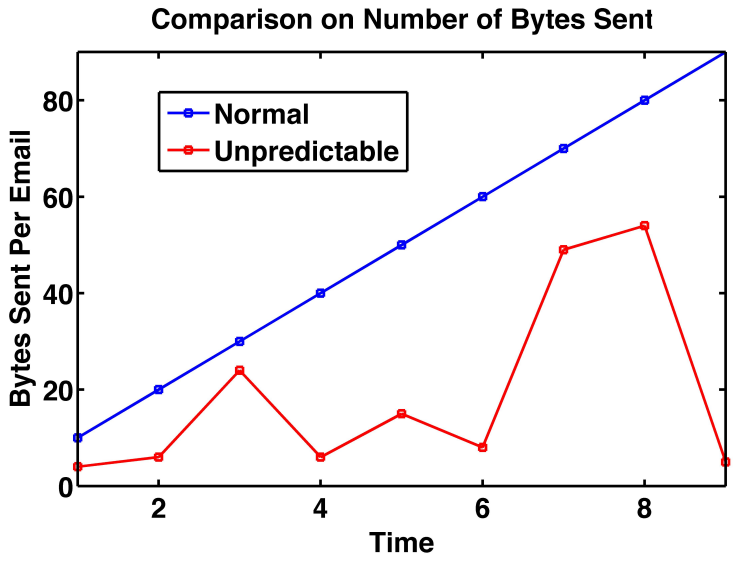
- Hypothesis
  - Malware are more sensitive to unpredictable behavior
- Methodology [more in paper]
  - Interfere with common malware system calls
- Example Strategies
  1. Ignore the system call
  2. Change buffer bytes (read, write, send)
  3. Increase wait time
  4. Change file pointer (inject a seek)

Keylogger with Unpredictability

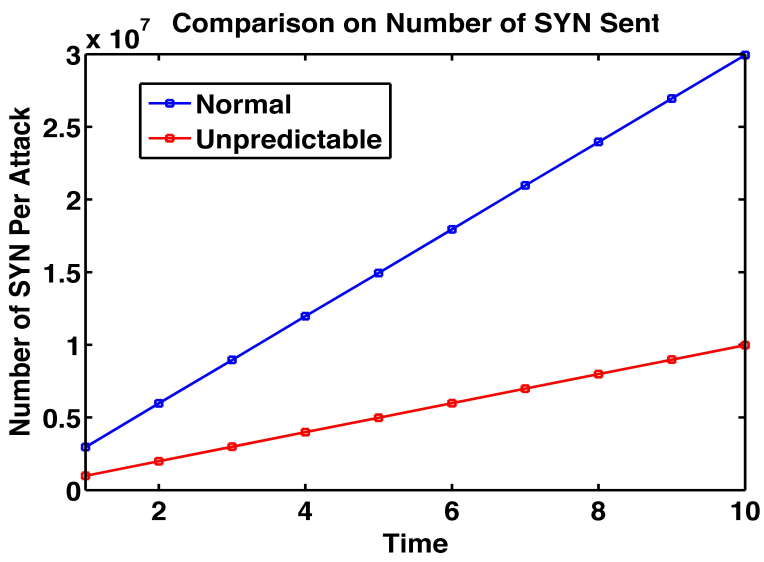
- Strategies on Keylogger
  - Change `write( fd, *buf, size)` buffer;
  - Change `lseek( fd, offset, whence)` pointer;

Botnet with Unpredictability

- Strategies on Botnet
  - Silence `read(fd, *buf, size);`
  - Silence or reduce `len` in `sendto(sockfd,*buf,len,…);`



Spam truncated with bytes lost



3 bots needed to do 1 bot's job

What About Benign Software?

- Firefox, Thunderbird and Skype work(ish)



  - Works normally most of the time
  - Occasional warnings (click “ok”)
  - Some functionality temporarily unavailable
    - Example: webpage or contacts won’t load
    - Usually fixed by retrying

Unpredictability can **disproportionately** harm malware!

Lots to Figure Out

- More precise strategies for unpredictability
  - Malware-specific system call sequences?
  - Other rules or policies for unpredictability
  - Experiment with more software and malware
- User studies with real Bobs (and Alices)
- Abuse OS classes to implement 50+ lib. instances

Conclusion

- Unpredictability can thwart attacker with less effort than generating attacks
- Chameleon's three environments:
  - Diverse: reduce monoculture of benign software
  - Unpredictable: raise engineering effort for malware to at least match other software
  - Deceptive: lures adversaries into revealing strategies

Ruimin Sun:
gracesrm@ufl.edu