On the Practical Exploitability of Dual EC in TLS Implementations

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"…[Dual EC] contains a weakness that can only be seen as a backdoor." — *Bruce Schneier, 2007*

Exclusive: Secret contract tied NSA and security industry pioneer

REUTERS

IN WAKE OF LATEST CRYPTO REVELATIONS, 'EVERYTHING IS SUSPECT'

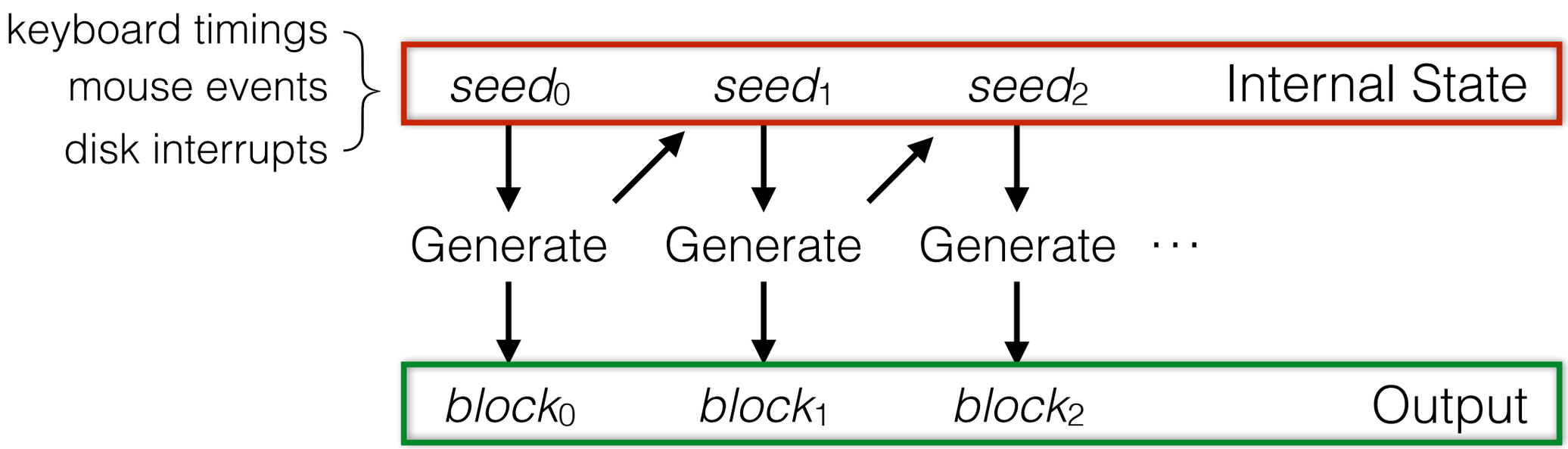
threatpost

Exclusive: NSA infiltrated RSA security more deeply than thought - study

REUTERS

Randomness and Bits

- Dual EC DRBG is a *deterministic random bit generator* included in NIST SP 800-90 until April 2014
- A DRBG turns a small random string (a *seed*) into a large (approximately) random one



Dual EC — A Provably Secure DRBG*

*Not actually true

- Dual *Elliptic Curve* DRBG relies on two points on an elliptic curve (*P* and *Q*)

- Based on "elliptic curve discrete logarithm problem": given *P* and *Q*, find *a* such that *Q* = *aP*

DualEC ↦ (

Random Data

Seed for next time

- But if I can choose *P*, *Q*, then I can design ***F***:

F(block) ↦ *seed*

Runs in ~2^{15}

Shumow & Ferguson, 2007

Dual EC — A Provably Secure DRBG*

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- Dual *Elliptic Curve* DRBG relies on two points on an elliptic curve (*P* and *Q*)

The question driving the controversy is:
did someone choose P and Q so that they could design F?

Random Data

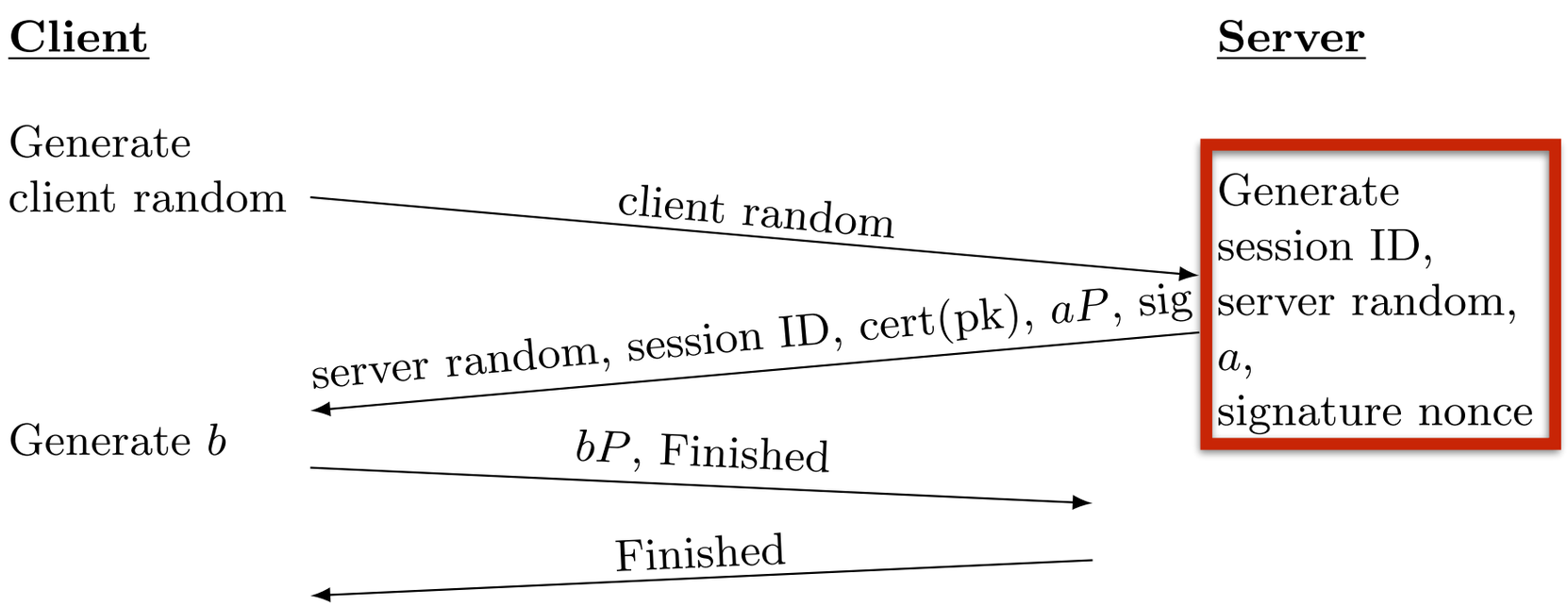
Seed for next time

- But if I can choose *P*, *Q*, then I can design ***G***:

$$G(P, Q, block) \mapsto seed$$

Runs in ~2^{15}

Why is this a problem?



$$\text{Master Secret} = \text{PRF}(x(abP), \text{“master secret”}, \text{client} \parallel \text{server random})$$

DualEC ↦ [*server random*

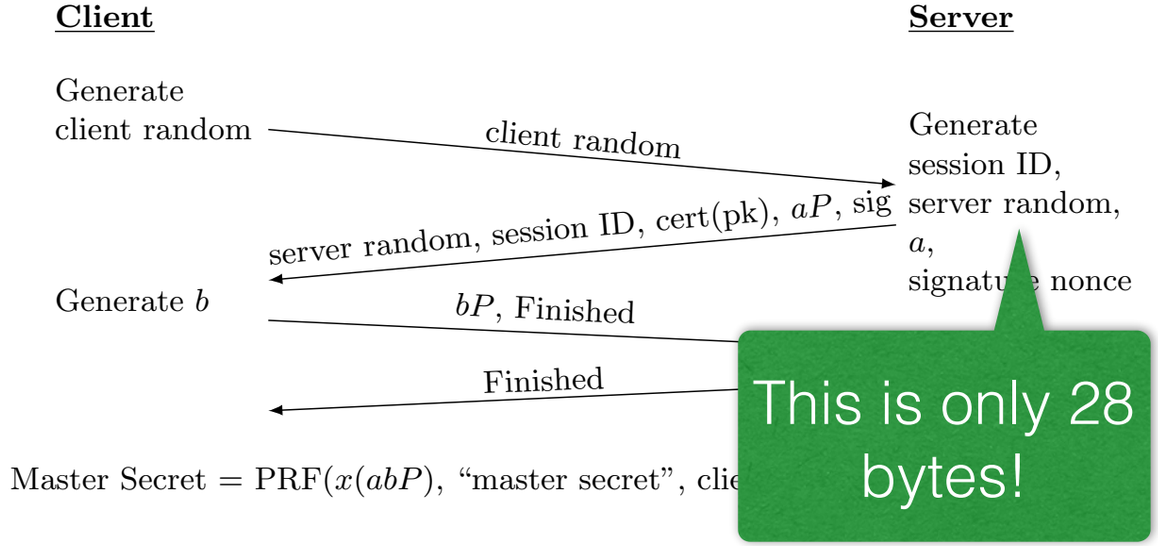
F(server random) ↦ *seed*

DualEC ↦ [

Attacker and Server do the same thing

Maybe not?

- In reality, the server might…
  - Not release enough Dual EC output (we need 30 bytes)
  - Mix other entropy into Dual EC
  - Re-seed often
  - Share state with other sessions
  - Implement the spec wrong



Testing Practical Exploitability

- We tested RSA's BSAFE, Microsoft's SChannel, OpenSSL-FIPS

- Focused on server, ECDHE cipher suites

- We *assume* the attacker has ***F***, sees network traffic

- Modified each implementation to use *P, Q* such that we know ***F***

  - Significant amount of reverse-engineering on SChannel and BSAFE

Results: OpenSSL

- We found: OpenSSL is impossible to exploit!

List: openssl-announce
Subject: Flaw in Dual EC DRBG (no, not that one)
From: Steve Marquess <marquess () opensslfoundation ! com>
Date: 2013-12-19 14:08:20
Message-ID: 52B2FDD4.5080701 () opensslfoundation ! com
[Download message RAW]

-----BEGIN PGP SIGNED MESSAGE-----
Hash: SHA1

This is an unusual bug report for an unusual situation. I'm using it
as an opportunity to point out some considerations that have not been
widely reported.

The nature of the bug shows that no one has been using the OpenSSL
Dual EC DRBG.

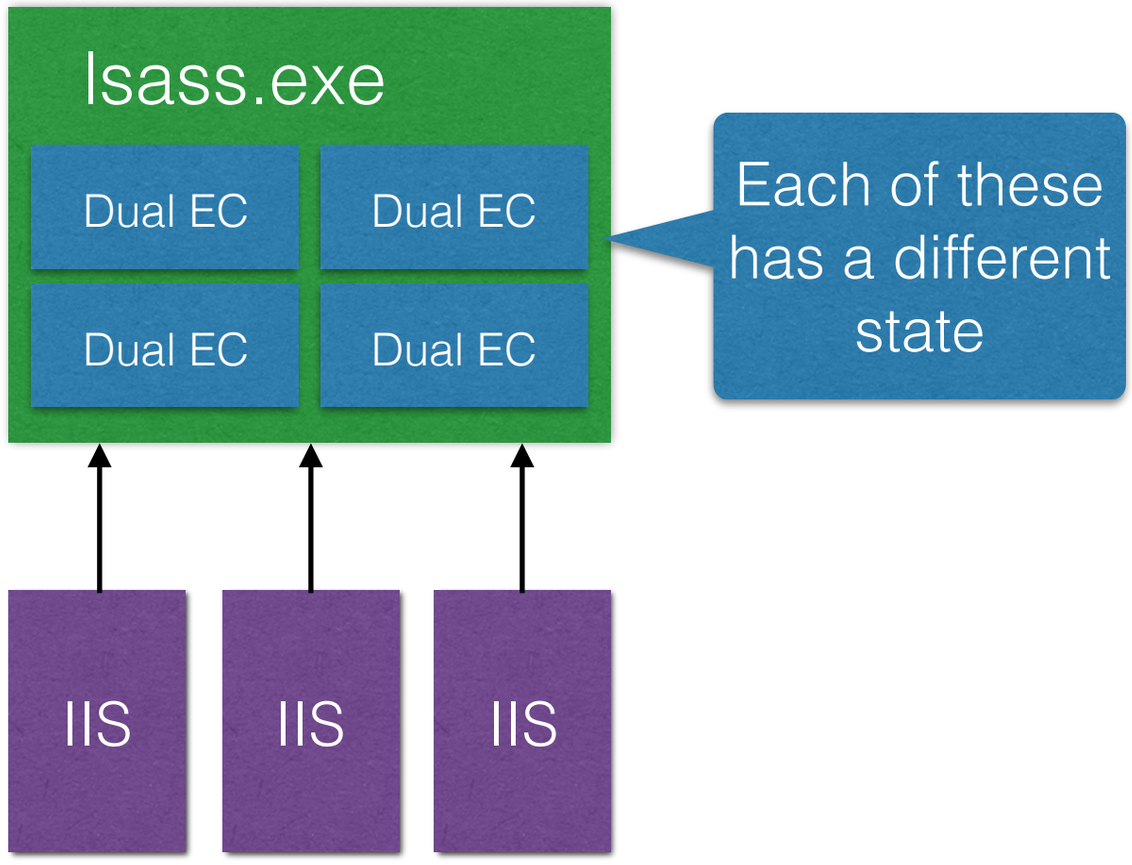
Given the current status of Dual EC DRBG (now disowned[1] by the NIST
CMVP[2] and pretty much toxic for any purpose) we do not plan to
correct the bug. A FIPS 140-2 validated module cannot be changed

Results: OpenSSL

- Uses Dual EC to generate a 32-byte session ID
- …but it also uses 20—45 bits of other entropy per call
  - time secs‖time μsecs‖counter‖PID
  - Complexity depends on guessability of counter, PID
- If we know (time secs, counter, PID), attack runs in 1.2 seconds

Results: SChannel

- Only sends 28 bytes of Dual EC output
- Does not use additional entropy or re-seed
- Also has an implementation flaw
  - …that happens to make the attack slightly faster
- Leveraging attack on future sessions more difficult
- Attack possible in ~63 minutes



Results: BSAFE

- Dual EC is the default RNG!
- Does not use additional entropy or re-seed often
- BSAFE-C caches unused outputs
- Releases variable amounts of output:
  - 31-60 bytes for BSAFE-C
  - 28 bytes for BSAFE-Java

BSAFE-C	2.4 seconds
BSAFE-Java	64 minutes

Good enough for massive surveillance

Fine for targeted sessions

Conclusions

- Dual EC *might* contain a backdoor
  - Need concrete evidence that someone knows ***F***
- If it does, they should hire better hackers
  - Fragile to low-level implementation choices
  - Only works for certain types of protocols
  - Design was suspicious from the start
- **Read the full paper at dualec.org**

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