The Logjam (and Another) Vulnerability against Diffie-Hellman Key Exchange

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The Logjam (and Another) Vulnerability against Diffie-Hellman Key Exchange

Logjam is a new attack against the Diffie-Hellman key-exchange protocol used in TLS. Basically:

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The Logjam attack allows a man-in-the-middle attacker to downgrade vulnerable TLS connections to 512-bit export-grade cryptography. This allows the attacker to read and modify any data passed over the connection. The attack is reminiscent of the FREAK attack, but is due to a flaw in the TLS protocol rather than an implementation vulnerability, and attacks a Diffie-Hellman key exchange rather than an RSA key exchange. The attack affects any server that supports DHE_EXPORT ciphers, and affects all modern web browsers. 8.4% of the Top 1 Million domains were initially vulnerable.

Here's the academic paper.

One of the problems with patching the vulnerability is that it breaks things:

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On the plus side, the vulnerability has largely been patched thanks to consultation with tech companies like Google, and updates are available now or coming soon for Chrome, Firefox and other browsers. The bad news is that the fix rendered many sites unreachable, including the main

website at the University of Michigan, which is home to many of the researchers that *found* the security hole.

This is a common problem with version downgrade attacks; patching them makes you incompatible with anyone who hasn't patched. And it's the vulnerability the media is focusing on.

Much more interesting is the other vulnerability that the researchers found:

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Millions of HTTPS, SSH, and VPN servers all use the same prime numbers for Diffie-Hellman key exchange. Practitioners believed this was safe as long as new key exchange messages were generated for every connection. However, the first step in the number field sieve—the most efficient algorithm for breaking a Diffie-Hellman connection—is dependent only on this prime. After this first step, an attacker can quickly break individual connections.

The researchers believe the NSA has been using this attack:

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We carried out this computation against the most common 512-bit prime used for TLS and demonstrate that the Logjam attack can be used to downgrade connections to 80% of TLS servers supporting DHE_EXPORT. We further estimate that an academic team can break a 768-bit prime and that a nation-state can break a 1024-bit prime. Breaking the single, most common 1024-bit prime used by web servers would allow passive eavesdropping on connections to 18% of the Top 1 Million HTTPS domains. A second prime would allow passive decryption of connections to 66% of VPN servers and 26% of SSH servers. A close reading of published NSA leaks shows that the agency's attacks on VPNs are consistent with having achieved such a break.

Remember James Bamford's 2012 comment about the NSA's cryptanalytic capabilities:

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According to another top official also involved with the program, the NSA made an enormous breakthrough several years ago in its ability to cryptanalyze, or break, unfathomably complex encryption systems employed by not only governments around the world but also many average computer users in the US. The upshot, according to this official: "Everybody's a target; everybody with communication is a target."

[...]

The breakthrough was enormous, says the former official, and soon afterward the agency pulled the shade down tight on the project, even within the intelligence community and Congress. "Only the chairman and vice chairman and the two staff directors of each intelligence committee were told about it," he says. The reason? "They were thinking that this computing breakthrough was going to give them the ability to crack current public encryption."

And remember Director of National Intelligence James Clapper's introduction to the 2013 "Black Budget":

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Also, we are investing in groundbreaking cryptanalytic capabilities to defeat adversarial cryptography and exploit internet traffic.

It's a reasonable guess that this is what both Bamford's source and Clapper are talking about. It's an attack that requires a lot of precomputation—just the sort of thing a national intelligence agency would go for.

But that requirement also speaks to its limitations. The NSA isn't going to put this capability at collection points like Room 641A at AT&T's San Francisco office: the precomputation table is too big, and the sensitivity of the capability is too high. More likely, an analyst identifies a target through some other means, and then looks for data by that target in databases like XKEYSCORE. Then he sends whatever ciphertext he finds to the Cryptanalysis and Exploitation Services (CES) group, which decrypts it if it can using this and other techniques.

Ross Anderson wrote about this earlier this month, almost certainly quoting Snowden:

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As for crypto capabilities, a lot of stuff is decrypted automatically on ingest (e.g. using a "stolen cert", presumably a private key obtained through hacking). Else the analyst sends the ciphertext to CES and they either decrypt it or say they can't.

The analysts are instructed not to think about how this all works. This quote also applied to NSA employees:

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Strict guidelines were laid down at the GCHQ complex in Cheltenham, Gloucestershire, on how to discuss projects relating to decryption. Analysts were instructed: "Do not ask about or speculate on sources or methods underpinning Bullrun."

I remember the same instructions in documents I saw about the NSA's CES.

Again, the NSA has put surveillance ahead of security. It never bothered to tell us that many of the "secure" encryption systems we were using were not secure. And we don't know what other national intelligence agencies independently discovered and used this attack.

The good news is now that we know reusing prime numbers is a bad idea, we can stop doing it.

EDITED TO ADD: The DH precomputation easily lends itself to custom ASIC design, and is something that pipelines easily. Using BitCoin mining hardware as a rough comparison, this means a couple orders of magnitude speedup.

EDITED TO ADD (5/23): Good analysis of the cryptography.

EDITED TO ADD (5/24): Good explanation by Matthew Green.
