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New Threat Models for Cryptography

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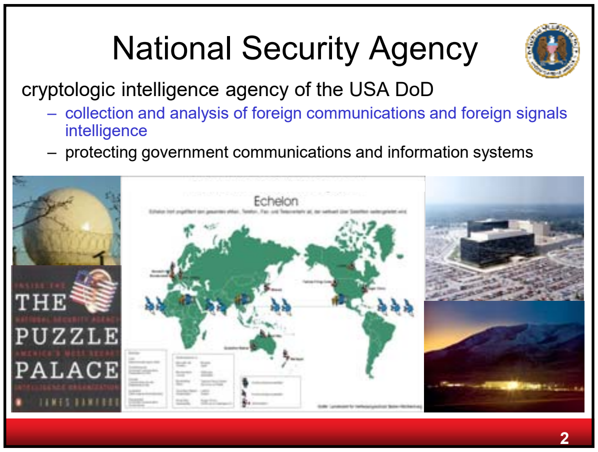
3 August 2016

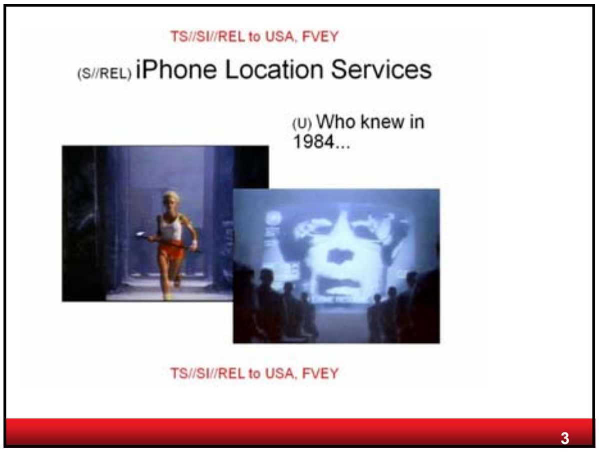


National Security Agency

cryptologic intelligence agency of the USA DoD

- collection and analysis of foreign communications and foreign signals intelligence
- protecting government communications and information systems

Echelon
INSIDE THE
THE
PUZZLE
PALACE
JAMES BAMFORD



TS//SI//REL to USA, FVEY

(S//REL) iPhone Location Services

(U) Who knew in 1984...

TS//SI//REL to USA, FVEY

TS//SI//REL to USA, FVEY

(S//REL) iPhone Location Services

(U) …that this would be big brother...

TS//SI//REL to USA, FVEY

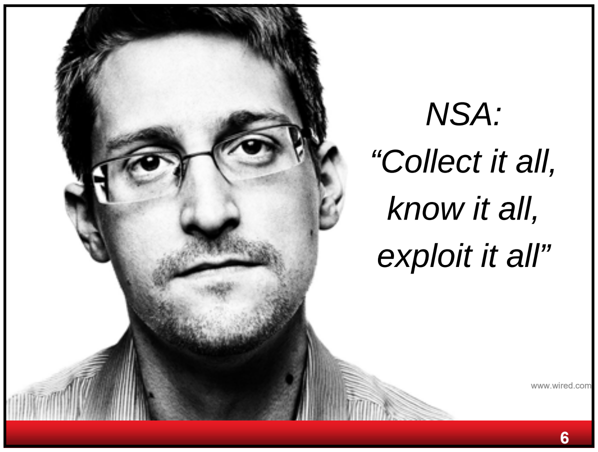
NSA calls the iPhone users public 'zombies' who pay for their own surveillance

TS//SI//REL to USA, FVEY

(S//REL) iPhone Location Services

(U) ...and the zombies would be paying customers?

TS//SI//REL to USA, FVEY



NSA:
“Collect it all,
know it all,
exploit it all”

www.wired.com

Outline

- Snowden revelation: the essentials
- Going after crypto
- Impact on systems research and policy

Snowden revelations

most capabilities could have been extrapolated from open sources

But still…

massive scale and impact (pervasive)

level of sophistication both organizational and technical

- redundancy: at least 3 methods to get to Google's data
- many other countries collaborated (beyond five eyes)
- industry collaboration through bribery, security letters*, …
  - including industrial espionage

undermining cryptographic standards with backdoors (Bullrun) … and also the credibility of NIST

* Impact of security letters reduced by Freedom Act (2 June 2015)

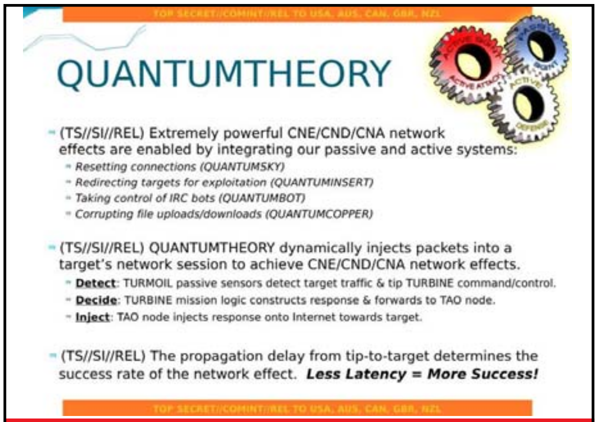
Snowden revelations (2)

Most spectacular: **active defense**

- networks
  - Quantum insertion: answer before the legitimate website
  - inject malware in devices
- devices
  - malware based on backdoors and 0-days (FoxAcid)
  - supply chain subversion

Translation in human terms: **complete control** of networks and systems, including bridging the air gaps

No longer deniable
Oversight weak



TOP SECRET//COMINT//REL TO USA, AUS, CAN, GBR, NZL

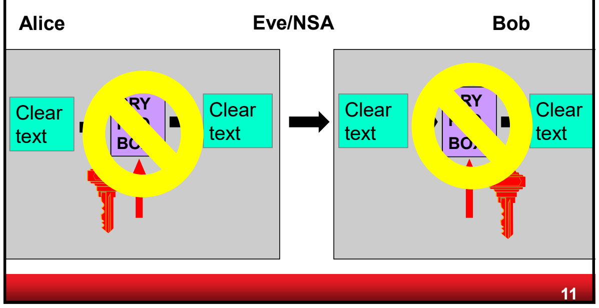
QUANTUMTHEORY

ACTIVE SIGINT
ACTIVE ATTACK
PASSIVE
SIGINT
ACTIVE
DEFENSE

- (TS//SI//REL) Extremely powerful CNE/CND/CNA network effects are enabled by integrating our passive and active systems:
  - *Resetting connections (QUANTUMSKY)*
  - *Redirecting targets for exploitation (QUANTUMINSERT)*
  - *Taking control of IRC bots (QUANTUMBOT)*
  - *Corrupting file uploads/downloads (QUANTUMCOPPER)*
- (TS//SI//REL) QUANTUMTHEORY dynamically injects packets into a target's network session to achieve CNE/CND/CNA network effects.
  - **Detect**: TURMOIL passive sensors detect target traffic & tip TURBINE command/control.
  - **Decide**: TURBINE mission logic constructs response & forwards to TAO node.
  - **Inject**: TAO node injects response onto Internet towards target.
- (TS//SI//REL) The propagation delay from tip-to-target determines the success rate of the network effect. ***Less Latency = More Success!***

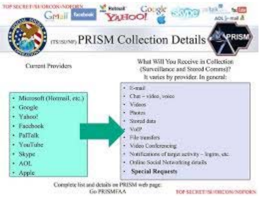
TOP SECRET//COMINT//REL TO USA, AUS, CAN, GBR, NZL

Rule #1 of cryptanalysis: search for plaintext [B. Morris]



Where do you find plaintext? SSO: Special Source Operations

1. PRISM (server) 2. Upstream (fiber)



TOP SECRET//SI//ORCON//NOFORN

Gmail
facebook
Hotmail
YAHOO!
Google
skype
paltalk
YouTube
AOL mail
PRISM

(TS//SI//NF) PRISM Collection Details

Current Providers

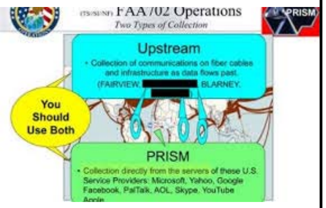
- Microsoft (Hotmail, etc.)
- Google
- Yahoo!
- Facebook
- PalTalk
- YouTube
- Skype
- AOL
- Apple

What Will You Receive in Collection (Surveillance and Stored Comms)? It varies by provider. In general:

- E-mail
- Chat – video, voice
- Videos
- Photos
- Stored data
- VoIP
- File transfers
- Video Conferencing
- Notifications of target activity – logins, etc.
- Online Social Networking details
- **Special Requests**

Complete list and details on PRISM web page: Go PRISMFAA

TOP SECRET//SI//ORCON//NOFORN



(TS//SI//NF) FAA702 Operations
Two Types of Collection

PRISM
You Should Use Both

Upstream

- Collection of communications on fiber cables and infrastructure as data flows past. (FAIRVIEW, [redacted] BLARNEY,

PRISM

- Collection directly from the servers of these U.S. Service Providers: Microsoft, Yahoo, Google Facebook, PalTalk, AOL, Skype, YouTube Apple.

Tempora

3. Traffic data (meta data) (DNR)

traffic data is not plaintext itself, but it is very informative

- who talks to whom from where and with which device
- URLs of websites
- locations of devices
- it allows to map networks and identify social relations

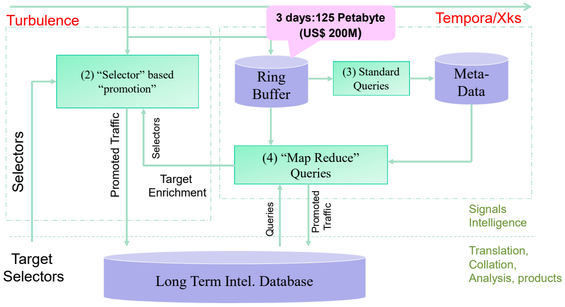
4. Client systems (TAO)

hack the client devices

- use unpatched weaknesses (disclosed by vendors or by update mechanism?)
- sophisticated malware

TEMPORA architecture

(1) Gain "access" to raw content: intercept (cable, satellite), hack, buy, ask.



Slide credit: George Danezis, UCL

* Tempora ~ Deep Dive Xkeyscore (NSA)

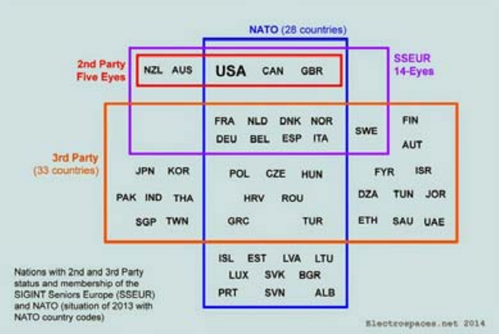
Which questions can one answer with mass surveillance systems/bulk data collection?

Tempora (GCHQ) ~ Deep Dive Xkeyscore (NSA)

- I have one phone number – find all the devices of this person, his surfing behavior, the location where he has travelled to and his closest collaborators
- Find all Microsoft Excel sheets containing MAC addresses in Belgium
- Find all exploitable machines in Panama
- Find everyone in Austria who communicates in French and who use OTR or Signal

BND has spied on EU (incl. German) companies and targets in exchange for access to these systems

NSA is not alone



Nations with 2nd and 3rd Party status and membership of the SIGINT Seniors Europe (SSEUR) and NATO (situation of 2013 with NATO country codes)

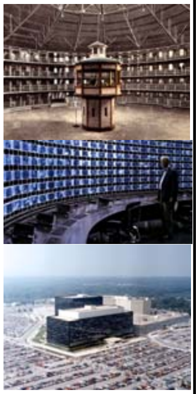
If data is the new oil, data mining yields the rocket fuel

industry
users
government

Mass Surveillance

panopticon
[Jeremy Bentham, 1791]

discrimination
fear
conformism - stifles dissent
oppression and abuse



Lessons learned

Economy of scale

Never underestimate a motivated, well-funded and competent attacker

Pervasive surveillance requires pervasive collection and active attacks (also on innocent bystanders)

Active attacks undermines integrity of and trust in computing infrastructure

Emphasis moving from COMSEC to COMPUSEC (from network security to systems security)

Need for combination of industrial policy and non-proliferation treaties

Outline

- Snowden revelation: the essentials
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- Impact on systems research and policy

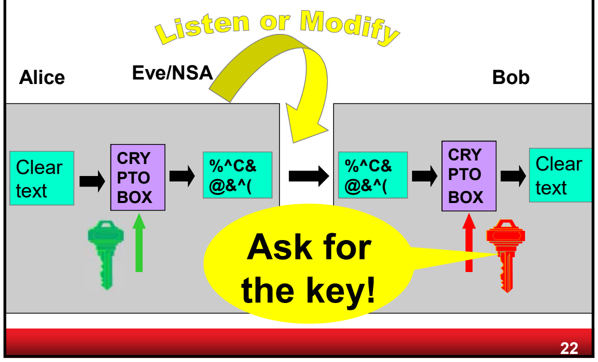
NSA foils much internet encryption

NYT 6 September 2013

The National Security Agency is winning its long-running secret war on **encryption**, using supercomputers, technical trickery, court orders and behind-the-scenes persuasion to undermine the major tools protecting the privacy of everyday communications in the Internet age

[Bullrun]

If you can’t get the plaintext



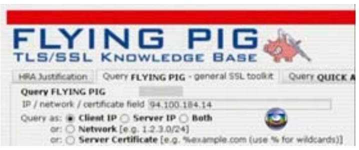
Asking for the key

- (alleged) examples – through security letters?
  - Lavabit email encryption
  - CryptoSeal Privacy VPN
  - SSL/TLS servers of large companies?
  - Silent Circle email?
  - Truecrypt??

Find the Private Key (Somehow)

- Logjam: TLS fallback to 512-bit export control legacy systems
- 1024-bit RSA and Diffie-Hellman widely used default option not strong enough

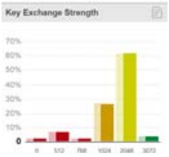
- GCHQ Flying Pig program


FLYING PIG
TLS/SSL KNOWLEDGE BASE

HRA Justification | Query FLYING PIG - general SSL toolkit | Query QUICK A

Query FLYING PIG
IP / network / certificate field: 94.100.184.14
Query as: ● Client IP ○ Server IP ○ Both
or: ○ Network [e.g. 1.2.3.0/24]
or: ○ Server Certificate [e.g. %example.com (use % for wildcards)]

[Adrian+] Imperfect Forward Secrecy: How Diffie-Hellman Fails in Practice, CCS 2015



Source: SSL Pulse

If you can't get the private key, substitute the public key

12M SSL/TLS servers

fake SSL certificates or SSL person-in-the-middle as commercial product or government attack

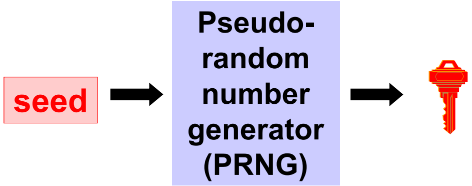
- 650 CA certs trustable by common systems
- Comodo, Diginotar, Turktrust, ANSSI, China Internet Network Information Center (CNNIC), Symantec
- Flame: rogue certificate by cryptanalysis

Let's Encrypt live since November 2015
https://letsencrypt.org/isrg/

[Holz+] TLS in the Wild, NDSS 2016
[Stevens] Counter-cryptanalysis, Crypto'13

If you can't get the key

make sure that the key is generated using a random number generator with trapdoor



seed → Pseudo-random number generator (PRNG) →

trapdoor allows to predict keys

Dual_EC_DRBG

Dual Elliptic Curve Deterministic Random Bit Generator

- ANSI and ISO standard
- 1 of the 4 PRNGs in NIST SP 800-90A
  - draft Dec. 2005; published 2006; revised 2012
- Two "suspicious" parameters P and Q
- Many warnings and critical comments
  - before publication [Gjøsteen05], [Schoenmakers-Sidorenko06]
  - after publication [Ferguson-Shumov07]

Appendix: The security of Dual_EC_DRBG requires that the points P and Q be properly generated. To avoid using potentially weak points, the points specified in Appendix A.1 should be used.

Dual_EC_DRBG

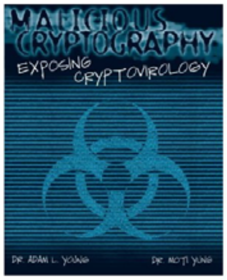
- 10 Sept. 2013, NYT: "internal memos leaked by a former NSA contractor suggest that [..] the Dual EC DRBG standard […] contains a **backdoor** for the NSA."
- 16 Sept. 2013: NIST **"strongly recommends" against the use of Dual_EC_DRBG**, as specified in SP 800-90A (2012)
- Nov. 2013: RSA's BSAFE library chooses DUAL_EC as default
- Dec. 2015: Juniper announces Dual_EC problems for Netscreen
  - 08: 6.2.r01 uses Dual_EC in a way it can be exploited
  - 12: someone changed the backdoor (6.2.r015)

[Checkoway+] On the Practical Exploitability of Dual EC in TLS Implementations, Usenix Security 2014

[Checkoway+] A Systematic Analysis of the Juniper Dual EC Incident, Cryptology ePrint Archive, Report 2016/376

Cryptovirology [Young-Yung]

http://www.cryptovirology.com/cryptovfiles/research.html



Title: Malicious Cryptography – Exposing Cryptovirology

Authors: Adam Young
Moti Yung

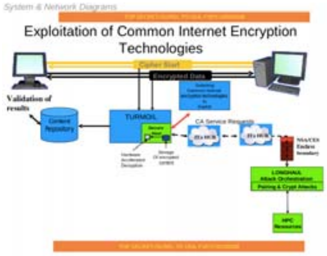
Date: February, 2004

Publisher: John Wiley & Sons

NSA can (sometimes) break SSL/TLS, IPsec, SSH, PPTP, Skype

end 2011:

decrypt 20,000 VPN connections/hour



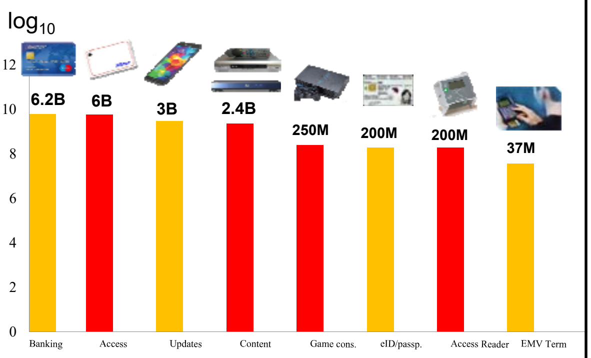
- http://www.spiegel.de/international/germany/inside-the-nsa-s-war-on-internet-security-a-1010361.html
- http://blog.cryptographyengineering.com/2014/12/on-new-snowden-documents.html

Fighting cryptography

- Weak implementations: PRNG or more
- Going after keys
- Undermining standards
- Cryptanalysis

- Increase complexity of standards
- Export controls
- Hardware backdoors
- Work with law enforcement to promote backdoor access and data retention

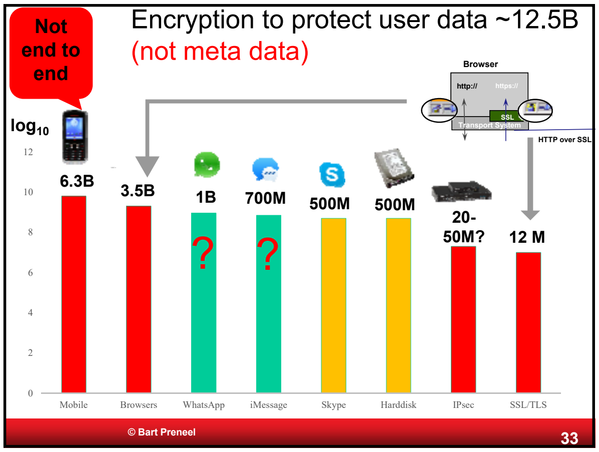
Encryption to protect industry ~18.3B



© Bart Preneel

Not end to end

Encryption to protect user data ~12.5B
(not meta data)



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Outline

- Snowden revelation: the essentials
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COMSEC - Communication Security

Secure channels: still a challenge

- authenticated encryption studied in CAESAR http://competitions.cr.yp.to/caesar.html

Forward secrecy: Diffie-Hellman versus RSA

Denial of service

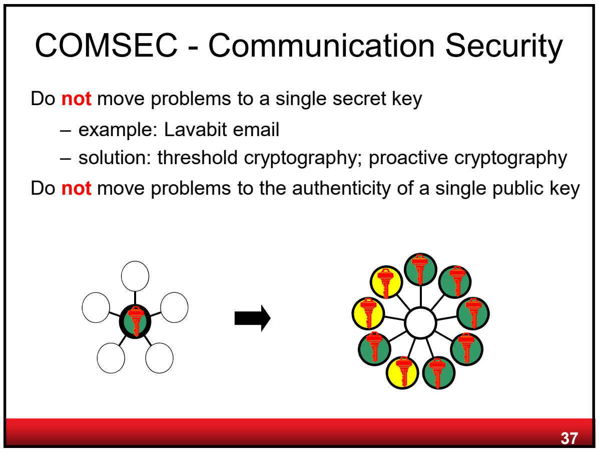
Simplify internet protocols with security by default: DNS, BGP, TCP, IP, http, SMTP,…

COMSEC - Communication Security **meta data**

Hiding communicating identities

- – few solutions – need more
- – largest one is TOR with a few million users
- – well managed but known limitations
  - e.g. security limited if user and destination are in same country

Location privacy: problematic



COMSEC - Communication Security

Do **not** move problems to a single secret key

- example: Lavabit email
- solution: threshold cryptography; proactive cryptography

Do **not** move problems to the authenticity of a single public key

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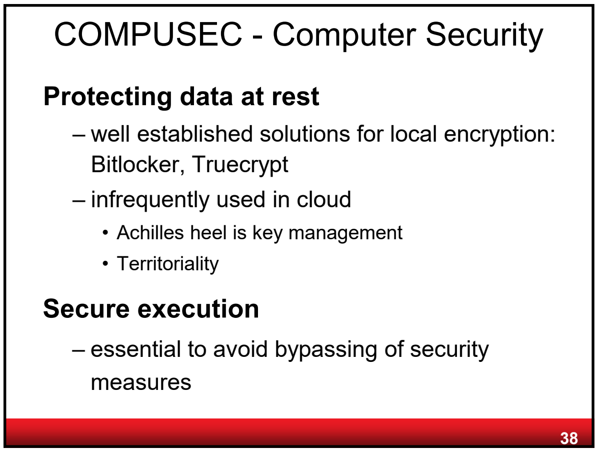

COMPUSEC - Computer Security

Protecting data at rest

- well established solutions for local encryption: Bitlocker, Truecrypt
- infrequently used in cloud
  - Achilles heel is key management
  - Territoriality

Secure execution

- essential to avoid bypassing of security measures

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Architecture is politics [Mitch Kaipor'93]

Control:

avoid single point of trust that becomes single point of failure

Stop massive data collection

big data yields big breaches (think pollution)

this is both a privacy and a security problem (think OPM)

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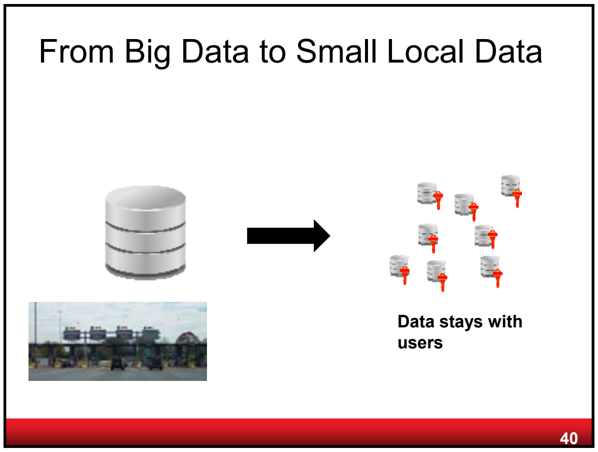
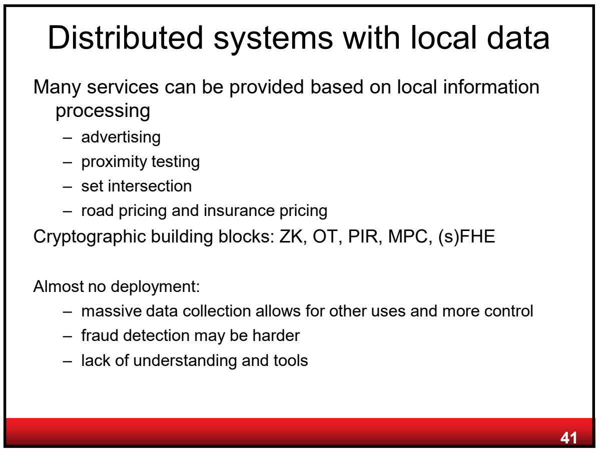


From Big Data to Small Local Data

40



Distributed systems with local data

Many services can be provided based on local information processing

- advertising
- proximity testing
- set intersection
- road pricing and insurance pricing

Cryptographic building blocks: ZK, OT, PIR, MPC, (s)FHE

Almost no deployment:

- massive data collection allows for other uses and more control
- fraud detection may be harder
- lack of understanding and tools

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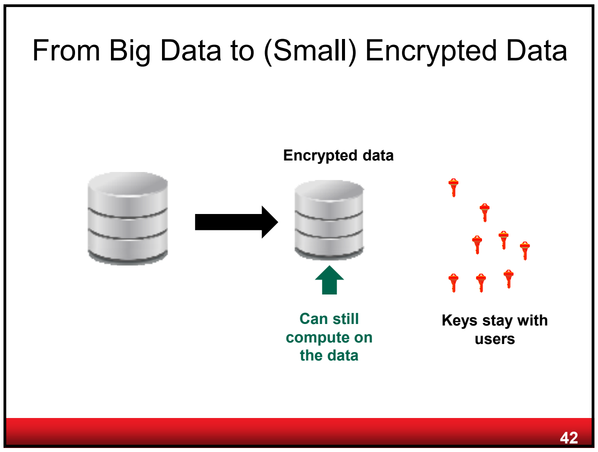

From Big Data to (Small) Encrypted Data

42

Centralization for small data

exceptional cases such as genomic analysis

- pseudonyms
- differential privacy
- searching and processing of encrypted data
- strong governance: access control, distributed logging

fascinating research topic but we should

favor local data

not oversell cryptographic solutions

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Open (Source) Solutions

Effective governance

Transparency for service providers

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Conclusions (research)

- Rethink architectures: distributed
- Shift from network security to system security
- Increase robustness against powerful opponents who can subvert many subsystems during several lifecycle stages
- Open technologies and review by open communities
- Keep improving cryptographic algorithms, secure channels and meta-data protection

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Conclusions (policy)

- Pervasive surveillance needs **pervasive collection** and **active attacks** with massive collateral damage on our ICT infrastructure
- Back to targeted surveillance under the rule of law
  - avoid cyber-colonialism [Desmedt]
  - need industrial policy with innovative technology that can guarantee economic sovereignty
  - need to give law enforcement sufficient options

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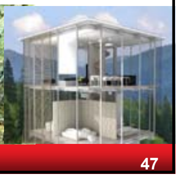
It's all about choices

Thank you for your attention

"Optimism is a moral duty" [Immanuel Kant]



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Further reading

Books

- Glenn Greenwald, No place to hide, Edward Snowden, the NSA, and the U.S. Surveillance State, Metropolitan Books, 2014

Documents:

- https://www.eff.org/nsa-spying/nsadocs
- https://cjfe.org/snowden

Articles

- Philip Rogaway, The moral character of cryptographic work, Cryptology ePrint Archive, Report 2015/1162
- Bart Preneel, Phillip Rogaway, Mark D. Ryan, Peter Y. A. Ryan: Privacy and security in an age of surveillance (Dagstuhl perspectives workshop 14401). Dagstuhl Manifestos, 5(1), pp. 25-37, 2015.

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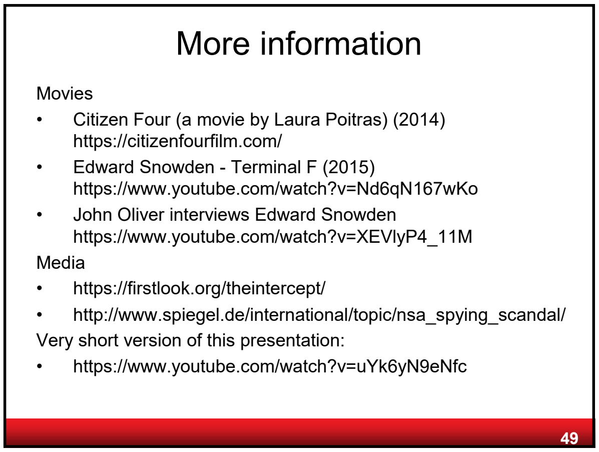

More information

Movies

- Citizen Four (a movie by Laura Poitras) (2014)
  https://citizenfourfilm.com/
- Edward Snowden - Terminal F (2015)
  https://www.youtube.com/watch?v=Nd6qN167wKo
- John Oliver interviews Edward Snowden
  https://www.youtube.com/watch?v=XEVlyP4_11M

Media

- https://firstlook.org/theintercept/
- http://www.spiegel.de/international/topic/nsa_spying_scandal/

Very short version of this presentation:

- https://www.youtube.com/watch?v=uYk6yN9eNfc