Actual Cryptography at the Age of Evolving Ecosystems

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Talk Agenda

- Part I: Crypto as part of general engineering projects
- Part II: Adx– Review
- Part III: Adx– Crypto solutions
- Part IV: Conclusions

From Abstract to Actual Crypto

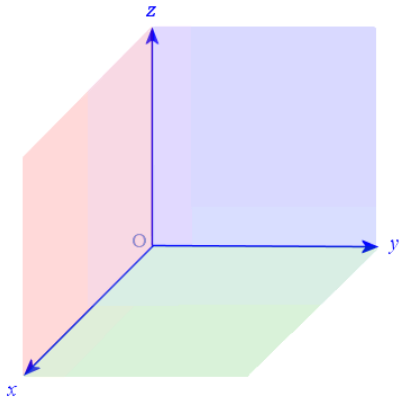
- Abstract: Cryptographers deal with models, nicely quantified “adversarial power,” then definitions, constructions, proofs, complexity,….
- Applied: looks at systems context and either applies a model to a sub-problem (authenticated key exchange, fast software encryption) and uses implementable primitives...
- Applied security system: natural; creating building blocks/ systems/ protocols/ standards: EAS, RSA, TLS, SHA..
- Actual crypto eng.: deploy specialized or novel custom made crypto in general system within actual development and deployed systems.

My Goals in this talk

- **Actual crypto is different from abstract crypto since it is working in an actual systems context: development, maintenance, business.**
- **Try to reflect upon these questions:**
  - **How to take part in a global ecosystem dvelopment process (& its specialized crypto needs)?**
  - **How to make sure crypto extends and survives as the systems evolve?**
  - **The differences eastetics/ measures of achievement**

Actual Crypto does not live alone

- Security is often at odds with, e.g.:
  - System Function
  - Performance
  - Usability (the User factor)



- Crypto is best applied when the above conflicts do not apply (e.g., hidden from the end user), or when the security requirement dominates (absolutely or to a large degree) and crypto aid security. (→ There is incentive to use crypto…)
  - This is an industrial perspective which is not in the textbook on crypto

The Economics of Development

- Computers and systems are design to "compute a task" not to "be secure," so we need to optimize the deployment of crypto; and this is an art (it may be formalized and cases have been analyzed: economics of secure systems: where the incentive lies?)
- →Security is a fundamental issue (needed/ hard), but of secondary importance (tolerated/ be cheap)
- → Security cannot be retrofitted, but it always is!! Since non-experts do not see a need....
- →Crypto/ security eng. has to be (positively) opportunistic!

Examples: crypto missed

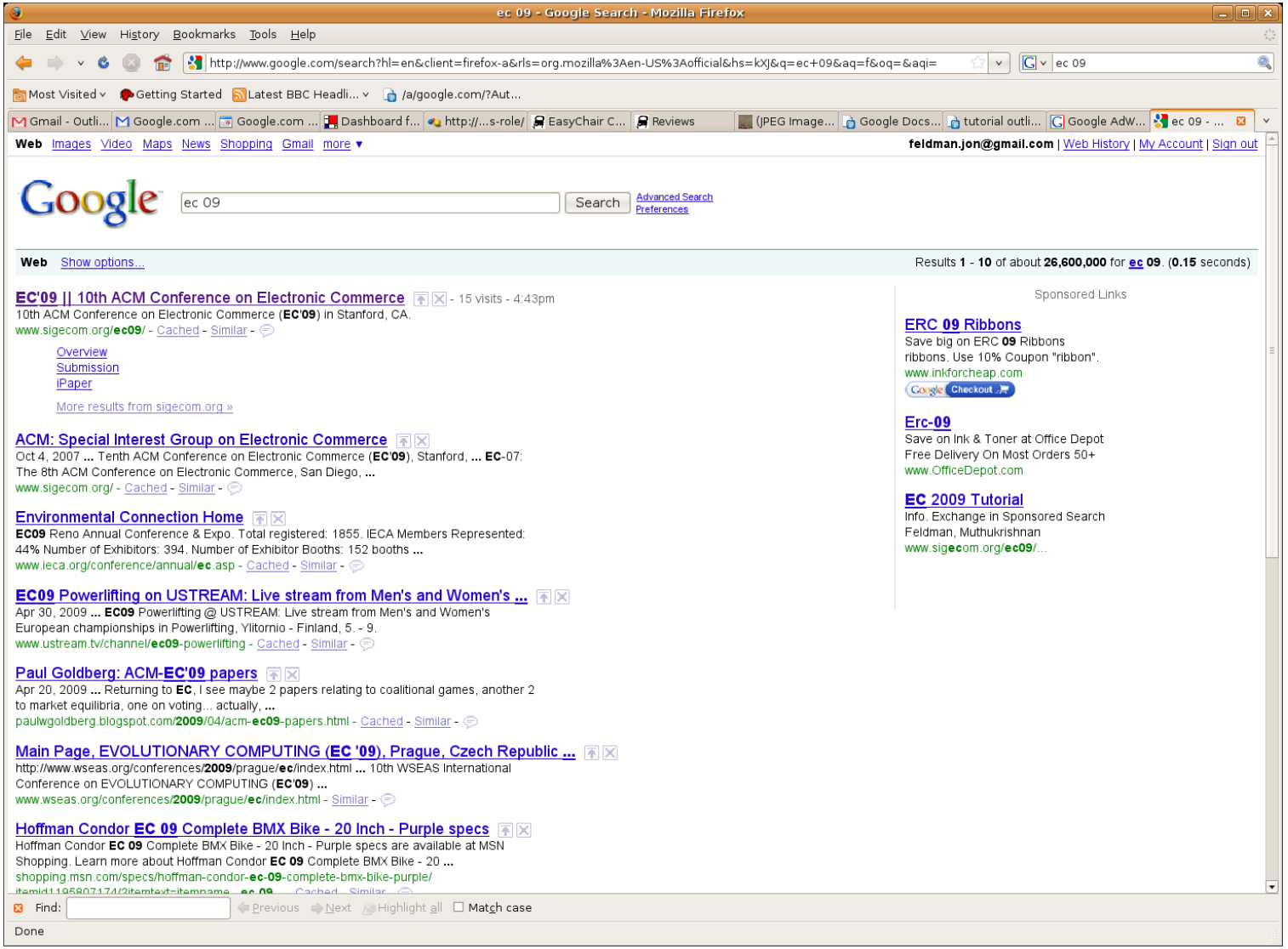
- Database: not encrypted since relational algebra is hard on encrypted data…. (crypto goes against functionality and against performance)
- Early “secure mail” hard to configure so users chose the “insecure mode” as a default
- All routers same password: scalability of maintenance comes first, neglecting “real” security
- IBM’s SNA: password on the clear! Rely on physical security, when “network scaled across same branch” problem ignored!
- Protocol extended: security not reviewed!

Thus: we see

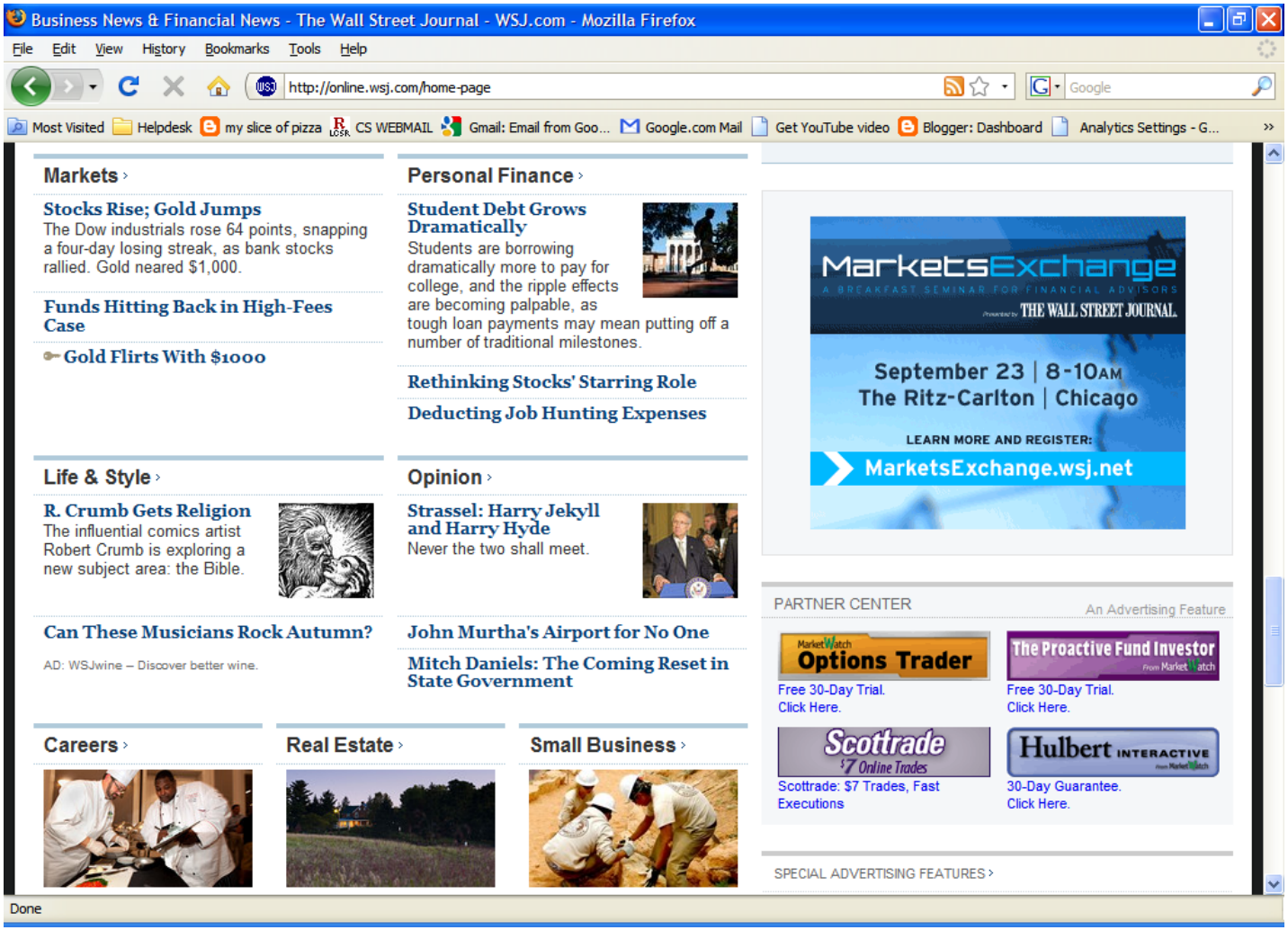
- After attacks which reduce the system's availability to users, hurt performance and function, people will tend to invest more in security (incentives)
- Mission critical system: security is part of function
- The need for crypto may come from different sources, may be implicit in the spec, so need to look for where it applies first..(the path of least resistance). → Need to be involved early!...and think carefully:
  - What is possible under the constraints?
  - Where and how to use the opportunity in the overall product context? Identifying intial well recognized need is important!

To Ad Exchange (ADX)

Internet Ads: Sponsored Search



Internet Ads: Display Ads



Internet/ Mobile Ads: Display Ads

- Traditional Online publishers and advertisers work together:
  - Negotiate offline or via intermediate networks,
  - Use planning, static policy, pricing and ad serving systems
    - DoubleClick, Microsoft's aQuantive, AOL's ADTECH AG, WPP's 24/7 Real Media.
  - Efficiency, effectiveness of this bulky "brand advertiser" model?
- The Newest Proposal for display ad business:
  - Two-sided real-time marketplace for matching online publishers and ("direct response") advertisers.
  - Yahoo's RightMedia, Google's Ad Exchange, Microsoft's AdECN.
- It applies to web and mobile advertisements

Exchange

- On one side there are publishers (web pages) that have space for putting ads
- On the other side there are Ad Networks (buyers) representing companies that want to advertize. There are a few hundreds of those
- Ads are “added” to web pages

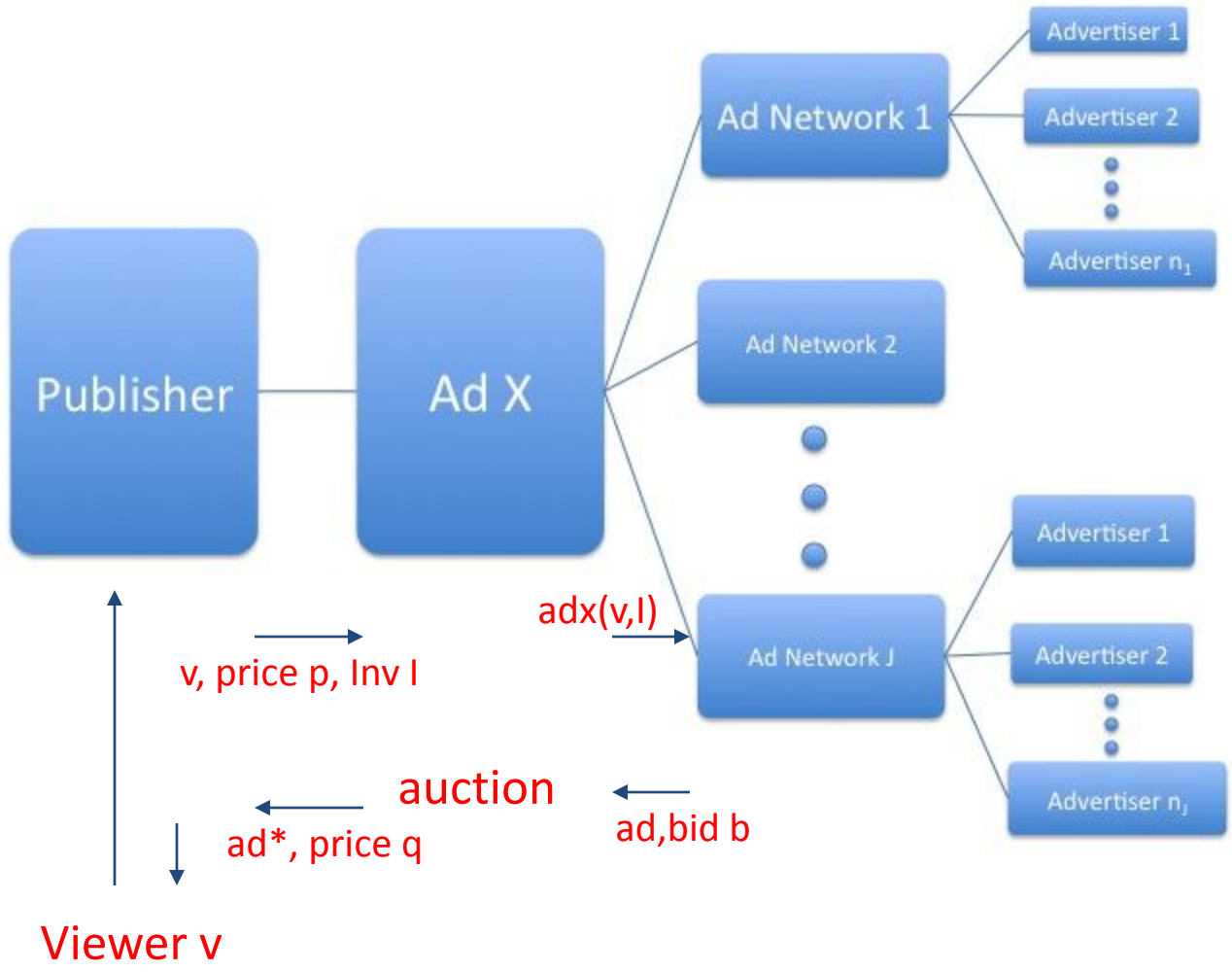
- There are many “viewers” of pages at publishers: every one browsing (essentially). Thus, this is a very huge scale Internet wide application

Advertizing

- Can be done by and via Ad networks directly (buying an ad)
- Can be done via the exchange/ mixed models

- Let us review the Adx whichs resides in Google Cloud

AdX Model


Publisher
Ad X
Ad Network 1
Ad Network 2
Ad Network J
Advertiser 1
Advertiser 2
Advertiser n_1
Advertiser 1
Advertiser 2
Advertiser n_j
adx(v,I)
v, price p, Inv I
auction
ad*, price q
ad,bid b
Viewer v

Architecture:

- Viewer: you!
- Publisher: www.cnn.com
- AdX: the exchange hosted in Google Infrastructure available globally
- Ads Agency: Ads producer for companies (Coca Cola ads to be inserted) and distributers
- Advertiser: Coca Cola.

Evolution of AdX

- Doubleclick: modify to an exchange..
- Paper design, one server, three....
- Now: billions of transactions/ day, global exchange...
- The ecosystem of display is changing: mobile, apps, and so on...

To Security & Privacy

Immediate security

- The first goal in security was systems orinted: secure the user interfaces/ web/ ads/ anti-malware...
- …and then we thought to crypto-secure the bids when needed since others should not learn them (according to the contract)...
  - Where are the possible leaks?

Then, we reviewed business and design and looked at added needs where is security/ crypto/ related issues needed?

AdX characteristics

- Speed:
  - Everything has to be done FAST (cannot slow down the Internet !!!).
- Volume/ Scale:
  - For a few years AdX runs ~billions auctions /day with a few (~thousands) networks.
  - High bandwidth requirement
- Evolution: design system for evolving "market place" & added requirements

Interesting Issue: After the Auction

- "Viewer's page" redirected to Ad Network with "I frame for display" that has the winning price embedded in it (winning price macro) pull model
- Viewer gets the ad, winning price exposed to user (violates business agreement (contract) and practical engineering of exchange) → ??? "a problem"
  - Note it is not "on the wire" but at the browser!
- This is a call for action: an immediate issue needs solution, and an opportunity to introduce cryptography!

Security & Performance & Cost Align

- Embedded price in the macro (I frame) at the user possession that is used to pull the ad (for optimization need to send the price)
- This macro is the only way for the agency to know the price (second price auction; communication piggybacked).
- Otherwise: Hard to connect the price in another way to the agency (even if can double the bandwidth to the agency).
- → Best way to send via the user the price (in fact, security is secondary to the need to employ the user as a channel). Thus: Security and Performance/ cost align together!!!!
- Gap between Business model (service agreement) and Engineering needs → crypto to the rescue!!

Needed

- Secure delivery
- → analyze what encryption can be used (performance, context dependencies, security needs)
- → key management support

Crypto Designer Goals

- Have a general encryption utility for current and FUTURE security needs. Cannot utilize standard solutions (SSL…)– be opportunistic!
- Separate key management: generation, distribution, rotation (which can exploit existing components) and customized on-line operations.
- Provide a solution for secrecy and integrity.
- Volume implies: many times over the same cleartext values (same price again and again). Need to retain (semantic) security nevertheless→ special security needs

Crypto Designer Goals cont.

- Stay in touch with engineering team....since needs will surely come, and the tools/ hooks are already in the system!

Key management

- Auctioneer (Adx) and Ad Agency will exchange keys externally
  - Use out of band methods..
  - Or: use TLS/SSL relies on public key technology and on key exchange protocol (Signed Diffie-Hellman key exchange)
  - Typical solution: use the exchanged key. Can employ TLS w/ both sides having a public-key (server side and client side keys)
  - Result: both parties share a key for symmetric key use

Side remark: The guts of TLS/SSL

- A→B: g^A signed by public key of A
- B→A: g^B signed by public key of B

- (g^A)^B= (g^B)^A= g^(A*B) is joint key from which to derive the key.

- This is just standard protocol but 1000 agencies and a single auctioneer can do it at no problem! Offline…
- Industry – you exploit existing solutions

Security in Operation

- The encrypted price goes via the user browser to the agency, user can learn &modify!
- Need to make sure the encryption is valid (unless user erases/spoils the encryption, in which case the agency knows not to take it into account→ need to detect manipulations).
- The encryption has to be authenticated as original

Authenticated Encryption

- Combines Encryption and Authentication of the Encryption
  - Privacy: provides good hiding of the message
  - Authenticity: assures receiver that it comes from the original party
  - → any attempt to forge will fail with very high probability
- Around 2000 it began to be an area of research

Authenticated Encryption

- Preneel van Oorschut: pointed at the primitive and claimed that MAC = Hash with a key (private key signature), and good encryption will solve it; asked if there is “one pass method.”
- Katz-Y. FSE 2000: first answer YES (under the name “unforgeable encryption”
- An-Bellare-Rogaway, Bellare-Rogaway, Bellare-Nemprepre, Krawczyk,…

Types of AE

- Krawczyk analyzed Paradigms for separable AE
  - Encrypt-then-MAC: C=E(k1,M), H=MAC(k2,C) and send both
  - MAC-then-Encrypt: H=MAC(k2,M), C=E(k1, M||H) and send C
  - Encrypt-and-MAC: C=E(k1,M), H=MAC(k2,M)
- All are possible specifically some are generically good (any Mac and any encryption will do)
- Fast solutions one-pass (Rogaway, Jutla, Gligor....etc.)…
- NIST standards….

Encryption via the user: solution

- Use Authenticated Encryption: with Encryption field and an Authentication field. Encrypt and MAC (parallel on server side) checking sequential.
- Use Pseudorandom Function based encryption:
  - Each display has a large enough "unique context"= seed; No need to extract real randomness (costly);
  - Derive from the seed a random pad;
  - use pad to exor with messages.
  - For more usage (forward looking design): enhance seed with action control in deriving the pad for cryptographic separation/ various length solution

Encryption- in Adx context

- There is a unique tag, and the shared key is a seed of a Pseudorandom function F.
- Since it is unique per auction, every pseudorandom application gives fresh (pseudo)randomness, so we have strong security called: “Semantic Security” (cannot understand the content!)
- C= [F(k1,tag, action) exor M],
- H= MAC(k2,M)

Advantages

- Fast, does not slow operation!
- Semantic security (due to unique display context tag)
- Flexible utility: F is variable size fields from small to large (for various extensions); authentication only/ encryption only modes can be used.
- Minimal added function (reuse existing/ standardized components whenever possible and research the core new components).
- For security→ The system has crypto engine built in which can be used for other purposes!!!! Can be used to encrypt initial bids if so desired… etc.

Summary for Adx Security

- The system works in this large scale of billions of transactions being encrypted per day (performance tested extensively!!)
- Helped engineering and business!
- The encryptor is essentially: a multi-use, different field size adaptable, enc+auth system.

- (There are other security/crypto/ privacy components)

Crypto Designer Goals Achieved

- General utility for privacy and/or integrity for online operation
- Out of band/ SSL/TLS/ etc. in use for key management

- → in ADX/ display ads engineering group: security/ crypto awareness was raised: crypto can solve business issues! Can help engineering!
- Crypto is a friend not a foe!

Indeed.. Extensions came..

- Moving to mobile: need to encrypt certain info of mobile user/ device properties, from Adx to the agencies!
- Encryptor easily extended in no time....

Next: two more contributions:

Privacy and data Liberation

- Adx notifies agencies all info it collects on them
- Adx hides the cookie of users by encrypting them with agency specific keys that Adx keep to itself (the agency does not know the key)
  - This prevents agencies from correlating and finding a common user via the “google cookie”
  - This is a “user privacy issue” solved via encryption
  - If two agencies merge business wise: matching of cookies can be done by Adx!

Verifiability

- Ability to verify correctness of auctions was designed to be very fast (built upon encrypted globally available bidding). Not implemented but disclosed as a possibility to partners.

Summary

- The AdX system has been challenging
- Scale and Speed constraints
  - Security: “Extreme” yet complete Crypto
  - Privacy challenges
  - Only as much as needed
- It posed, both, engineering and research challenges (since 2008):
  - Initial security and privacy solutions have been deployed; while raising the bar for future issues!
  - Future issues became present issues!

Crypto in Engineering- general conclusions

- There is no fixed recipe for it, just general principles; "results" much less structured than in crypto papers, very few people understand the challenges (rare deployments in general), and getting it right is challenging and satisfying.
- Required the right interpretation of the theory
- Attack models and risk management apply, incentives for adoption (i.e., business issues related to the recent area "economics of security systems") and liabilities (i.e., legal issues) apply as well.
- Secure components still matter but should be mixed with "added value security" design (the economics behind what the business is investing in).

Differences: theory vs. practice

- Robust Design: Proximity to the system: Requires close interactions w/ engineers, business leaders
- The more “actual solutiuon” is viewed as reducing headaches (enabler), the more credibility and potential future influence.
- Tchnical clavoyance always helps (is part of the achievement, technical beauty): systems evolve, need to design crypto that is extendible, while current op ongoing.... (true to cloud ecosystems).
- Practice has to be based on solid theory &more..

Thanks!