Secret Shuffling: A Novel Approach to RFID Private Identification

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Identification, Authentication, Private communication

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- Hash-lock based: tree-like, synchronisation-type, mixed
- Intelligent systems outside the tag: non-authorised readers are not permitted to send identification requests. E.g. RFID blocker tag
- Ultra-lightweight crypto-primitives: lightweight implementations of ECC, AES, and totally new primitives (e.g. Vajda&Buttyán)

Protocol description

Protocol setup:

- Each tag has a constant, random K long key, k_i, that is a unique bitstring($k_i[1] \ldots k_i[K]$) for each tag $\mathcal{T}_i$

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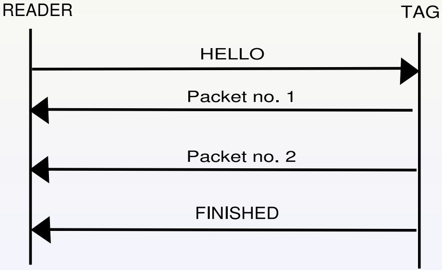
How it works:



Description of a packet

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- Consists of L number of indexes from the key of the tag. Each index can be either inverted or not. No indexes are repeated
- Has the following interesting property: $\sum_{j=1}^{L} k_i[a_j] \oplus b_j = L/2$ where $a_j \xleftarrow{r} [1, K]$ is a random index, and $b_j \xleftarrow{r} \{0, 1\}$ is a random bit $b_j \xleftarrow{r} \{0, 1\}$

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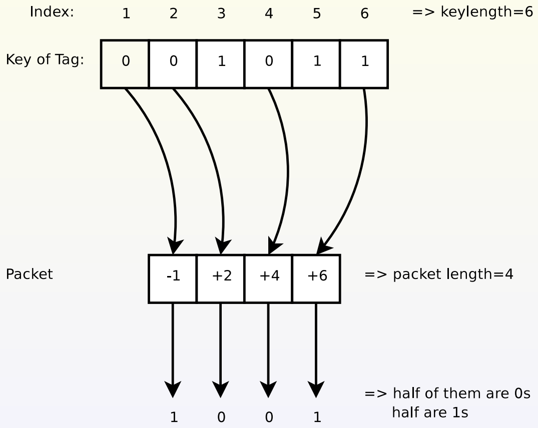

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- The packet is a constraint satisfaction problem (specifically, a linear pseudo-boolean constraint satisfaction problem)
- The packet is an $L/2$-in-L LSAT problem
- These problems are equivalent and NP-hard (Shaefer's dichotomy theorem)

Number of packets per identification

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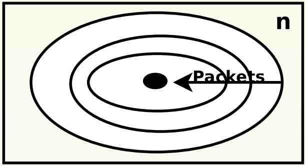
- The number of packets needed for a given false positive rate is then: $fp \approx \frac{log(fp/n)}{log(R)}$
- For $fp = 0.1$, i.e. for 90% identification chance, if $K = 400, L = 10$ and $n = 1\ million$, $P = 13$

Graphic example

From the point of view of the size of the solution space:

- Reader's point of view:



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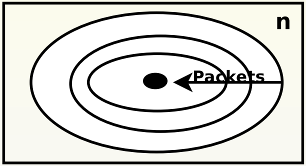
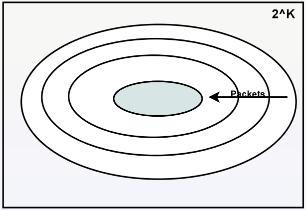


- Attacker's point of view:



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- Pre-construct look-up lists for all key's indexes:

	List[1]	List[2]	List[3]	List[4]
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- Go through the look-up table for the indexes in the packet, and calculate the shown sum for each packet. The tag that has $L/2$ for all packets is the one that is sending them

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We use Juels and Weis' "strong privacy" model:

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7. The attacker must tell if $\mathcal{T}_C = \mathcal{T}_A$ or $\mathcal{T}_C = \mathcal{T}_B$ with sufficient probability

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- Find the solution to the constraint satisfaction problem defined by the packets $Run_A \cup Run_C$

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- Find the solution to the constraint satisfaction problem defined by the packets $Run_A \cup Run_C$
- If the solution is UNSAT, then the two tags must be different – packets sent by $\mathcal{T}_A$ always have solution k_A
- If the solution is SAT, then:
  - Either $\mathcal{T}_A \neq \mathcal{T}_C$ BUT we did not gather enough packets to show they are different
  - OR $\mathcal{T}_A = \mathcal{T}_C$. – if we have gathered enough for sure, we can safely say this. 'Enough' in this context is defined as P_{att}

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Best algorithm to attack the system:

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We decided on Minisat (best of the 2005&2006 SAT competition). It is fast, open-source and readily modifiable

Threshold phenomenon

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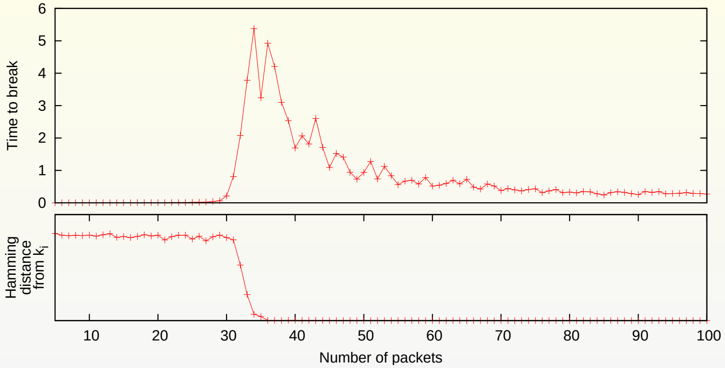
- After a certain point, the chance to find solution changes very rapidly from 100% to 0%, and at the same time, the difficulty to find a solution jumps to very high levels. This is the *threshold point*.
- After the threshold point, the chance to find a solution is almost 0%, but if there exists a solution (or if it does not), it becomes exponentially easier to find it (or find that it does not exist respectively) in respect to the number of constraints.

Graphically



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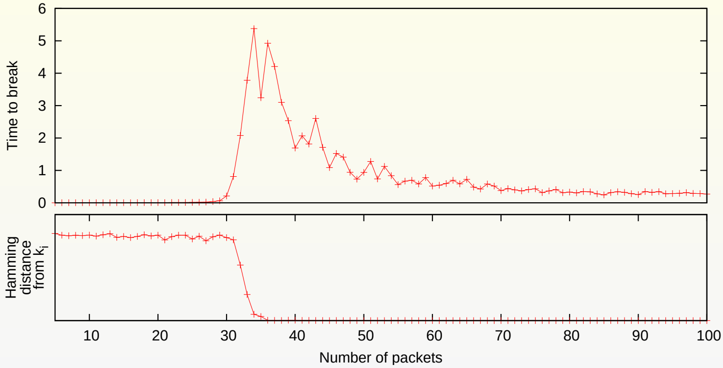

The attacker can only use the right side of the graph

Results

packets/K	100	200	400	1000
$1{*}P_{att}$	$1.47e2$ s	$3.17e11$ s	$1.46e28$ s	$1.46e78$ s
$3{*}P_{att}$	$3.33e1$ s	$7.41e5$ s	$3.67e14$ s	$4.49e40$ s
$9{*}P_{att}$	$6.31e0$ s	$4.54e3$ s	$2.35e9$ s	$3.27e26$ s
$27{*}P_{att}$	$4.27e0$ s	$6.37e2$ s	$1.42e7$ s	$1.57e20$ s
$64{*}P_{att}$	$4.02e0$ s	$4.87e2$ s	$7.15e6$ s	$2.27e19$ s
$192{*}P_{att}$	$5.34e0$ s	$7.31e1$ s	$1.37e4$ s	$9.01e10$ s
$576{*}P_{att}$	$1.00e1$ s	$7.28e1$ s	$3.86e3$ s	$5.74e8$ s

Table: Time to break the anonymity

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- We are at the moment developing an improvement of the presented protocol

Thank you for your time

Are there any questions?