Recovering the S-boxes of 24-Round Reduced GOST (or How to Combine the Cycle Structure with Slide Attacks)

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Topics of the Talk

• Short Description of Slide Attacks
• New idea: studying the cycle structure
• Attacking 24-round GOST with unknown S-boxes
• Attacking 30-round GOST with known S-boxes
Slide Attacks [BW99]

- Applied to ciphers with the same applied keyed permutation
Slide Attacks

- Seeks slid pairs \((P, P')\) s.t.

\[ f_k(P) = P' \Rightarrow f_k(C) = C' \]
Slide Attacks

- If $f_k$ is "simple" enough, given one slide pair the key $k$ can be found.

- The attack is independent of the number of times $f_k$ is applied.
Generating Slid Pairs

- Using birthday paradox (requires $\sim 2^{n/2}$ KP)
- Identification can be done by treating each pair as a slid pair and analyzing it

- For Feistel block ciphers it can be reduced to $\sim 2^{n/4}$ CP
- Identification is also easier
Making Simple More Complex

- In [BW00] some advanced slide techniques were presented
- Most interesting property observed:
  - If \((P, P')\) is a slid pair, then so does \((E_k(P), E_k(P'))\)
Allowing More Complex "Simple" Functions

- [BW00,F01]: It is possible to use the observation to attack $f_k$ using a KP attack (that uses $m$ KP).
- Take $\sim 2^{n/2}$ KP, and iteratively encrypt each of them $m$ times.
- Try all pairs among the $2^{n/2}$ starting points.
- Apply the KP attack with $m$ pairs for each candidate slid pair (T.C. = $m2^n$).
Making the Complex - Real

- Our technique solves two problems:
  - Finding the slid pairs easily
  - Allowing chosen plaintext attacks (even ACPC)
- How?
Making the Complex Become Real – Considering Cycles

- Let $E_K(P) = f_K^m(P)$
- Choose $P_0$ randomly
- Iteratively encrypt $P_0$ until $P_0$ is obtained again
Making the Complex Become Real – Considering Cycles

- The cycle is actually also a multiple of the cycle of $f_k$ as well!
- Let $\text{Cycle-E}_k = l$, $\text{Cycle-f}_k = r$
- Then $l*m = C*r$ for some constant $C$
- if $\gcd(m,r)=1$, then $r=l$
So You Have Cycles... So What?!

- The information on the cycle can be used to find slid pairs
- Once one slid pair is found, we can find as many pairs as there plaintexts in the cycle
- We can use CP attacks (and even ACPC attacks) on $f_k$
GOST

- Russian encryption standard
- 32-round Feistel construction
- 64-bit block, 256-bit key
- Round function consists of key addition, eight 4x4 S-boxes, rotate to the left by 11
- S-boxes are unknown...
GOST

- Simple key schedule:
  - rounds 1-8: $k_1 \ k_2 \ k_3 \ k_4 \ k_5 \ k_6 \ k_7 \ k_8$
  - rounds 9-16: $k_1 \ k_2 \ k_3 \ k_4 \ k_5 \ k_6 \ k_7 \ k_8$
  - rounds 17-24: $k_1 \ k_2 \ k_3 \ k_4 \ k_5 \ k_6 \ k_7 \ k_8$
  - rounds 25-32: $k_8 \ k_7 \ k_6 \ k_5 \ k_4 \ k_3 \ k_2 \ k_1$

$$GOST_\mathbf{K} = g_\mathbf{K} \circ f_\mathbf{K}^3$$

24 - Round

$$GOST_\mathbf{K} = f_\mathbf{K}^3$$
24-Round GOST (Unknown S-boxes)

- Using a 6-round truncated differential (with prob. \(~2/3\)) we attack 8-round GOST
- We find subkey material and unknown S-boxes
- Data Complexity: \(2^{63}\) ACPC or almost \(2^{64}\) KP
- Time Complexity: \(~2^{64}\)
30-Round GOST (Known S-boxes)

- Guess subkey of last six rounds
- Partially decrypt all ciphertexts 6 rounds
- Apply 24-round attack
- Data Complexity: almost $2^{64}$ KP
- Time Complexity: $\sim 2^{254}$
Questions?

Thank you!