Cryptanalysis of KeeLoq with COPACOBANA

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Case Study Access Control

Simple access controls: fixed code (“password”)

code

eavesdropper duplicates key (cloning)

but the industry learned…

Case Study Access Control

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advanced theft control: rolling code

$code = e_k(n_i)$

rolling code (or hopping code)

$code = e_k(n)$

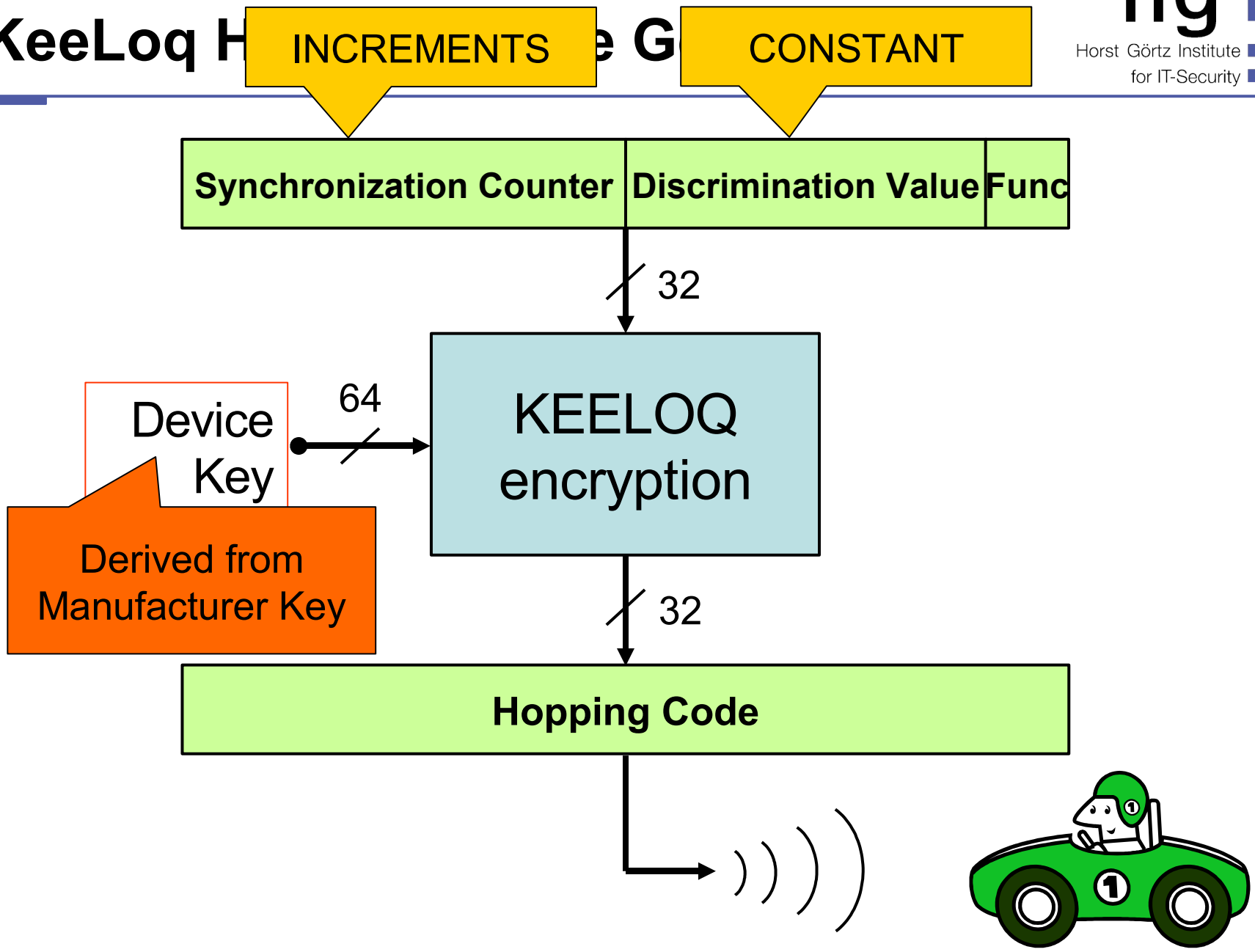
$code = e_k(n+1)$

$code = e_k(n+2)$

….

$e_k()$ is often a block cipher

KeeLoq H e G


INCREMENTS
CONSTANT
Synchronization Counter
Discrimination Value
Func
32
Device Key
64
KEELOQ encryption
Derived from Manufacturer Key
32
Hopping Code

So what can we do now?

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If we have ~~access~~ to a remote

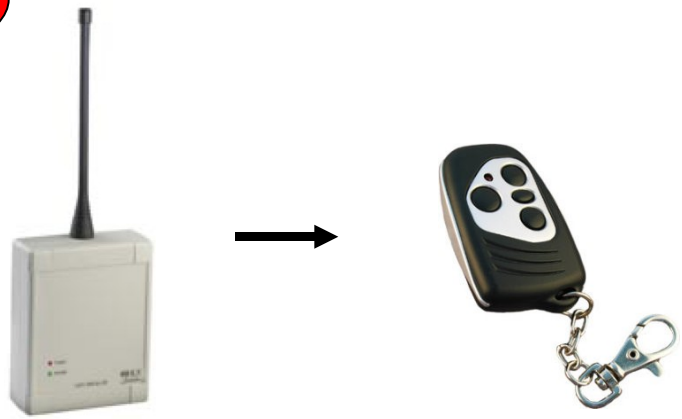
Recover **device key** and clone the device

People usually do not lend their keys to unknown people

In a shop

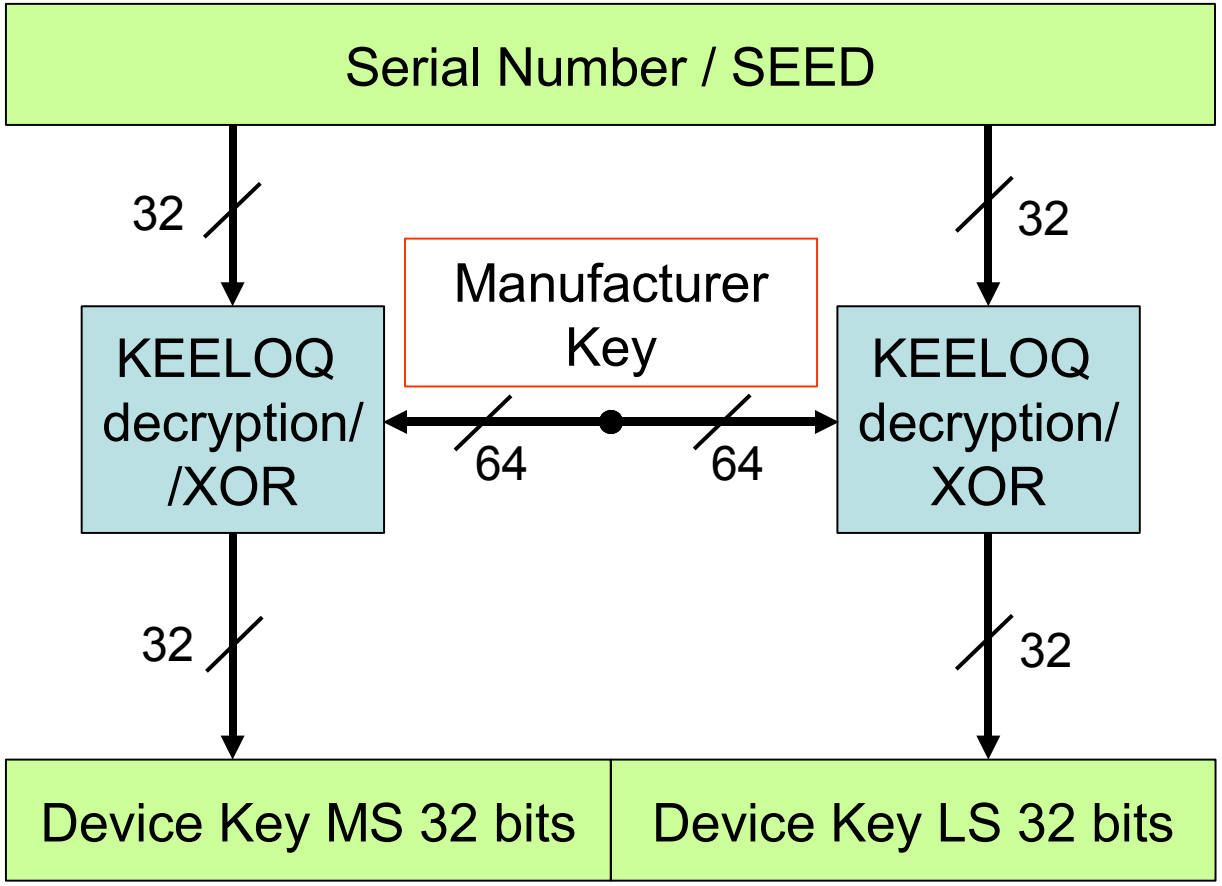
If we have access to a receiver

Recover **manufacturer key** and generate new remotes



Identical for all *GarageOpeners2000* and corresponding remotes

Device Key Derivation



So what can we do now?

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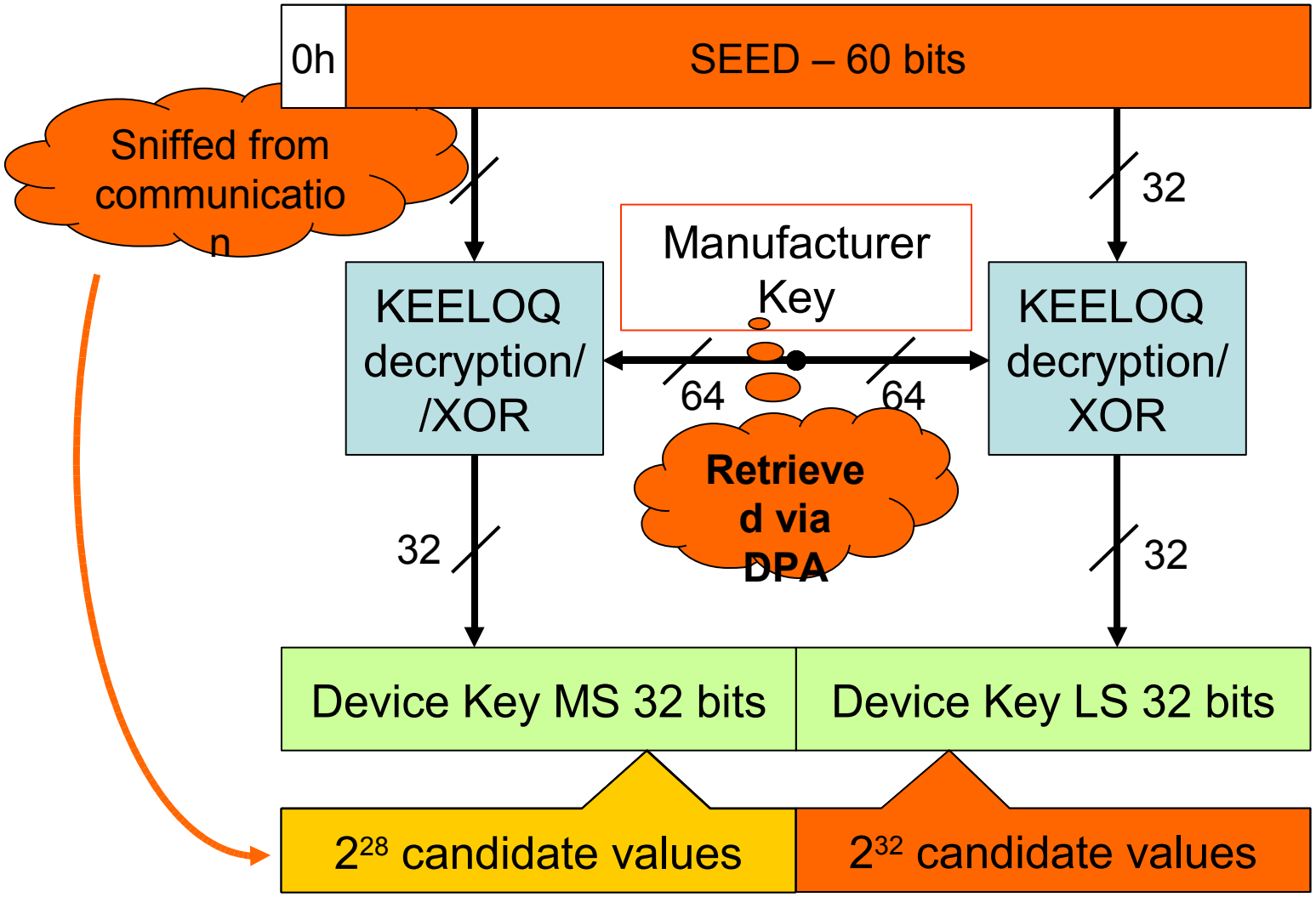
After extracting of manufacturing key:

Remotely eavesdrop on 1-2 communications & clone key!

Serial Number,
KeeLoq(n+1)

Device Key Derivation



KeeLoq Cracker

KeeLoq Cracker

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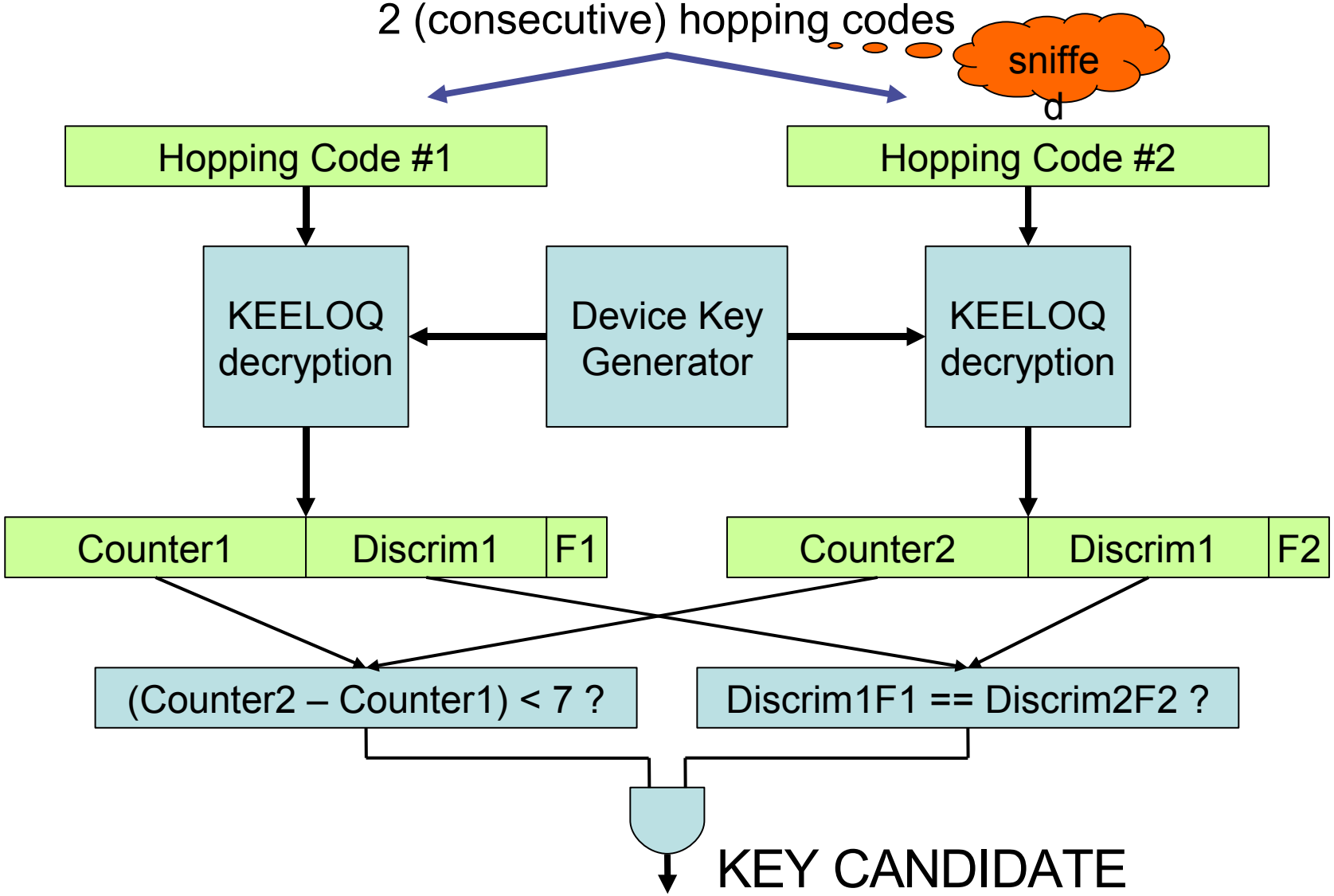
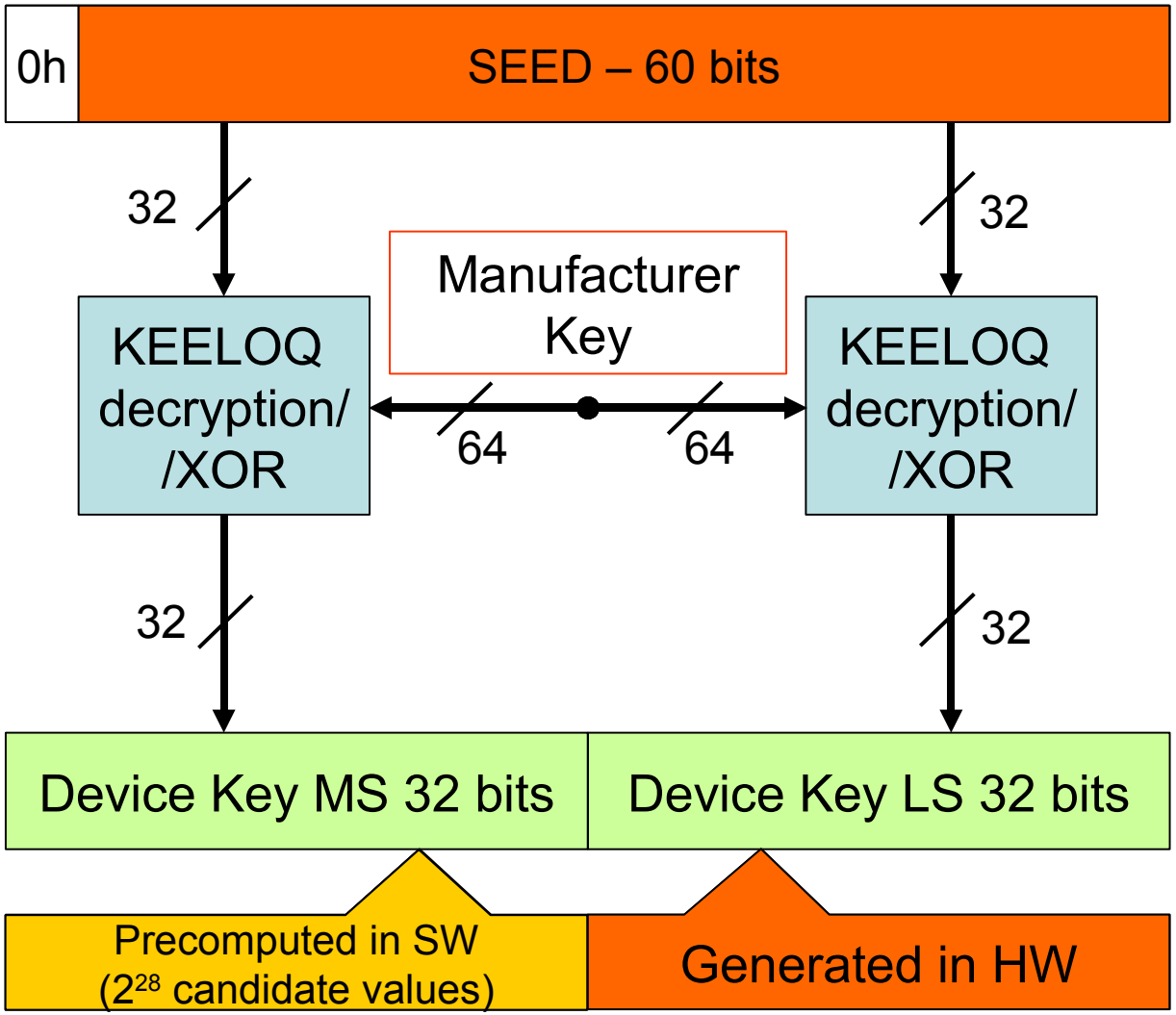


Device Key Derivation



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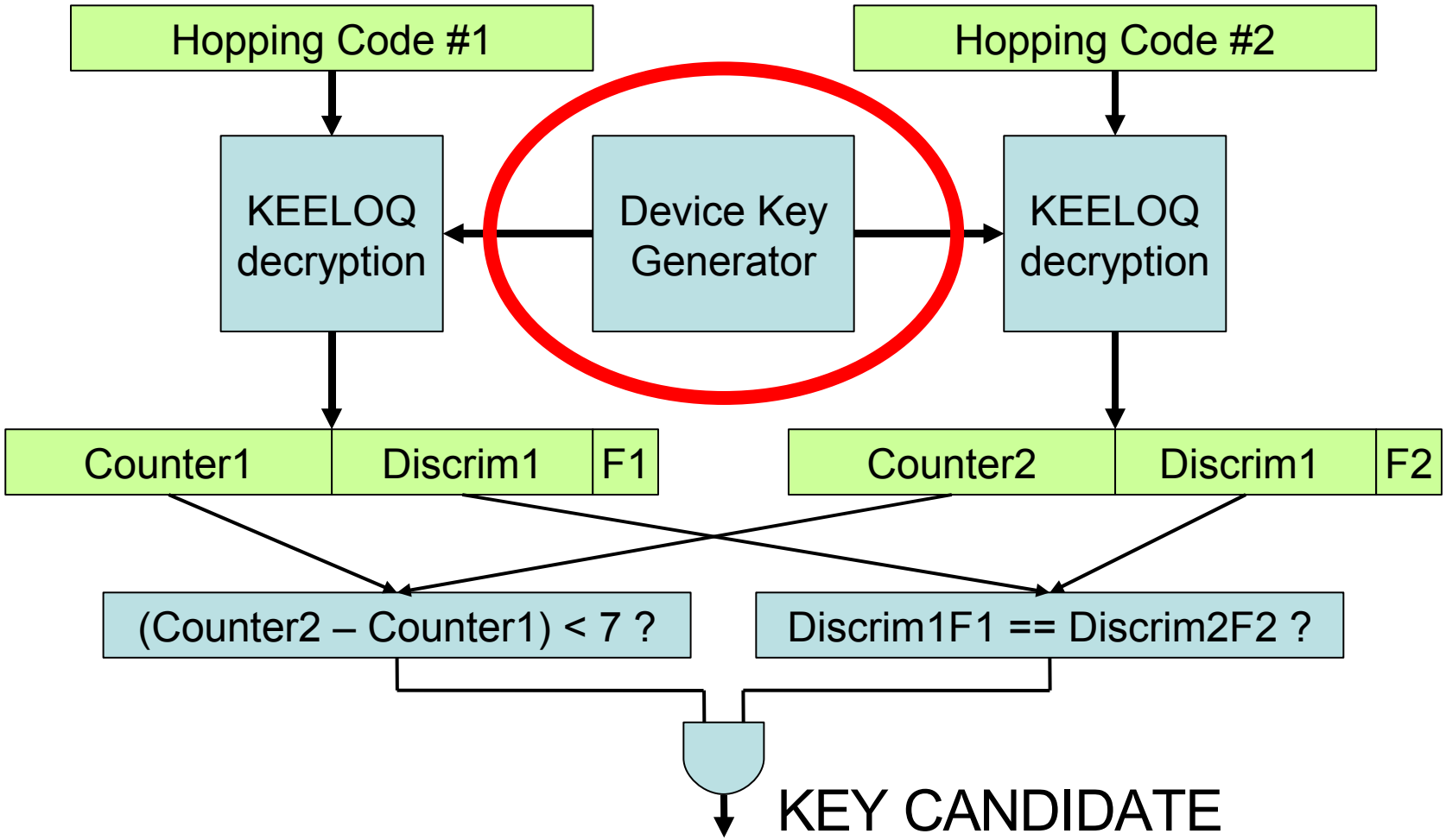
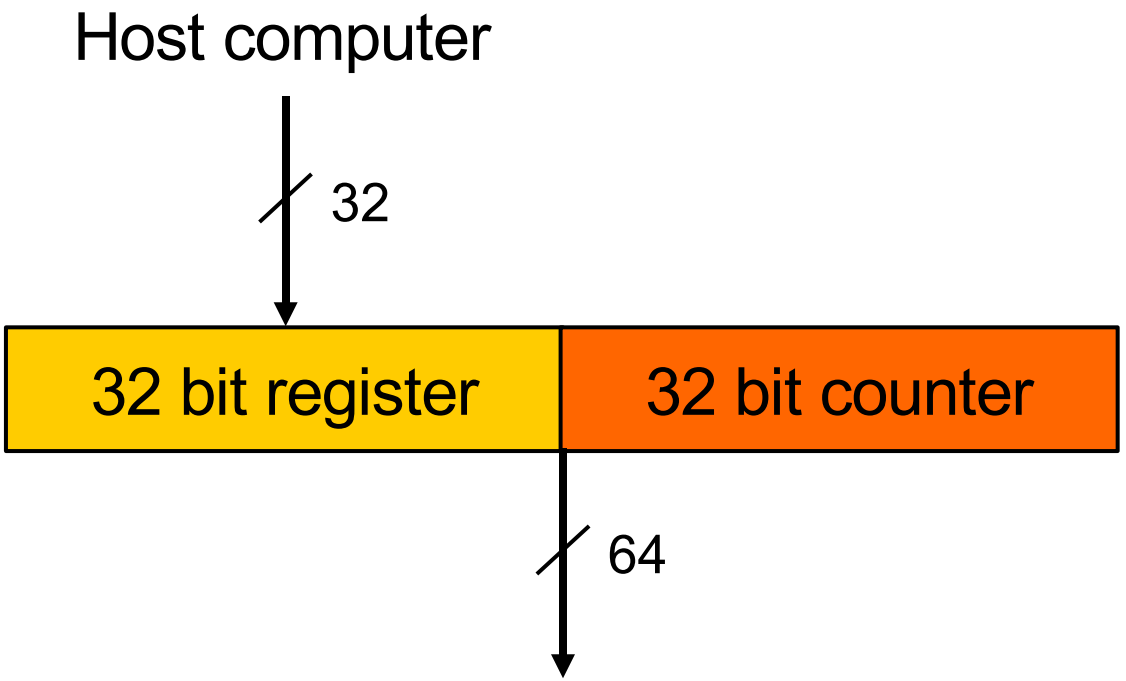
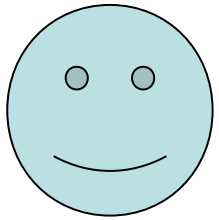
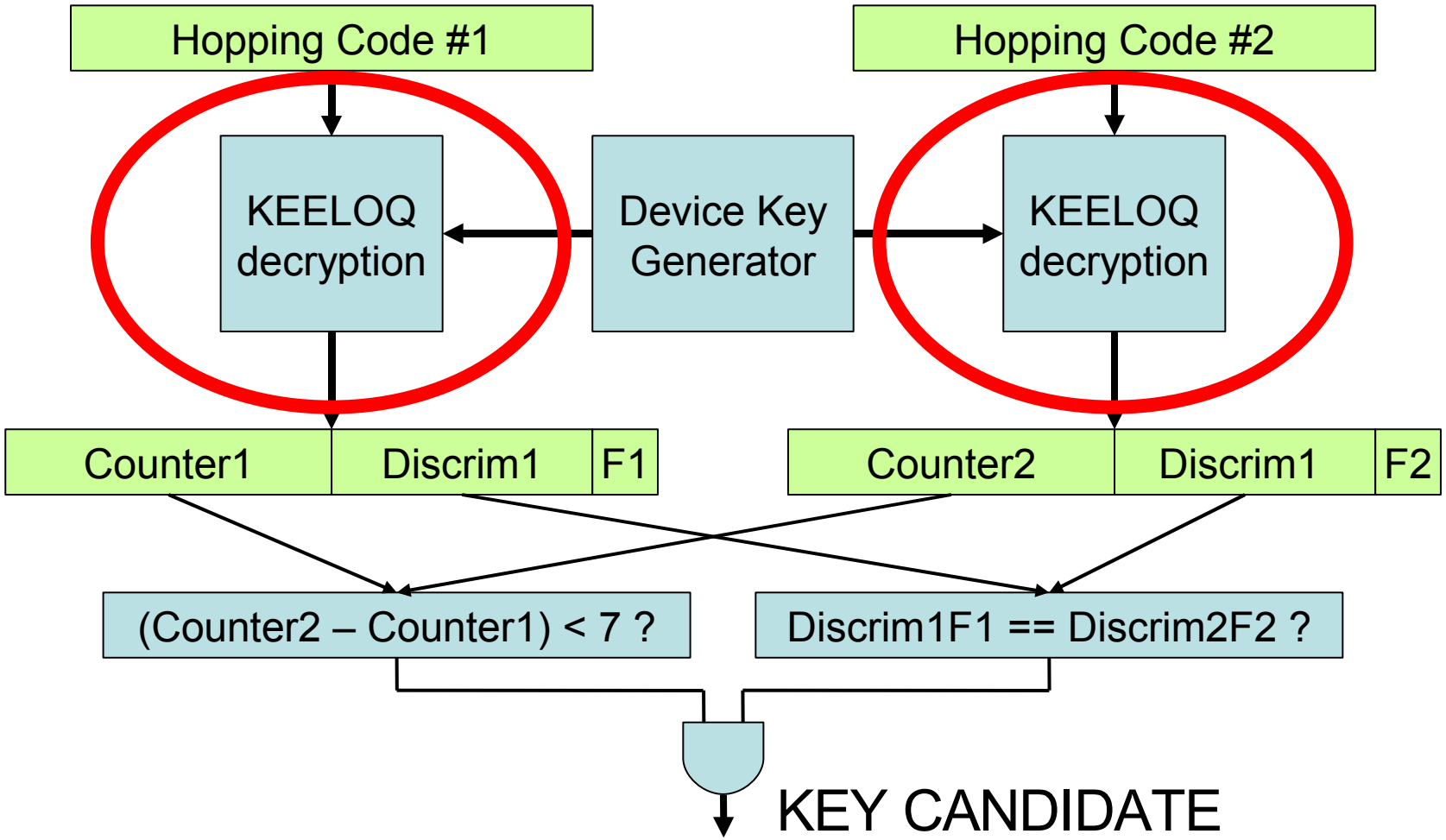


Device Key Generator





KeeLoq Cracker



KeeLoq – The Algorithm

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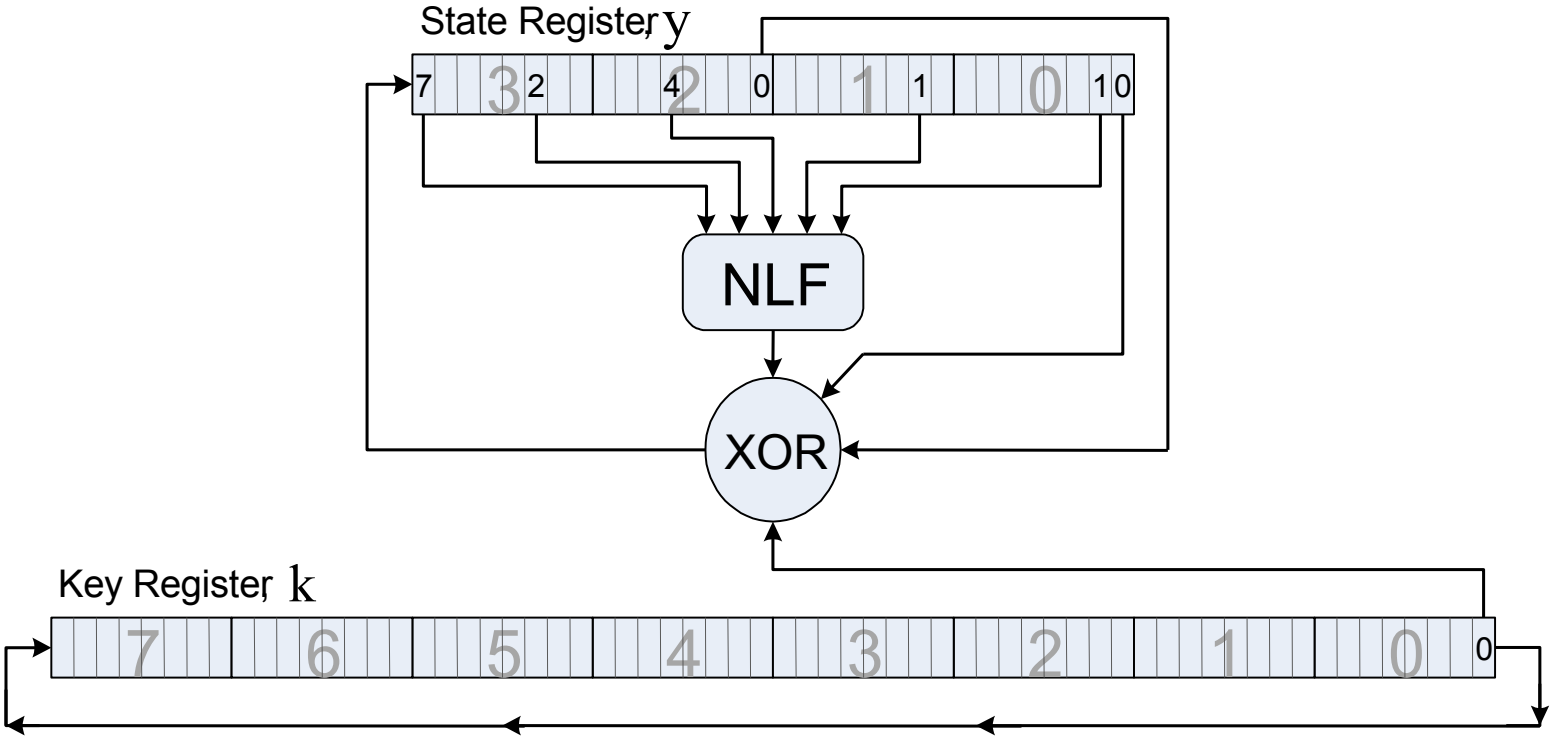


64 bit key, 32 bit block length

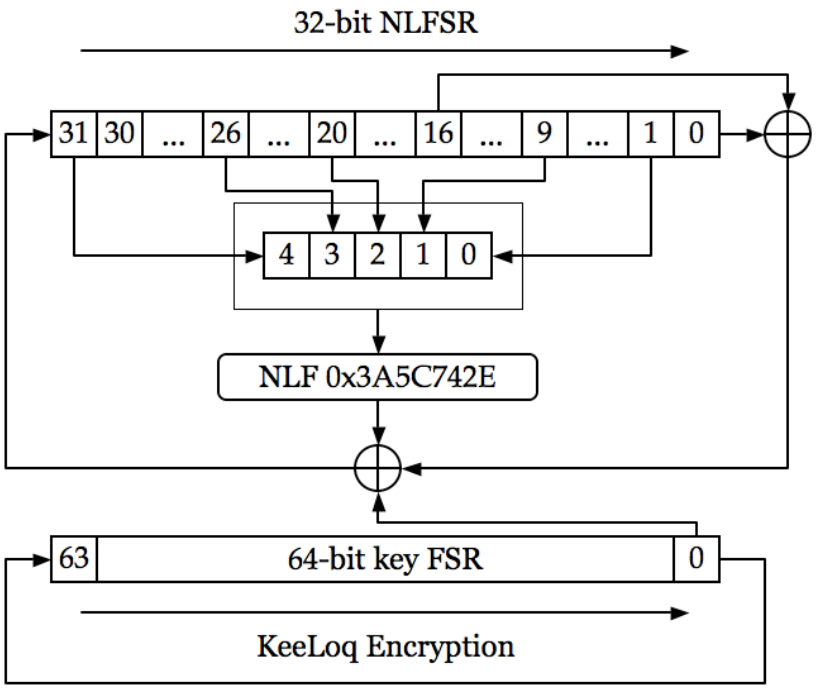
NLFSR comprising a 5x1 non-linear function

Simple key management: key is constantly rotated

528 rounds, each round one key bit is read

→ Lightweight cipher – cheap and efficient in hardware

KeeLoq Encryption

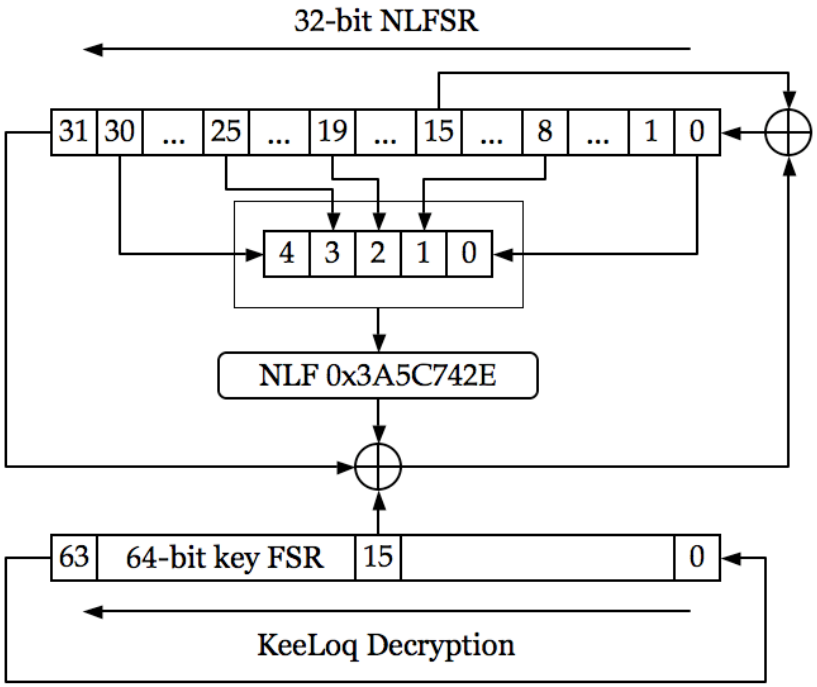


- 32 bit block length, 64 bit key
- NLFSR comprising a 5x1 non-linear function
- Simple key management: key is constantly rotated
- **528** rounds, each round one key bit is read

✂ → Lightweight cipher – cheap and efficient in hardware

source: Wikipedia

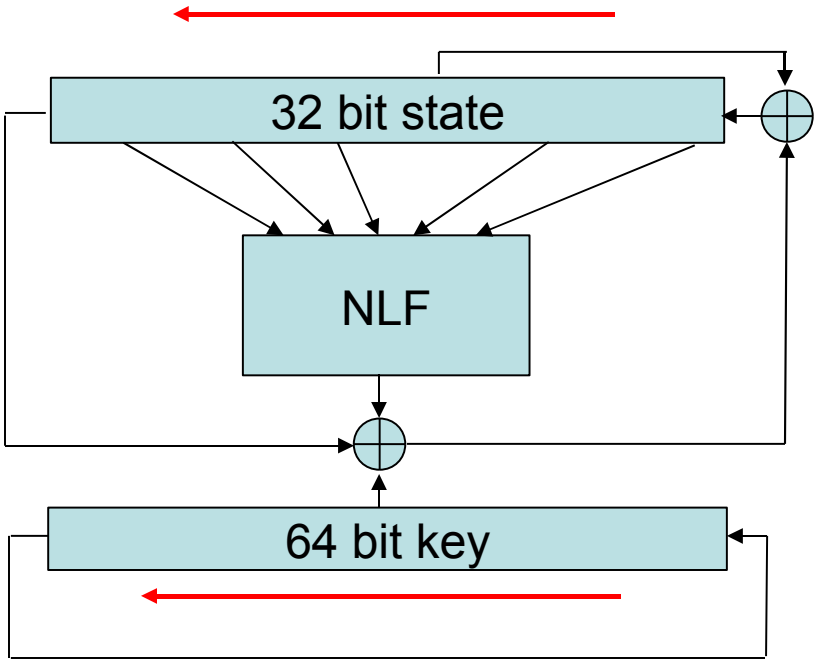
KeeLoq Decryption



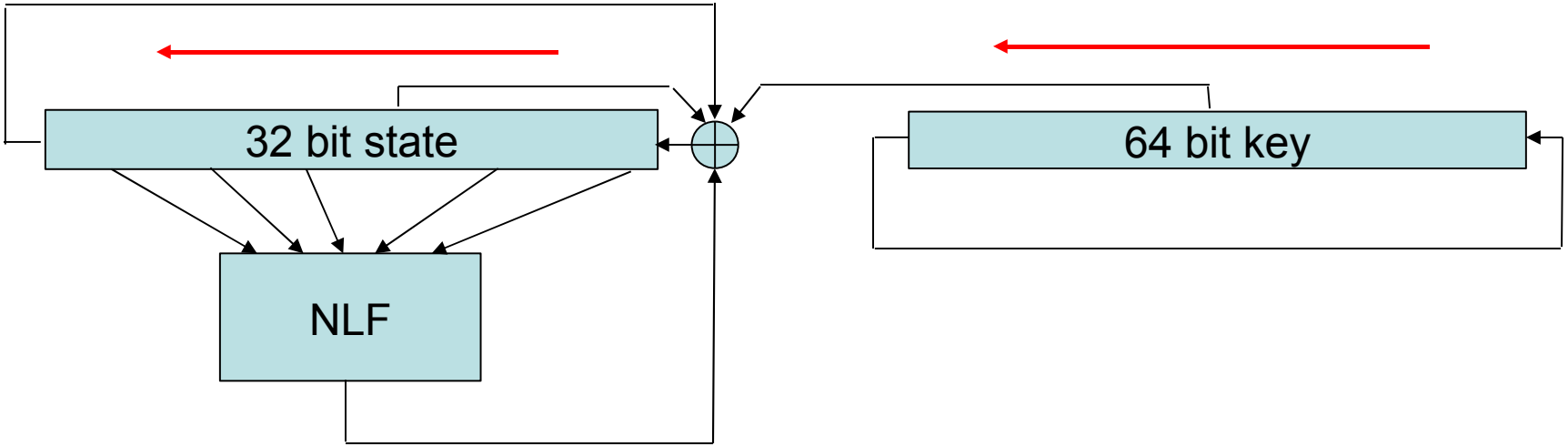
like encryption, but
in reverse order ☺

source: Wikipedia

KeeLoq Decryption



KeeLoq Decryption



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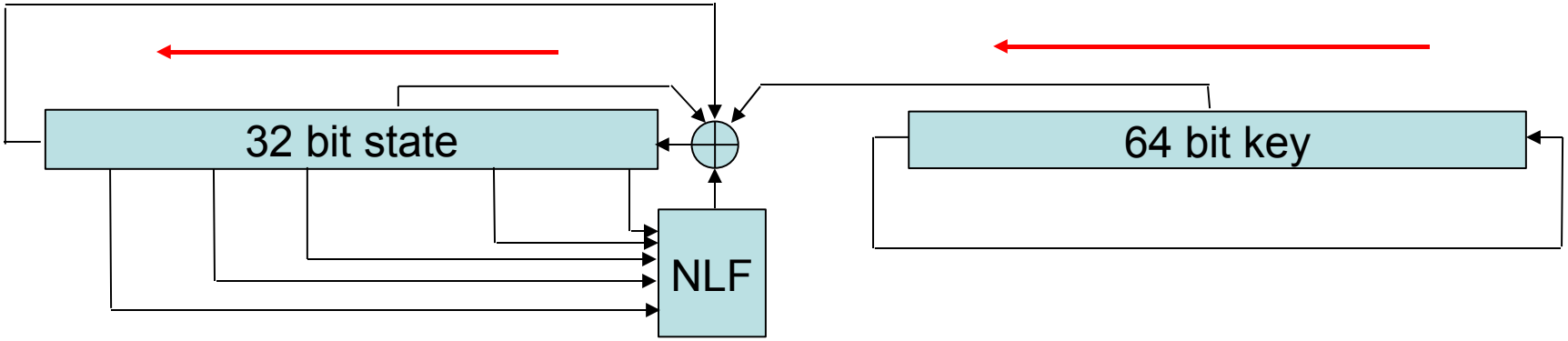

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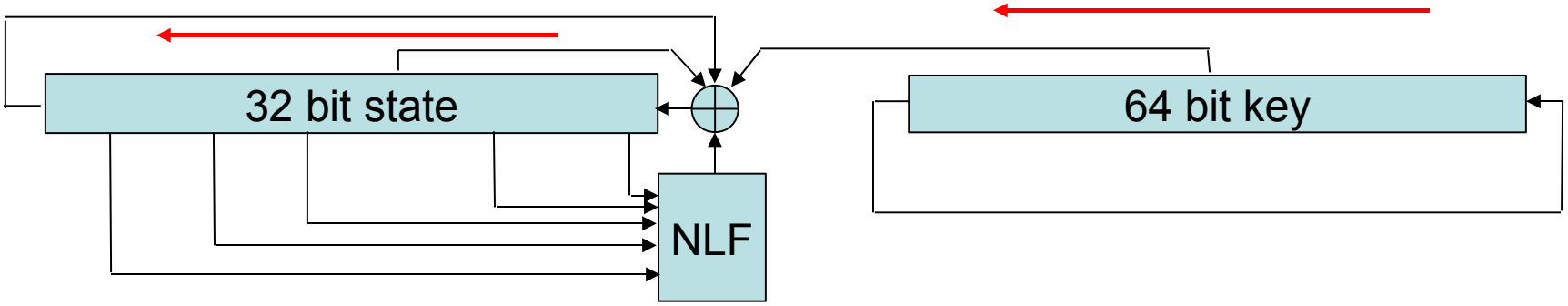

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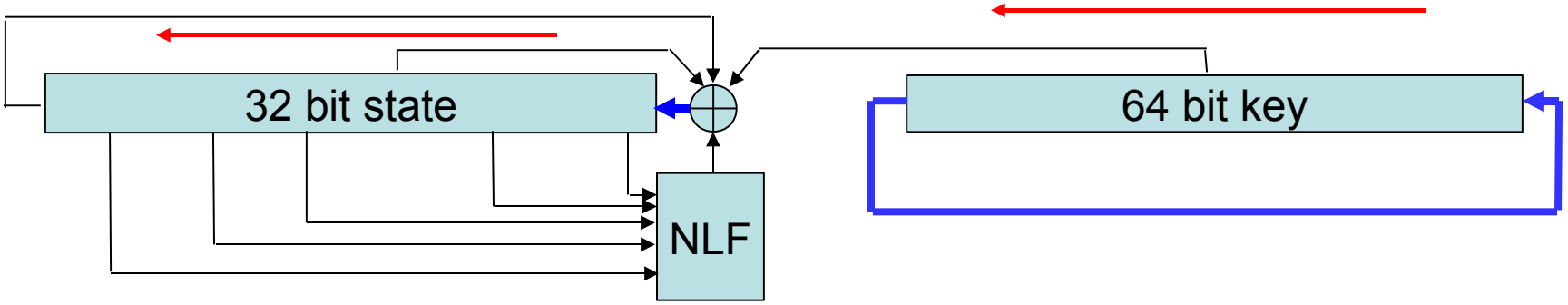
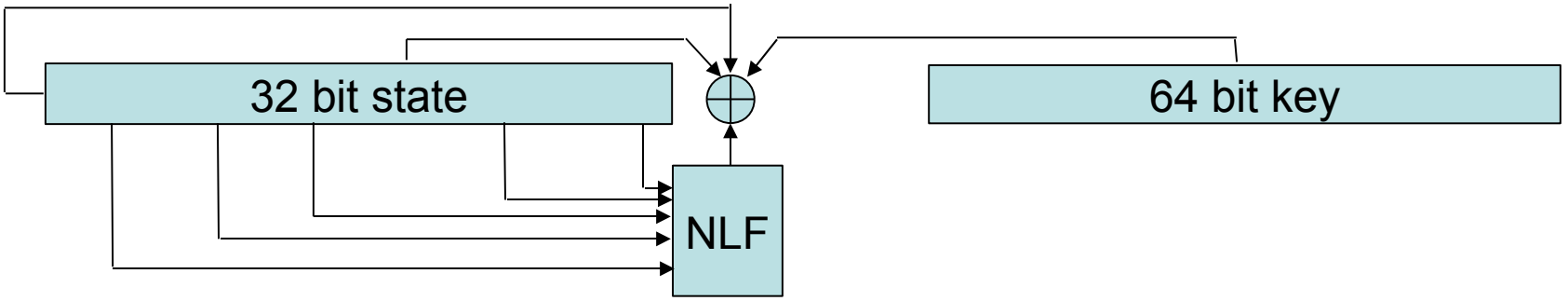


Unrolled KeeLoq Decryption



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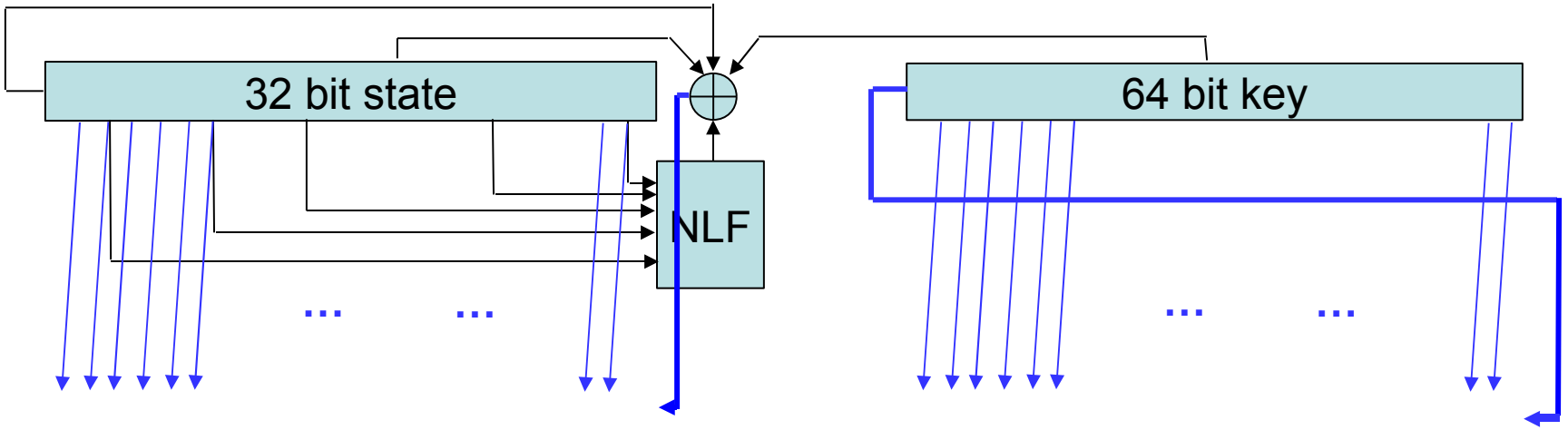

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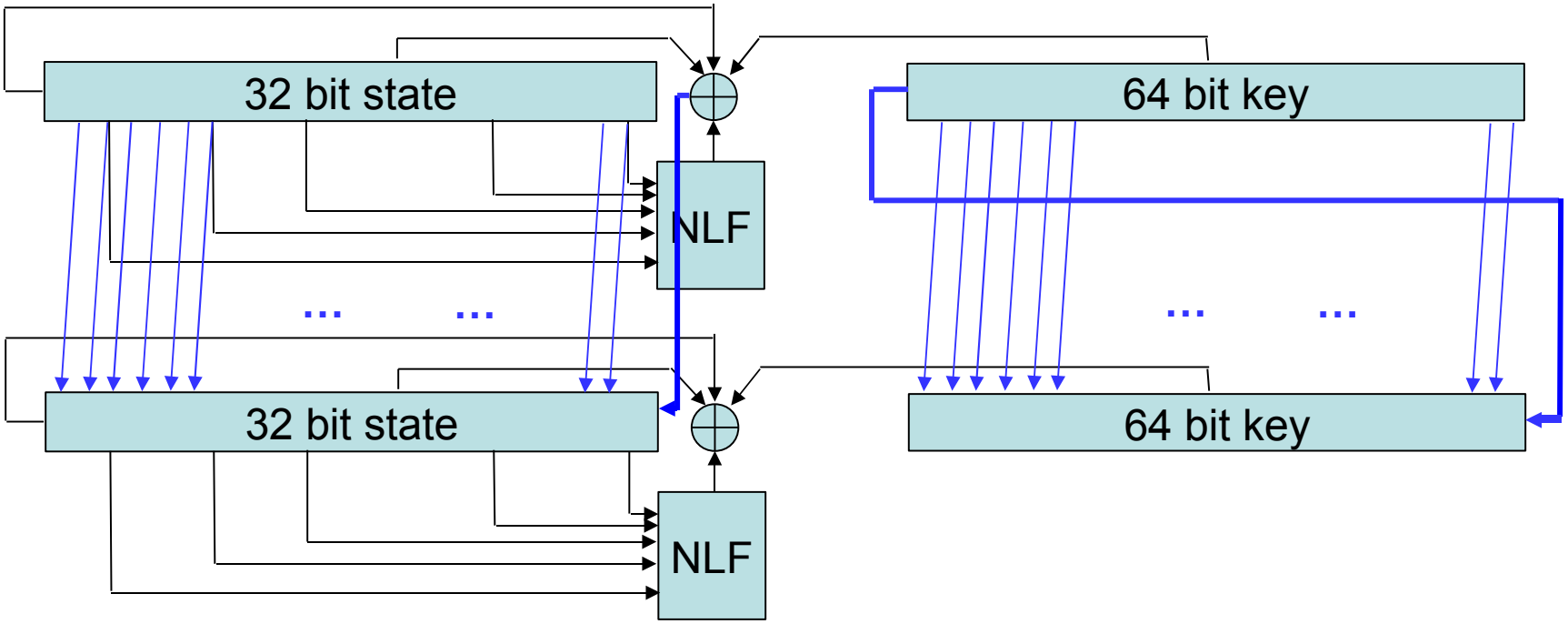

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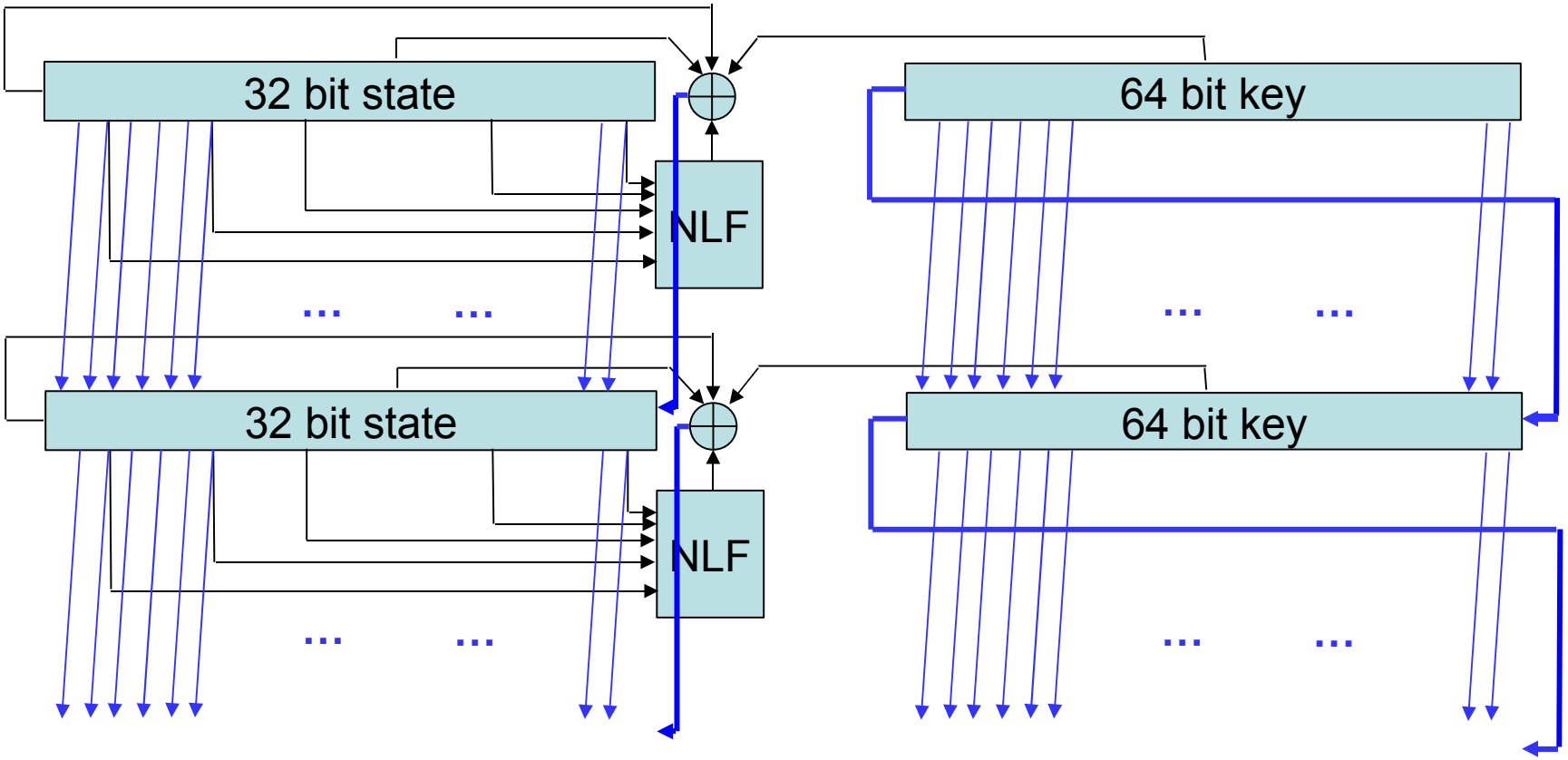

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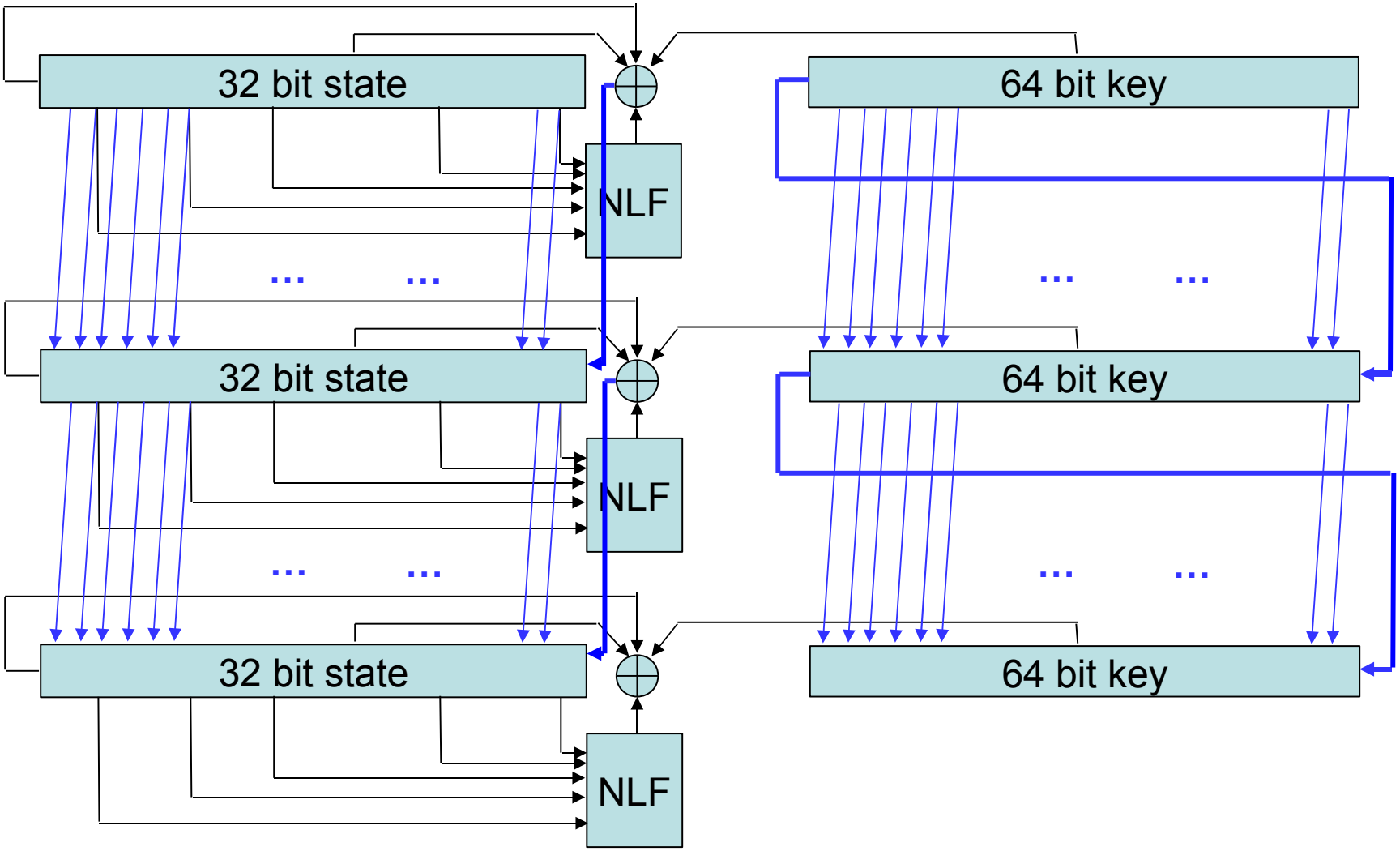

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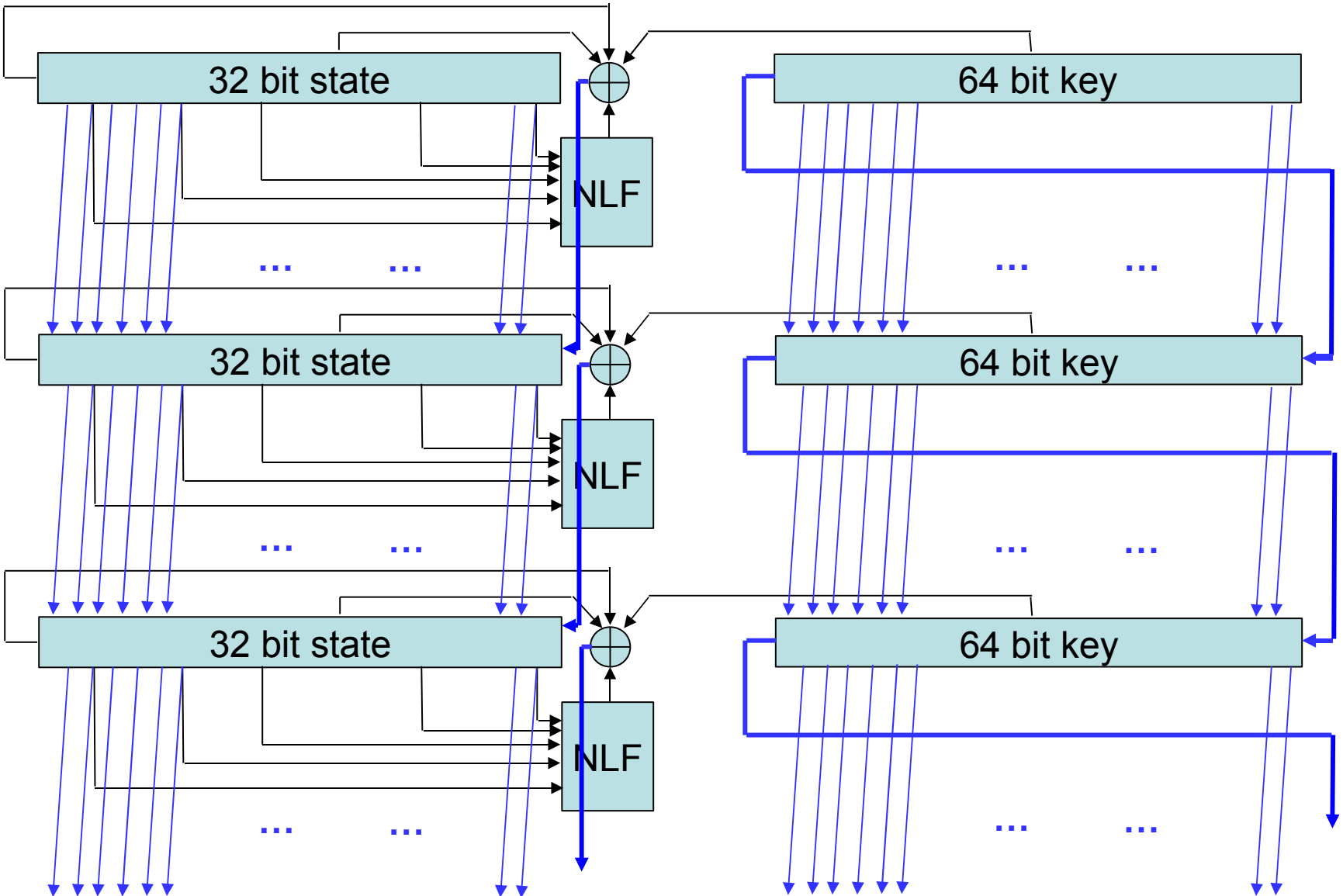

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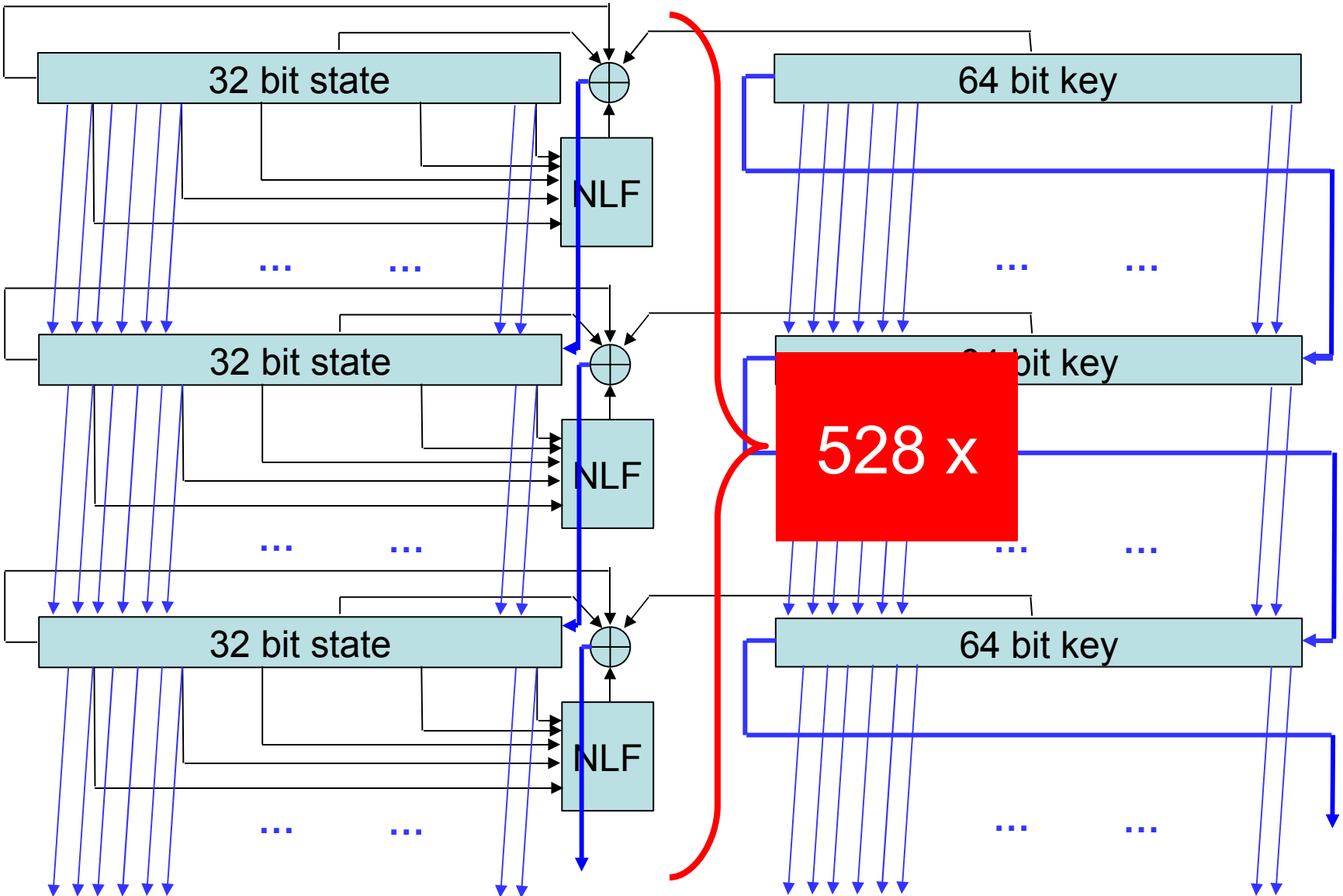

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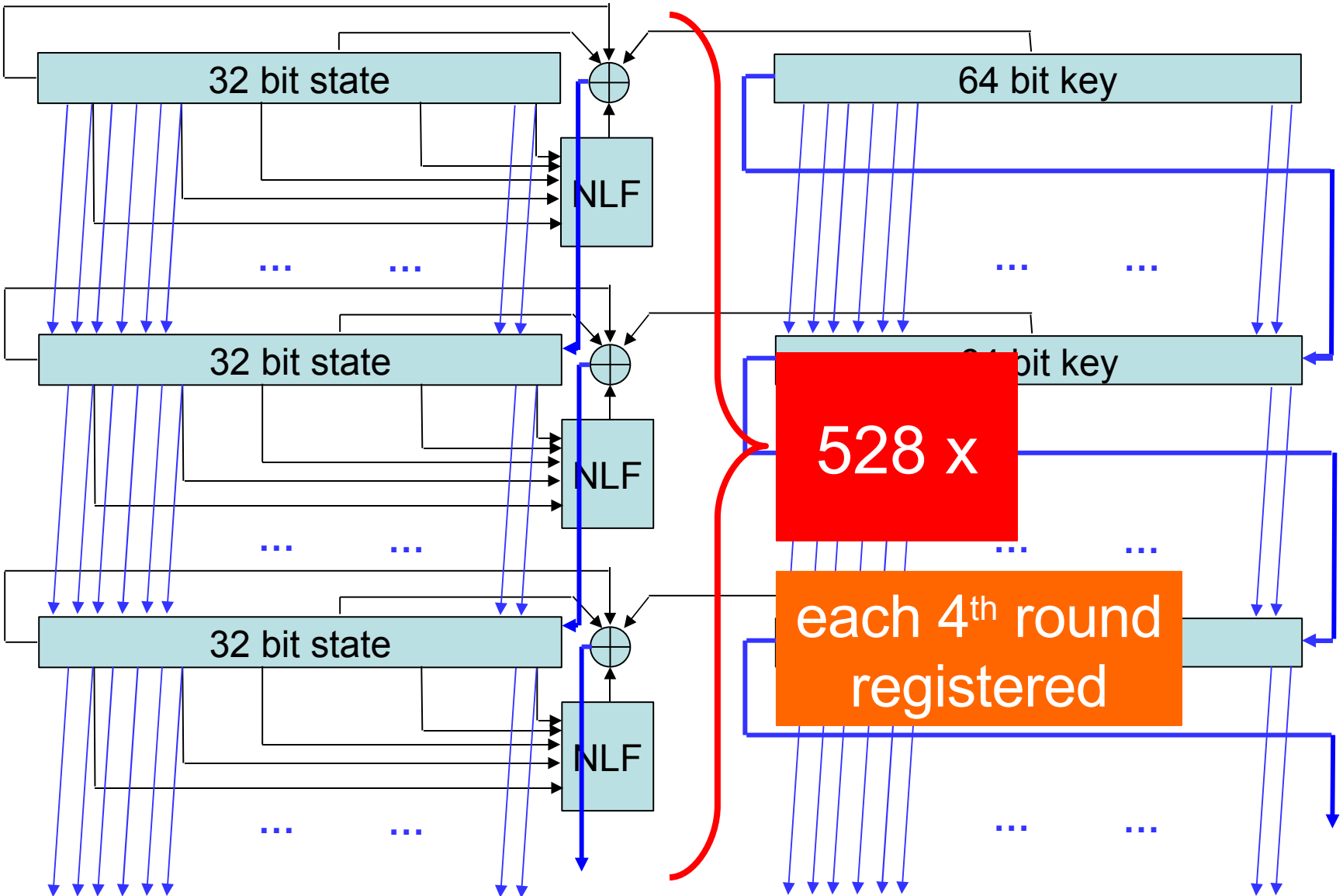

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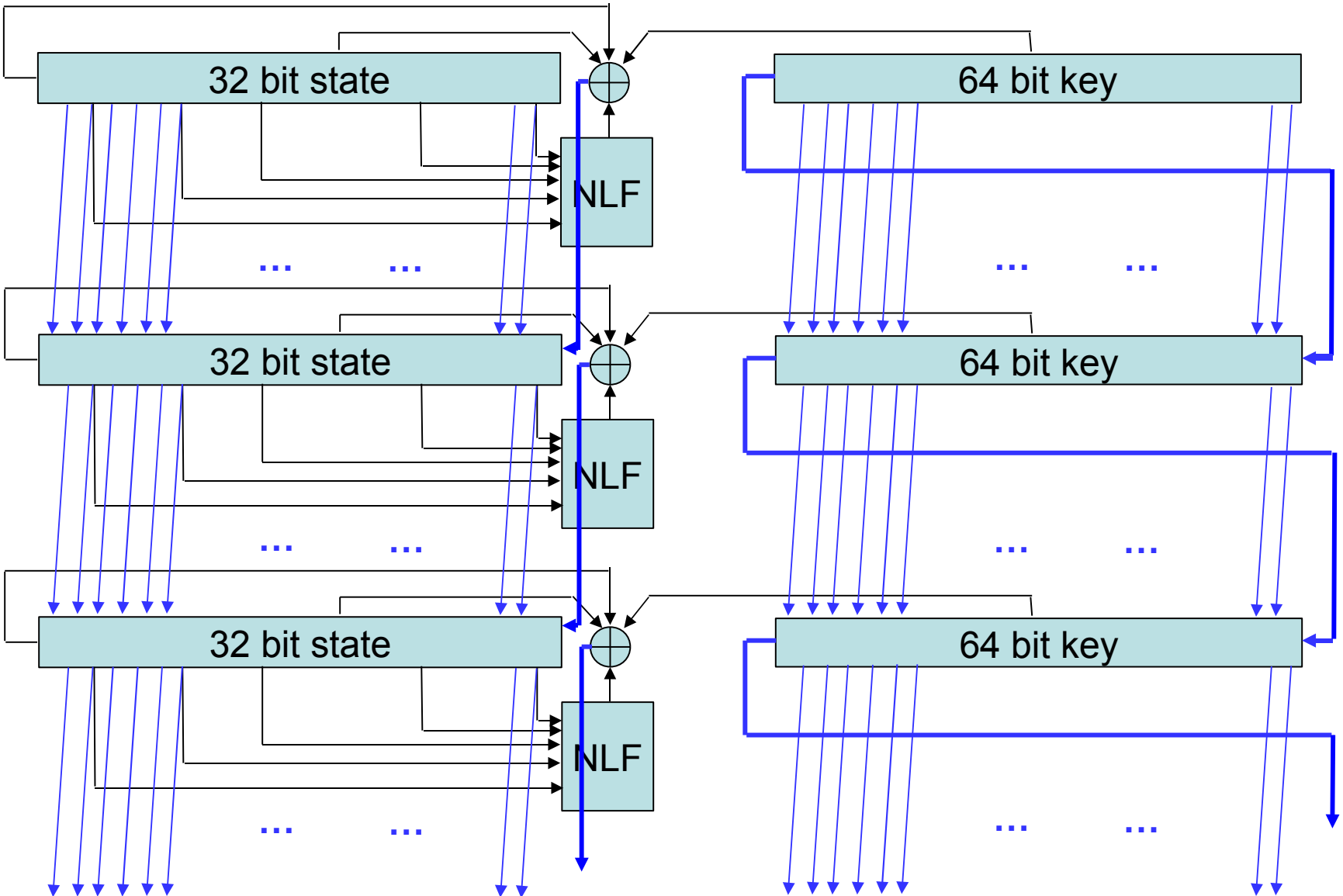

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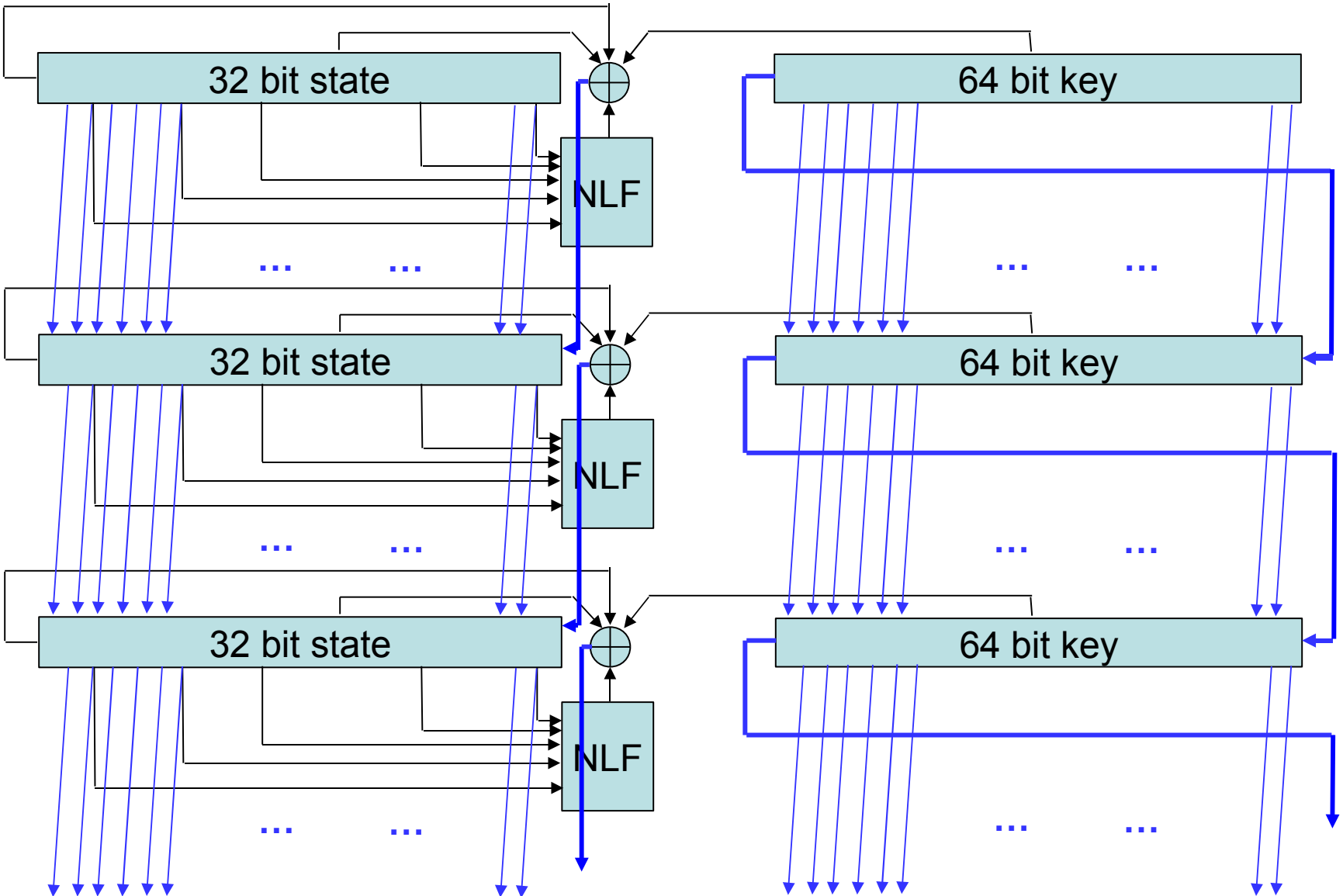

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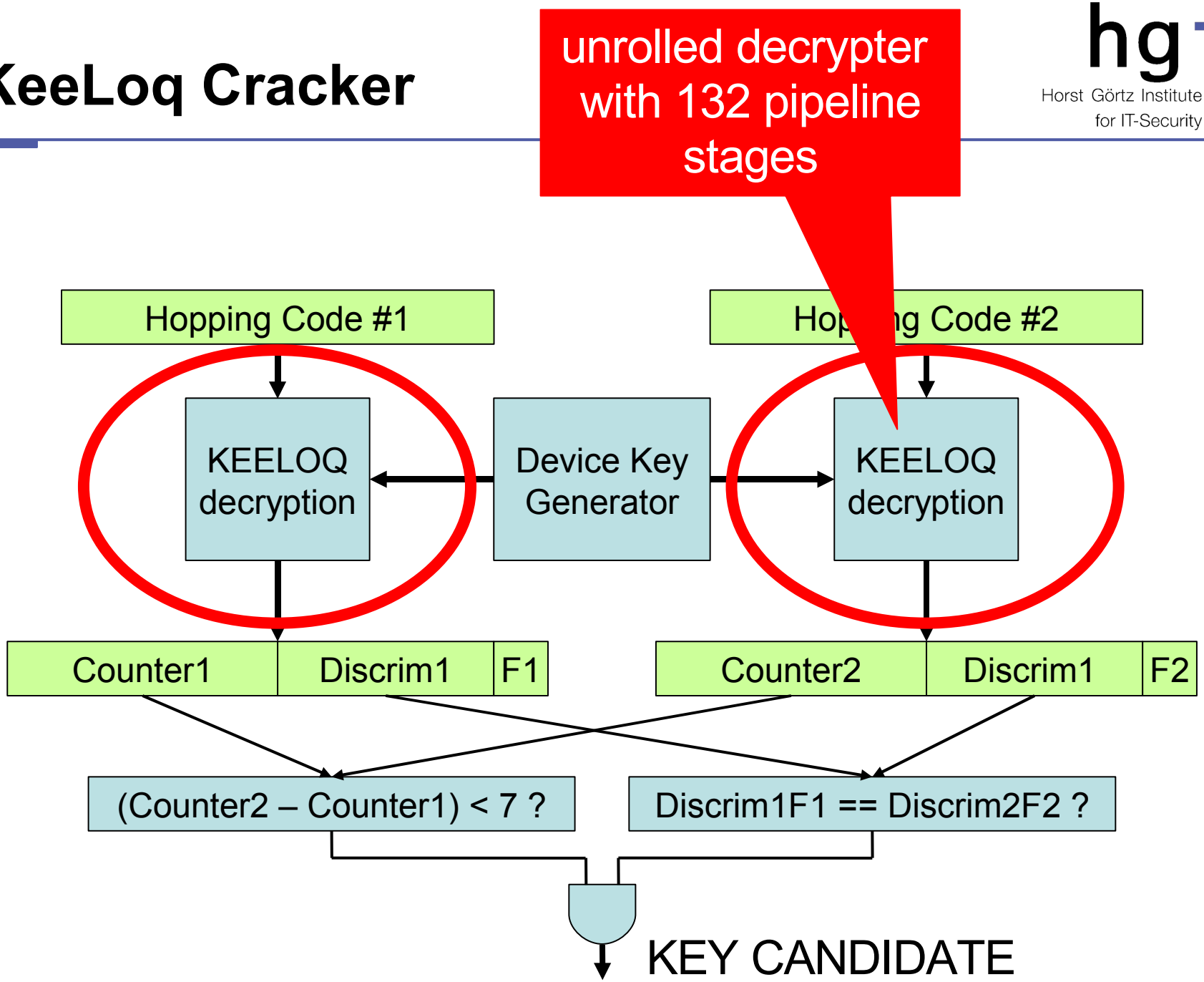

Results

f_{max} = 110 MHz

110 million keys/s verified in 1 FPGA Spartan 3-1000

32 bit seed:	39 seconds / 1 FPGA
48 bit seed:	5.9 hours / 1 COPACOBANA
60 bit seed:	1011 days / 1 COPACOBANA