Implementation of Naive DES, BitSlice DES, and AES on a PC

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Outline

- Implementation Description
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Implementation Description
Naive DES

- Follows the description given in the class lecture notes
- Does the computation in a block on a bit level
- The permutation are performed bit by bit
- The S-boxes are implemented with table lookups
- Encrypt one block at a time (64 bits)
Following the description given in class lecture notes and the paper by Eli Biham:

- Encryption is performed on 32 blocks in parallel.
- Bit $i$ from each block is placed in the $ith$ word.
- Permutation is performed by exchanging words.
- Substitution is not done with table lookups because each word contains bits from different blocks.
- Substitution is done with Boolean functions.
A paper by Matthew Kwan gives the S-boxes in terms of Boolean functions (XOR, OR, AND, NOT)

Each S-box takes an average of 56 Boolean operations to compute

Since encryption is performed on multiple blocks in parallel, CBC mode is not possible on a sequence of blocks

But CBC mode can be done on multiple sequences of blocks (encrypt first block from multiple sequences together, then XOR and encrypt second block from each sequence)
Follows the description given in class lecture notes
Uses T-boxes, which combines SubByte step with the MixColumn step
The T-boxes are generated before encryption in GF($2^8$)
The implementation uses AES-256 (256 bit key length, 128 bit block length)
The key expansion takes the 256 bit key and generates 15 128-bit round keys
This implementation is oriented toward performance, but it happens to be relatively resistant to side-channel timing attacks since the implementation uses table lookups, XORs, and does not have conditional statements that introduce timing differences
After implementation, some of the test values on the NIST website for DES and AES were used to check for correctness of the implementation.

- The test values consist of known plaintexts, keys, and ciphertexts.
- About ~15 test values were used to check for correctness.
- For AES-256, the round key expansion was also checked for 2 test keys.
Performance Tests

Testing Environment:
- Language: C/C++ with Visual C++ compiler
- CPU: Intel Core 2
- Operating System: Windows 2000

The encryptions are done with no feedback
- Key expansion time for 1,200,000 repetitions: 1.688s
- Encryption time for 3,000,000 repetitions: 5.172s
- Encryption speed: 37.1 Mbps
- The encryption is done after the round key expansion
Performance Tests
Bitslice DES

- Conversion to bitslice time for 320,000 repetitions: 1.657s
- Conversion from bitslice time for 320,000 repetitions: 1.156s
- Key expansion time for 1,600,000 repetitions: 1.687s
- Encryption time (no conversion) for 350,000 repetitions: 2.844s
- Encryption time (with conversion at start and end) for 350,000 repetitions: 5.938s
- Encryption speed (no conversion): 252 Mbps
- Encryption speed (with conversion): 120.7 Mbps
Conversion is done on 32 blocks
Each encryption is done on 32 blocks in parallel
Doing two conversions for each encryption reduces the speed by about 50%
Performance Tests
AES-256

- Round key expansion time for 4,000,000 repetitions: 1.297s
- Encryption time for 16,000,000 repetitions: 5.218s
- Encryption speed: 392.5 Mbps
The AES implementation is about 55% faster than the bitslice DES implementation and about 950% faster than the naive DES implementation during encryption.

The DES implementation uses 56-bit key, but the AES implementation uses 256-bit key.

AES is faster and more secure than DES on PC.
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