*UBI/UTI 523 Cryptosystems and Cryptographic Protocols*

*Homework questions*

**3.4.** What is the output of the first round of the DES algorithm when the plaintext and the key are both all ones?

**3.6.** An avalanche effect is also desirable for the key: A one-bit change in a key should result in a dramatically different ciphertext if the plaintext is unchanged.

1. Assume an encryption with a given key. Now assume the key bit at position 1 (prior to PC−1) is being flipped. Which S-boxes in which rounds are affected by the bit flip during DES encryption?
2. Which S-boxes in which DES rounds are affected by this bit flip during DES decryption?

**3.12.** We study a real-world case in this problem. A commercial file encryption program from the early 1990s used standard DES with 56 key bits. In those days, performing an exhaustive key search was considerably harder than nowadays and thus the key length was sufficient for some applications. Unfortunately, the implementation of the key generation was flawed, which we are going to analyze. Assume that we can test 106 keys per second on a conventional PC.

The key is generated from a password consisting of 8 characters. The key is a simple concatenation of the 8 ASCII characters, yielding 64 = 8· 8 key bits. With the permutation *PC*−1 in the key schedule, the least significant bit (LSB) of each 8-bit character is ignored, yielding 56 key bits.

1. What is the size of the key space if all 8 characters are randomly chosen 8-bit ASCII characters? How long does an average key search take with a single PC?
2. How many key bits are used, if the 8 characters are randomly chosen 7-bit ASCII characters (i.e., the most significant bit is always zero)? How long does an average key search take with a single PC?
3. How large is the key space if, in addition to the restriction in Part 2, only letters are used as characters. Furthermore, unfortunately, all letters are converted to capital letters before generating the key in the software. How long does an average key search take with a single PC?

4. Show that the effective key length for 3DES is 112 bits.