```
      page number   | page offset
+----------+----------+-------------+
|    p1    |    p2    |     d       |
+----------+----------+-------------+
    10          10          12
     |           |
     |           `-> pointing to 1k frames
     `--> pointing to 1k page tables
```

```
                        +---------------+
                        | Intel Core 2  |
                        |   Processor   |
                        |     (CPU)     |
                        +---------------+
                                |
                         Front Side Bus
                                |
 +------------+   DDR2    +-------------+      +---------------+
 | System RAM |<--------->| Northbridge |<--->| Graphics Card |
 +------------+  Channel  |    Chip     |      +---------------+
                          +-------------+
                                |
                          DMI Interface
                                |
+----------------------+   +-------------+      +------------------
| BIOS (flash memory)  |<--->|             |<--->| Power management
+----------------------+   | Southbridge |      +------------------
| Serial ATA Ports     |<--->|    Chip     |<--->| Clock generation
+----------------------+   |             |      +------------------
| USB Ports            |<--->|             |<--->|    PCI Bus
+----------------------+   +-------------+      +------------------
```
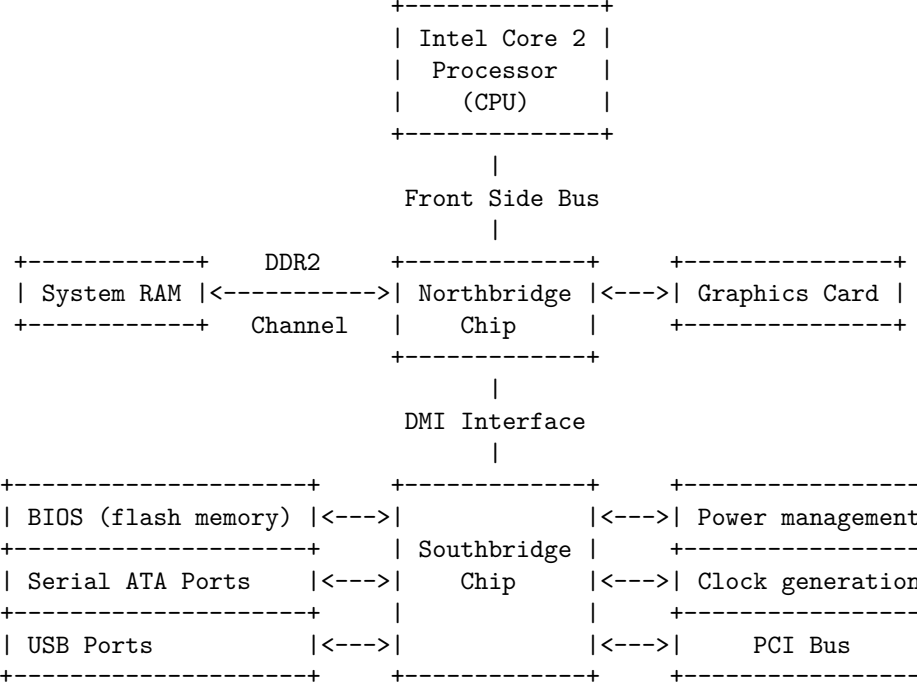
```
     ,--------> inode number
     |    ,---> record length
     |    | ,---> name length
     |    | | ,---> file type
     |    | | |   ,----> name
  +----+--+-+-+----+
0 | 21 |12|1|2|.   |
  +----+--+-+-+----+
12| 22 |12|2|2|..  |
  +----+--+-+-+----+----+
24| 53 |16|5|2|hell|o   |
  +----+--+-+-+----+----+
40| 67 |28|3|2|usr |
  +----+--+-+-+----+
52| 0  |16|7|1|oldf|ile |
  +----+--+-+-+----+----+
68| 34 |12|4|2|sbin|
  +----+--+-+-+----+
```
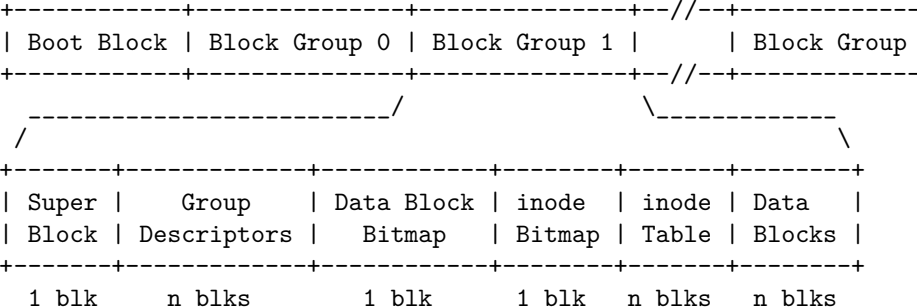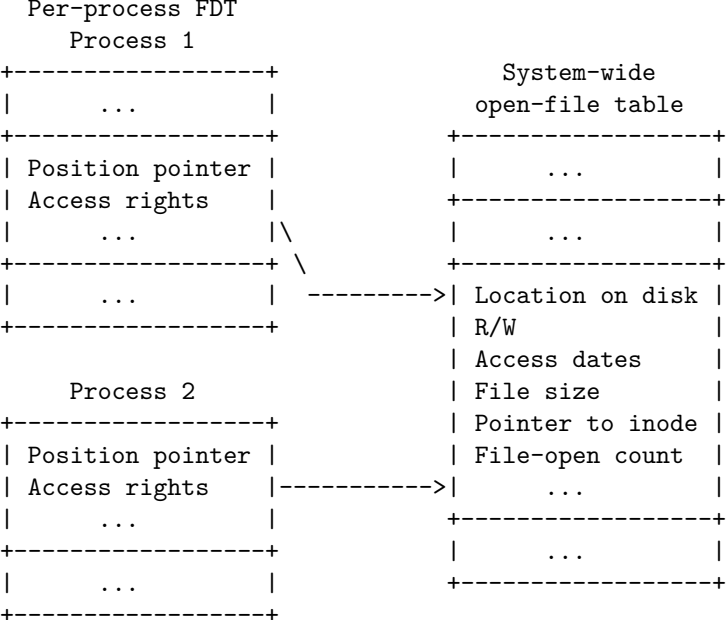
```
+-------------+-----------------+-----------------+--//--+------------
| Boot Block | Block Group 0 | Block Group 1 |      | Block Group
+-------------+-----------------+-----------------+--//--+------------
     _____/            _____
    /                                                   \
+-------+-------------+-------------+--------+-------+--------+
| Super |    Group    | Data Block  | inode  | inode | Data   |
| Block | Descriptors |   Bitmap    | Bitmap | Table | Blocks |
+-------+-------------+-------------+--------+-------+--------+
  1 blk     n blks        1 blk       1 blk   n blks  n blks
```

```
    user FDT        file table           inode table
 +--------+     +-----------+        +----------------+
0| STDIN  |     |    :      |        |       :        |
 +--------+     +-----------+        |       :        |
1| STDOUT |     | count  R  |        |       :        |
 +--------+ -->|    1      |\        +----------------+
2| STDERR | /  +-----------+ `---->| (/etc/passwd) |
 +--------+/   |    :      |  ,-->|    count 2    |
3|        |    +-----------+  |   +----------------+
 +--------+    | count  RW |  |   |       :        |
4|        |--->|    1      |\ /   +----------------+
 +--------+    +-----------+ \/   |    (local)    |
5|        |    |    :      | /\--->|    count 1    |
 +--------+\   +-----------+/      +----------------+
 :   :   : \  | count  W  |        |       :        |
 +--------+ -->|    1      |        +----------------+
              +-----------+
```

```
  user FDT
   proc A                  file table
  +--------+            +-----------+              inode table
0| STDIN  |            |    :      |           +----------------+
  +--------+            +-----------+           |     :          |
1| STDOUT |            | count   R |           |     :          |
  +--------+  ------->|   1       |\          +----------------+
2| STDERR | /          +-----------+ \--------->| (/etc/passwd)  |
  +--------+/           |    :      |   ----->|   count 3      |
3|        |            +-----------+   /   ->|                |
  +--------+            | count  RW |  /   /  +----------------+
4|        |-------->|   1       |\ /   /   |     :          |
  +--------+            +-----------+ \/   /   |     :          |
5|        |            |    :      | /\   /   +----------------+
  +--------+\          +-----------+/ -------->| (local)        |
  :   :   : \  ---->| count   R |  /     |   count 1      |
  +--------+  \/     |   1       | /       +----------------+
            /\       +-----------+ /       |     :          |
   proc B   | \      |    :      | /       |     :          |
  +--------+ |  \     +-----------+/        +----------------+
0| STDIN  | |   -->| count   W |   ------->| (private)      |
  +--------+ |      |   1       | /         |   count 1      |
1| STDOUT | |       +-----------+ /         +----------------+
  +--------+ |      |    :      | /         |     :          |
2| STDERR | /       +-----------+/          |     :          |
  +--------+/        | count   R |           +----------------+
3|        | .------>|   1       |
  +--------+/        +-----------+
4|        |
  +--------+
  :   :   :
  +--------+
```

```
Per-process FDT
    Process 1
+-------------------+                         System-wide
|       ...         |                        open-file table
+-------------------+               +-------------------+
| Position pointer  |               |       ...         |
| Access rights     |               +-------------------+
|       ...        |\               |       ...         |
+-------------------+ \              +-------------------+
|       ...         | ---------->| Location on disk  |
+-------------------+               | R/W               |
                                    | Access dates      |
    Process 2                       | File size         |
+-------------------+               | Pointer to inode  |
| Position pointer  |               | File-open count   |
| Access rights     |---------->|       ...         |
|       ...         |               +-------------------+
+-------------------+               |       ...         |
|       ...         |               +-------------------+
+-------------------+
```

```
 0 1 2 3 4 5 6 7 8  ..  n-1
+-+-+-+-+-+-+-+-+-+-//-+-+
|0|0|1|0|1|1|1|0|1| .. |0|
+-+-+-+-+-+-+-+-+-+-//-+-+
```

```
|<---------------------- Entire disk ----------------------->|
+-----+------------+------------+------------+------------+
| MBR | Partition 1 | Partition 2 | Partition 3 | Partition 4 |
+-----+------------+------------+------------+------------+

     _____/            _____
    /                                                     \
+---------------+----------------+-------------------+---//--+
| Boot Ctrl Blk | Volume Ctrl Blk |   Dir Structure   | Files |
| (MBR copy)    | (Super Blk)    | (inodes, root dir) | dirs  |
+---------------+----------------+-------------------+---//--+
```
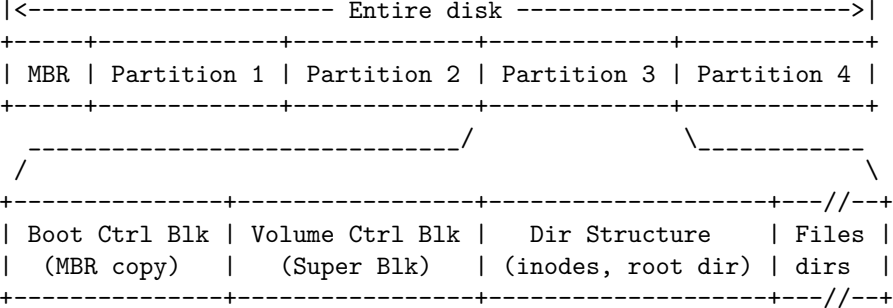
```
 31                                    12 11                        0
+-----------------------------------+-------+---+-+-+---+-+-+
|                                   |       |   | | |   |U|R| |
|     PAGE FRAME ADDRESS 31..12     | AVAIL |0 0|D|A|0 0|/|/|P|
|                                   |       |   | | |   |S|W| |
+-----------------------------------+-------+---+-+-+---+-+-+
        P      - PRESENT
        R/W    - READ/WRITE
        U/S    - USER/SUPERVISOR
        A      - ACCESSED
        D      - DIRTY
        AVAIL  - AVAILABLE FOR SYSTEMS PROGRAMMER USE

        NOTE: 0 INDICATES INTEL RESERVED. DO NOT DEFINE.
```

```
  +----------------+
0 |     4096       |
  +----------------+                ---->+----------+  Byte 9000 in
1 |     228        |               /     |   367    |       |
  +----------------+              /      | Data blk |       v
2 |    45423       |             /       +----------+  8th blk, 808t
  +----------------+            /
3 |      0         |           /          -->+------+
  +----------------+          /           / 0|      |
4 |      0         |         /           /   +------+
  +----------------+        /           /    :  :  :
5 |    11111       |       /           /     +------+          Byte
  +----------------+      /    ->+-----+/   75| 3333 |           in
6 |      0         |     /    / 0| 331 |      +------+\
  +----------------+    /    /   +-----+      :  :  : \
7 |     101        |   /    /    |     |      +------+  \        816
  +----------------+  /    /     |  :  |   255|      |   \-->+---
8 |     367        | /    /      |  :  |      +------+       |
  +----------------+/    /       |  :  |        331          | Da
9 |      0         |    /        |     |   Single indirect   +---
  +----------------+   /         +-----+
S | 428 (10K+256K) |  /       255|     |
  +----------------+ /           +-----+
D |     9156       | /           9156           /***************
  +----------------+        Double indirect     What about the
T |     824        |                            ***************
  +----------------+
```

```
|<-------------Master Boot Record (512 Bytes)------------->|
0           439      443   445                   509     511
+----//-----+----------+------+------//---------+---------+
| code area | disk-sig | null | partition table | MBR-sig |
|    440    |    4     |  2   |    16x4=64      | 0xAA55  |
+----//-----+----------+------+------//---------+---------+
```

```
max  +------------------+
     |      Stack       |  Stack segment
     +--------+---------+
     |        |         |
     |        v         |
     |                  |
     |        ^         |
     |        |         |
     +--------+---------+
     | Dynamic storage  |  Heap
     |(from new, malloc)|
     +------------------+
     | Static variables |
     | (uninitialized,  |  BSS   segment
     |  initialized)    |  Data segment
     +------------------+
     |       Code       |  Text segment
  0  +------------------+
```

```
     0        1        2      3~8       9
+--------+--------|--------+---//---+--------+
| Segment selector| Micro program register  |
+--------+--------|--------+---//---+--------+
    Programmable         Non-programmable
```

```
  selector | offset
+-----+-+--+--------+  s - segment number
|  s  |g|p |        |  g - 0-global; 1-local
+-----+-+--+--------+  p - protection use
  13   1 2     32
```

```
  selector  | offset
+----+---+---+--------+
| s  | g | p |        |
+----+---+---+--------+
  13    1   2     32
```
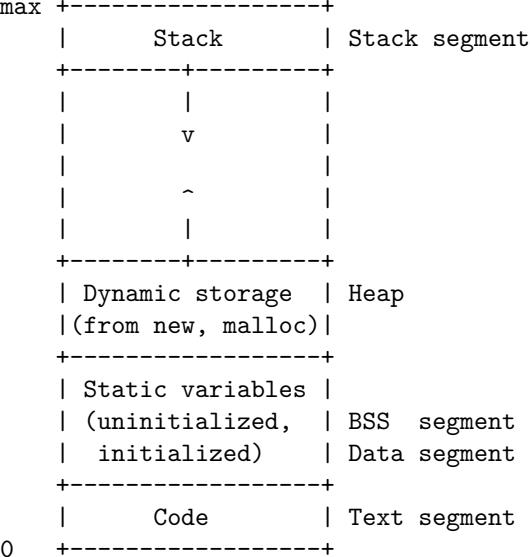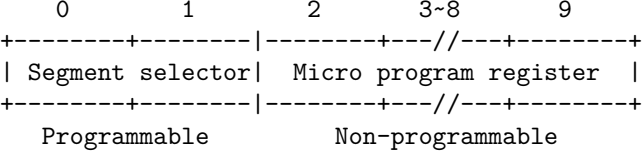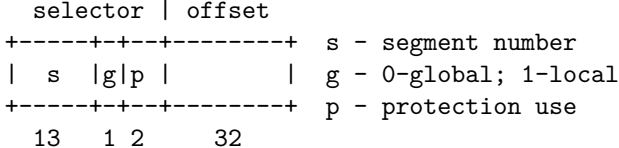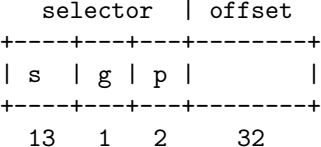
```
      DESCRIPTOR TABLE                SEGMENT
      +--------------+              +------+
      |     ...      |    ,------->|      |<--.
      +--------------+    |        |      |   |
 .--->|   Segment    |____/        |      |   |
 |    |  Descriptor  |             +------+   |
 |    +--------------+                        |
 |    |     ...      |                        |
 |    +--------------+                        |
 |                                            |
 |                       Nonprogrammable      |
 |    Segment Registor     Register           |
 \__+-----------------+---------------------+____/
    | Segment Selector | Segment Descriptor |
    +-----------------+---------------------+
```

```
+-------------------+
|  process state    |
+-------------------+
|       PID         |
+-------------------+
| program counter   |
+-------------------+
|    registers      |
+-------------------+
|  memory limits    |
+-------------------+
| list of open files|
+-------------------+
|      ...          |
+-------------------+
```

```
process
+-------+
| stack | 4M
+-------+
|       |
| ...   | unused
|       |
+-------+
| data  | 4M
+-------+
| code  | 4M
+-------+
```
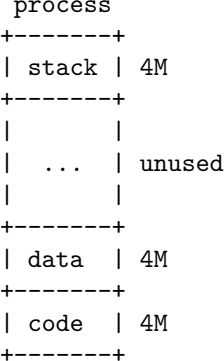
```
  page frame address | info
+--------------------+------+
|         20         |  12  |
+--------------------+------+
```

```
  pid | virtual page number | info
+-----+---------------------+------+
| 16  |         52          | 12   |
+-----+---------------------+------+
```

```
  selector | offset
+-----+-+--+--------+  s - segment number
|  s  |g|p |        |  g - 0-global; 1-local
+-----+-+--+--------+  p - protection use
  13   1 2      32
```

```
 Program 1      Program 2      Program 3
+---------+    +---------+    +---------+
| fork()  |    | vfork() |    | clone() |
+---------+    +---------+    +---------+
     |              |              |
  +--v-----------v----------v--+
  |          C Library         |
  +---------------o------------+
                  |                        User space
-----------------|----------------------------------
  +--------------v-------------+          Kernel space
  |         System call        |
  +--------------o-------------+
                  |      +---------+
                  |      :  ...    :
                  |    3 +---------+  sys_fork()
                  o------>| fork()  |---------------.
                  |      +---------+                |
                  |      :  ...    :                |
                  |  120 +---------+  sys_clone()   |
                  o------>| clone() |---------------o
                  |      +---------+                |
                  |      :  ...    :                |
                  |  289 +---------+  sys_vfork()   |
                  o------>| vfork() |---------------o
                         +---------+                |
                         :  ...    :                v
                         +---------+          do_fork()
                    System Call Table
```
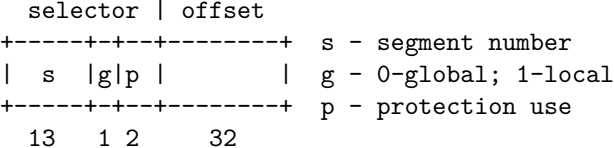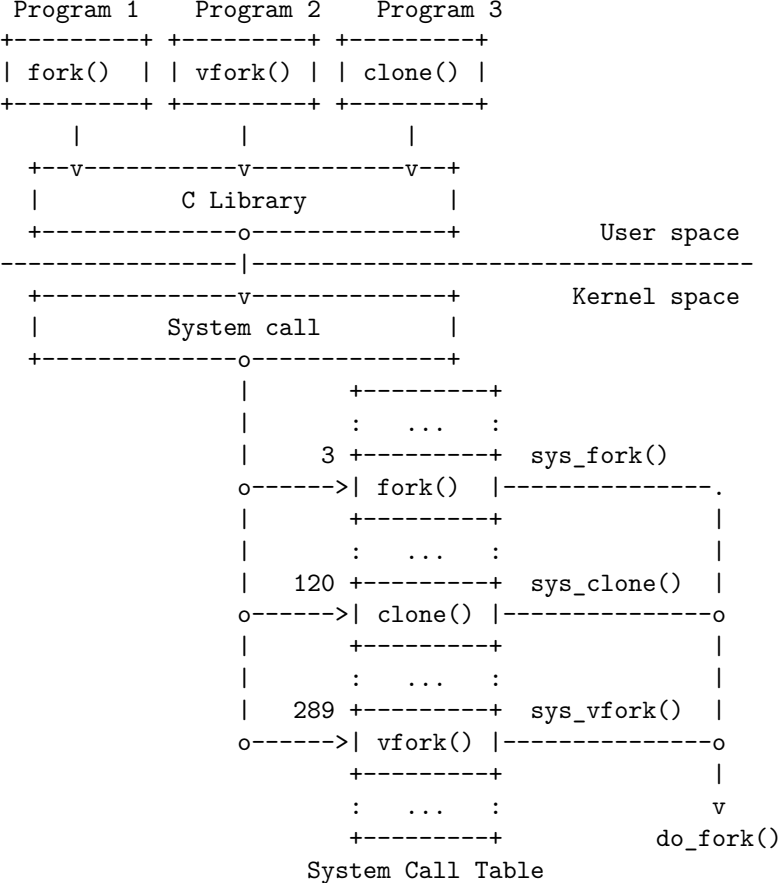
```
+-------------------------------------+
| code, data, open files, signals... |
+-----------+-----------+-------------+
| thread ID | thread ID | thread ID   |
+-----------+-----------+-------------+
|  program  |  program  |   program   |
|  counter  |  counter  |   counter   |
+-----------+-----------+-------------+
|  register |  register |   register  |
|    set    |    set    |     set     |
+-----------+-----------+-------------+
|   stack   |   stack   |    stack    |
+-----------+-----------+-------------+
```