Improving Non-Functional Properties of Operating Systems with Reconfigurable Hardware

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Motivation

- Achieving system properties purely in software can be hard:
  - **Security:** Running software must not alter security policies
  - **Safety:** Entering a safe state, even when the system crashes
  - **Determinism:** Enforcing hard limits to reach real-time goals
  - **Performance:** Increasing system throughput

- Reconfigurable hardware is becoming a commodity
  - But only used for user space applications

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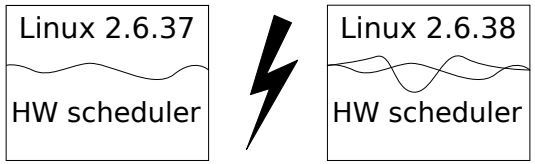
Solution

⇒ Use custom hardware in the operating system!

- Reconfigurable hardware is becoming a commodity
  - But only used for user space applications

Problem

- Custom hardware needs to know about the OS
  - No stable kernel API



(see `linux-2.6/Documentation/stable_api_nonsense.txt`)

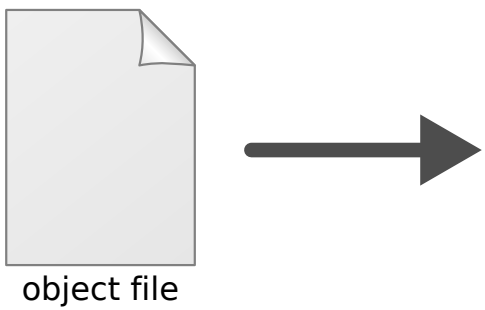
  - Transforming system state to a hardware-defined format is expensive
  - Manually adapting hardware to changing software is fragile

Solution

Generate hardware interfaces automatically

Compile-Time

- Idea: Use debug symbols
  - Memory layout as created by the compiler
  - Used for HDL interface generation
  - Stable interface for hardware implementation
  - Incompatible OS changes are detected
  - Integrateable in kernel build process



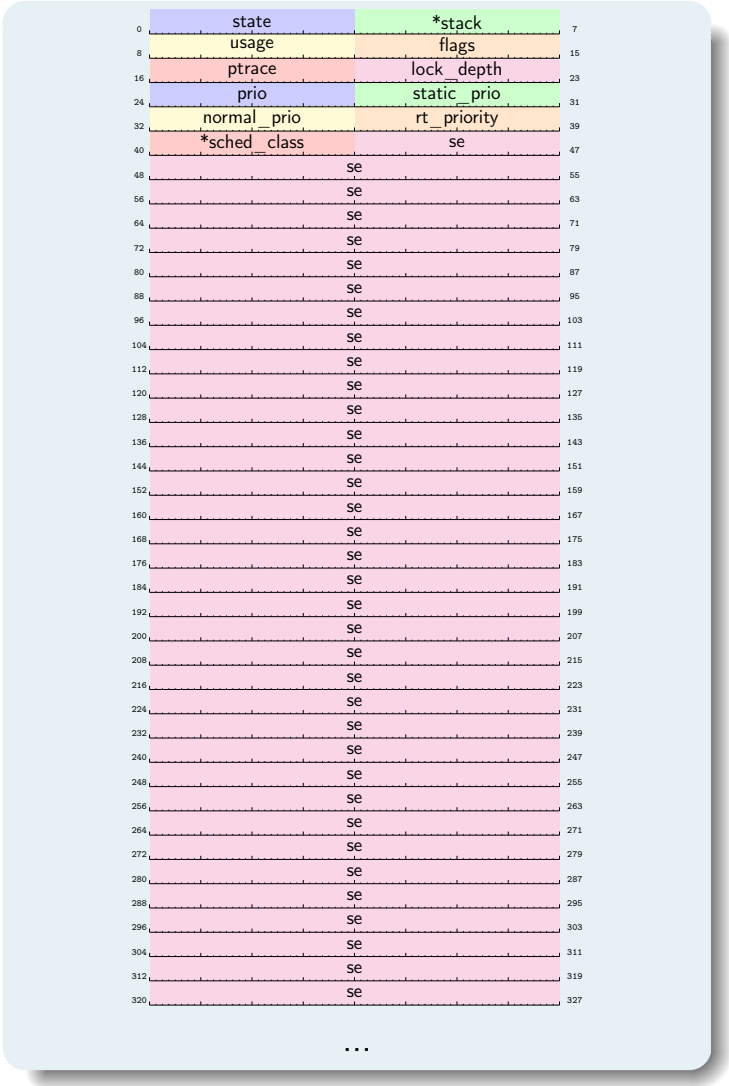

```
entity struct_simple is port (
  signal flags_i: in std_logic;
  signal info_i: in std_logic;
  signal data_i: in std_logic;

  signal base_addr_i: in std_logic_vector(31 downto 0);
  signal addr_o: out std_logic_vector(31 downto 0);
  signal clk_i: in std_logic);
end entity struct_simple;

architecture struct_simple__arch of struct_simple is
begin
  process (clk_i)
  begin
    if (clk_i'event and clk_i = '1') then
      if (flags_i = '1') then
        addr_o <= base_addr_i + 0 + 0;
      elsif (info_i = '1') then
        addr_o <= base_addr_i + 0 + 2;
      elsif (data_i = '1') then
        addr_o <= base_addr_i + 0 + 4;
      else
```

Run-Time

- Access to system data via DMA
- Generated hardware can be activated on-the-fly
- Passive and active functionality possible



Status and Future Work

- What is working so far?
  - Interface generation and hardware build process
  - Integration into Linux
    - Detecting and terminating prohibited processes on the system
- What am I working on?
  - Implementation of more hardware functions
    - **Security:** Hardware-based policy enforcement
    - **Determinism:** Real-time scheduling
    - **Performance:** Network routing
  - Semi-automatic transformation of kernel code