Transmeta Architecture

Major Ideas
General Architecture
Emulated Precise Exceptions
What to do with It

Background

- Transmeta Corporation
  - Paul Allen (Microsoft), George Soros (Soros Funds)
  - David R. Ditzel (Sun) CEO
  - Edmund J. Kelly, Malcolm John Wing, Robert F. Cmelik (?)
  - Linus B. Torvalds, February 1997 → ...
- Patent 5958061
  - applied July 24, 1996
  - granted September 28, 1999
  - other patents …
- Crusoe prosessor
  - published January 19, 2000

Basic Idea

faster

cheaper

- Create a new processor which, when coupled with "morph host" emulator, can run Intel/Windows code faster than state-of-the-art Intel processor
- New processor can be implemented with significantly fewer gates than competitive processors
- Compete with Intel, friendly with Microsoft
  - sell chip with emulator code to system manufacturers (Dell, IBM, Sun, etc etc)
- x86 binary is new binary standard
- Native OS not so important
  - could be Linux

Major General Ideas

- Emulation can be faster than direct execution
- TLB used to solve new problems
  - track memory accesses for memory mapped I/O
  - track memory accesses for self-modifying code
- Most of executed code generated "on-the fly"
  - not compiled before execution begins
  - extremely optimized dynamic code generation
- Optimized code allows for simpler machine

Major General Ideas (contd)

- Self-modified code (dynamically created code) can be generated so that it is extremely optimized for execution
  - issue dependencies, reorder, reschedule problems solved at code generation
  - processor does not need to solve these
- Optimize for speed only when needed
  - do not optimize for speed when exact state change is required
- Alias detection to assist keeping globals is registers

Major Emulation Ideas

- Target processor state kept in dedicated HW registers
  - working state, committed state
- Memory store buffer keeps uncommitted emulated memory state
- Specific instructions support emulation
  - commit, rollback (exact exceptions)
  - prot (aliases)
- TLB (and VM) designed to support emulation
  - A/N-bit (mem-mapped I/O), T-bit (self-mod. code)

General Architecture

- VLIW implementation
  - 4 simultaneous RISC instructions
    - one each of float, int, load/store, branch,
  - no circuitry for issue dependencies, reorder, optimize, reschedule
    - compiler takes care of these
  - what about data, control and structural dependencies?
    - part of issue dependencies
    - data & structural dependencies under compiler control?

General Architecture (contd)

- Large register set
  - native regs: 64 INT, 32 FP
    - extra regs for renaming
  - target architecture regs: complete CPU state
    - INT, FP, control
    - working regs for normal emulation
    - committed regs for saving emulated processor state

~~Reax, Recx, Rseq, Reip~~

General Architecture (contd)

- TLB
  - new features to solve new problems
    - earlier used to solve also memory protection problems in addition to plain VM address mapping
  - A/N-bit for memory-mapped I/O detection
    - trap to emulator, which creates precise code
    - memory-mapped I/O requires precise emulated processor state changes
  - T-bit for self-modifying code detection
    - trap to emulator, which recreates emulating code in instruction cache (“translation buffer”)

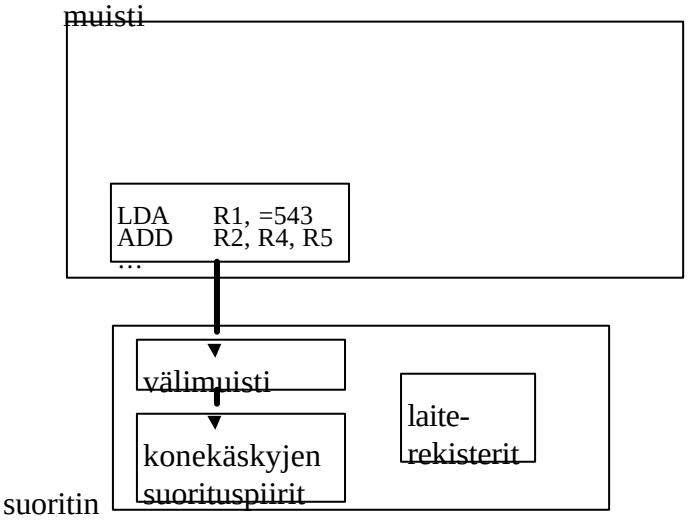
General Architecture (contd)

- Target memory store buffer
  - implemented with special register to support emulation
  - keeps track on which target processor memory stores are committed and which are not
  - uncommitted memory stores can be discarded at rollback
    - modify HW registers implementing it
    - commit & rollback controlled from outside, not internally as is usual with speculative instructions

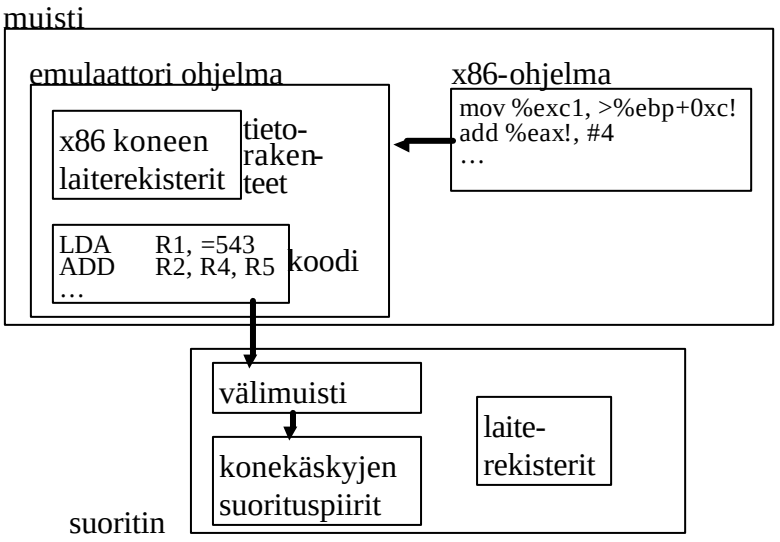
General Architecture (contd)

- RISC instruction set
  - explicitly parallel code (VLIW)
  - commit instruction supports emulation
    - commits emulated processor and memory state
    - use only when coherent target processor state!
  - rollback instruction (?) supports emulation
    - some or all of it can be in emulator code
    - recover latest committed emulated register state
    - delete uncommitted writes from store buffer
    - retranslate emulation code for precise state changes
      - commit after every emulated instruction
  - prot instruction for alias detection

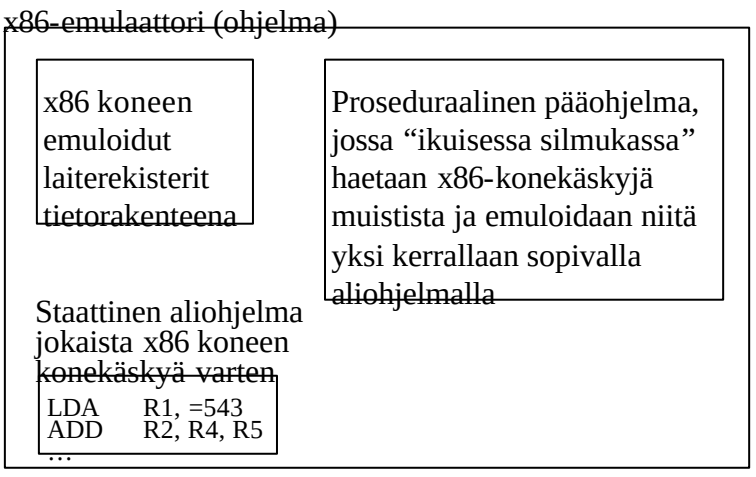
Tavallisen ohjelman suoritus



Emulaattoriohjelman suoritus



Tavallinen emulaattoriohjelma



Transmetan emulaattoriohjelma

(x86 koneen emuloidut laiterekisterit laitteistossa)

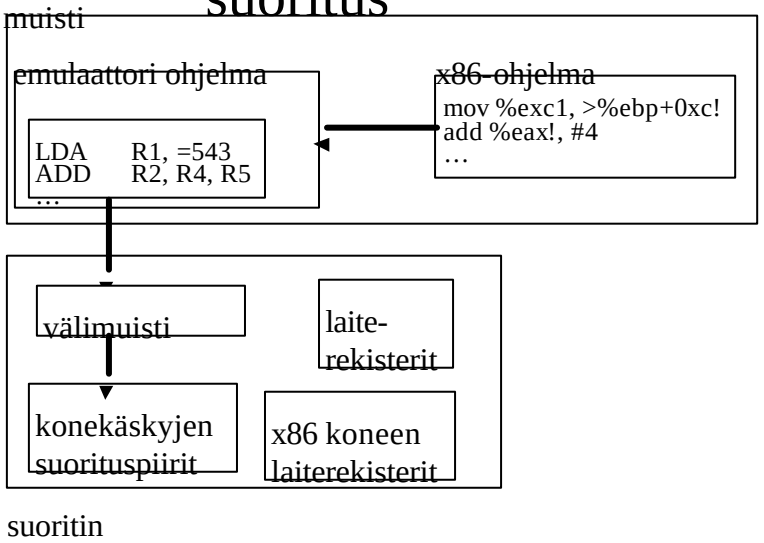
Dynaamisesti generoidut (optimoitut) käskysarjat x86-koneen konekäskyjoukkoja varten

```
LDA     R1, =543
ADD     R2, R4, R5
…
```

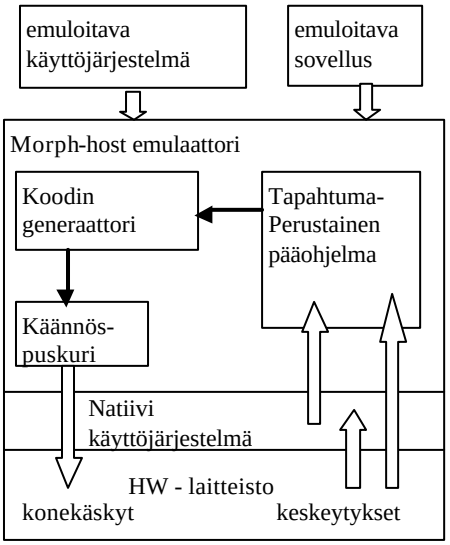
Tapahtumaperustainen pääohjelma, joka valvoo emulointia ja generoi suoritettavia konekäskyjä välimuistiin:

- jos emuloitavaa käskysarjaa ei vielä ole generoitu omalle konekielelle, niin generoi se (käännöspuskuriin) ja anna sille suoritusvuoro
- jos emuloitu epätarkka keskeytys, niin peruuta talletettuun tilaan, generoi hidas mutta täsmällinen emulointikoodi ja jatka.
- jos emuloitu tarkka keskeytys, niin käsittele se ja jatka nopealla suorituksella (optimoidut käskysarjat)

Transmetan emulaattoriohjelman suoritus



Transmetan prosessorin looginen rakenne



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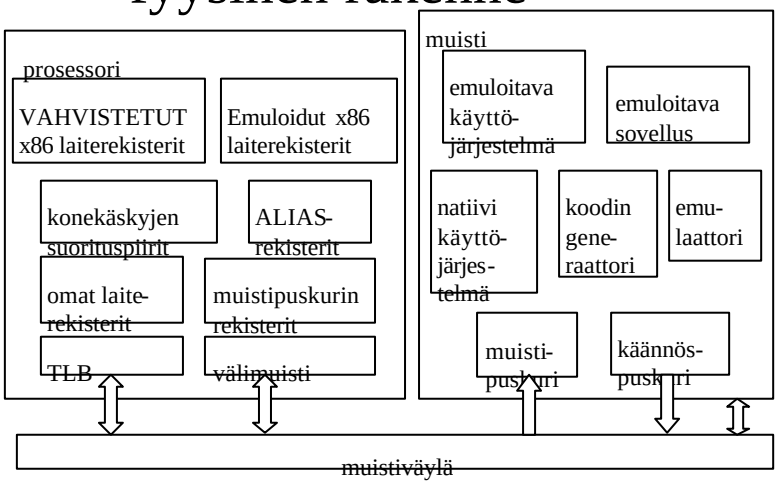
Transmetan prosessorin fyysinen rakenne



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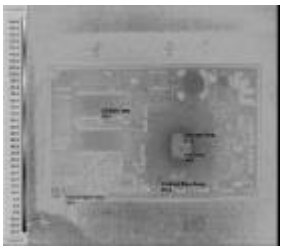
What Will Transmeta do with Crusoe?

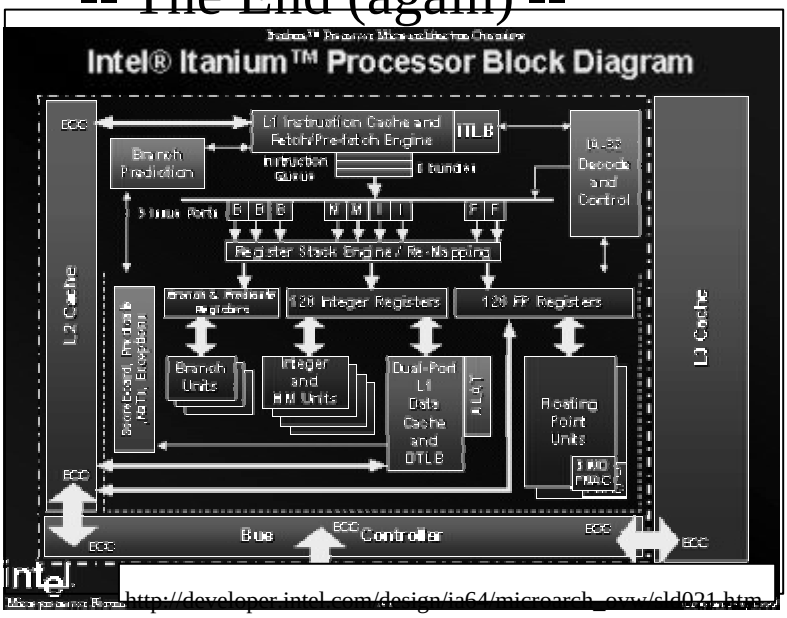


- Optimize for speed or size?
  - Small size ⇒ cheaper, less power
- License it to Intel?
- Have someone else manufacture it and compete with Intel?
  - IBM
  - Motorola, AMD?
- Make products based on Crusoe?
  - Internet window?
  - Visual phone?

TM3120, TM5400

low power

-- The End (again) --



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