



IP9 Communicating Embedded Systems

Reconfigurable Hardware in Wireless Networks

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Advantages of Reconfigurable Hardware

IP 9 deals with the design of Communicating Embedded System (CES) such as Terminodes. This work investigates reconfigurable hardware in wireless network nodes.

Project Goal

A Terminode is ...

- a heterogeneous device
- a terminal to user (audio- and video coding, sensor data processing, ...)
- a network node (store and forward, QoS routing, cryptography, ...)

Terminodes require ...

- occasionally a high amount of local processing power
- flexibility to reprogram and update

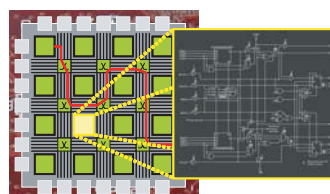


Performance / Flexibility Trade-Off

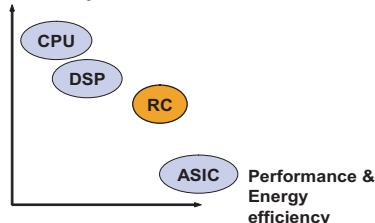
Goal: Design of Flexible Terminode Platform for High Performance Streaming Applications

Advantages of Reconfigurable (RC) Hardware

Predominant device: FPGA



Flexibility



RC most efficient for:

- regular and parallelizable operations
 - bit-level operations
 - custom bitwidths
- } DSP
Crypto
Communication

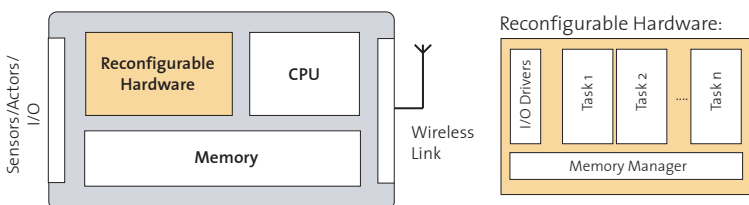
Examples:

Mencer et al [ICASSP'98]: IDEA encryption:

| Type | Device | Mbit/s | Mbit/Ws |
|------|------------------|--------|---------|
| CPU | StrongARM SA-110 | 32.0 | 32.0 |
| DSP | TI TMS320C6x | 53.1 | 8.9 |
| FPGA | Xilinx XC4020XL | 528.0 | 167.6 |

Research Issues

Target Hardware Architecture



Prototyping Platform



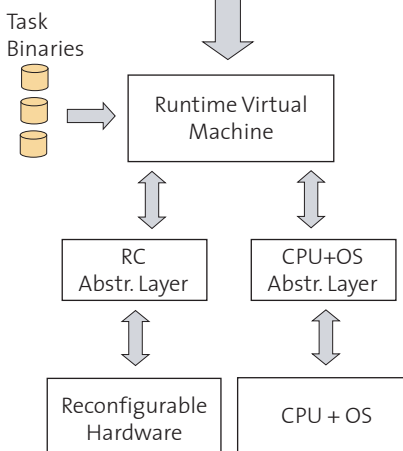
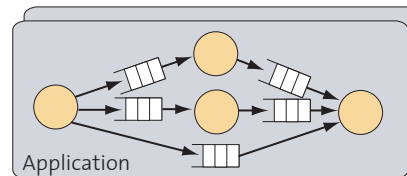
CPU + OS, IPAQ h3970:

- Intel xScale @ 100-400 MHz
- PocketPC 2003 (WinCE 4.1) real-time operating system
- integrated Bluetooth IF
- optional WLAN

Reconfigurable Hardware:

- Xilinx Spartan II FPGA (200k Gates)
- CPLD, 1Mbit SRAM, 8Mbit Flash

Programming Model - Virtual Machine



Model of Computation:

- Focus on stream-based applications, specified as Process Networks.
- Task coordination language:
 - in interpretable format
 - clear semantics to check real-time properties

HW/SW Tasks:

- Task implementations are platform optimized:
 - > no performance loss
- downloadable over wireless network

Abstraction Layer:

- Virtualization of reconfigurable logic
- provides a common interface to the virtual machine

Publications / Related Work

Publication:

- Plessl, C. et al.: *The case for reconfigurable hardware in wearable computing*, Personal and Ubiquitous Computing, Springer-Verlag, Vol. 7, No. 5, pages 299-308, Oktober, 2003.

Wireless Network Nodes and Virtual Machine:

- Levis, P.; Culler, D.: *Mate: a tiny virtual machine for sensor networks*, SIGPLAN-Notices, Oct. 2002; -> **difference to this work**: focus on code size minimization, assembler-like code, not suited for high performance tasks.
- Liu, T.; Martonosi, M.: *Impala: A Middleware System for Managing Autonomous, Parallel Sensor Systems*, PPOPP'03; June 2003; -> **difference to this work**: focus on remote update, no task coordination.
- Henzinger, T.-A.; Kirsch, C.-M.: *The Embedded Machine: Predictable, Portable Real-time Code*, PLDI'02, May 2002; -> **difference to this work**: designed for control applications, not suited for streaming applications, synchronization by explicit driver calls.

Reconfigurable Computing:

- Yajun, H. et al.: *A hardware virtual machine for networked reconfiguration*, RSP'00, June 2000; -> **difference to this work**: direct byte code interpreter for FPGA circuits, virtualization of FPGA-routing -> performance loss.
- Nollet, V. et al.: *Designing an operating system for a heterogeneous reconfigurable SoC*, IPDPS'03, April 2003; -> **difference to this work**: no specific model of computation.