# Linux on the Cell processor

## Linux Kernel Hacking Free Course — IV edition

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# What is Cell?

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- Cell is a multiprocessor system on single chip developed by IBM in collaboration with Sony and Toshiba

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- Cell has a non homogeneous architecture
- One general purpose processor (*PPE*)
- Eight special purpose processors (*SPE*)
- To fully exploit the Cell architecture a new programming approach is required

# Architectural Overview

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- Based on a 64 bit RISC architecture conforming to the PowerPC Architecture version 2.02

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- A dual-threaded general purpose processor
- Based on a 64 bit RISC architecture conforming to the PowerPC Architecture version 2.02
- Has vector/SIMD multimedia extensions

# *PPE* simple block diagram

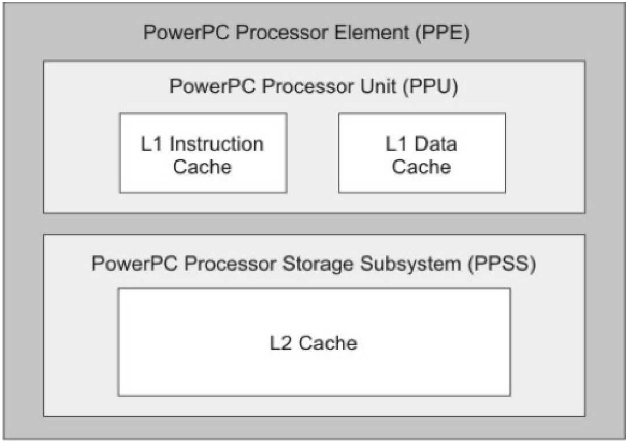


Image taken from CBE Programming Tutorial v. 3

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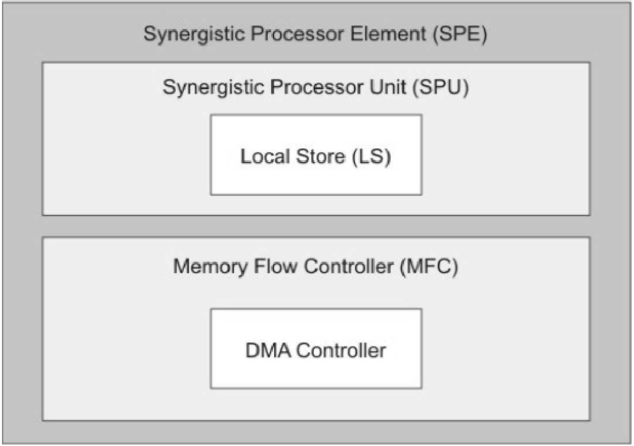
- Slave processor: it execute tasks spawned from the *PPE*
- Based on a 128 bit RISC architecture specialized for computing intensive SIMD applications

# *SPE* simple block diagram

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- The *SPU* fetches instructions and load/store data from/to its own Local Store

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- Contains a DMA controller for DMA transfers support
- In order to support the DMA controller, the MFC maintains a queue of DMA commands
- After a DMA command has been queued, the SPU can continue to execute instructions while the MFC processes the DMA command

# DMA tranfers

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- The *SPU* associated with *MFC* can issue a DMA-list of up to 2048 DMA

# High level programming

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- To fully exploit the Cell performance you must write two different software programs:
- *PPE program* — a program running on PowerPC core that offloads task to SPE
- *SPE program* — a program running on SPE processor that uses the SPU Instruction Set

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- *spe_program_load()* – load an SPE program into the context
- *spe_context_run()* – execute a context on a physical SPE

# Creating a SPE thread from PPE and libspe2

- The function aboves are in libspe2, which is an implementation of the *SPE Runtime Management Library* developed by IBM under GPL license and downlodable from http://sourceforge.net/projects/libspe

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- A SPE program transfers data from/to main memory to/from Local Store through DMA transfers

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- Use double buffering

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- For example a scalar load must be rotated into the preferred slot

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- Data and code must fit in 256 KB Local Store

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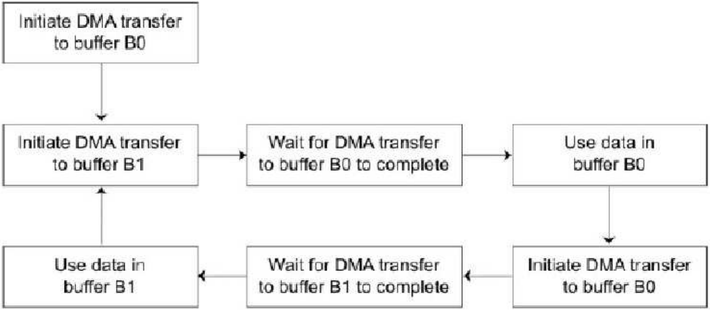
- In the Cell architecture DMA transfers are asynchronous
- This feature allow the programmer to schedule the transfers so that the latency of memory accesses can be hidden by overlapping the transfers in one buffer with computations in another

# Double buffering (2/2)

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- The first folder includes code for supporting the native Cell
- The second folder include code for supporting the Cell on Sony PlayStation 3

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- In native Cell the Linux kernel runs directly on hardware
- In ps3 the Linux kernel runs in a virtualized environment

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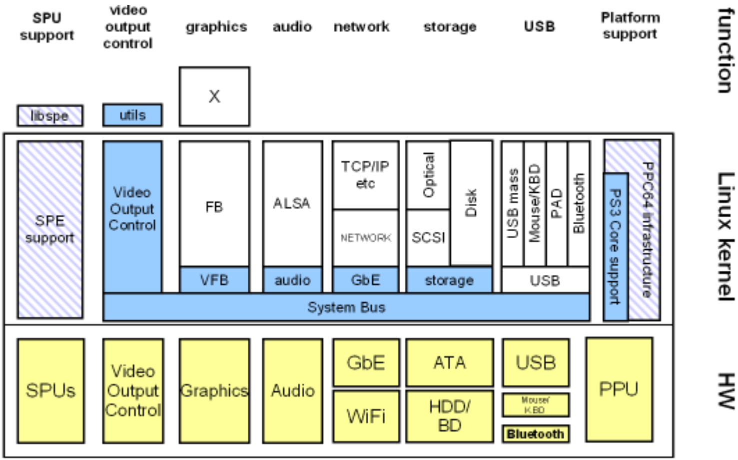
- Why there are different platforms for Cell native and Cell on ps3?
- The presence of a virtualization layer imposes different low level interactions between hardware devices and kernel

# Kernel execution overview on native Cell



# Kernel execution overview on PlayStation3

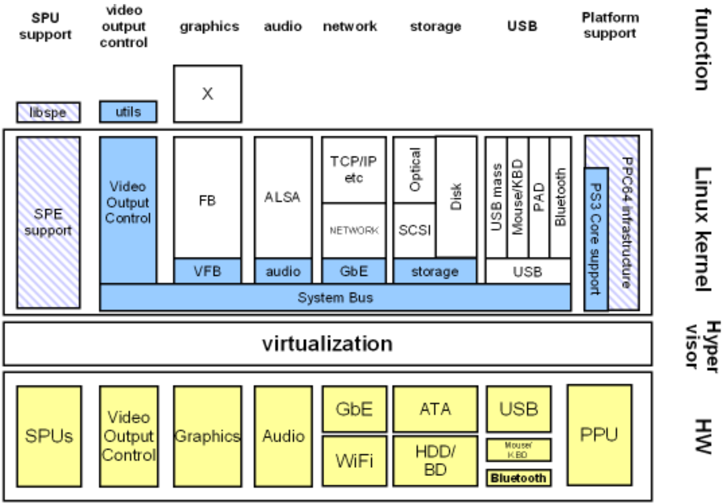



Image taken from http://www.kernel.org/pub/linux/kernel/people/geoff/cell/

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- The *spu_create()* system call creates a spu context in kernel memory and return an open file descriptor for the directory (in /spu) associated with it.

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- Interaction with these contexts can happen through file operations like open, read, write, etc.

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- *mem* – The local memory of a SPE context. Mainly used to load the executable file of the program to be run onto the SPE
- *regs* – The general purpose registers of an SPE. Normally can't be accessed directly but they can be saved in a context in kernel memory

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- Context switching on SPE is very inefficient

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- Thus, the SPE ELF object file is loaded into the context directly from user space

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- Each SPE thread is associated with one PPE thread

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- The University of Massachusetts Dartmouth uses a cluster of sixteen ps3 for astrophysics analysis

# Performance scaling with implementation

- 2048x2048 float matrix multiplication on single SPE

| Implementation | Execution time (ms) |
|---|---|
| Scalar | 338687.230514 |
| Vectorial | 336059.746404 (-0,77%) |
| Vectorial - Unrolling | 280815.662356 (-17%) |
| Vectorial - Unrolling con spu_madd | 262594.693659 (-23%) |
| Vectorial - spu_madd | 75076.210915 (-78%) |
| Vectorial - spu_madd - spu_gcc -O3 | 18072.911028 (-95%) |
| Vectorial - spu_madd - with Double Buffering | 10509.868133 (-97%) |

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- Fully exploiting Cell capabilities is not easy