Software Defined Radio

15.2.2005
Kari Pietikäinen
Communications Laboratory
Outline

- Motivation
- Concept
- Applications
- Features
- Programmability
- Architecture
- Implementation
- Drawbacks
- Conclusion
- Homework
- References
What?

"...a radio that includes a transmitter in which the operating parameters of the transmitter, including the frequency range, modulation type or maximum radiated or conducted output power can be altered by making a change in software without making any hardware changes"

-FCC definition

FCC, federal communications commission
Motivation (1/2)

- Continuous transition from analog to digital
  - software defines waveforms
  - analog signal processing is replaced with DSP
- Evolving technologies
  - NMT >> GSM >> UMTS >> ???
  - infrastructure upgrades
- Multimode devices
  - 4G devices
  - legacy devices
  - same device for different networks
Motivation (2/2)

- Reusable devices
  - devices can be upgraded
  - software update
- Increasing DSP capabilities
  - computational power increases
  - power consumption decreases
- Money
Concept

- Software replaces hardware as much as possible
  - reduces costs
  - increases versability
- Equipment/infrastructure ’recycling’
  - by software updates
- Anything is possible
  - within the current limits
Applications

- Military
  - real-time flexibility
  - secure
- Commercial
  - international connectivity
- Civilian
  - portable command for crisis management

- Bluetooth, WLAN, GPS, Radar, WCDMA, GPRS, GSM, PCS, DECT, AM, FM, etc.
Features (1/3)

- Reconfigurability
  - co-existence of multiple software modules implementing different standards
  - dynamic configuration both in terminals and in infrastructure equipment
  - future-proof, multi-service, multi-mode, multi-band, multi-standard terminals and infrastructure equipment
Features (2/3)

- Ubiquitous Connectivity
  - if the terminal is incompatible with the network technology, an appropriate software module is installed (over-the-air)
  - the infrastructure equipment can adjust to the legacy terminals
Features (3/3)

- Interoperability
  - SDR facilitates implementation of open architecture radio systems
  - End-users can use third-party applications seamlessly

SDR, software defined radio
Programmability (1/2)

- Hardware radio
  - no software changes

- Software controlled radio
  - in PDR, BB operations and link layer protocols are implemented in software.

- Software defined radio
  - SDR system is one in which the BB processing as well as DDC/DUC modules are programmable.

PDR, programmable digital radio
BB, baseband
DDC/DUC, digital down/up converter
Programmability (2/2)

- Ideal software radio
  - programmability is extended to the RF section

- Ultimate software radio
  - in a single chip, no external antenna and no restrictions on operating frequency
  - intended for comparison purposes only
Architecture (1/3)

- The digital radio system consists of three main functional blocks
  - RF section
  - IF section
  - BB section
- RF section is essentially analog hardware
- IF and BB are digital

RF, radio frequency
IF, intermediate frequency
Architecture (2/3)

- BB operations include
  - channel coding
  - source coding
  - control functionality

- BB modem functionality
  - new and adaptive modulation schemes
  - self-adaptive or download control

- IF signal processing
  - terminal capable to adapt to multiple radio interface standards
Object-oriented approach
- hardware abstraction
- SW portability
- definition of interfaces (API)

Parameter approach
- general structure is the same
- modules configured by changing parameters

API, application programming interface
Implementation (1/2)

- Operations can be implemented with
  - ASIC, FPGA, DSP
  - each has its benefits and drawbacks

ASIC, application specific IC
FPGA, field programmable gate array
DSP, digital signal processor
## Implementation (1/2)

<table>
<thead>
<tr>
<th></th>
<th>FPGA</th>
<th>DSP</th>
</tr>
</thead>
<tbody>
<tr>
<td>Programming language</td>
<td>VHDL, Verilog</td>
<td>C, Assembly</td>
</tr>
<tr>
<td>Performance</td>
<td>Can be very fast</td>
<td>DSP chip clock speed</td>
</tr>
<tr>
<td>Reconfigurability</td>
<td>SRAM-type FPGAs: infinite</td>
<td>Changing the program</td>
</tr>
<tr>
<td>Advantages against the other</td>
<td>FIR &amp; IIR filters, correlator, convolver, FFT, etc…</td>
<td>Signal processing program of sequential nature</td>
</tr>
<tr>
<td>Parallelism</td>
<td>Can be parallized to achieve high performance</td>
<td>Sequential, cannot be parallized.</td>
</tr>
</tbody>
</table>

- Multiantenna systems
Drawbacks (1/2)

- Wide instantaneous bandwidth and high dynamic range both in analog and digital domains required.
- As the receiver bandwidth increases, it becomes more susceptible to more interferes
- Support for multiple channels/modes simultaneously?
Drawbacks (2/2)

Multimode

- e.g. transceiver should support WCDMA, CDMA-2000, GSM, D-AMPS etc…

- Spectrum allocations
  - bands from 400 MHz to more than 2,2 GHz
  - SDR front end should be capable to cover wide range with high dynamic range
Conclusions (pro)

- With SDR anything is possible
  - within the current limits
- From hardware desing to software desing
- Reusability, reconfigurability, recycling
- Multimode devices
  - single device is adequate
- Cheaper
Conclusions (con)

- Large computational power is needed
  - especially IF section (modem, DDC/DUC)
- Power consumption
  - battery sizes
- Complexity
  - multimode devices
- A/D performance
  - accuracy, linearity, sampling rate, resolution
- Higher initial costs
Homework

What is Software Defined Radio?  
(FCC definition is not accepted)
References

- Software-Defined Radio, White Paper, Wipro Technologies
- Software-Defined Radio: Facets of a Developing Technology, IEEE Personal Communications, April 1999