Software Defined Modems for “The Internet of Things”

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www.cognovo.com
What things?

- “20 billion connected devices”
- Manufactured for global markets
- Low cost
- Lifetimes from months to decades
- Different...
  - Networks
  - Frequencies
  - Protocols
- Evolving networks & spectrum allocations
- Versatility & programmability required
Multiple systems and bands

- Cellular
  - GSM, HSPA, LTE(A), EVDO, WiMax,...
- Short range
  - WiFi, Zigbee, UWB, Bluetooth,...
- Emerging techniques
  - “WhiteSpace”
- Other systems
  - Tetra & derivatives
- Conventional cellular bands, 400 – 2600 MHz
- License-exempt – 2400 & 5800 MHz
- “Digital Dividend” spectrum
- “Shared” bands
Focus on the *radio modem*

- **Radio**
  - **“Photons”**
  - **Modem – HSPA, LTE etc.**
  - **OS – Android etc.**
    - **“Apps”**
  - Digital processing
    - IP packets
    - I/Q stream
    - “Photons”
Relative computational load for LTE

- DSP arithmetic: ~50 GO/s
- Video decoder: ~500 MO/s

LTE Modem
Baseband Complexity

...Arithmetic

Bit shuffling...
Conventional Modem Architecture

- Hardware is inflexible
  - Different / upgraded / new protocols
  - Multi-mode needs separate hardware engines – increases chip area & cost
  - Distributed memory less efficient, increases area / cost

- Difficult development process
  - FPGA prototyping cannot fully model final device
  - Software development depends on chip availability
  - Hardware bugs need software work-arounds which may not be ideal

- Cost of large chip developments rising exponentially
  - Need to amortise over maximum number of applications
Product development – the software paradigm

- Processor System
- Application software
- Drivers
- “Real-world” interfaces

My PC is a...
- Typewriter
- Calculator
- Phone
- TV receiver
- Music player
...often simultaneously!

Software development...
- Is well understood
- Allows continuous improvement
- “Infinite flexibility”
- A platform for unpredictable products
Example - universal radio/TV receiver for the PC


http://www.mirics.com/
Software Defined Modem (a/k/a SDR)

- Hardware architecture becomes standards – independent
- Simplify production logistics – single hardware platform for multiple standards & standards combinations – the “world modem”
- Update firmware in the field to fix problems and/or change air interface
- Extend product lifetime
Barriers to SDM

Computation load – Moore’s Law is not enough!

- As geometry gets smaller, voltage gets lower, clock speeds static or decreasing
- Overall single processor Mips/MHz/mW stops improving
- Large processor systems have to become multi-core

Standards complexity

- Ever more complex modulation & coding schemes
- Wider RF bandwidth
- Need for legacy support
- Management of task scheduling within and amongst protocols

RF technology

- Wideband operation, multiple frequencies
- Time and frequency duplex modes
Lifting the barriers

Vectorisation
- Operate on large blocks of samples (vectors) (e.g. FFT)
- SIMD computing architectures apply same operation on multiple data values in the same processor cycle - **vector arithmetic**

Multi-processing
- VLIW computing architectures allow **multiple operations on independent data** in the same processor cycle
- **Multiple processors** on same die to increase MiPs/MHz/mW
- Novel hardware architectures to enable deterministic performance

Programming
- Automatic **compilers** to support multiprocessing
- **SDM OS** to support task scheduling across multiple cores
- **System tools** for multiprocessing design, development and debug
Lifting the barriers

Integrated RF technologies

- New methods such as MEMs for RF switching
- Monolithic filtering technologies such as FBARs
- DPD / ET for efficient wideband power amplifiers

- Multi-mode & multi-band integrated radios
Software Defined Modem (SDM)

Applications

Protocol Plane
Layers 2, 3, 4 Protocol Stack

Control Plane
Layer 1

Data Plane
Physical Layer

Design Environment
System integration & modelling

Kernel SDK

System SDK

Generic s/w execution environment

Modem specific operation

Software Hardware

Protocol Processor System

Modem Compute Engine
Layer 1 Processor
PHY Processor

PHY Kernel Library

SDM-OS

DigRF

RADIO
Ideal M2M module architecture

- Flexible broadband RF
- Software defined modem
- All signal processing in programmable processor
- Air interface defined by software download, at any stage in product life-cycle

yields...

- One hardware platform for all standards
- Upgrade / change air interface during end-product manufacture or after sale
Standardisation & regulatory barriers to SDM

- **Mode incompatibility**
  - Device may need to be multiple-network aware
  - Protocols need to permit “listening” for “foreign” air-interfaces – difficult for “legacy” modes

- **Approvals**
  - Approvals given for defined hardware platform and software version – SW version may change frequently as bugfixes & improvements are made
  - Tests may need to recognise operation in “foreign” modes
  - Separate approval regimes may apply to modes in the same device
SDM as an enabler for the “Internet of Things”

- Advances in silicon integration & computer architectures now allow advanced radio modems to be implemented in software (the “software defined radio”)
- RF technology allows multi-band / multimode operation
- Future products will be able to have a single radio platform to provide radio connectivity across many diverse networks and bands - massive scale economies can result
- Standards and approvals regimes need to adapt to the new possibilities that SDM creates