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An Optimal Architecture for a Multi-Standard Reconfigurable Radio: Cost-Minimizing Common Operators Under Latency Constraints

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CHOOSING BETWEEN EXTREMES

- Design of multi-standard reconfigurable radio: **choice** between **two extremes**
- One extreme: go "Velcro" : one self-contained module per standard
- Other extreme: go "primitive"
  - Use only adders, multipliers, etc.
  - provide "higher" functions by multiple calls
- **Trade-offs**:
  - Velcro provides best performance, but at highest cost (and possibly size/weight)
  - Other extreme likely minimises cost but at unacceptable performance

WHAT TO DO??

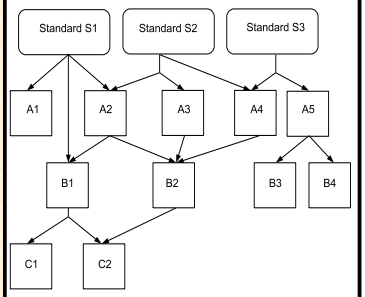
OUR APPROACH

- **Find**:
  - **BEST TRADE-OFF** between **PERFORMANCE** and **COST**
- **To do it** :
  - build a **mathematical model** to find the **optimal point** between the two **extreme architectures**

OVERVIEW

- Model radio as graph of progressively simpler functional modules
- Module can be implemented in 2 ways:
  - Install a dedicated component
  - invoke lower level modules
- 2 critical parameters per component:
  - money and time (computational delay)
- When necessary, a component is called multiple times (not replicated)
- Each top level module ("standard") has a "deadline" (execution time constraint)
- Optimal design: costs less among those which respect the deadlines

TRI-STANDARD RADIO



A Realistic "Sub-Design"

- Want design to support 3 main functional modules: OFDM, Equalisation, and Channelisation (Multichannel processing)
- Equalisation (to compensate for multipath) can be implemented via
  - FIR filtering
  - FFT (great for long impulse responses)
- Channelisation function needed by BS to process many channels in parallel.

  Two options:
  - "Classical" channel per channel
  - Filter bank channeliser (which can be implemented via FFT)

Optimisation: Install or Invoke

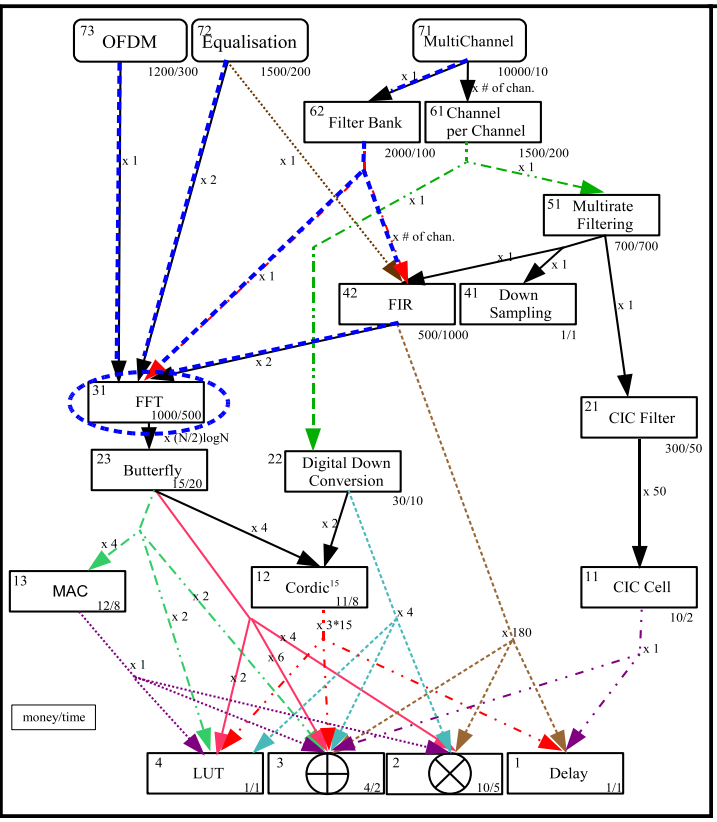
- **Key** question: for given module, should we
  - **install** a self-contained component, **OR**
  - **invoke** lower level modules/components?
- A component is characterised by: monetary cost and performance (execution time)
- Algorithm: exhaustive search here ("network design", simulated annealing, done elsewhere)
- Use graph to list each possible design
- For each design, calculate its total:
  - cost, and
  - time to perform each top module
- Choose least expensive design that satisfies the "deadline" of each top module

Numerical Illustration

Equalisation	Multichannel	Filter Bank	Channel per Channel	Multirate Filtering	FIR	Down Sampling	Digital Down Conversion	Butterfly	FFT	Cordic	MAC	CIC Filter	CIC Cell	Delay	LUT	Cost	T1	T2	T3
72	71	62	61	51	42	41	31	25	22	21	13	12	11	1	4	11	6144	12288	313344
					1							1				12	6144	12288	307625
							1									15	3840	7680	195840
					1											511	6144	1000	31144
					1		1									515	3840	1000	28840
									1							1,000	500	1000	25500
									1							3,000	500	1000	100
								1								12,700	300	200	10

T1, T2 & T3 are execution times for OFDM, equalisation and the channeliser, respectively, under a given design.

- CORDIC-only design costs less but is too slow.
- butterfly-only design costs a little more but performs much better.
- An FFT-only design could be optimal for "medium" deadlines.
- An FFT + Filter bank design performs comparably to "Velcro" but costs a lot less.



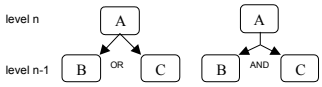
DISCUSSION

- Our approach finds and architecture for a multi-standard reconfigurable radio that minimises cost within performance limits
- Results of simple "sub-design" are intuitive:
  - tight performance constraints lead to complex components (expensive but high performing)
  - Lenient "deadlines" allow the choice of simple, inexpensive, reusable but low performing components
- It is easier to visualise "components" as "chips", but our approach is quite general
- For instance, for a DSP-based design:
  - a "component" can be an "object" (as in object-oriented programming) which can be "outsourced"
  - But the price/performance trade-off of the DSP itself should also enter the analysis

Ongoing/Future Work

- Rebuilding the hypergraph of design choices. Researchers seek:
  - to include complete communication standards and track their evolution
  - new operators (modules) common to several communication "blocks"
  - to replace time-domain with new frequency-domain algorithms
- Consideration of:
  - Choice between several "models" of a component to reflect market choices
  - time needed to re-configure the radio while switching standards
  - possible contention for the service of a (lower-level) module

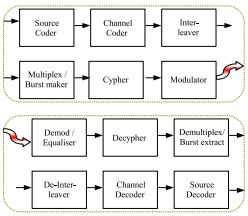
Two Possible Dependencies



Left:
Module A needs:
EITHER B **OR** C

Right:
Module A needs
BOTH B **&** C

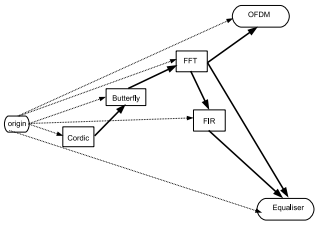
Key to Finding deadlines: The Transmission Chain



Shown is the GSM transmission chain.
A chosen architecture must support end-to-end communication under any supported standard.

Equivalent representation:

The NETWORK DESIGN PROBLEM



To gain access to an extensive literature, we can recast the graph of design choices as a **network design problem**. More at PIMRC 2006

Related Publications

- V. Rodriguez, C. Moy, and J. Palicot, "*An optimal architecture for a multi-standard reconfigurable radio: A network theory re-formulation*", IEEE PIMRC, Finland, Sep. 2006
- V. Rodriguez, C. Moy, and J. Palicot, "*An optimal architecture for a multi-standard reconfigurable radio: Cost-minimising common operators under latency constraints*", IST Mobile & Wireless Summit, Greece, Jun 2006
- C. Moy, J. Palicot, V. Rodriguez, and D. Giri, "*Optimal Determination of Common Operators for Multi-Standard Software Defined Radio*", 4th Karlsruhe Workshop on Software Radios, Germany, Mar 2006

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