Optimal Determination of Common Operators for Multi-Standard Software Defined Radio

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Outline

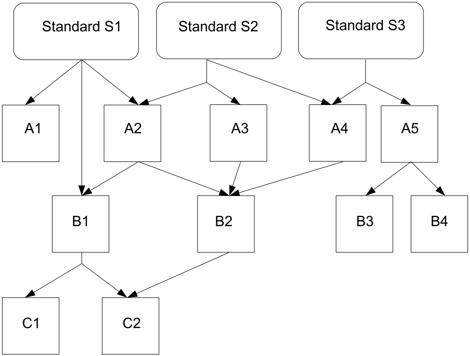
Problem statement

- The optimal design of a multistandard reconfigurable radio is the right choice between two extremes:
  - One extreme: the “Velcro” solution (one self-contained complex module for each supported standard)
  - Other extreme: install only the most “primitive” components (adders, multipliers, etc), and provide ”higher level” functionality through multiple calls
- Trade-off:
  - Velcro architecture generally provides best performance, but at highest manufacturing cost (and size/weight)
  - Other extreme likely minimises cost (& size/weight) but at unacceptable performance (multiple calls add latency!)
- Our approach : build a mathematical framework to find the optimum between these extremes

Overview

- We model the reconfigurable radio as a (hyper)graph of progressively simpler functional modules
- The functionality of a given module can be provided in 2 ways:
  - installing a dedicated component optimised for that task
  - invoking (repetitively) lower level modules
- With each module we associate 2 “costs”: monetary and computational (delay)
- When a lower-level module is needed several times it is invoked multiple times (not physically replicated)
- The cost of a design is a weighted sum of the totals of both costs
- To find the optimum, we use: (1) exhaustive search & (2) simulated annealing

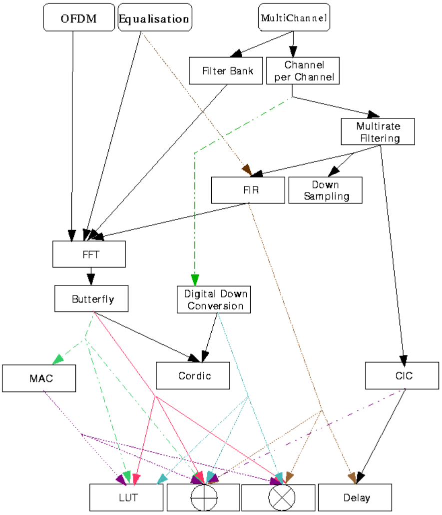
A graph for a tri-standard radio



A realistic “sub-design” example

- Want an architecture to support 3 main functional modules: OFDM, Equalisation, and Multichannel processing
- Presumably these modules are part of grander design
- Equalisation (to compensate for multipath) can be implemented via
  - FIR filtering
  - FFT (great for channels with long impulse responses)
- Multichannel refers to channelisation function of BS (needs to process many channels in parallel). Two options:
  - “Classical” channel per channel
  - Filter bank channeliser (which can be implemented via FFT)

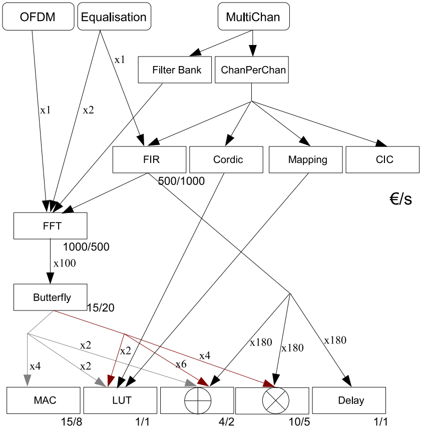
Sub-graph of design choices I



Performing the optimisation

- Key question: should we install a self-contained/dedicated component to perform a given functionality, or should we invoke lower level modules/components?
- Each component is characterised by 2 “costs”: monetary, and “computational” (time)
- When a lower-level module is needed several times it is invoked multiple times (not physically replicated)
- Choose components to minimise a weighted sum of total monetary plus total computational costs
- Algorithms:
  - Exhaustive search (“brute force”)
  - Simulated annealing

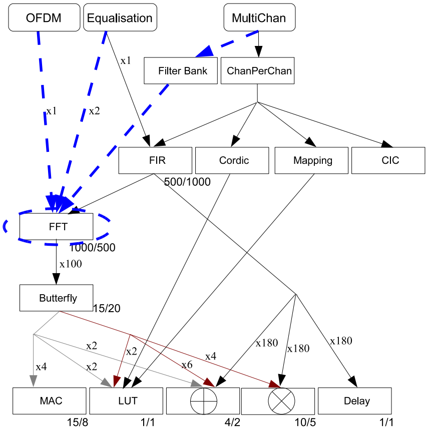
Sub-graph with some parameters



Results

- Results are heavily influenced by chosen weights (monetary vs. computational)
  - when “delay” costs weigh heavily, complex, expensive but high-performing dedicated components are chosen
  - when “delay” costs weigh less, simpler, reusable components are chosen (leading to a less expensive design but with higher latency)
- Above agrees with intuition

An optimal design



Discussion

- We presented a mathematical framework to find an optimal architecture for a multistandard reconfigurable radio
- Key: graph of progressively simpler functional modules, showing their interdependencies (AND, OR)
- Key question: install (specialised component) or invoke (lower levels)?
- Choose components to minimise weighted sum of 2 “costs”: money and delay
- A realistic “sub-design” has been solved both by “brute force” and by simulated annealing
- Results are highly influenced by weights, and are intuitive

Immediate Future (in progress)

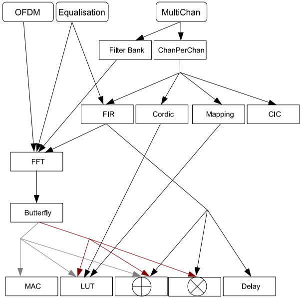
- Re-building the hypergraph of design choices. Researchers seek:
  - new operators that may be common to several communication blocks
  - to replace time-domain with new frequency-domain algorithms (which would add arcs pointing to FFT)
  - to include more communication standards in the graph, and track their evolution
- Change objective function to minimise (monetary) cost only, subject to delay constraints (“deadlines”)
- Transform the architecture optimisation into a “network design problem” (to access extensive literature with many algorithms and results)

In the more distant horizon

Consideration of:

- multiple instances of same component (butterfly, FFT, etc) to reflect real market choices
- time needed to re-configure the radio while switching standards
- “travel time” of signals from a component to another
- possible contention among high level modules for the service of the same lower-level module (which may be critical if the SDR needs to support simultaneous operation over several standards)

A glance into the future: graph/network



A glance into the future: graph/network