INSTITUT D'ÉLECTRONIQUE ET DE TÉLÉCOMMUNICATIONS DE RENNES

An Optimal Architecture for a Multi-Standard Reconfigurable Radio:
A Network Theory Re-formulation

by

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Outline

- Overview of our approach:

  choosing between extremes

- A multi-standard radio as a graph
- A "realistic" mini-design (larger design in paper)
- The network design problem
- Available promising algorithms
- Discussion/Outlook

Choice between Extremes

- To design a multistandard reconfigurable radio one must:

choose between 2 extremes

- **One extreme**: go **"Velcro"** :

one self-contained component per standard

- **Other extreme**: go "primitive" :
  - Use only adders, multipliers, etc.
  - provide "higher" functionality by multiple calls
- **Trade-offs**:
  - Velcro provides best performance, but at highest manufacturing cost (and size/weight)
  - Other extreme likely minimises cost (and size/weight) but at unacceptable performance

WHAT TO DO??

OUR APPROACH

- Find:

BEST TRADE-OFF between
PERFORMANCE and **COST**

- To do it :
  - build a mathematical model
  - Use suitable algorithm to solve model. In present paper, we use the:

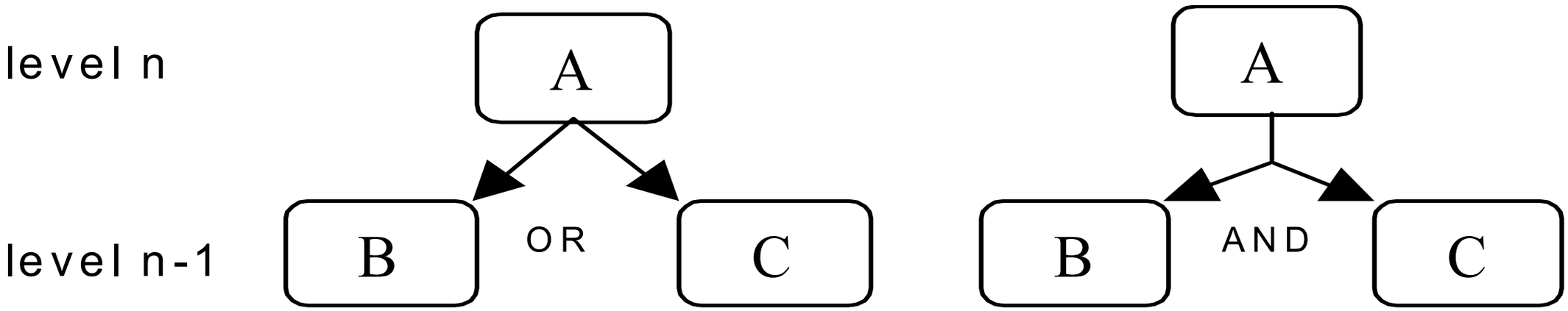
NETWORK DESIGN PROBLEM

Overview

- Model radio as graph of progressively simpler functional modules
- Module can be implemented in 2 ways:
  - Install a dedicated component
  - invoke (repetitively) lower level modules
- Two critical parameters per component:
  - money and time (computational delay)
- Two approaches for considering money and time:
  - Minimise weighted sum of money and time
  - Minimise monetary cost subject to "deadlines" for top modules
- The optimal design costs less (among those which respect the deadlines if applicable)
- In present work, to find the optimum we recast design as:

NETWORK DESIGN PROBLEM

Possible Dependencies



Left:

Module A needs:

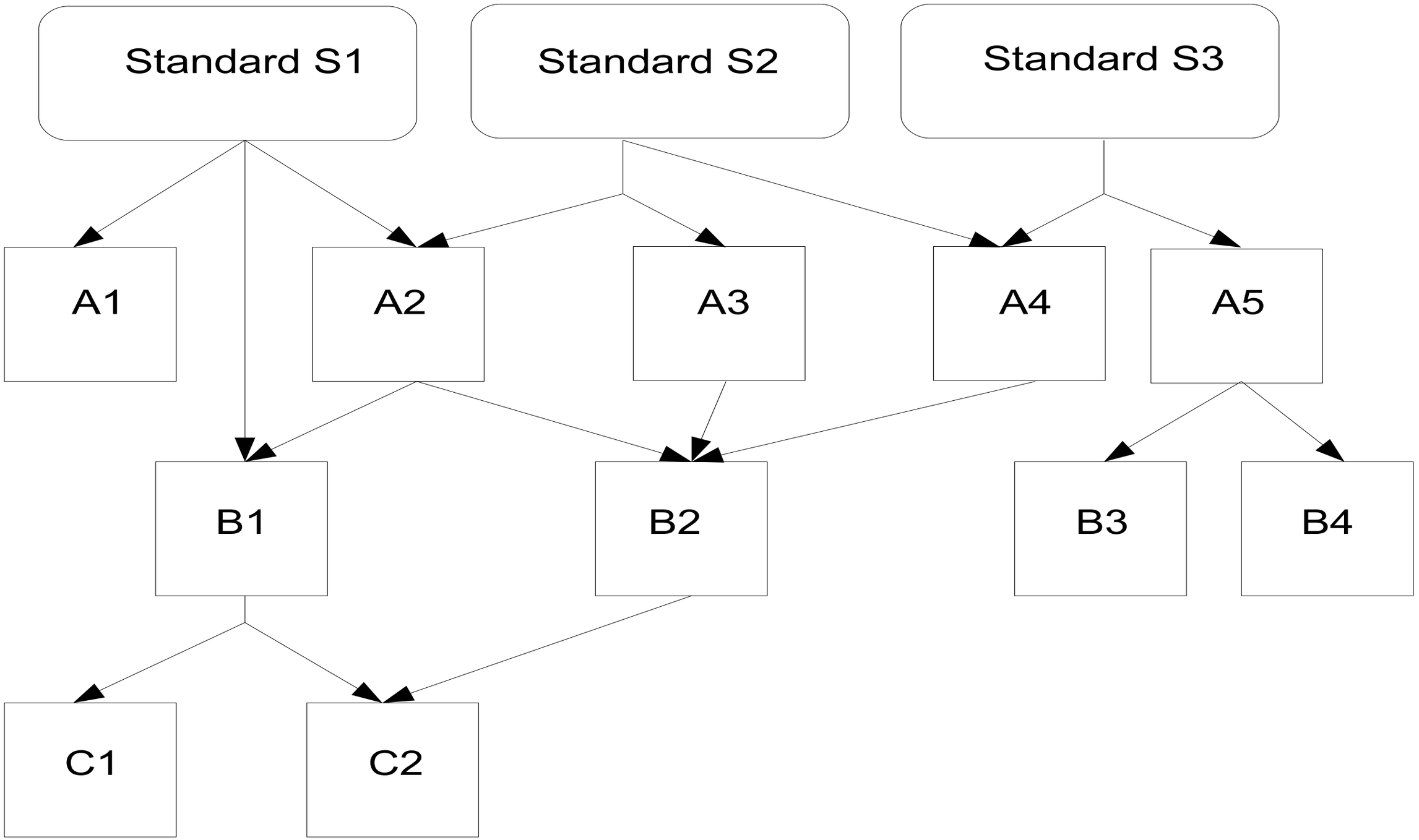
EITHER B **OR** C

Right:

Module A needs

BOTH B **&** C

A Tri-standard Radio



A Realistic "mini-design"

- Want a design to support 2 main functional modules: OFDM and Equalisation
- OFDM needs fast Fourier transform (FFT)
- Equalisation (to compensate for multipath)

can be implemented via

  - FIR filtering,

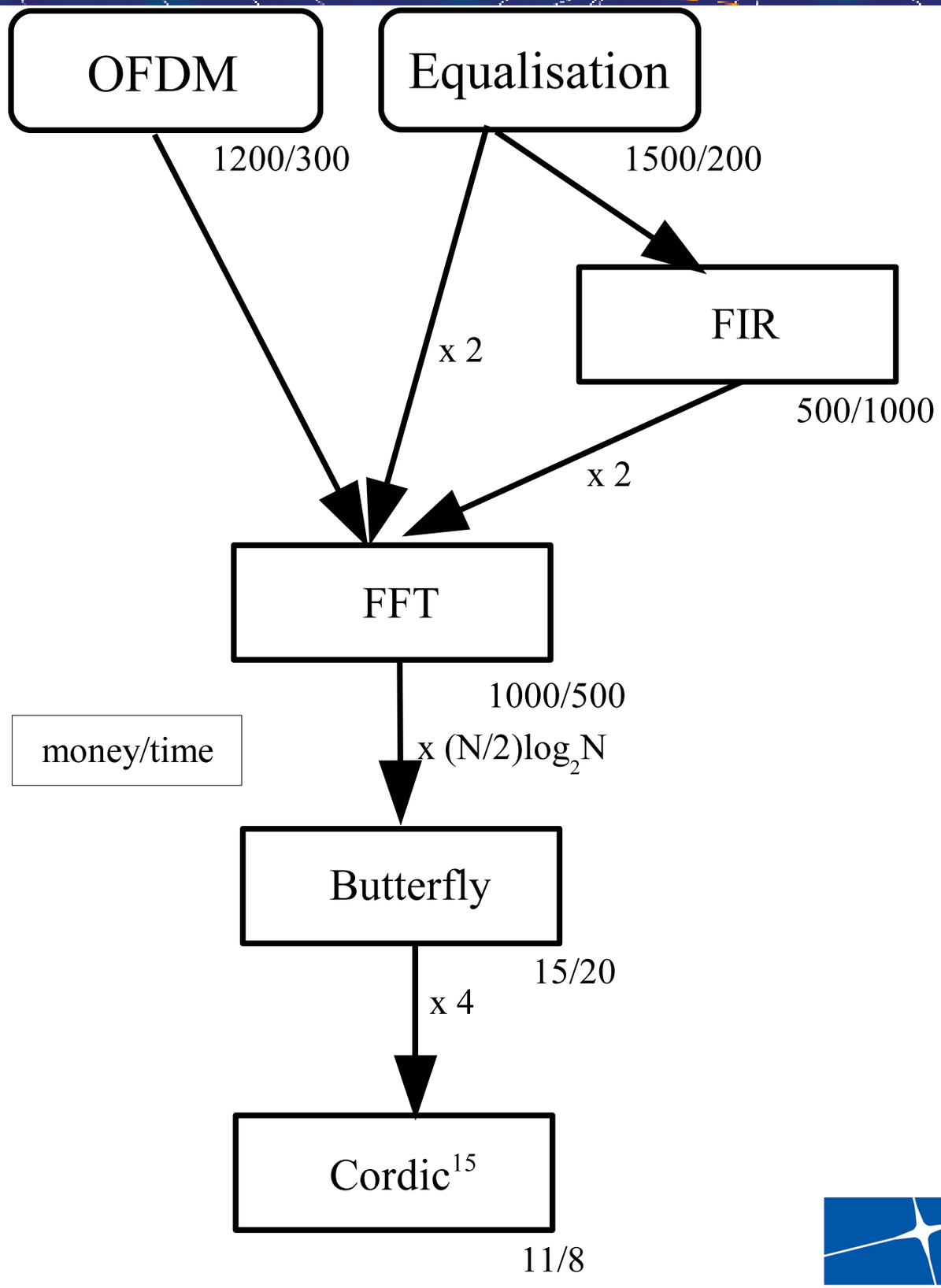
    OR

  - FFT (great for channels with long impulse responses)

Install or Invoke?

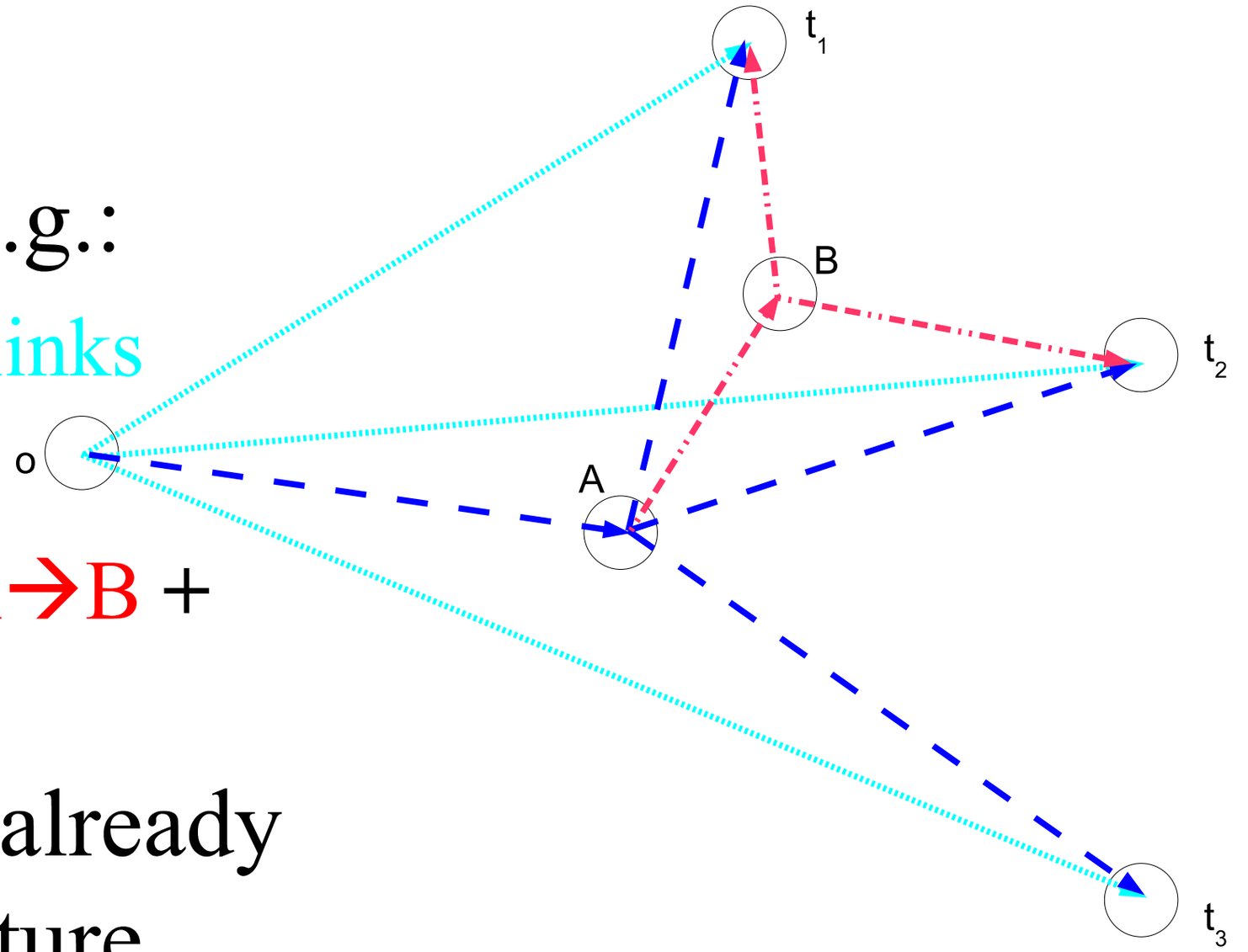
- **Key** question: should we
  - **install** a self-contained/dedicated component to perform a given functionality, **OR**
  - **invoke** lower level modules/components?
- A component is specified by: monetary cost and performance (execution time)
- When a lower-level component is needed several times it is called multiple times
- Choose least expensive design (that satisfies the "deadline" of each top module if applicable)
- Algorithm: based on network design here (exhaustive search, simulated annealing, used elsewhere)

Graph of Design Choices



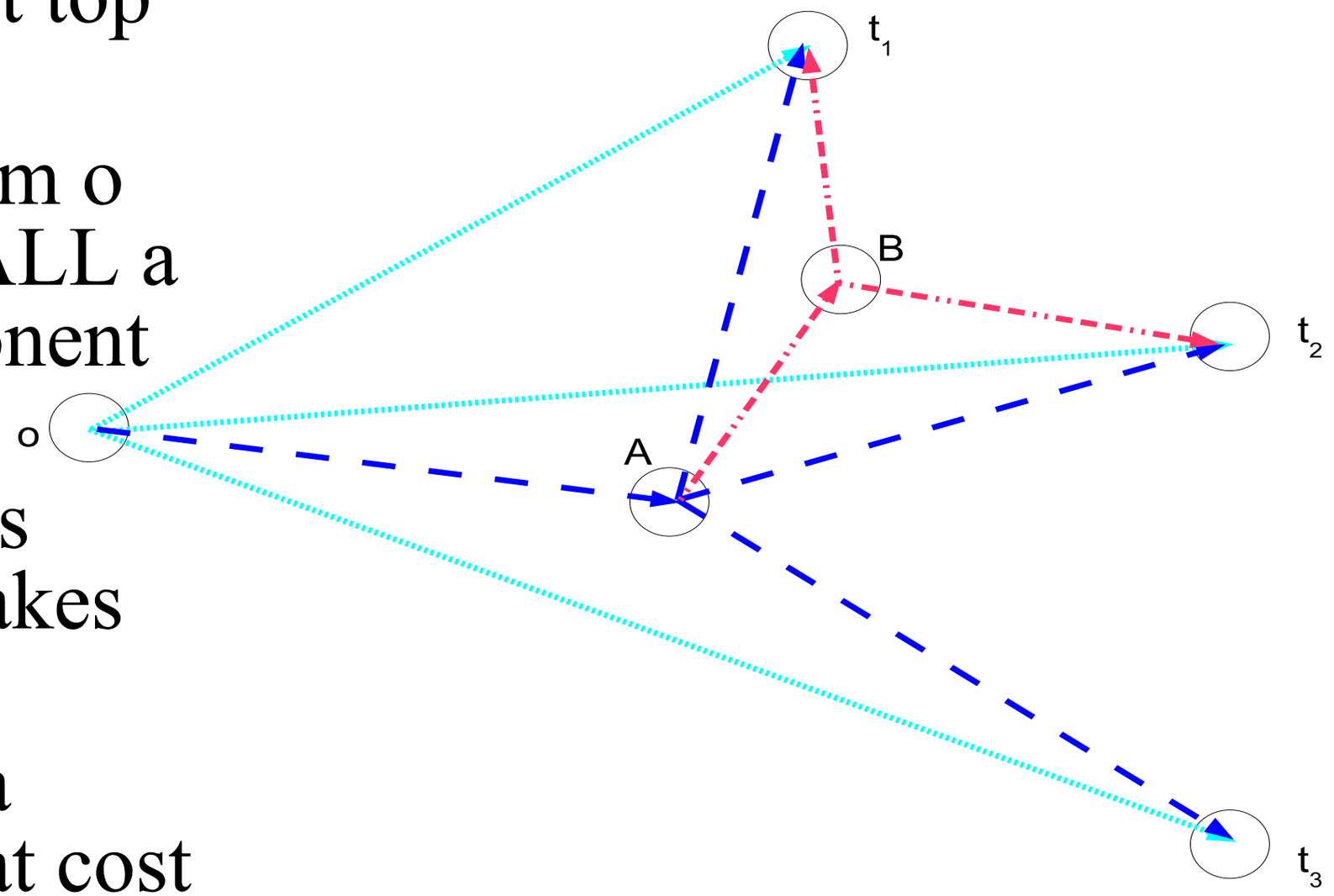
Network Design Problem

- Want "road network" to connect "o" to each terminal t_i "efficiently"
- Many possibilities. E.g.:
  - "Fastest": 3 "direct" links
  - O → A , A to each t_i
  - O → A + A → t_3 + A→B + B→ t_1 + B→ t_2
- Good algorithms are already available in the literature

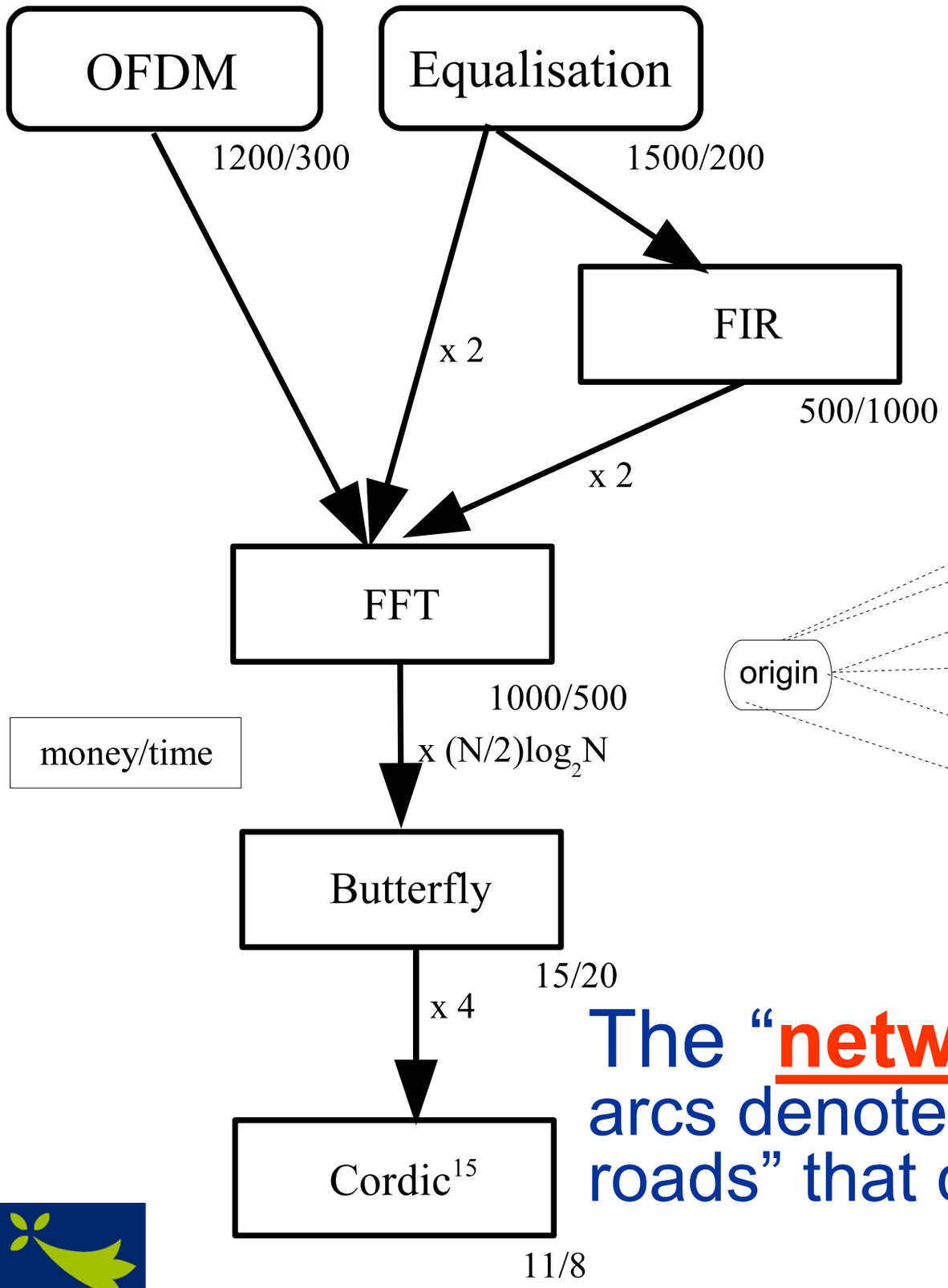


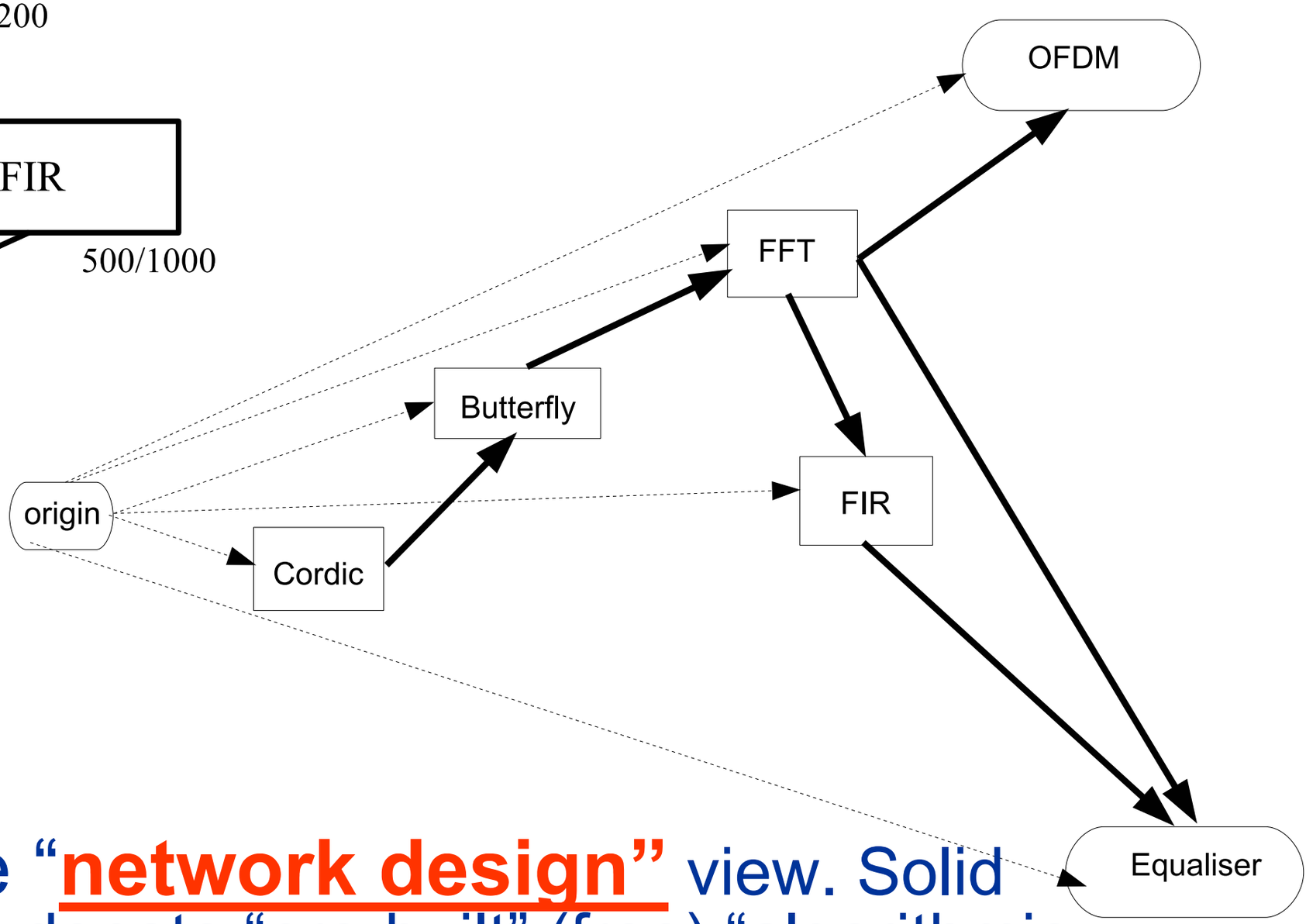
Network Design and OUR Problem

- "Terminals" are top modules ("standards")
- "Reaching t_i from o" means we can support top module t_i .
- "Building a road" from o to A means to INSTALL a self-contained component for A
- Generally, a link costs money to build and takes time to travel
- A "pre-built link" is a known algorithms that cost no money (but takes time)



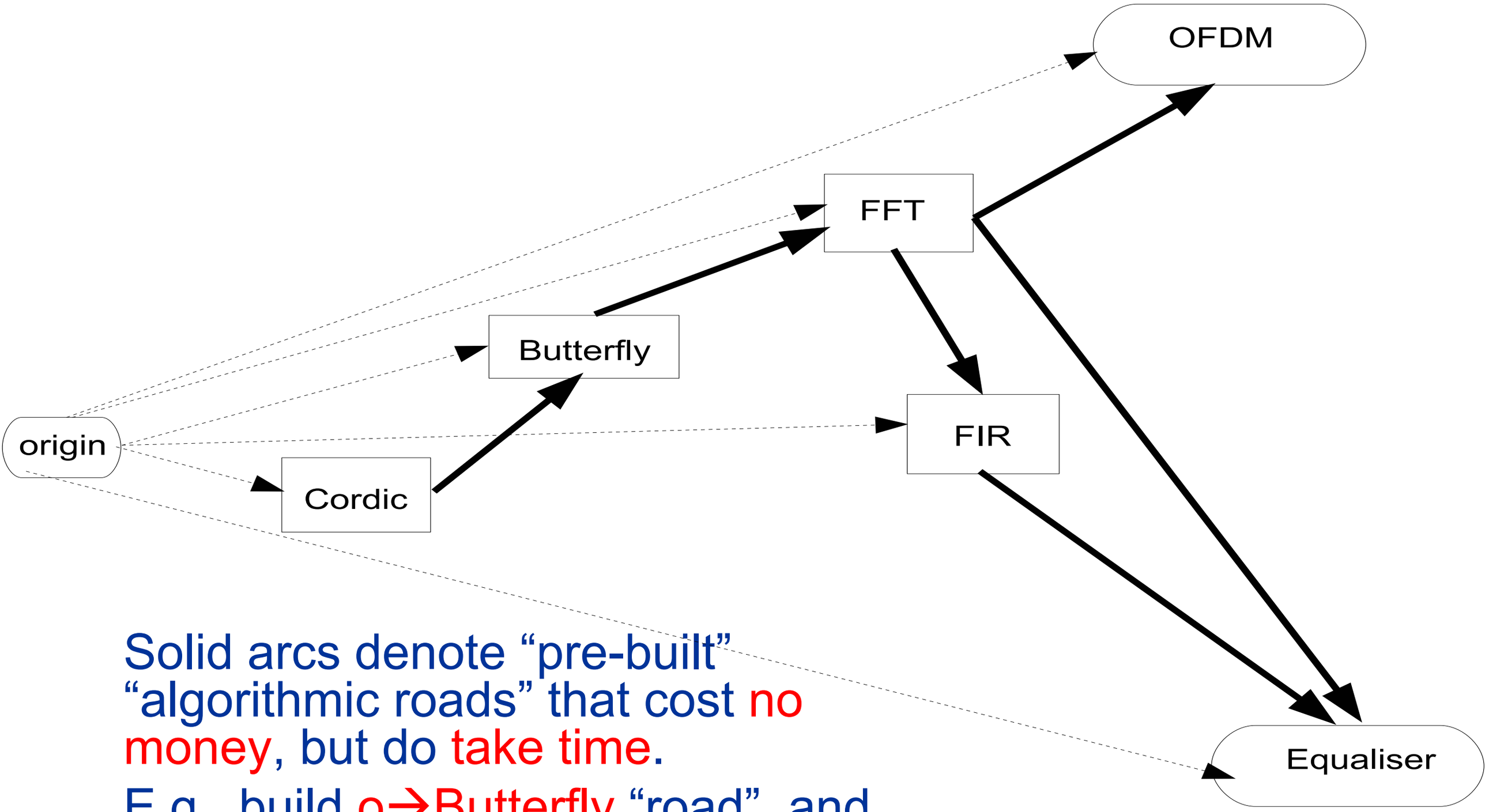
Graph → Network Design





The "**network design**" view. Solid arcs denote "pre-built" (free) "algorithmic roads" that cost time but not money.

Network Design in Greater Detail



Solid arcs denote "pre-built" "algorithmic roads" that cost no money, but do take time.

E.g., build o→Butterfly "road", and "travel free" to FFT, and from FFT, also free to each destination.

Available Algorithms

- Bi-criteria ("cost-distance") network-design algorithms fit well with our formulation (distance → execution time)
- Minimise weighted sum of money and time:
  - Meyerson, et al., "Cost-distance: two metric network design" in Proc. of Foundations of Computer Science, 2000
  - Chekuri , et al., "A deterministic algorithm for the cost-distance problem" in Proc. of ACM-SIAM Symposium on Discrete Algorithms, 2001
- Minimise cost subject to time constraint:
  - Marathe, et al., "Bicriteria network design problems" Journal of Algorithms, 1998

Discussion

- To find an architecture for a multi-standard reconfigurable radio that minimises cost while considering performance objectives we model the radio as a graph of progressively simpler modules
- KEY: install (a component) or invoke (simpler modules)?
- Easier to visualise "components" as "chips", but approach is quite general: If DSP-based design, view "component" as "object" (object-oriented progr.). But introduce in the analysis the price-performance trade-off of the processor itself.
- To search efficiently the solution space, presently we convert graph to "NETWORK DESIGN PROBLEM"
- A simple but realistic "mini-design" illustrates our approach
- Available, promising "bi-criteria" algorithms have been cited
- Even an imperfect graph-network mapping may yield a design close to "true" optimum

Ongoing/Future Work

- Rebuilding the hypergraph of design choices. Researchers seek:
  - new operators (modules) common to several communication “blocks”
  - to replace time-domain with new frequency-domain algorithms (which would add arcs pointing to FFT)
  - to include complete communication standards in the graph, and track their evolution
- Consideration of:
  - Price/performance trade-off of DSP itself
  - multiple instances of same component (butterfly, FFT, etc) to reflect 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 radio needs to support simultaneous operation over several standards)

THANK YOU !!

Questions?

www.rennes.supelec.fr/ren/rd/scee/

Thanks to "**Région Bretagne**", France