



# Cognitive Heterogeneous Reconfigurable Optical Network

Project Number: **258644**

Call Identifier: **FP7-ICT-2009-5**

Funding Scheme: **Collaborative project**

CCW 2011 – energy efficient networking

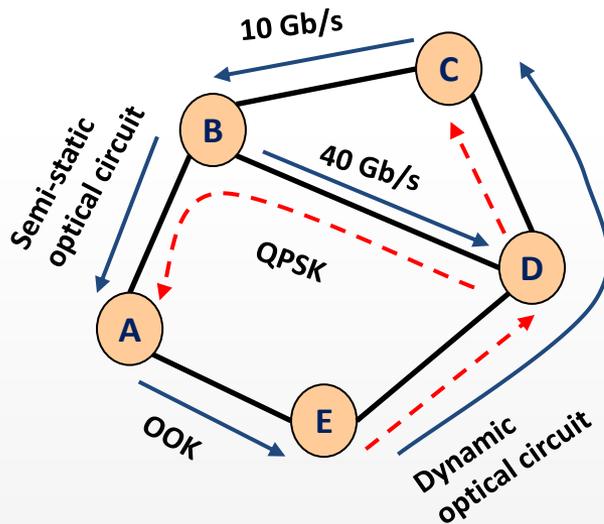
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# Cognitive Heterogeneous Reconfigurable Optical Network

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## ❖ Current **optical transport networks** are facing increased levels of **heterogeneity**

- Different *transmission technologies* (coding/modulation formats, data rates)
- Different *switching paradigms* (e.g., semi-static and dynamic wavelength switching)
- Different *services* with different QoS requirements
- Energy efficiency considerations

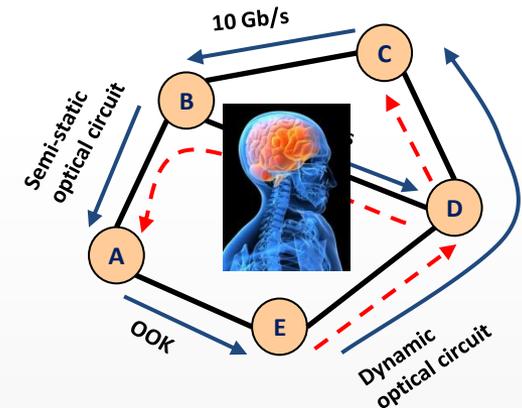
## ❖ Existing **monitoring and control systems** are not sustainable

**How to efficiently control and manage those heterogeneous resources?**

## Strategy: Use of cognitive techniques

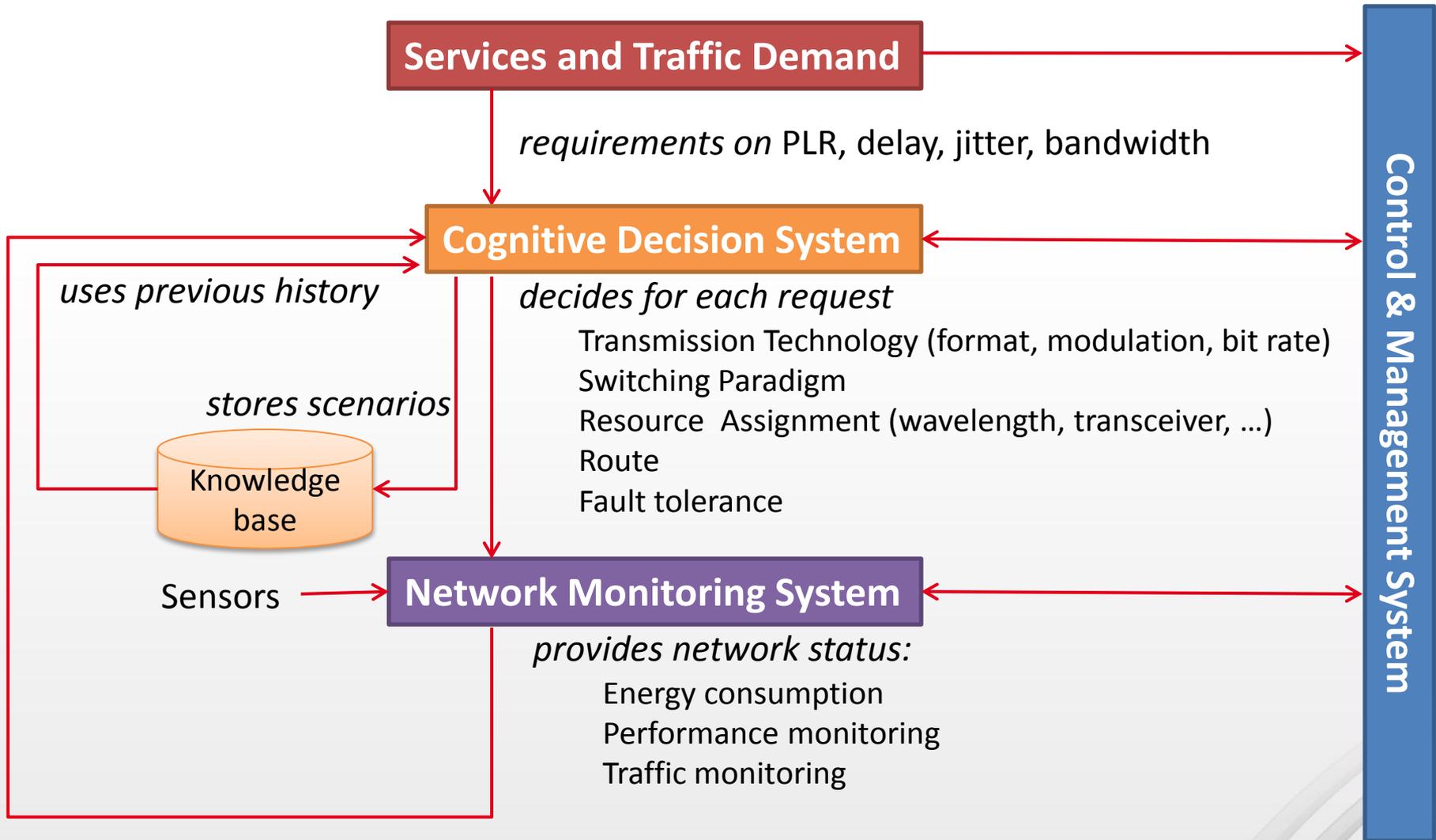
### ✿ What is a **cognitive** network?

- A network which **perceives current conditions**, then **plan, decide**, and **act** on those conditions.
- A network which **learns from those adaptations** and uses them to make future decisions, taking into account end-to-end goals.



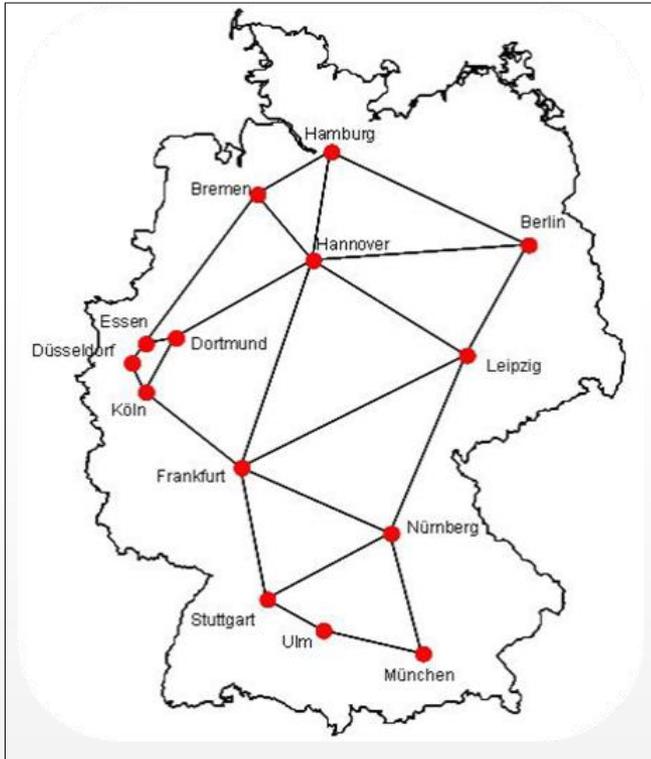
- ✿ Cognitive techniques are **promising for heterogeneous** environments (e.g., significant work on radio communications)

**CHRON** proposes the utilization of **C**ognitive techniques in **H**eterogeneous **R**econfigurable **O**ptical **N**etworks



- Evaluation and quantification of energy consumption of end-to-end paths
  - Modulation format
  - Spectral defragmentation
  - Mixed rate and modulation format
- Incorporate energy efficiency aspects into cognitive routing module
- Status monitoring of energy consumption
- Simulations and emulations scenarios
- 10G, 40G and 100G scenarios under consideration

**DT Network** [1]



14 nodes and 23 links

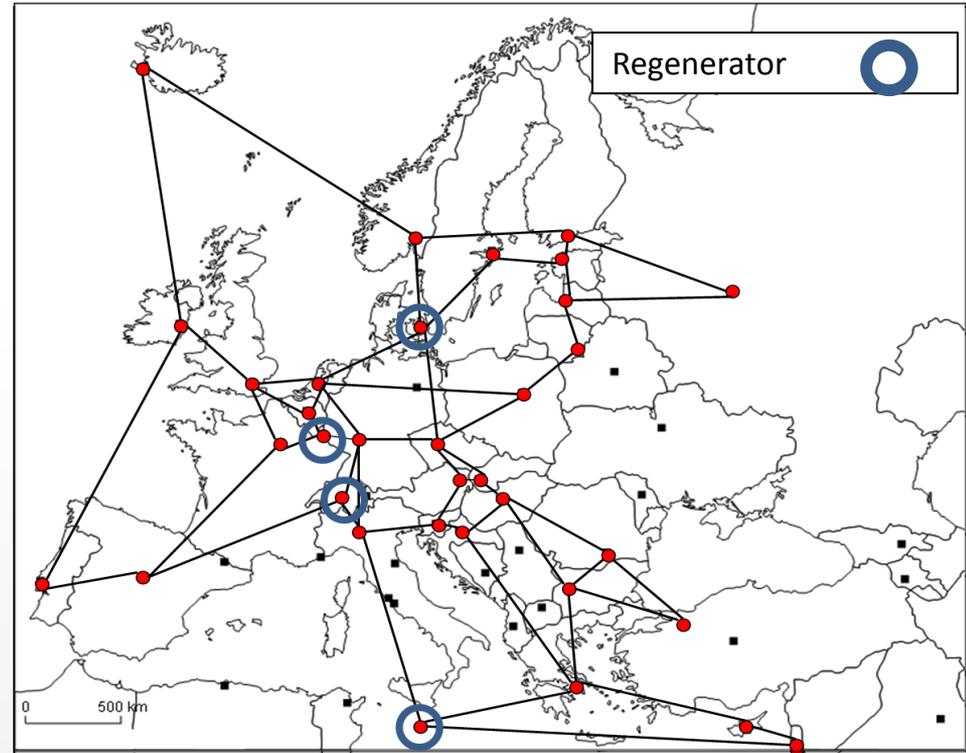
Traffic Matrix (2009) [1]

Avg. demand (2009): 15.34 Gb/s

Diameter of 874 km

Fully-transparent Network

**GÉANT2 Network** [1]



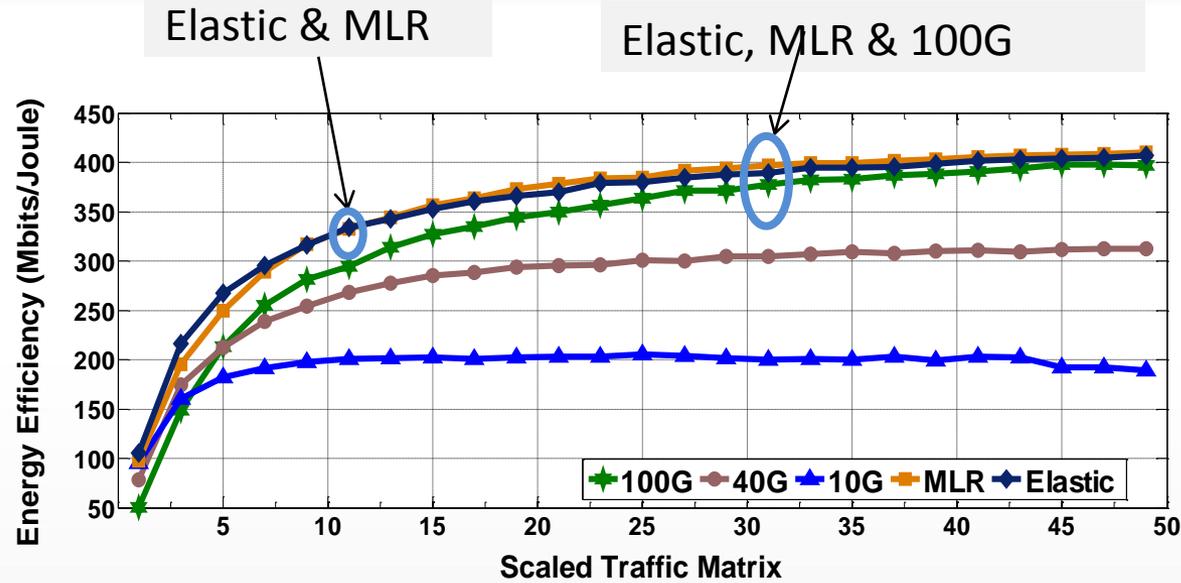
34 nodes and 54 links

Traffic Matrix (2009) [1]

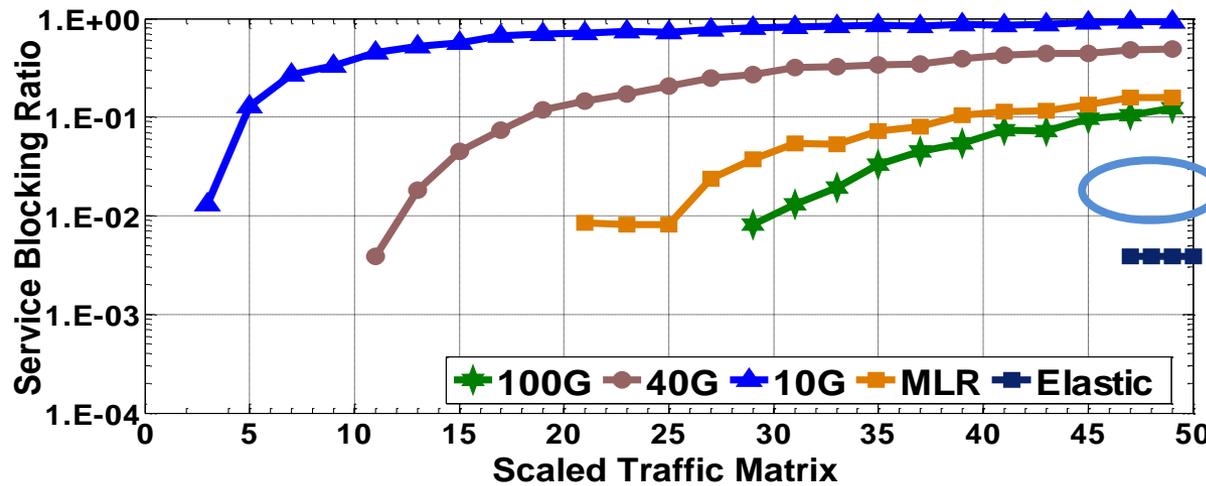
Avg. demand (2009): 2.39 Gb/s

Diameter of 7575 km

Translucent Network



**Energy Efficiency:**  
Elastic OFDM & MLR  
most efficient



**Blocking Ratio:** Elastic  
OFDM significantly  
lower

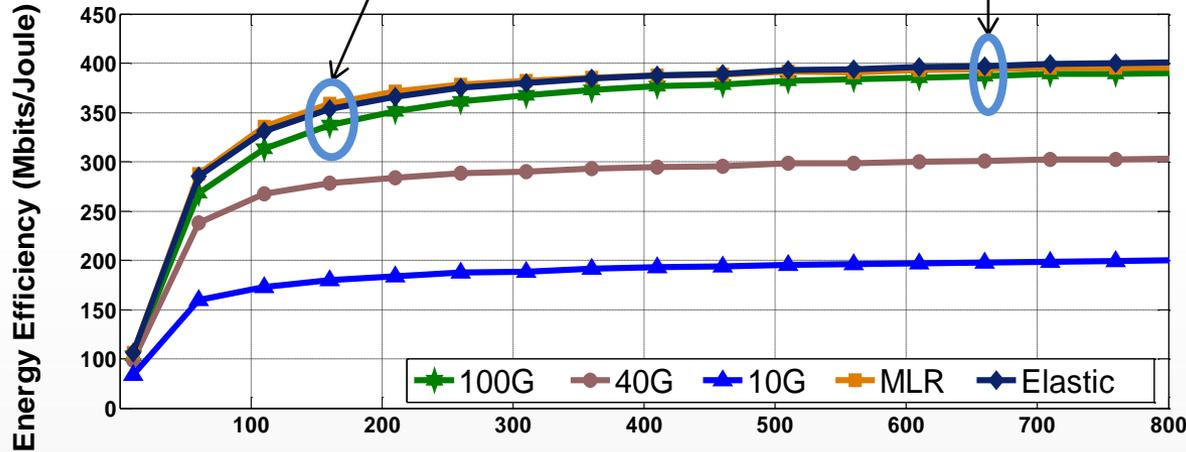
Zero blocking	Overall Traffic (Tb/s)	Avg. Demand (Gb/s)
100G	75.6	414.3
MLR	56	306.88
Elastic	128.8	705.83

**Conclusion:** Elastic OFDM-based network is the most energy efficient

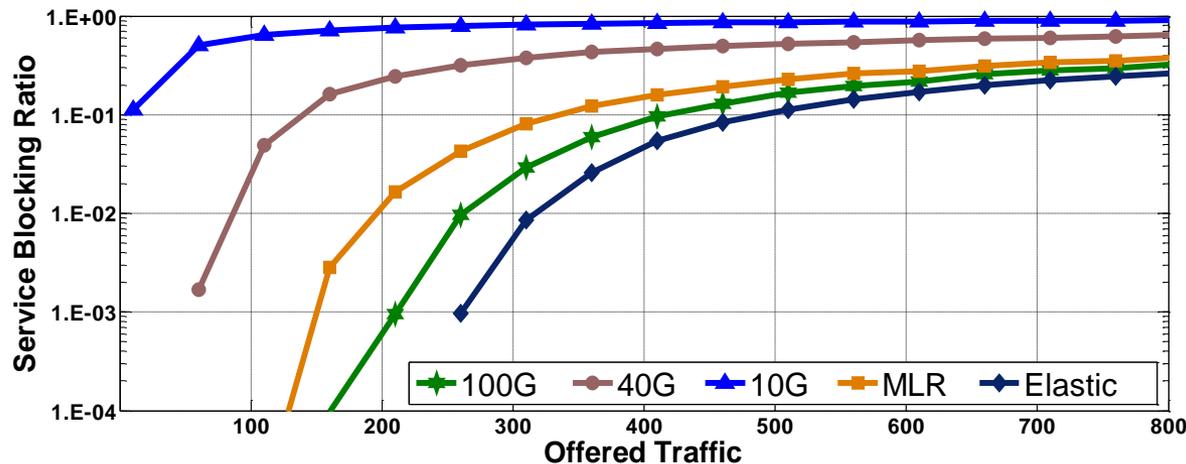
Average flow demand: 230.03 Gb/s

Elastic & MLR

Elastic, MLR & 100G



**Energy Efficiency:** Elastic OFDM & MLR most energy efficient



**Blocking Ratio:** Elastic OFDM significant lower blocking

**Conclusion:** Elastic OFDM-based network can be considered as the most energy efficient due to its significant lower blocking ratio.

Fine granularity brings significant benefits in energy efficiency

WDM network with MLR operation

Elastic OFDM-based network

Spectral efficiency directly affects energy efficiency: more traffic transported → reduction in power consumption

Further work in CHRON:

Incorporating energy efficiency in cognitive routing for heterogeneous optical networking