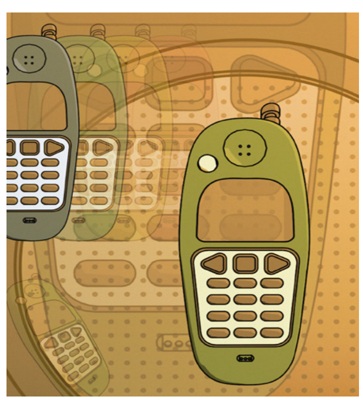
Collaborative Spectrum Sensing for Cognitive Radio

Kamran Arshad & Klaus Moessner
CCSR, University of Surrey
Guildford, United Kingdom
Email: k.arshad@surrey.ac.uk

Outline

- Motivation
- Cognitive Radio
- Collaborative Spectrum Sensing
- System Model
- Proposed weighted framework for collaborative spectrum sensing
- Results and discussions
- Conclusion

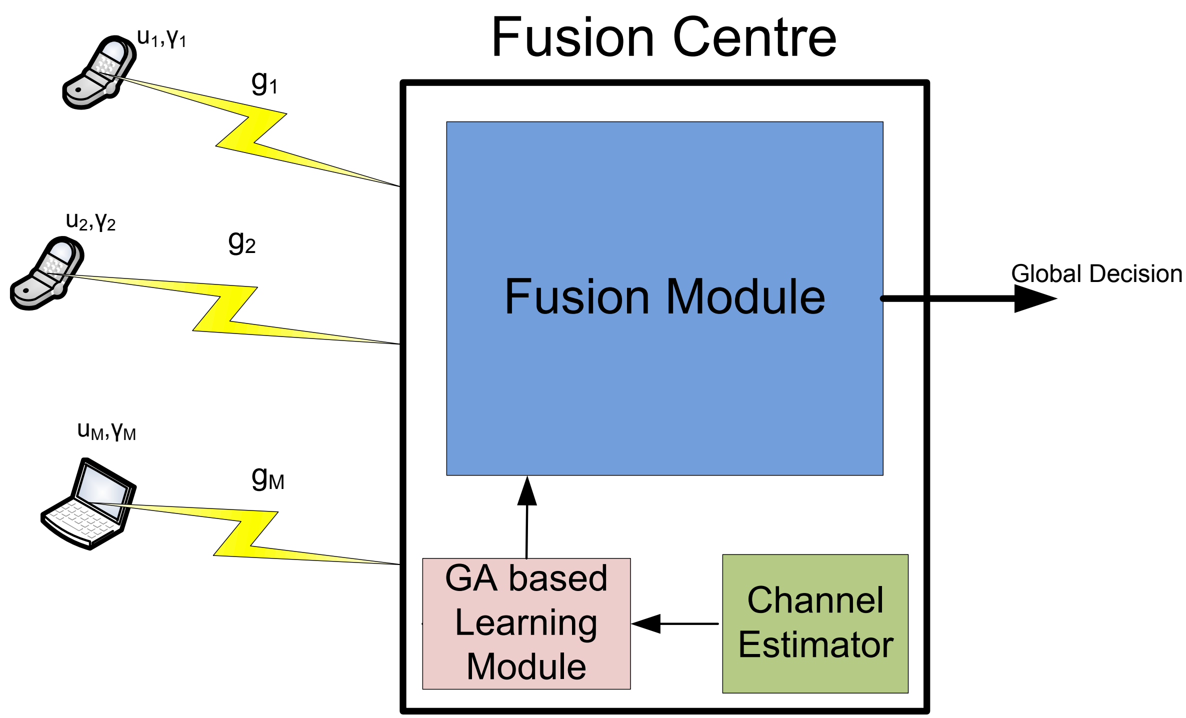
Main Contributions

Problem

How to fuse local observations of cognitive radios at fusion centre to decide globally the existence of licensed user?

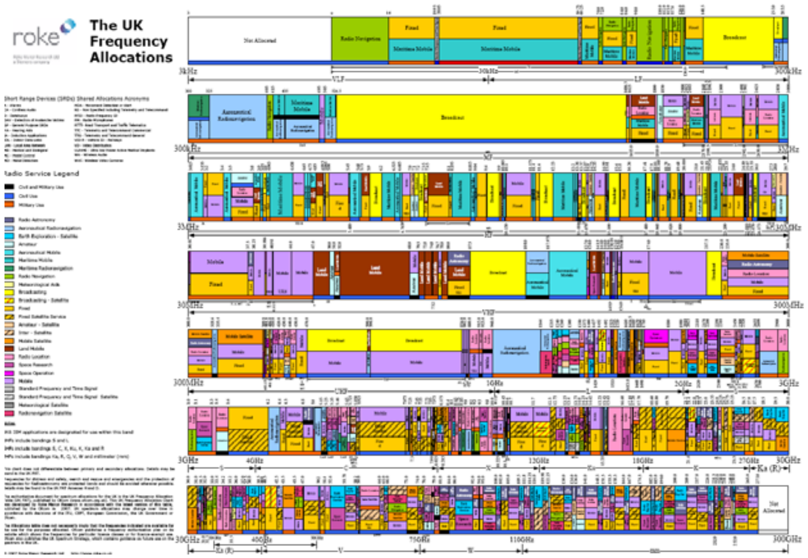
Solution Approach

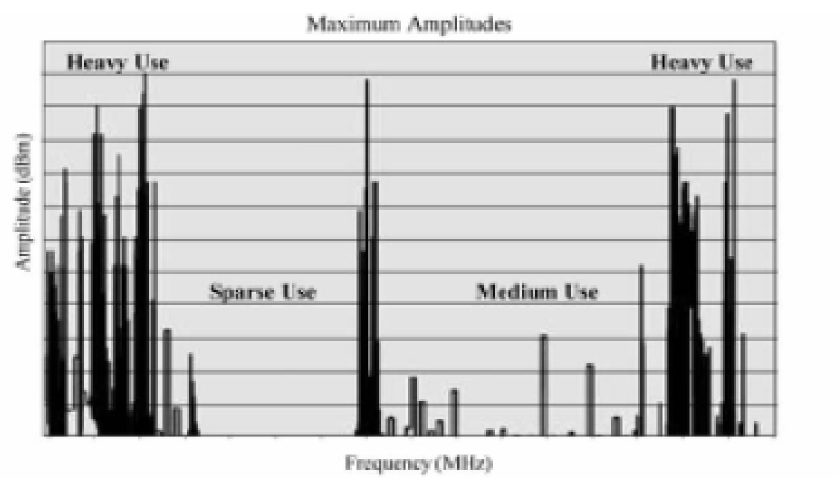
For a given channel conditions and targeted probability of false alarm, weights are assigned to the secondary user observations in such a way that it maximises global probability of detection. Optimum weights are calculated using genetic algorithm



Motivation

- Spectrum Scarcity Problem
  - Limited resource, overcrowded, future technologies need more spectrum
- Spectrum Underutilisation Problem
  - Studies by Ofcom and FCC show that at some locations 70% of the spectrum sitting idle

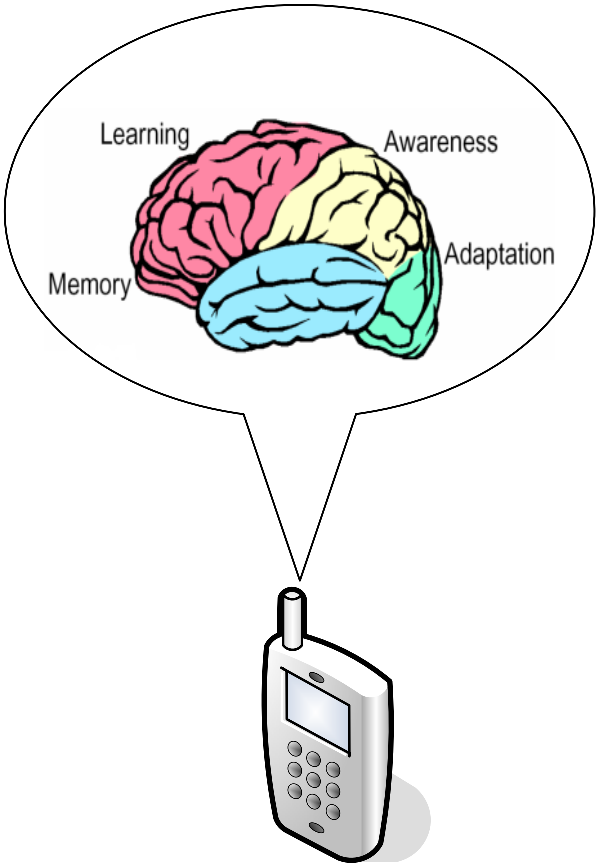




Technologu Research Programme: Research and Development at Ofcom 2004/05, issued: 24 October 2005, p.37

Cognitive Radio

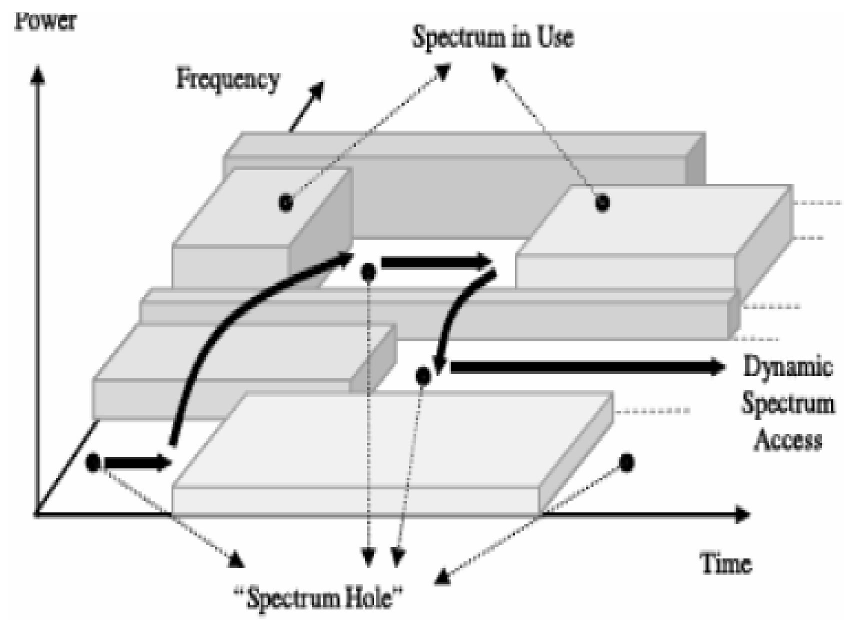
“Cognitive radio is a paradigm for wireless communication in which either a network or a mobile node changes its transmission or reception parameters to communicate efficiently in licensed or unlicensed band by avoiding interference with licensed users”



Why Cognitive Radio?

- Because Cognitive Radio:
  - significantly increase spectrum efficiency
  - optimise use of under utilised spectrum without (or with minimum) interference to the primary users
  - can access the large, normally hidden, spectral resource called, WHITE SPACE:

WHITE SPACE



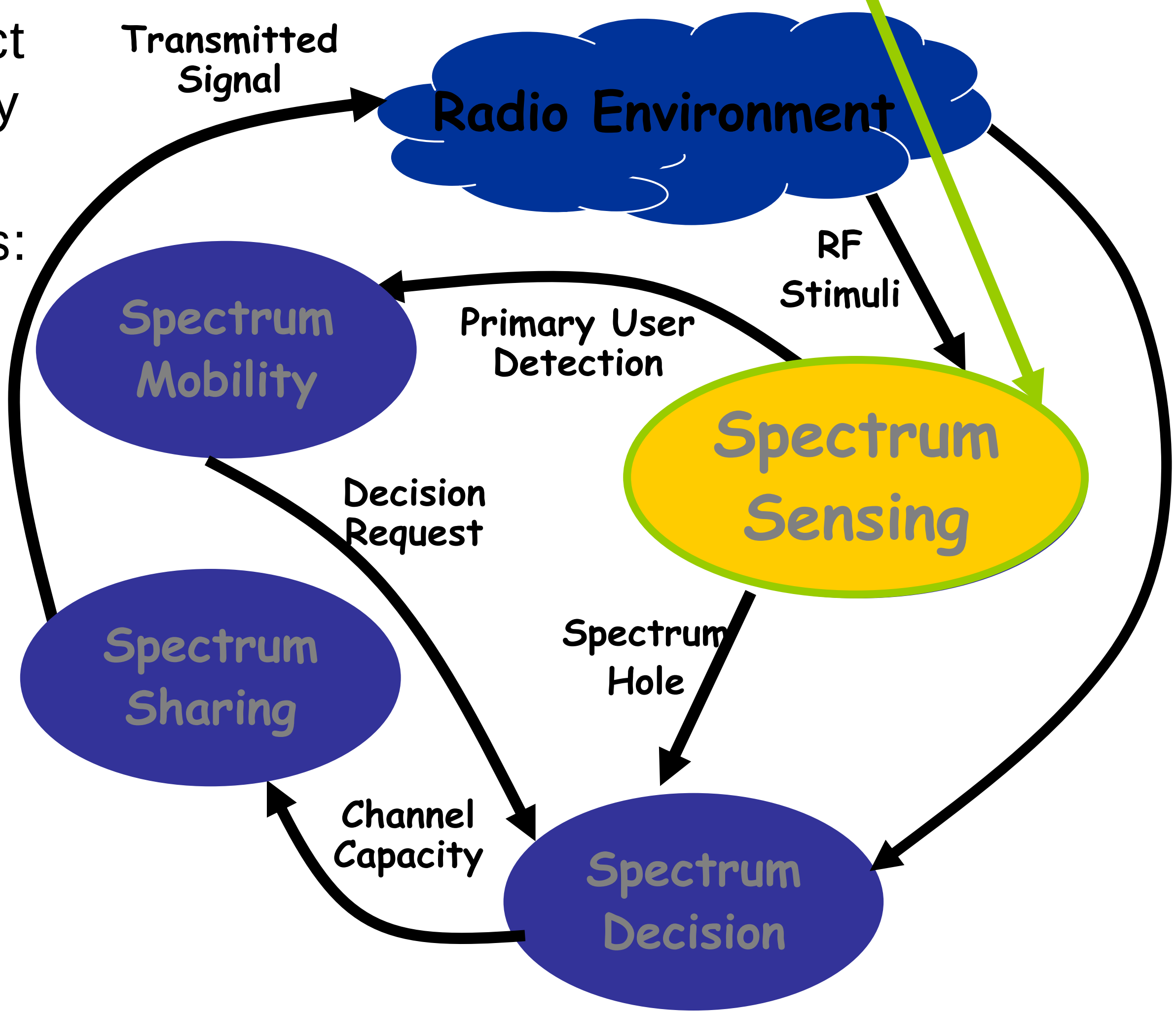
Spectrum Sensing

We are here!

- Goal is to reliably detect the presence of Primary (Licensed) User
- Three main approaches:
  - Match Filter detection
  - Energy Detection
  - Cyclostationary Feature Detection

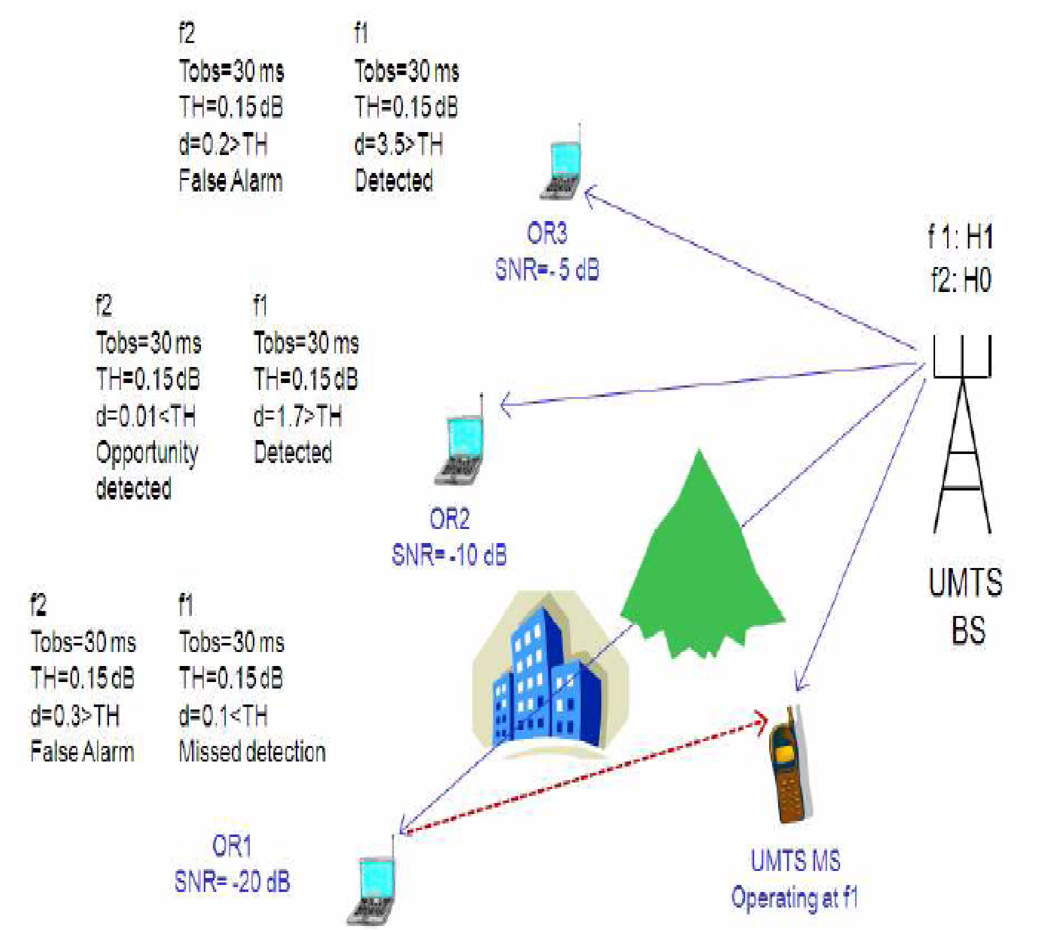
We use this!

- Optimal detector
- Simple architecture
- Easy to implement
- Less complexity

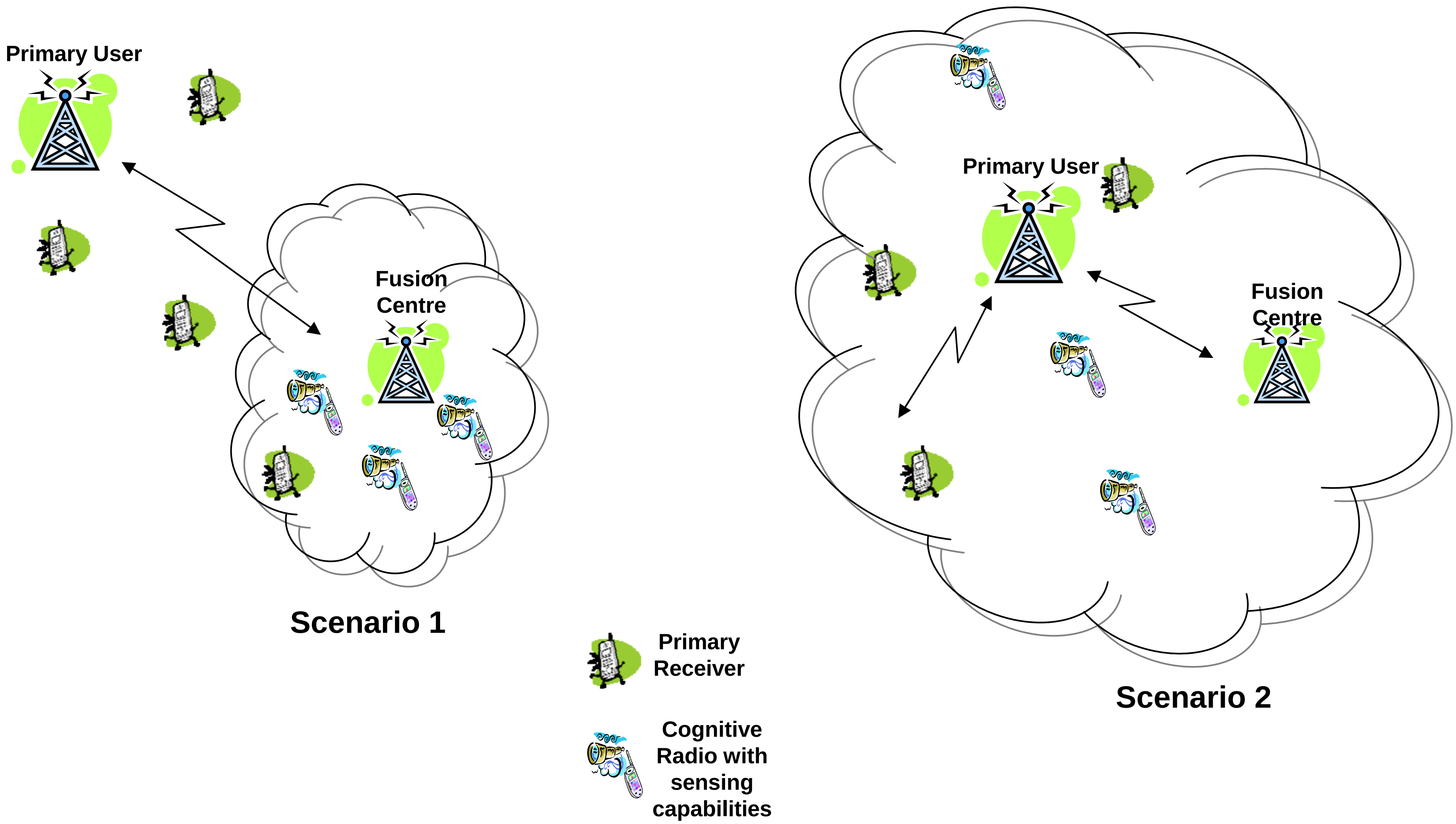


Collaborative Spectrum Sensing

- Local spectrum sensing limitations
  - Hidden node problem
  - Performance loss in fading and shadowing
- Solution
  - Collaborative or Cooperative Spectrum Sensing
- Collaborative Spectrum Sensing
  - Mechanism in which a number of cognitive radios share their sensing information with each other
  - Nodes send information to the fusion centre which combines local decision and make a global decision



System Model



Problem definition

- Maximise global probability of detection at the fusion centre, considering
  - Two scenarios (users with same mean SNR and with different mean SNR values)
  - Noisy reporting channels with channel gains
- Global probability of detection can be defined as Qd = Q(f(w)), where f(w) is given by

$$f(\mathbf{w}) = \frac{\sqrt{\mathrm{Var}[y_c/\mathcal{H}_0]}Q^{-1}(Q_f) + \mathrm{E}[y_c/\mathcal{H}_0] - \mathrm{E}[y_c/\mathcal{H}_1]}{\sqrt{\mathrm{Var}[y_c/\mathcal{H}_1]}}$$

$$= \frac{Q^{-1}(Q_f)\sqrt{\mathbf{w}^T\mathbf{A}\mathbf{w}} - \mathbf{w}^T[\mathrm{diag}(\mathbf{g})\mathrm{diag}(\boldsymbol{\sigma})]}{\sqrt{\mathbf{w}^T\mathbf{B}\mathbf{w}}}$$

where matrices $\mathbf{A}$ and $\mathbf{B}$ are defined as,

$$\mathbf{A} = 2N\mathrm{diag}^2(\mathbf{g})\mathrm{diag}^2(\boldsymbol{\sigma}) + \mathrm{diag}(\boldsymbol{\delta})$$

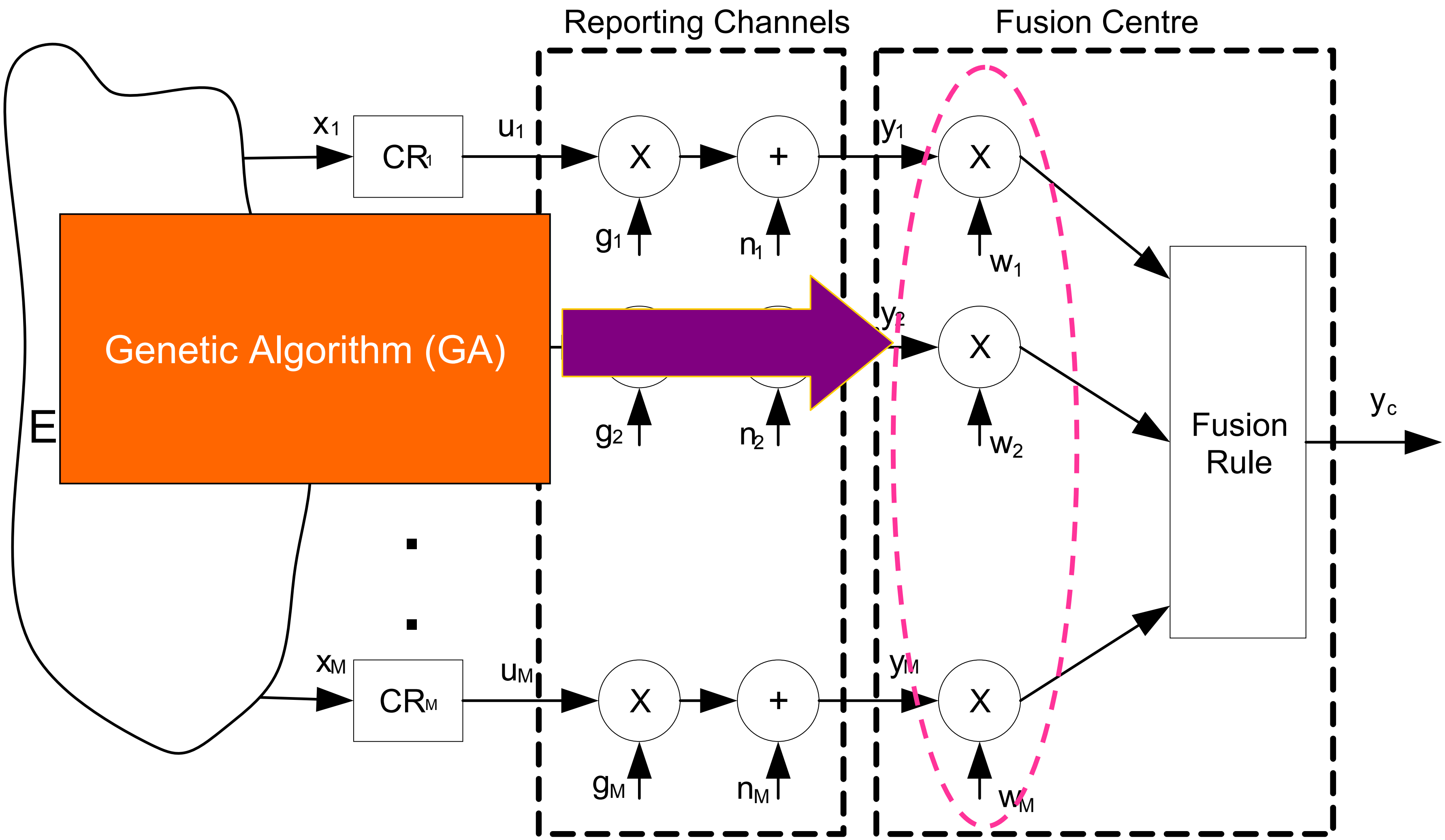
$$\mathbf{B} = 2(NI_M + 2\mathrm{diag}(\overline{\boldsymbol{\gamma}}))\mathrm{diag}^2(\mathbf{g})\mathrm{diag}^2(\boldsymbol{\sigma}) + \mathrm{diag}(\boldsymbol{\delta})$$

Problem

$$\text{minimise} \quad f(\mathbf{w})$$

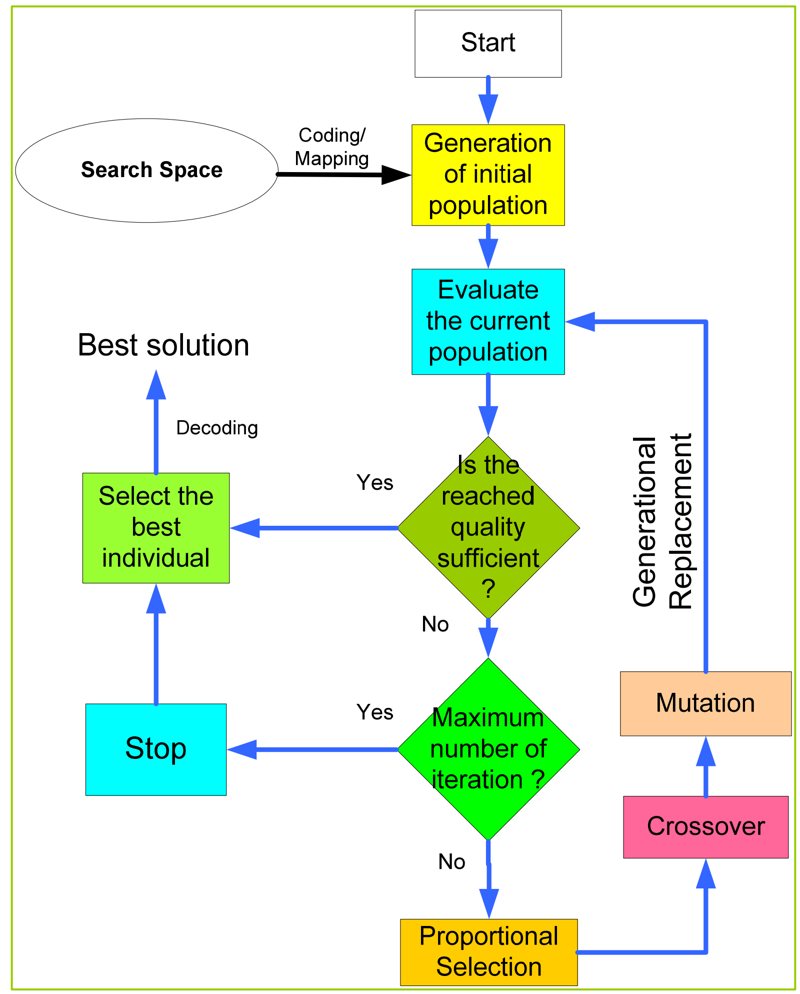
$$\text{st.} \quad ||\mathbf{w}||_2^2 = 1 \quad \text{and} \quad w_i > 0 \ \forall i \in \{1, 2, 3, ..., M\}$$

Proposed weighted framework



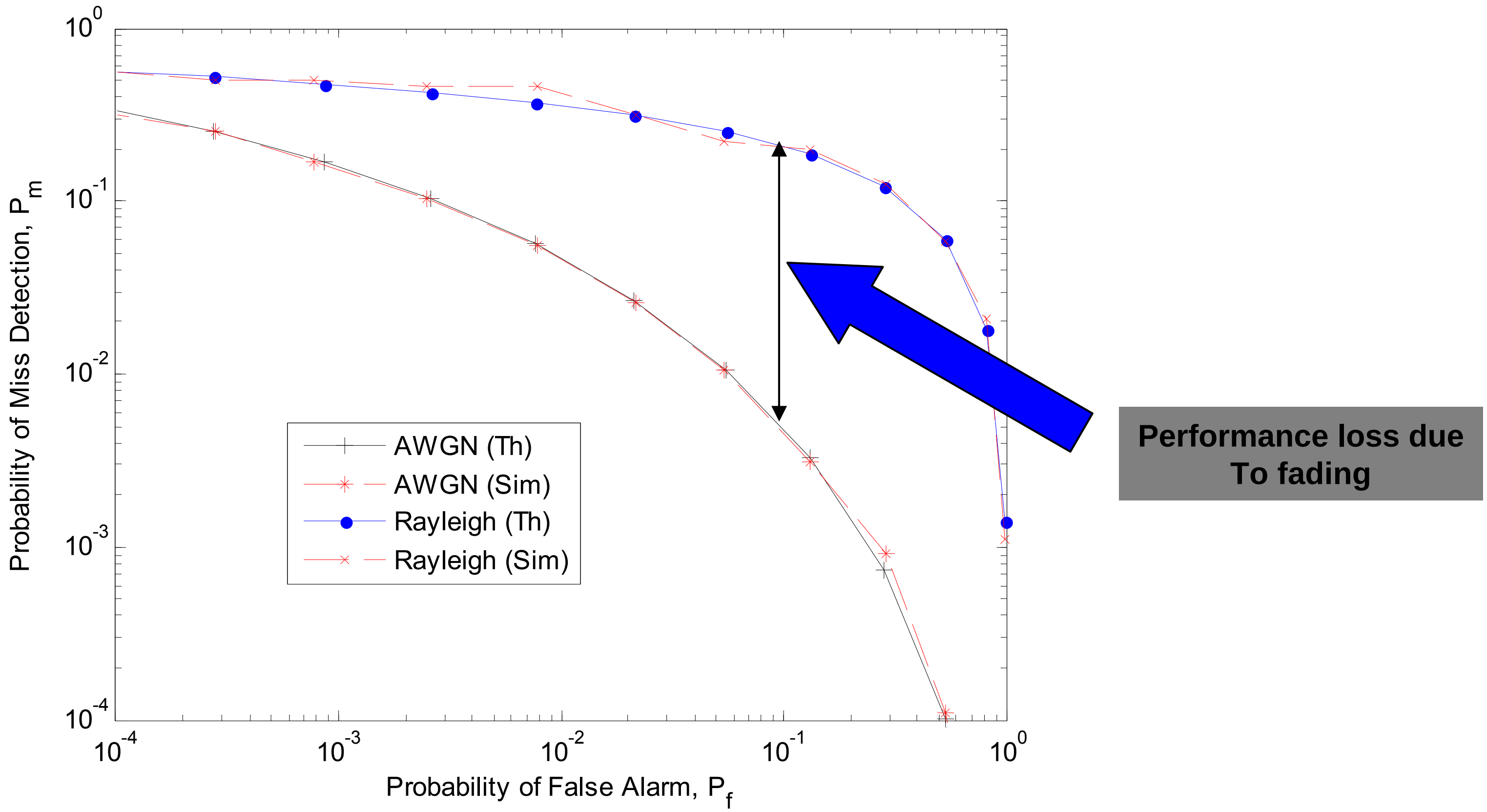
Why genetic algorithms?

- **Very useful for complex and loosely defined problems.**
- Quickly can scan a vast solution set.
- **Global optimisation technique.**
- Does not have to know any rules of the problem.
  - **It works by its own internal rules.**
- **Supports parallel processing.**
  - **Multiple solution capability**



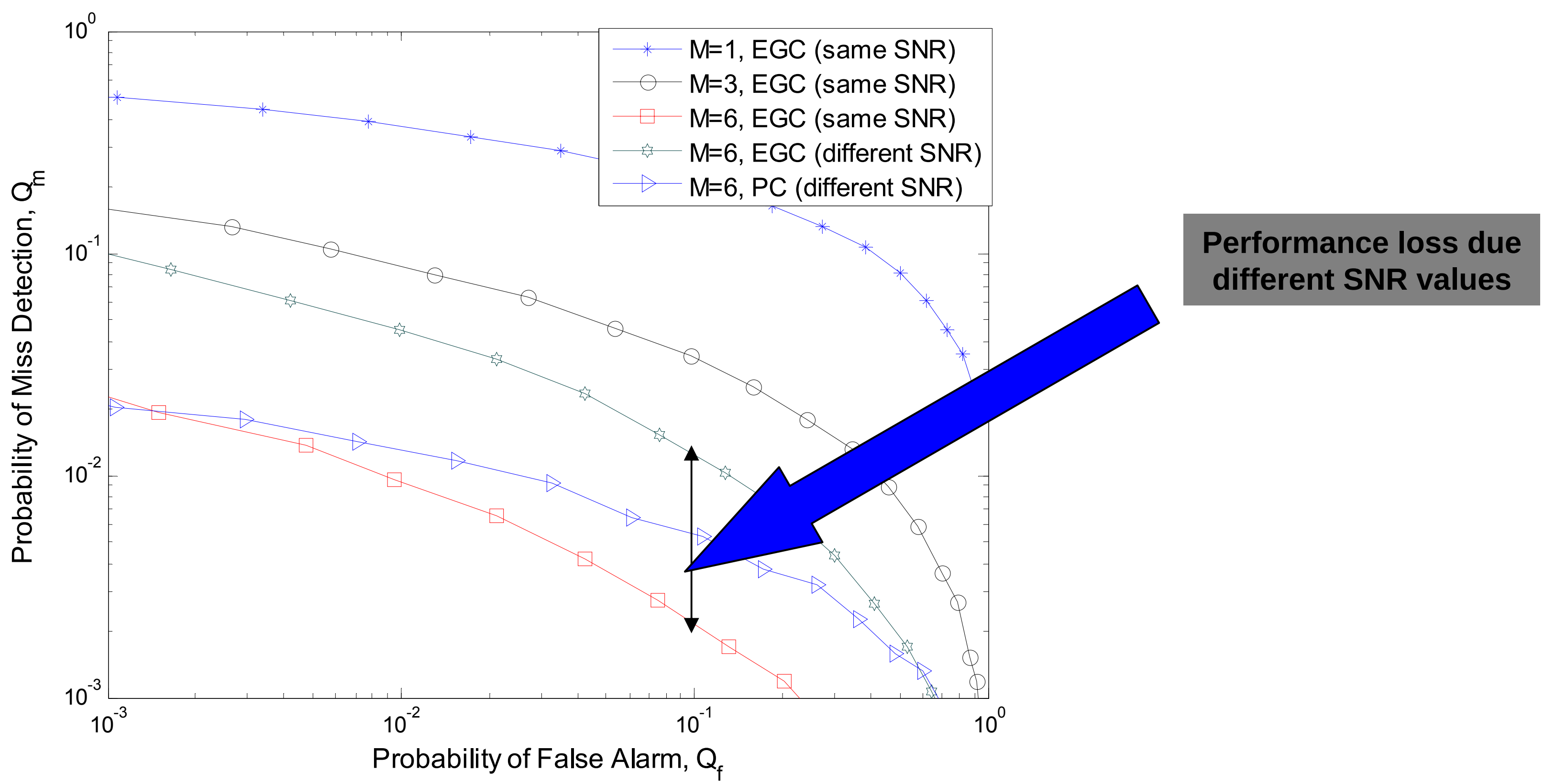
Results and Discussions (1/4)

ROC curves for single CR, SNR = 5B



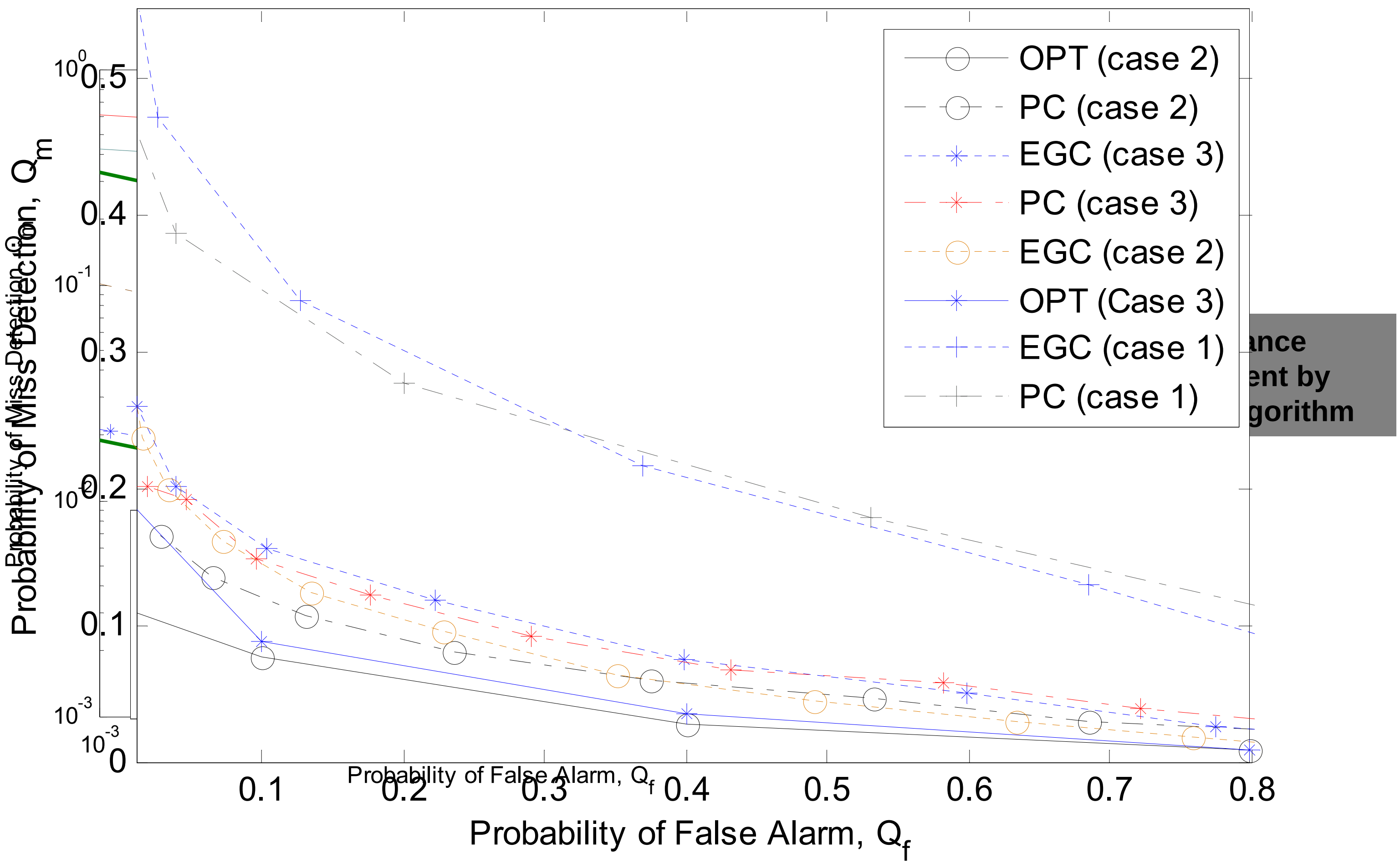
Results and Discussions (2/4)

Effect of different SNR values (perfect reporting channels)



Results and Discussions (3/4)
Performance of proposed scheme with 6 users and imperfect reporting channel

Rayleigh Channel



Conclusion

- Collaborative spectrum sensing improves sensing performance significantly
- Different SNR of users have significant effect on the performance of collaborative spectrum sensing
- Proposed Genetic Algorithm based weighted collaborative spectrum sensing improves sensing performance in all cases
- Proposed scheme requires knowledge about SNR of each user as well as channel conditions
  - Larger reporting channel bandwidths are required
  - Topic of our future research

Acknowledgment

This work was performed in project E3 which has received research funding from the Community's Seventh Framework programme. This paper reflects only the author's views and Community is not liable for any use that may be made of the information contained therein. The contributions of colleagues from E3 consortium are hereby acknowledged.

Questions ????