Cognitive Communications Research at the University of York

The Communications Research Group has one of the largest academic teams in the UK dedicated to Cognitive Radio (CR) and Cognitive Networking (CN). The field requires 'cross-layer' thinking to maximise the utility of the radio spectrum and can be applied to several layers of the protocol stack. Over the last 10 years or so we have carried out extensive research into radio resource and spectrum management, and have built up significant expertise, especially considering the impact of physical layer and of higher layers upon the data link layer. The Cognitive Communications Activity is expanding rapidly, and has recently been supported by a UK Ministry of Defence Competition of Ideas Project 'Cognitive Routing for Tactical Ad Hoc Networks'. Our activities also involve collaboration with members of the Intelligent Systems Research Group, and Physical Layer Research Group at York.

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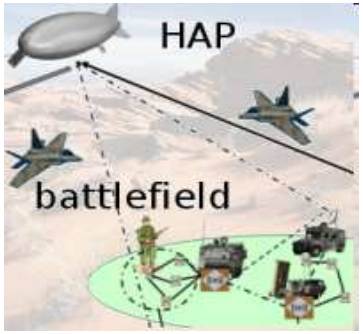
- ***Current and future research areas (over next few years):***
  - **Information-theoretic bounds on capacity of cognitive systems**
  - **Opportunistic assignment across multiple frequency bands/channels, including the intelligent coexistence of heterogeneous devices**
  - **The ability to cope with legacy systems and nodes with limited intelligence.**
  - **The application of game theory and economic principles to perform real-time efficient assignment of the radio spectrum.**
  - **The integration of routing and topology management with cognitive radio techniques for ad hoc networks.**
  - **Channel selection strategies that take into account traffic type and usage patterns.**
  - **New cognitive MAC layers to cope with new physical layer cooperative diversity techniques.**
  - **The impact of antenna directionality (including beamforming) and transmitter power control on cognitive radio terminals.**
  - **Development of firmware designs for cognitive radio.**
  - **“Green” cognitive radio**
  - **Reduced complexity cognitive radio**
  - **Robust cognitive radio based on intelligent “move if interfered” strategy**

- ***A selection of current areas are illustrated below***



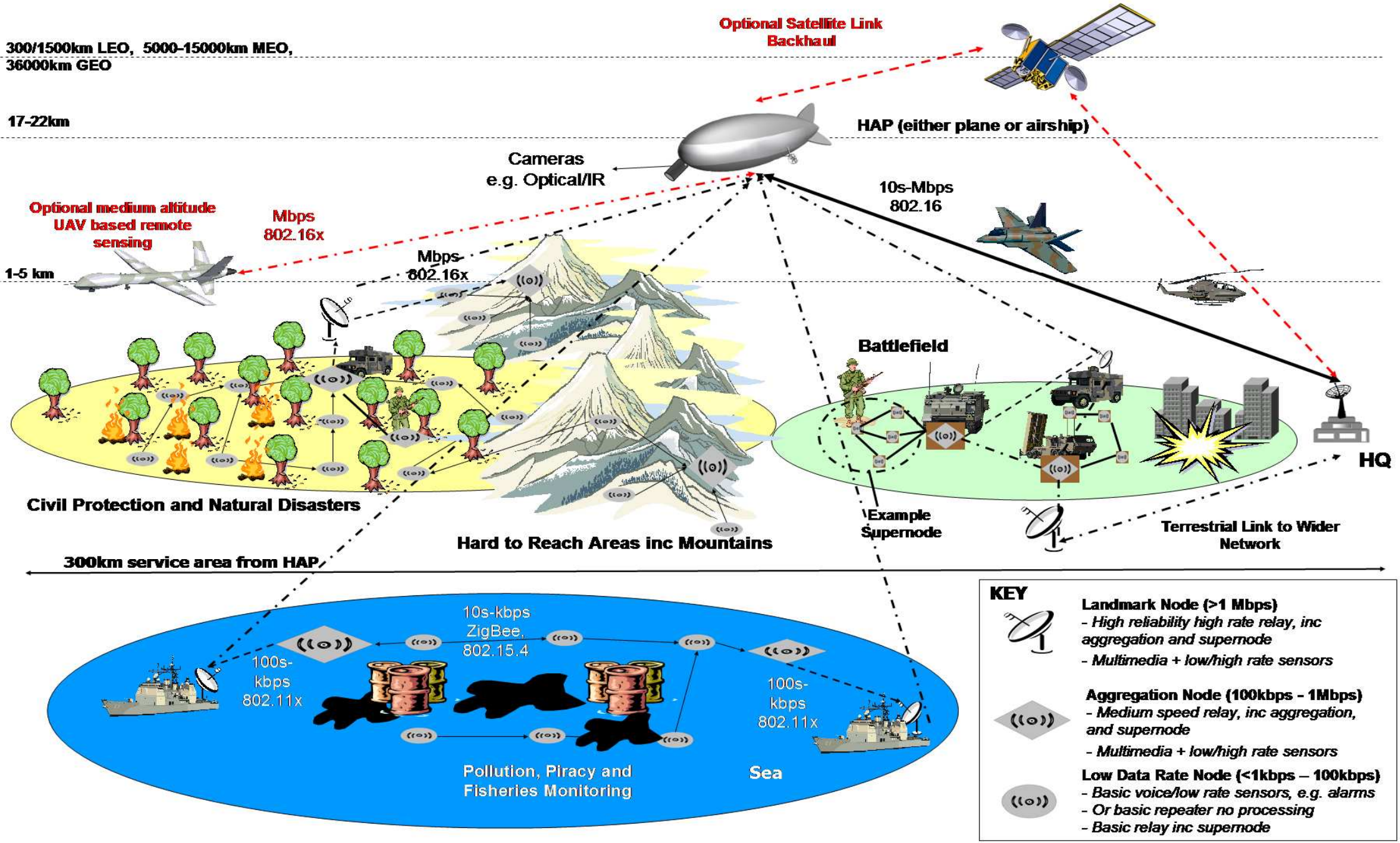
Cognitive Networks

This activity includes the recently completed MOD Competition of Ideas project on *'Cognitive Routing for Tactical Ad Hoc Networks*', which involved collaboration between the Communications and Intelligent Systems Research Groups at York, and dealt with hierarchical backhaul of military traffic. The project included:

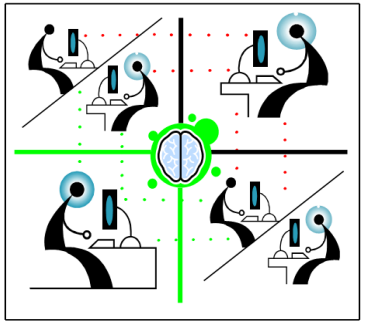
- Cooperative communications at the physical layer
- Cognitive radio based bandwidth assignment
- Routing strategies

Further activities include:

- Use of reinforcement learning to improve routing decisions on terrestrial ad hoc networks
- Reducing the relaying burden of nodes through network interaction and cognition
- Cognitive routing for heterogeneous networks involving satellites
- Cognitive sensor networks – improving energy efficiency by developing multiple access schemes that intelligently exploit network wide activities



Hierarchical backhaul wireless networks present a major challenge for designers. Cognitive techniques allow spectrum to be assigned more flexibly and routes to be established which take into account context information and node awareness.



Cognitive communications for indoor and smart environments

Conventional cognitive radios are designed to respond to changes in the environment. What if the environment can be changed using frequency selective surfaces within ‘smart’ infrastructures to respond to changes in cognitive radios?

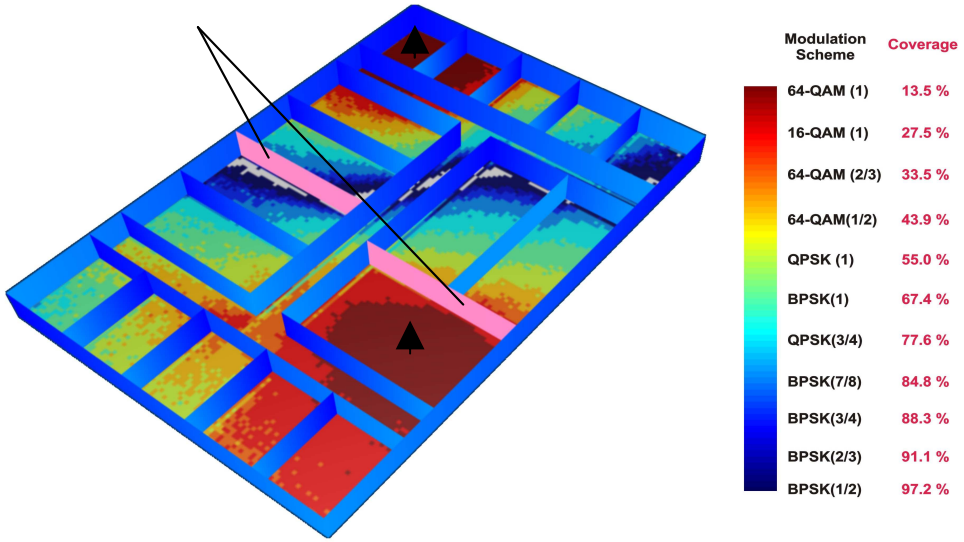
This activity includes work on:

- Range extension of MB-OFDM UWB by applying cognitive radio principles to increase the transmit power, by employing suitable spectrum detection and use, i.e. cognitive UWB.
- How 'smart' environments employing frequency selective surfaces can be controlled using cognitive principles, in order to improve future CR systems in such environments.

Using 3D ray launching it is possible to model the propagation behaviour inside ‘smart’ buildings. The frequency selective surfaces applied to the walls (shown in pink) can radically alter the coverage behaviour from a multiple access point system (two transmitters are shown) sharing a common channel. The left figure shows the situation when the FSS is off, with a standard wall attenuation of 3dB. On the right the FSS is turned on with the wall attenuation increasing to 30dB. This technique, once coupled with a cognitive engine can be used to dynamically alter system behaviour.

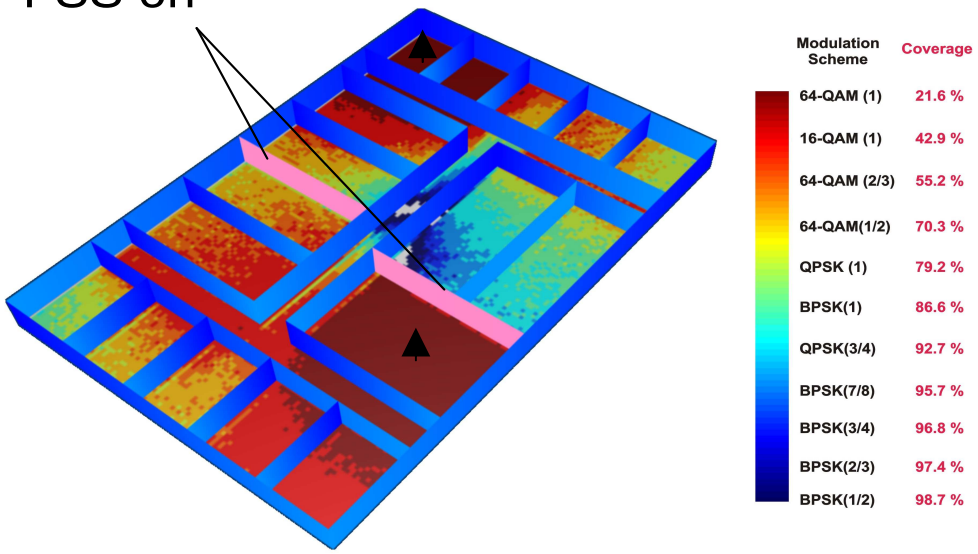
FSS off

Attenuation 3 dB

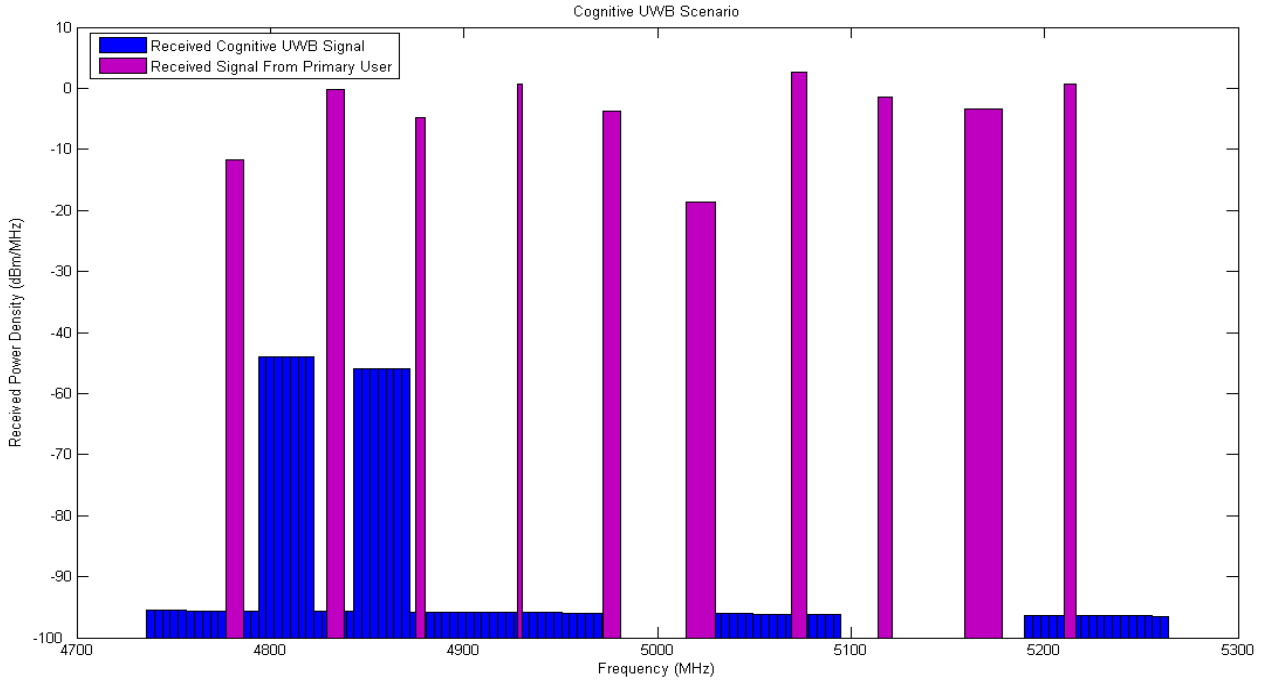


FSS on

Attenuation 30 dB

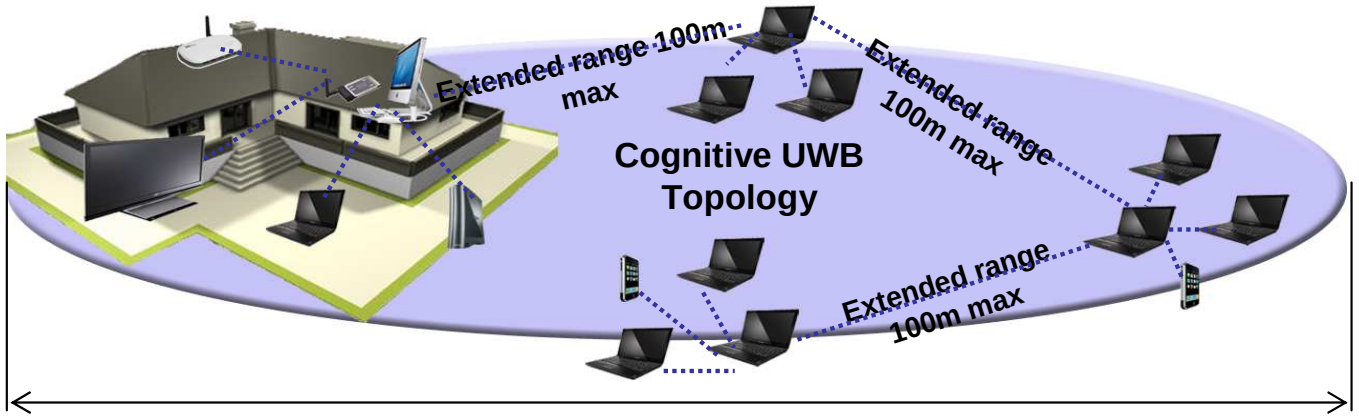


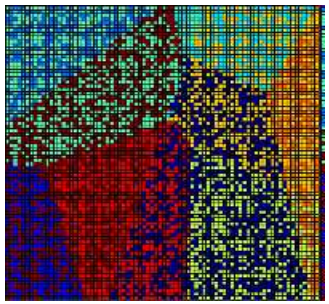
Extended Range Cognitive UWB Systems



This activity is exploring ways in which spectral sensing, cognition, and power efficient modulation can be used to increase the range of UWB systems up to 100m. Using MB-OFDM as a basis, transmit power above the normal UWB spectral mask is used in identified spectrum holes. Given the high data rates and portable devices involved, it is important that transmissions are as energy efficient as possible. Two topologies are being explored – master-slave and ad hoc.

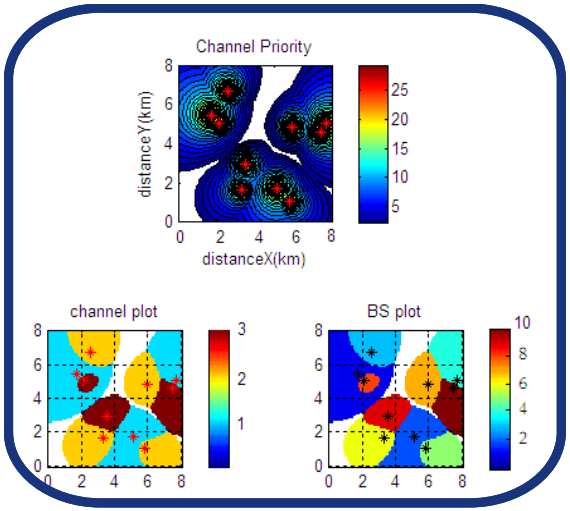
Possible applications include, Gigabit Ethernet and HDTV distribution within large buildings. There are strong links to work on 'Green' Cognitive Radio elsewhere in the Group.

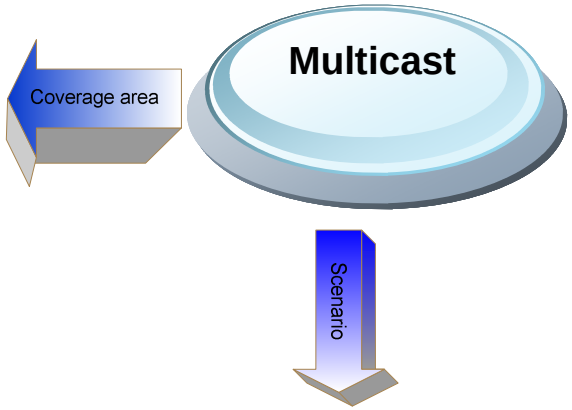


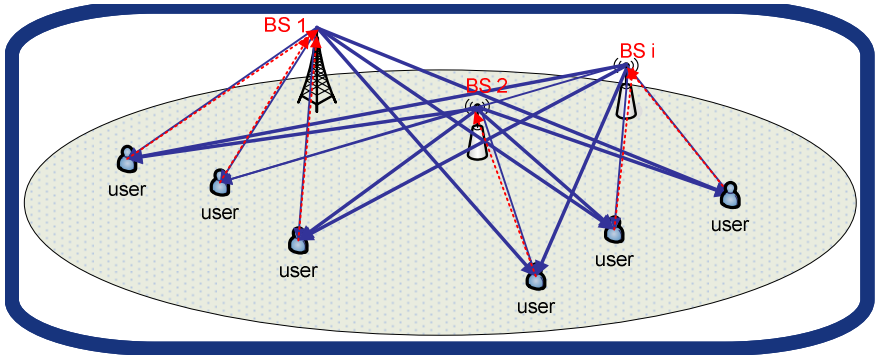


Cognitive Radio for Multicast Systems

Multicast communication systems have the promise to deliver new communications and services. Such systems can also exploit cognitive radio. Here it is important that the channel quality is sufficiently good at multiple locations simultaneously. In these situations distributed sensing can be readily exploited, given the topology, leading to significantly improved performance. Distributed reinforcement learning is being used to select suitable free areas of pooled spectrum.







WUN Cognitive Communications Consortium

Instigated and led by York under the auspices of the Worldwide Universities Network, this global Consortium of currently 25 academic and industrial organisations aims to

- *'play a leading role in Cognitive Communications research through global collaboration*'

Cognitive Communications requires a multi-disciplinary approach. The Consortium brings together people in the established areas of:

- Wireless communications
- Distributed artificial intelligence
- Electromagnetics
- Regulatory policy and economics
- Implementation

The Consortium currently is made up of 25 academic and industrial organisations from Europe, North America, Asia and Australasia

- National Technical University of Athens, Greece
- University of Bristol, UK
- BT, UK
- Czech Technical University
- CTVR, Trinity College Dublin, Ireland
- European University Cyprus
- Lehigh University, USA
- University of Illinois, Urbana-Champaign
- Jožef Stefan Institute, Slovenia
- University of Leeds, UK
- Pennsylvania State University, USA
- Peking University, China
- Philips, UK
- RF Engines Ltd, UK
- Simula Research Lab, Norway
- Shanghai University, China
- University of Surrey, UK
- University of Sydney, Australia
- Virginia Tech, USA
- TOT Public Company Limited, Thailand
- University of Twente
- Victoria University of Wellington
- University of Western Australia
- University of York, UK
- Zhejiang University, China

The First Meeting of WUN Cognitive Communications Consortium at the University of York in January 2009

For more information see: www.wun-cogcom.org

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WUN A Worldwide Universities Network Initiative