OverDRiVE

OverDRiVE's Approach for Spectrum Efficient Radio Resource Management

MMC 2003

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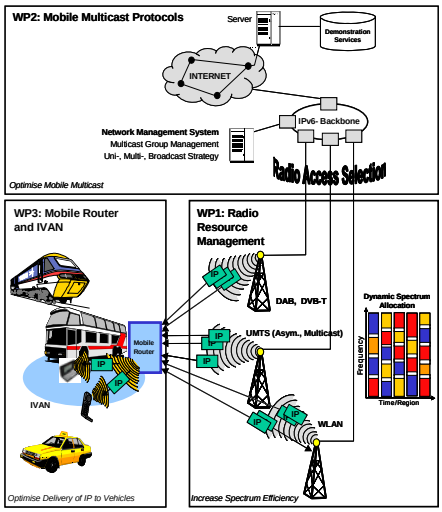
OverDRiVE Overview



- **OverDRiVE: Spectrum Efficient Uni and Multicast Services Over Dynamic Multi Radio Networks in Vehicular Environment**
- **WP3: Mobile Router and Intra-Vehicular Area Network**
- **WP2: Mobile Multicast Protocols**
- **WP1: Spectrum Efficient Radio Resource Management**

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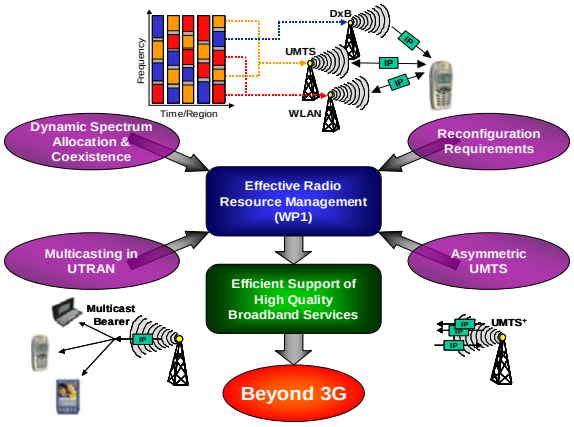
OverDRiVE WP1 Overview



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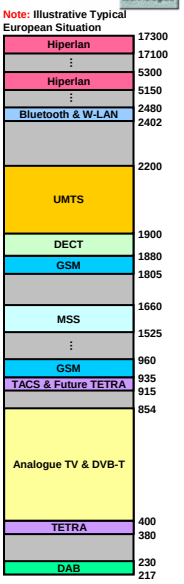
Outline

- Dynamic Spectrum Allocation & Coexistence
- DSA Requirements on Reconfigurability
- Multicasting in UTRAN
- Asymmetric UMTS
- Conclusion

Dynamic Spectrum Allocation & Coexistence

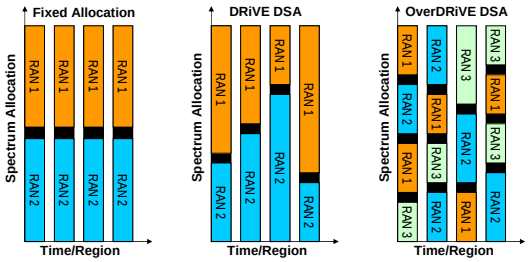
DSA Motivation and Concepts

- Current spectrum allocation method is a **fixed assignment**
  - Spectrum divided into non-overlapping blocks
  - Assigned to differing radio standards
  - Separated by guard bands
- Fixed spectrum allocations not always spectrum efficient
  - Spectrum usage time and space varying
  - DSA exploits these variations
  - Spectrum usage can be improved from **temporal load variations**
    - Demand for networks must have differing time varying loads e.g. cellular and broadcast
    - Unused spectrum on one network at some time can be given to another
  - Spectrum usage can also be improved from **spatial variations**
    - Different regions have different demands for services
    - Give different networks different spectrum allocations in different regions



DSA Evolution

- The general concept for DSA is to allow the spectrum allocations for RANs to change over time or region
- Initial work on DSA was performed in the DRiVE project
  - This DSA concept was called Contiguous DSA
- OverDRiVE develops and researches a new DSA method
  - Called Fragmented DSA



Aims and Scope of DSA Research

- The OverDRiVE research is divided into two main aspects
  - Dynamic spectrum allocation
  - System coexistence
- The dynamic spectrum allocation section aims to:
  - Enhance the DSA concepts developed in DRiVE
  - Make the schemes more general to any type and number of RANs
  - Allow for increased spectrum allocation flexibility
  - This is achieved through the development of the fragmented DSA
  - DSA is investigated in adapting to spatial or temporal changes in traffic demand
- The system coexistence section aims to:
  - Look into requirements in terms of guard bands and coordination distances for differing systems in the same spectrum
  - This serves as an input to the DSA to minimise wasted spectrum
  - Investigate how regions with differing allocations can coexist at the borders

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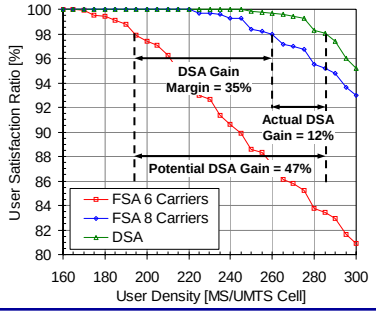
Spatial DSA

- Spatial DSA adapts to regional changes in spectrum demands by splitting an region up into areas with different spectrum allocations
  - Called DSA Areas
- The spatial DSA algorithm considers many DSA areas with differing demands and tries to find the best allocations to satisfy the demands
- Extra guard bands must be inserted to avoid interference at the borders of the DSA areas however



- The graph shows how the effect of inserting the guard bands affects the gain
- This is simulated through a Monte-Carlo simulator modelling UMTS and DVB-T
- The work will further investigate ways to minimise the additional guard bands
- The work will also be furthered to include a further RAN

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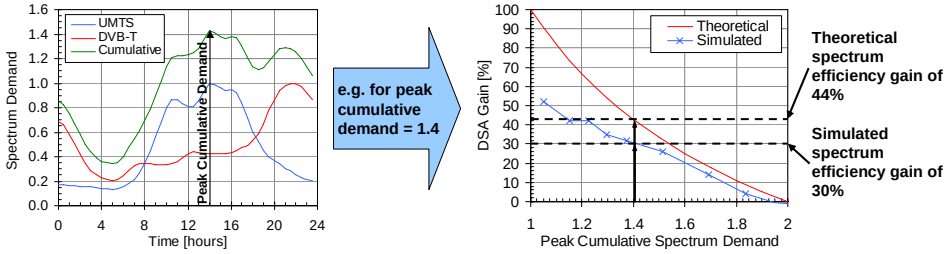
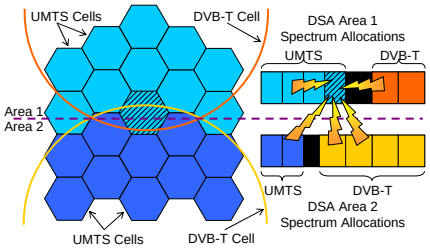
Temporal DSA

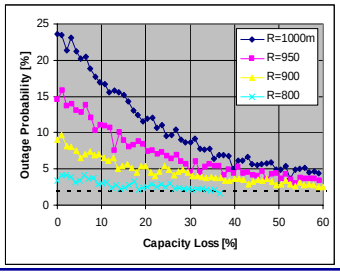
- Temporal DSA operates by allocating carriers to the RANs over time according to their demands
- If a RAN no longer needs a carrier the spectrum can be released and given to another RAN
- OverDRiVE has investigated bounds on the DRiVE DSA schemes performance
- Comparisons between theoretical and simulated results have highlighted limiting factors on DSA performance
- The work will be furthered by adding more RANs and newer carrier allocation algorithms to bring the simulated results closer to the theory



DSA Area Border Coordination

- Different spectrum allocations in differing regions ⇒ interference at borders
  - Potentially co-channel interference from another system
- It is important to understand what effect this will have on performance
- Methods to mitigate this interference are also investigated
- The graph shows capacity loss for UMTS in presence of interference from DVB-T for above scenario
- The interference effects can be reduced by shrinking UMTS cells at the border
- Other methods of handling interference will also be investigated





Guard Bands and Coordination Distances

- The fragmented DSA scheme has important impacts on guard bands
  - More guard bands may be needed in a block of spectrum
  - Any of the systems could potentially neighbour each other in the spectrum
- This requires the investigation of the guard band sizes required between each different system
- The required distance between different systems in order to allow operation on the same frequencies also gives important input to the optimisation of spatial DSA
- OverDRiVE uses the SEAMCAT and SAMO simulation tools to investigate coexistence of UMTS, DVB-T, WLAN, and GSM

DSA Requirements on Reconfigurability

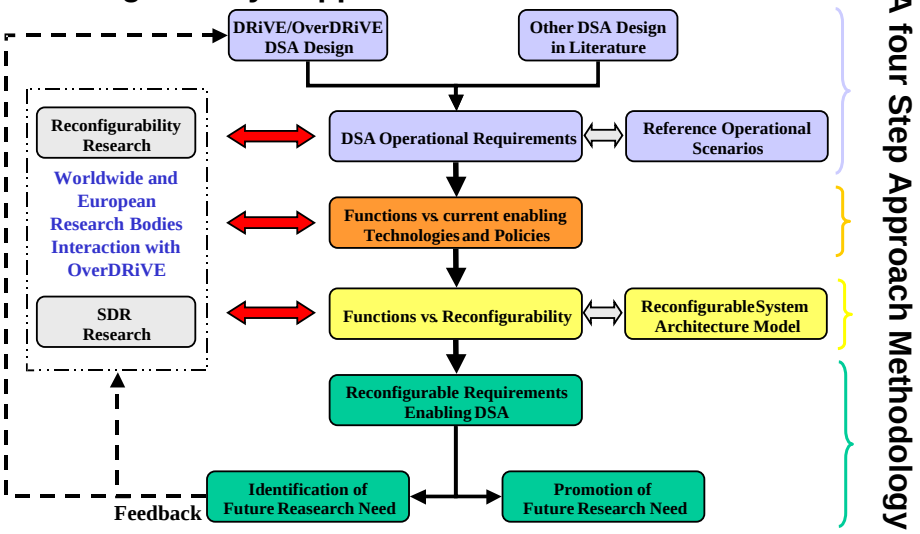
Reconfigurability - Motivation

- Current face of the telecommunications model is mainly drawn from the regulatory policies and not necessary by the economy and technologies themselves
- Current static spectrum management
  - Is a long term process
  - Can slow down potential initiatives and innovations for more flexible spectrum management
- Success of operational DSA deployment is related to changes in:
  - Technical area
  - Economical area
  - Regulatory area
- Reconfigurability can give support for operational DSA deployment
- Reconfigurability can have different meanings for each area

Reconfigurability - Objectives

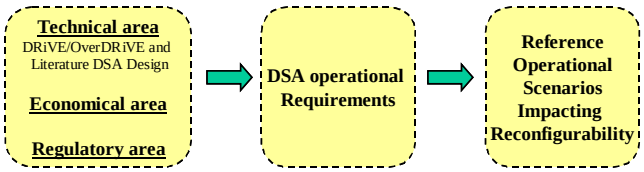
- Perform jointly DSA and Reconfigurability investigations
  - Identify where and how reconfigurability can give support to operational DSA deployment in a multi-radio environment
  - Identify how each technical, economical and regulatory area can be impacted by the operational DSA deployment
  - Identify how each technical, economical and regulatory area can impact and drive reconfigurability requirements
- Compile and promote future Research need in Reconfigurability for the DSA support

Reconfigurability - Approach



Step 1: Survey of the DSA Operational Requirements

- The transition from the Contiguous and Fragmented DSA Research concepts to the realistic operational DSA deployment is not straightforward!
  - The "DSA and System Co-existence" section addresses the overall concept from the technical perspective and the derived algorithms are designed for two RATs only
  - When moving from two RATs to several ones, new requirements raise and remain to be identified
- First purpose of this step is to identify exhaustively the DSA requirements derived from:
  - The DSA concepts and algorithms described in the "DSA and system co-existence" section
  - The additional issues encountered when going through (into more details) the operational DSA when more than two RATs are considered
- This is performed from the technical, economical and regulatory perspectives
- Second purpose of this step is to identify some reference scenarios which will be used as a basis for reconfigurability investigations



Step 2: DSA Functions vs. Current Enabling Technologies and Policies

- First purpose of this step is to derive the needed functions from the DSA operational requirements
  - DSA Spectrum playground, …
  - Equipment (end user terminal and access point) related aspects (Hardware, Software)
    - Frequency carrier synthesis
    - Frequency carrier switching
    - Signal filtering
    - Dynamic range of variable duplex, …
  - Network collaborative aspects
    - Spectrum negotiation
    - Decision-making, …
  - Control, monitoring, management aspects
- The DSA functions are often ahead of the existing technologies capabilities and supporting policies. Support of some functions can lead to deadlocks!
- Thus, the second purpose of this step is to identify to what extent these functions can (or not) be supported by:
  - The existing technologies
  - The existing spectrum management policies governed by the regulation and market players

Step 3: DSA Functions vs. Reconfigurability

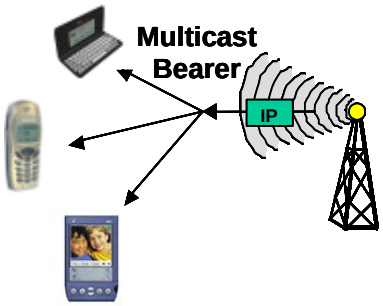
- First purpose of this step is to discuss where and how Reconfigurability can give support to DSA functions (meeting deadlocks today) at different levels of the communication system
  - Which functions need to be reconfigurable?
  - Why the function needs to be reconfigurable?
  - What level of reconfigurability is to be considered for each function?
  - What is the degree of complexity vs. required reconfigurability?
- Second purpose of this step is to identify the « Potential » of an architecture model supporting reconfigurable communication system enabling DSA
  - Research on reconfigurable DSA functions is linked to Research on architecture model for reconfigurable communication systems
  - Some architecture models exist, but they are:
    - Mainly based on ad-hoc approaches for specific problems
    - Not necessary appropriate for DSA operations
  - The open questions investigated are:
    - What is the « potential » of an architecture model relevant to the DSA operation?
    - To what extent a new architecture model could be applicable to, or complement other existing models?

Step 4: Future Research Need in Reconfigurability

- Purpose of this step is to identify and promote the future research need in Reconfigurability area to enable operational DSA deployment
- This effort is performed interactively with the Research community on specific issues (steps 1, 2 and 3). Effort is initiated with:
  - SDR Forum Technical Conference (Nov. 2002)
  - WWRF (7th meeting)
- Next actions
  - Presentation of the “DSA Requirements on Reconfigurability” investigations to the 10th Concertation Meeting of IST Communication and Network Technologies projects and associated clusters (Brussels, 10-12 March 2003)
  - Interaction with SDR Forum on peer physical layer topics (April 2003)

Multicasting in UTRAN

Multicast over UTRAN - Motivation



- The Radio Channel is a shared and limited resource
- Multiple point-to-point transmissions of the same high-bandwidth content is inherently inefficient
- Currently only point-to-point communication is supported by the radio interface
- If the service allows it to bundle user requests in time and space a point-to-multipoint transmission would be much more spectrum efficient

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Multicast over UTRAN - Objectives

- Development and proposal of UTRAN enhancements to provide spectrum efficient multicast services
  - Power Control
  - Radio Resource Management
  - Protocol extensions
  - Transmission techniques
- Comparison and Analysis of Multimedia Broadcast/Multicast Service (MBMS) approach
- Validations of the benefits by simulations
- Simulative performance evaluation of UTRAN based multicast with respect to
  - Spectrum efficiency
  - Quality of Service (QoS)

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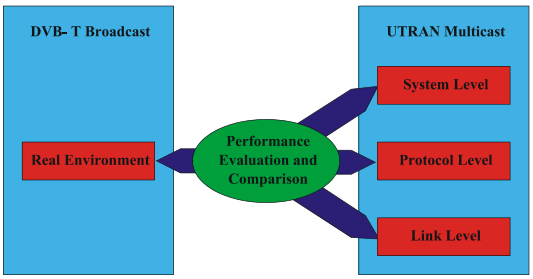
Multicast over UTRAN – Concept

- Use of existing channels with minor modifications (e.g. multicast addressing)
  - Dedicated Channel (DCH)
  - Forward Access Channel (FACH)
  - Downlink Shared Channel (DSCH)
  - High Speed Downlink Shared Channel (HS-DSCH)
- Development of new multicast Radio Bearers
- Elaboration and qualitative analysis of multicast using new concepts
  - Orthogonal Frequency Division Multiplexing (OFDM)
  - Hybrid ARQ (HARQ)
- Efficiency comparison of UTRAN concepts to scenario with DVB-T broadcast link

Multicast over UTRAN - Simulation Approach



- System level simulator primarily used for system capacity and radio resource management analysis
- UMTS radio interface simulator (URIS) to analyse protocol aspects
- Link level simulator for analysis of power control algorithms

- Simulations using DVB-T are used as a reference scenario

Multicast over UTRAN - New Concepts

- OFDM for UMTS
  - OFDM has been adopted for broadcast systems like DVB-T
  - Advantages in a multicast context are
    - Spectral efficiency
    - A good ability to cope with long delay spreads and fast channel variations
    - No need for a fast power control
- HARQ for UMTS
  - HARQ is a feature introduced to UMTS by the High Speed Downlink Packet Access (HSDPA)
  - HARQ combines
    - Forward error correction (FEC)
    - Retransmission of erroneous received packets with incremental redundancy and
    - Carrier to Interference (CIR) based scheduling

Asymmetric UMTS

Asymmetric UMTS - Objectives

- **Asymmetric Services are expected to dominate the forthcoming wireless communication scenario**
- **Web browsing, streaming, file downloading will lead to a downlink/uplink asymmetry of 3:1 in next years**
- **UMTS is designed to support a symmetric traffic and is assigned a symmetric band:**

OverDRiVE aims to show how UMTS can be enhanced as an asymmetric access system, to determine the spectral efficiency of asymmetric radio channels and to develop advanced radio resource management strategies

- **Asymmetric UMTS is achieved by:**
  - **Increasing the spectrum available for downlink operation**
  - **Increasing downlink spectrum efficiency by means of Physical Layer and Radio Protocol enhancements and advanced Radio Resource Management**

Asymmetric UMTS - Physical Layer Enhancements

- High Speed Downlink Packet Access (HSDPA) is a standardised 3GPP functionality that supports higher downlink peak rate, lower transmission delay and it is more spectrum efficient than current Dedicated channels
- Orthogonal Frequency Division Multiplexing (OFDM) was proposed in 3GPP for UTRAN Release 6 and a study item was opened to investigate OFDM performance in mobile environment
- OFDM advantages:
  - High bit rate transmission in time and frequency dispersive environments
  - Robustness against multipath propagation
  - Low implementation complexity
  - Robustness against Doppler effects
  - No intra-cell interference
- OFDM drawbacks:
  - Inter-cell interference (can be reduced by means of advanced techniques such as Frequency Hopping, Beamforming MIMO, …)
  - Frequency reuse factor of 1/3

Asymmetric UMTS - OFDM Investigations

- OFDM performance will be investigated by means of a physical layer simulator
- Multiple cells simulations will be carried out to evaluate impact of inter-cell interference
- OFDM will be assumed to operate on a separate downlink carrier, while signalling will be performed over WCDMA channels
- Carrier bandwidth will be assumed to be 5 MHz in first evaluation

Asymmetric UMTS - Additional Downlink Frequency Bands

- Available bands have been identified for UMTS operation other than current one: band II (2500-2690 MHz) and band III (1710-1785/1805-1880 MHz)
- Downlink band asymmetry affects Radio Resource Management (RRM) functions that aim at assigning, removing and reconfiguring the radio resource
- Two scenarios are envisaged:
  - Each Mobile Terminal is assigned one DL carrier
  - Each Mobile Terminal can receive signal from several DL carriers
- In both scenarios Mobile Terminals share the same uplink
- Both options require significant standard extensions and terminal modifications (e.g. Variable Duplex Technology is needed)

Asymmetric UMTS - RRM with Additional DL Frequency Bands

- Terminals are assigned one DL carrier
  - Each carrier can provide one Radio Bearer (RB) only or
  - Each carrier can provide all the possible RBs
  - Terminals are temporary assigned to DL carriers. RRM functions should manage this assignment in an efficient way
- Terminals can receive signal from more than one DL carrier
  - Each carrier bears the whole information or
  - The information is distributed over several carriers
  - Providing the information over several carriers heavily affects the distribution of RRM functions over the UTRAN
- Each RB can bear more than one service in both scenarios

<table>
<tr><th></th><th colspan="4">2500MHz</th><th>2690MHz</th></tr>
<tr><td>Scenario 1</td><td>UL Internal</td><td colspan="2">DL External</td><td>DL Internal</td></tr>
<tr><td>Scenario 2</td><td>UL Internal</td><td></td><td>DL External</td><td>DL Internal</td></tr>
<tr><td>Scenario 3</td><td colspan="2"></td><td colspan="2">DL External</td></tr>
<tr><td>Scenario 4</td><td colspan="4">DL External</td></tr>
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Table shows OverDRiVE spectrum scenarios in Band II

Asymmetric UMTS - Additional DL Frequency Bands Investigations

- A WCDMA dynamic radio network simulator will be used to evaluate spectrum efficiency of advanced RRM strategies with asymmetric radio channels
- Propagation model includes:
  - Antenna characteristics
  - User movement
  - Shadowing and fast fading
  - Frequency dependent distance attenuation
- Fast power control
- Soft handover
- Admission control
- Inter-frequency handover

Conclusion

- Dynamic Spectrum Allocation and System Coexistence
  - Dynamic spectrum allocation algorithms are developed to adapt to temporal and spatial traffic demands
  - The system coexistence work provides important input for optimising the DSA work
- Reconfigurability
  - Investigating where reconfigurability can give support to DSA operational deployment on the basis of reference scenarios
  - Identifying future key reconfigurability research topics needed for the support of DSA
- Multicast over UTRAN
  - Several concepts for UMTS multicast extensions are under development
  - Simulations on various levels will be used for a performance evaluation of UTRAN based multicast
- Asymmetric UMTS
  - OverDRiVE covers both the increase of available downlink spectrum and the increase of downlink spectrum efficiency
  - Several scenarios for additional spectrum are identified

OverDRiVE – WP 1 Contacts

- System Coexistence and Dynamic Spectrum Allocation
  - Paul Leaves (p.leaves@surrey.ac.uk)
- DAS Requirements on Reconfigurability
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- Multicast over UTRAN
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