

SDRF Cognitive Radio Activities & Dynamic Spectrum Management

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Introduction

1. Background
2. Cognitive Radio Working Group
3. Cognitive Applications Special Interest Group
4. CR and Dynamic Spectrum Management
5. Summary
6. Contact Information

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Background

Cognitive Radio - Several definitions (and variations) of Cognitive Radio exist:

- **Mitola** - Cognitive radio signifies a radio that employs model based reasoning to achieve a specified level of competence in radio related domains.
- **FCC** - A cognitive radio (CR) is a radio that can change its transmitter parameters based on interaction with the environment in which it operates.
- **Kolodzy** - A cognitive radio has the flexibility and the adaptability to change its operating conditions to its environment (either real or perceived)
- **Early SDRF Draft** - The term Cognitive Radio refers to a radio that has, in some sense, (1) awareness of changes in its environment and (2) in response to these changes adapts its operating characteristics in some way to improve its performance or to minimize a loss in performance.

Background

- Summary of some of the popular Cognitive Radio visions:
- Autonomously exploit locally unused spectrum to provide new paths to spectrum access.
- Roam across borders and adjust themselves to stay in compliance with local regulations.
- Negotiate with several service providers to connect a user at the lowest cost/maximum bandwidth.
- Autonomously adapt operational behavior and emissions.
- Understand and follow the actions and choices taken by their users.
- Learn to become more responsive and to anticipate (and even direct) user requirements.
- A unified, or common understanding of CR and CR terms is badly required.
 - Differences exist between European and US definitions also.

CRWG Background

CRWG is creating a document that intends to provide a unified view of what a CR is and what CR-related terms mean.

Timeline:

- Orlando –
 - Loosening of rigid, fixed licensing and spectrum allocation. Forum interest in understanding new ways agile radios can use spectrum
- Los Angeles
 - Announcement and call for participation “Spectrum Efficiency” WG under the System Interface WG
- Mainz
 - Ad-Hoc Cognitive Radio meeting.
 - Joint Spectrum Efficiency and Public Safety meeting. Measurement Campaign proposed.

CRWG Background

- **Phoenix**
 - Creation of Cognitive Applications SIG, Joint meeting
 - Working Group renamed “Cognitive Radio Working Group”
- **Austin**
 - Shared Spectrum publishes results of spectrum measurement study
- **Washington**
 - Advanced discussions on conceptual model for CR

Discussions during SDRF meetings and fortnightly conference calls
Submissions to the WG Chair (John Grosspietsch) and the email reflector: cognitiveradio@sdrforum.org

Definitions document to be presented to the SDRF for approval in Nov 05
(SDRF Anaheim)

Cognitive Radio 'IQ'

IQ Level	Adapt	Aware	Learning	Mistake Correcting	Autonomy No user inputs
0 toddler					
1 preschool		x			
2 child	x	x			
3 adolescent	x	x	x	Avoidance only	
4 teenager	x	x	x	x	
5 young adult	x	x	x	x	x

CR Conceptual Model (alternative view)

Environmental Domain

Local internal and external sensing, location-awareness

Radio Domain

Spectrum characterisation, available modules/hardware

Policy Domain

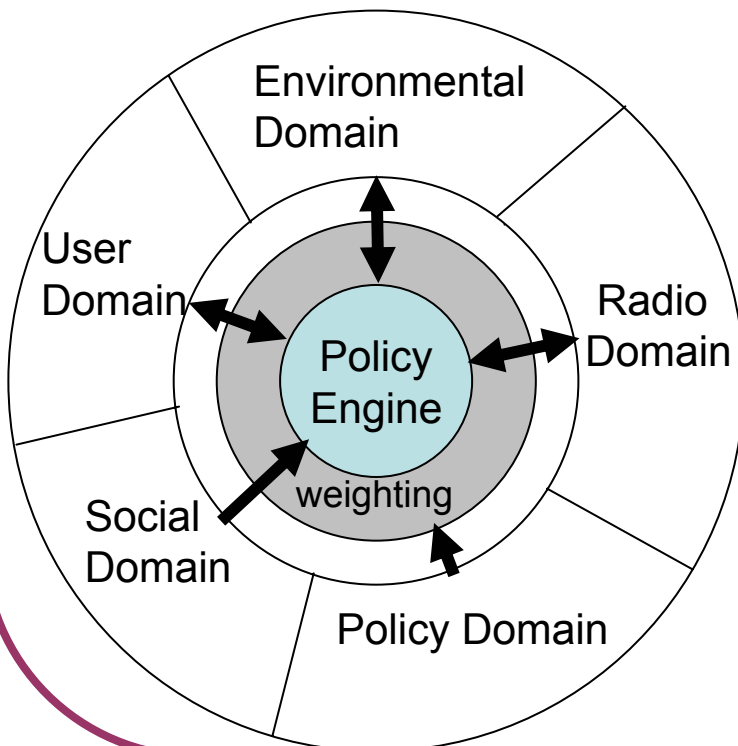
Operating policies:
bands/frequencies/power/time/location

Social Domain

Collaboration, Marketing & payment models

User Domain

Number of users/device, abilities, requirements
patterns, forecast of requirements, MMI complexity

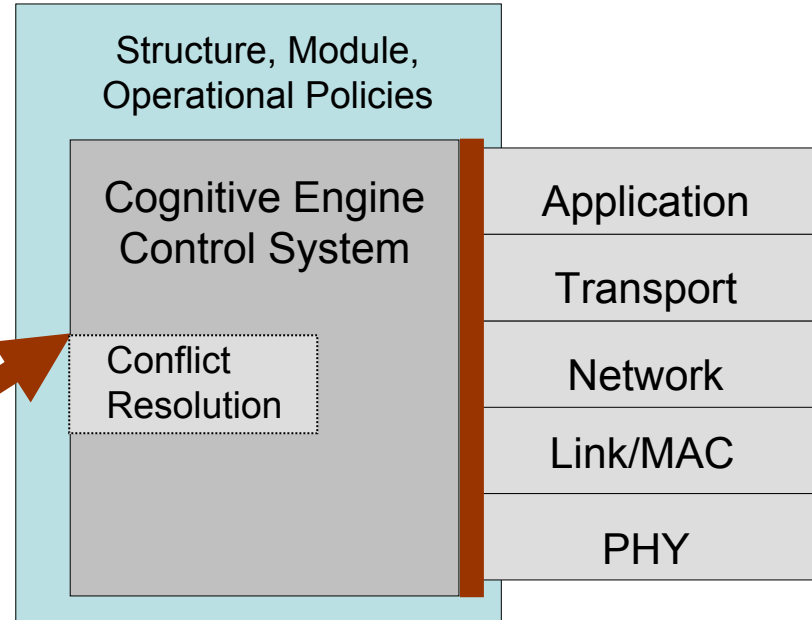
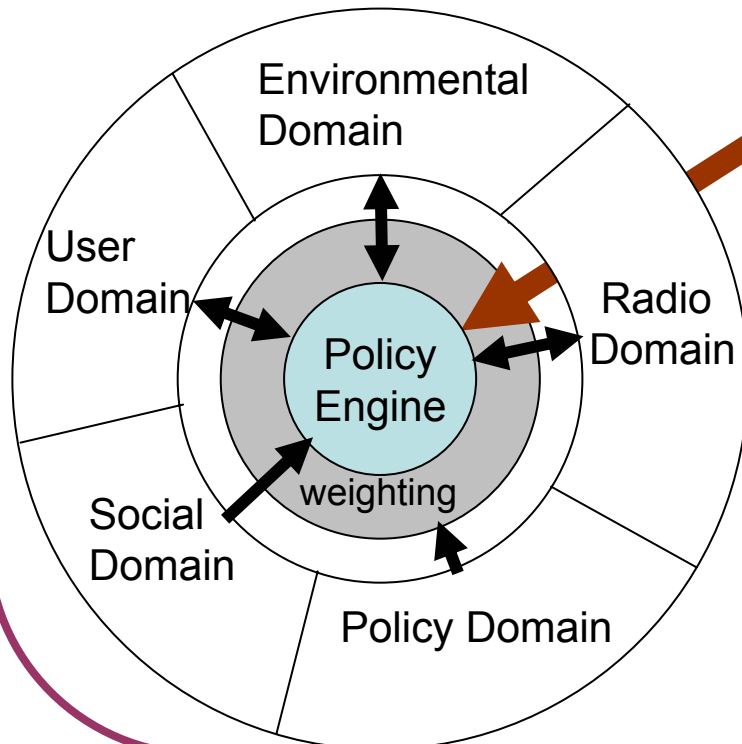


Policy weighting/influence

Variable biasing toward different domain combinations.

Learning vs. Educated CR scenarios

CR Conceptual Model (alternative view)



Policy weighting 'shape' varies in 2 dimensions
(or 3D, if policy-weighting is time-variant)

CRWG Summary

- Definitions relating to CR devices, Underlay & Overlay Cognitive Networks, Collaborative behavior using distributed CRs,
- “...without CR co-operation, the solution may be sub-optimal...” – Ashish Pandharipande
- Awareness – Spectrum, Energy, Radio Resources, Context, Consequences, Environmental, Spatial Awareness
- Adaptation – Using Awareness, Requirements/Goals, Unpredictable handoff/loss of connectivity...
- Conflict resolution, policies, policing, fairness....

CRWG Summary

- Graceful Advancement
Base-line CR Abilities to Educated CR
- Graceful degradation
Conventional sense but also in cognition abilities.
Focus depleting resources on priority services.
- Micropayments for message-relaying, emergency relays for non LoS.
 - Where the cost of payment collection using a centralised system is either not feasible or not cost-effective.
- Terms relating to behavior extending beyond the realm of today's and short-term communications and control objectives.
- Cannot limit ourselves to only thinking within current restrictions (power, current wireless applications, social interaction (or lack thereof!).)

Cognitive Applications SIG

- SIG in SDRF Markets Committee strand.
- Developing a Matrix of CR application requirements and where their main operational focus lies (security?, systems management?, physical layer...?) and what the anticipated market sector is (consumer, industrial...etc)
- Scenarios where CR and CR Apps could provide the best (or only) solution.
 - Not only Public Safety, Military... but Games, Biomedical, Advertising, new P2P....new niche?

Example: Use Cognition to reduce the complexity of the Man Machine Interface (MMI)

One touch or no-touch operation, behavior-linked operation....

“...25% of wireless device users have no technical expertise...”

-Stephen Hope (E2R)

- These scenarios will hopefully fuel CR App ideas.

Cognitive Applications SIG

- “....Wireless market is worth ~ \$1 Trillion...” – Peter Cook
- CA SIG also working a Glossary to support the Applications Matrix with strong input from CRWG.
- Working towards establishing a Cognitive Radio-based track in SDR Forum Technical Conference 2006.
- When Matrix & Glossary complete, approve as report to Markets Committee for broader dissemination to full SDRF membership.
 - Provides guidance to Cognitive Radio Working Group in the Technical Committee on the cognitive technologies that need to be developed to facilitate the envisioned applications.

Cognitive Radio Activities

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CR and Dynamic Spectrum Management

“...Dynamic Spectrum Management (DSM) comprises the identification and characterisation of available spectrum, the duration of availability of this spectrum, and allocation (and monitoring) of spectrum to a given node or nodes based on the number of nodes requiring access to spectrum and their desired service requirements. DSM must account for the destination(s)’s estimated receive capabilities and provision a means of source--destination co-ordination....”

Not just network operator-centric!

- Improve robustness, and/or channel-capacity usage, and/or connectivity of wireless comms using DSM.
- Interference-free and fair co-existence between primary users and opportunistic secondary users.

“Identify, Allocate, Use, Release”

Dynamic Spectrum Allocation

Paul Sutton – CTVR, TCD

Game theoretic analysis of radio resource management for Ad-Hoc networks, game theory and potential game theory for optimum distributed radio resource management – Game theory group, Mobile & Portable Research Group (MPRG) – Virginia Tech

www.mprg.org/people/gametheory

Temporal & Spatial DSA – optimized strategies for mitigating interference at DSA region borders. Tradeoffs between tweaking cell sizes at borders, guard band widths and system loads at borders, Spectrum Auctioning, Brokers – Work by Leaves & Moessner, E2R

Spectrum allocation policies – optimization of allocation policies (i.e. use of incentives) to achieve specific goals (i.e. fairness) – DimSumNet
Beaconing, yes probably but Common Access Band?

DARPA-XG – small granularity spectrum allocation.

Dynamic Spectrum Allocation

- Contiguous and fragmented DSA – optimum level of fragmentation for a given system. Tradeoffs between system flexibility and efficiency of spectrum use. – DRIVE and OverDRIVE projects

Spectrum Sensing

Radio resource measurements and spectrum opportunity recognition – Mangold, Challapali, Zhong – Wireless Comm. and Net. Dept., Philips Research

Implementation issues in spectrum sensing – Cabric – Berkeley Wireless Research Centre

Detection and efficient signalling of spectral resources – Weiss, Hillenbrand, Jondral, Krohn – University of Karlsruhe

Lots more...!

CR and Dynamic Spectrum Management

Spectrum Sensing

ID Existing Services

Identify

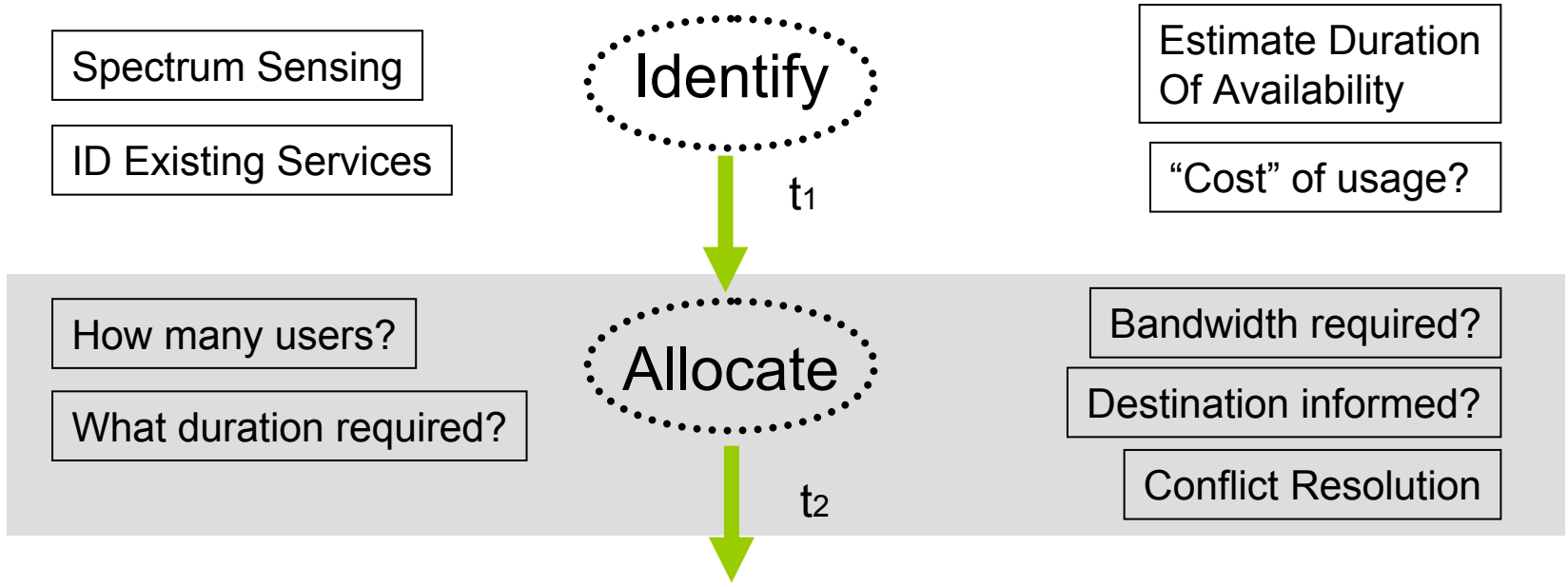
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Estimate Duration
Of Availability

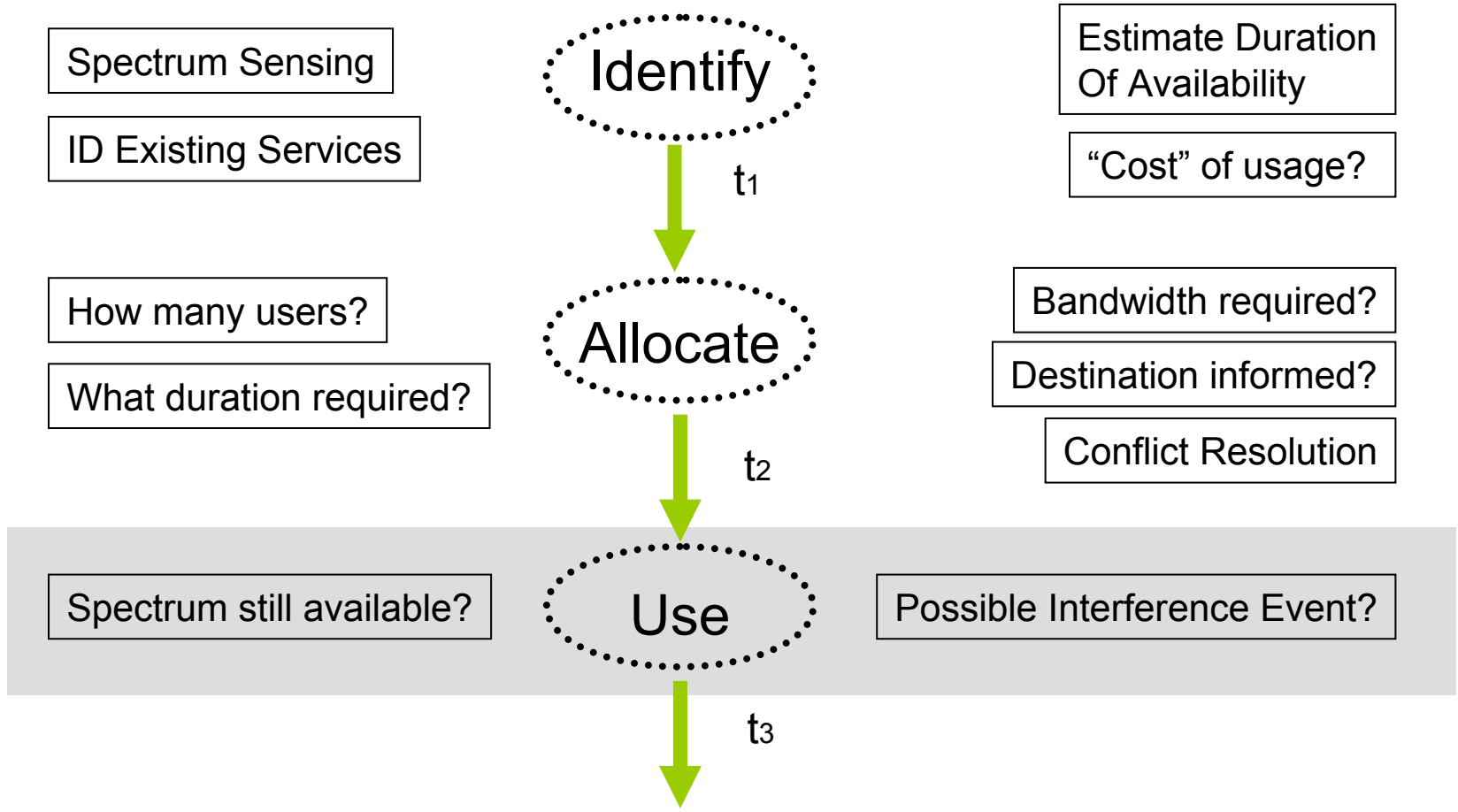
“Cost” of usage?



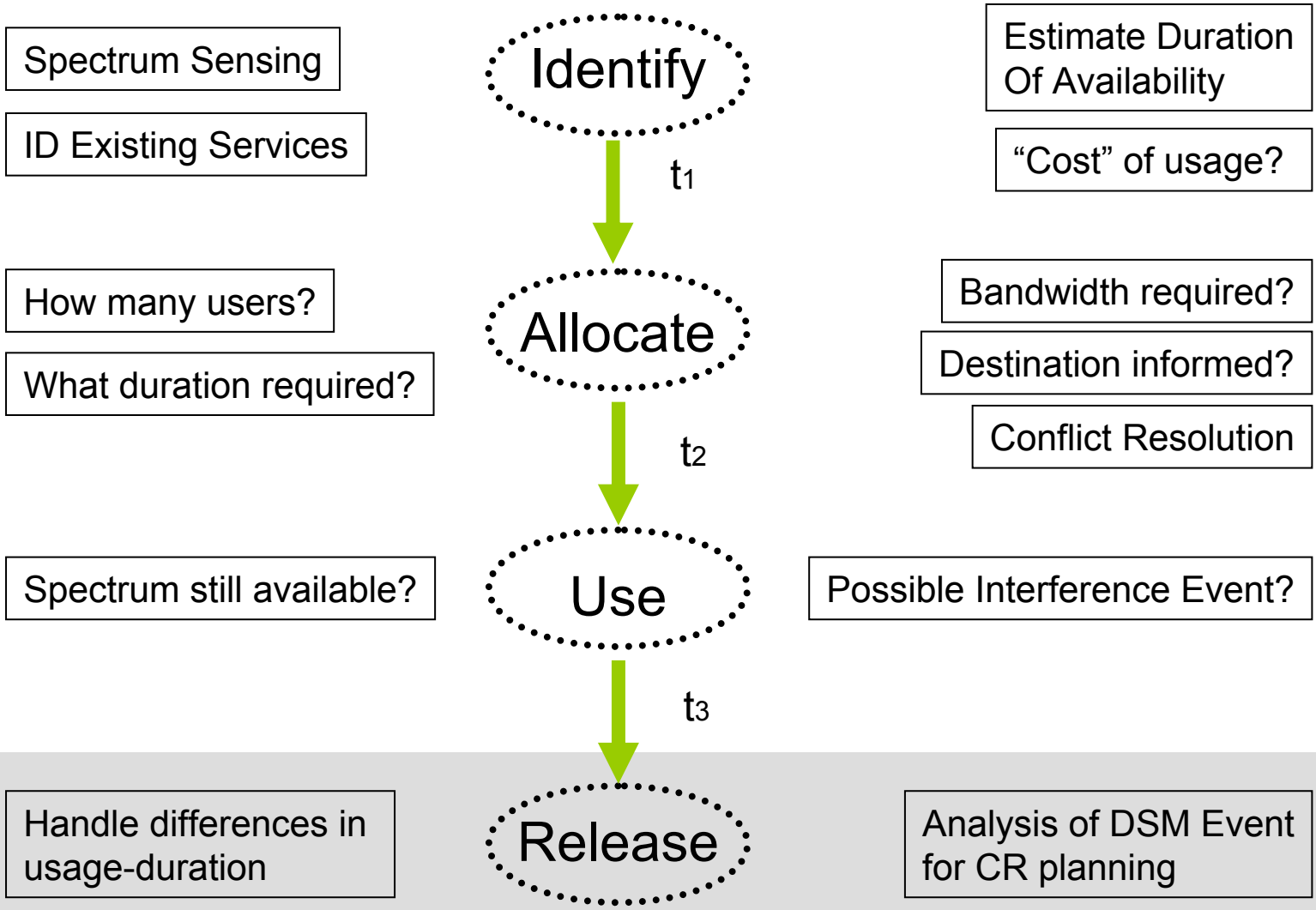
CR and Dynamic Spectrum Management



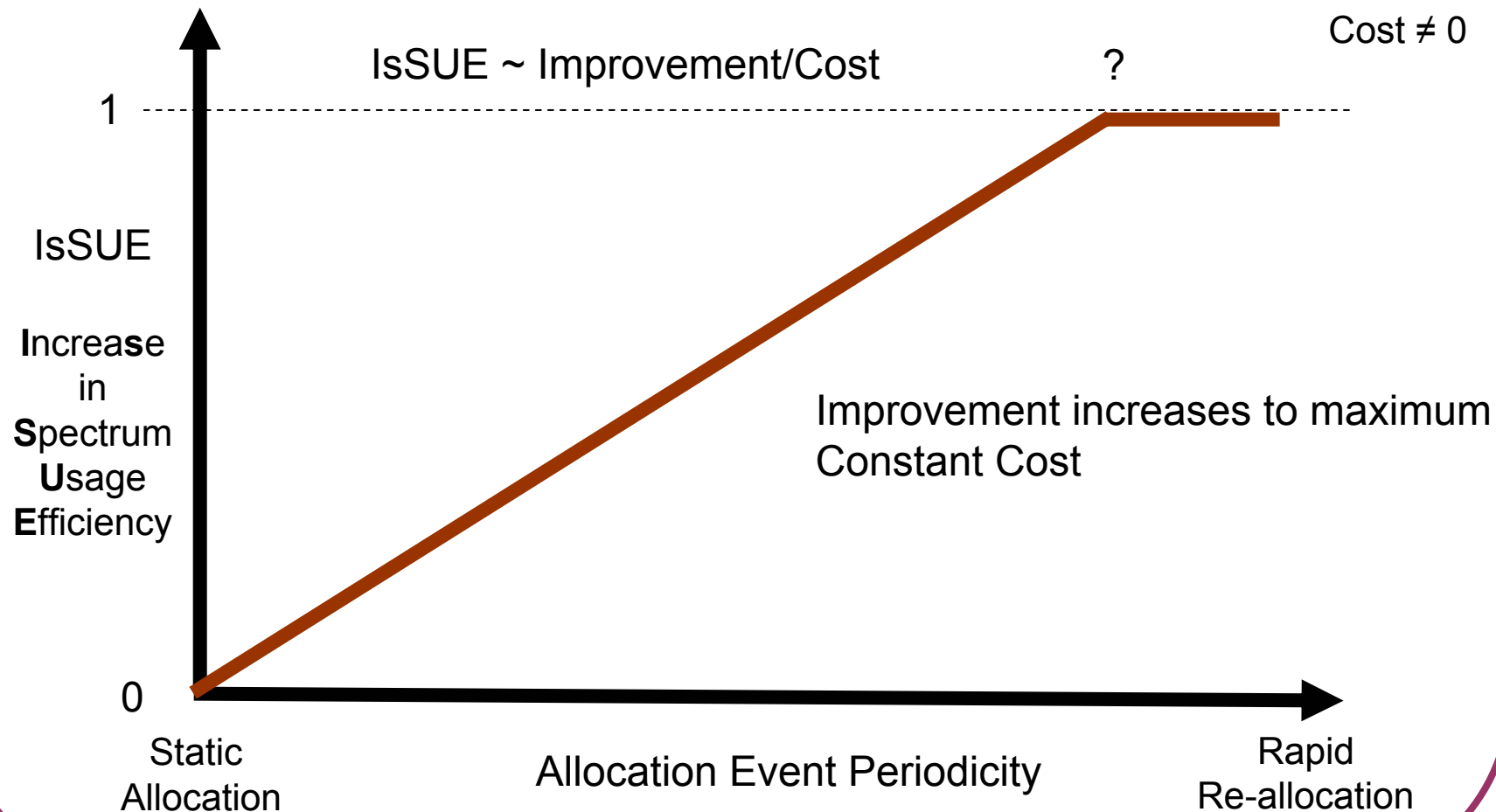
CR and Dynamic Spectrum Management



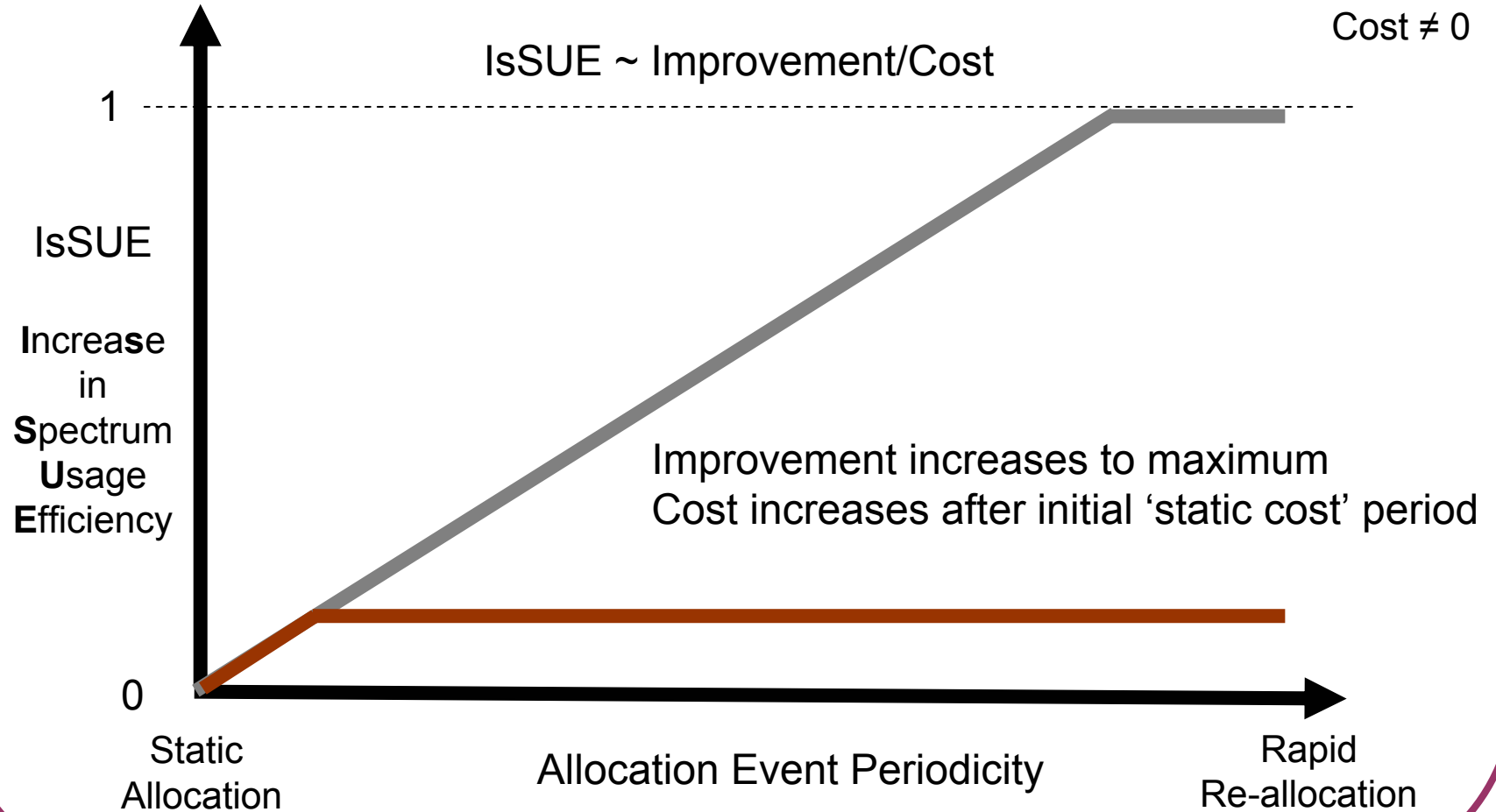
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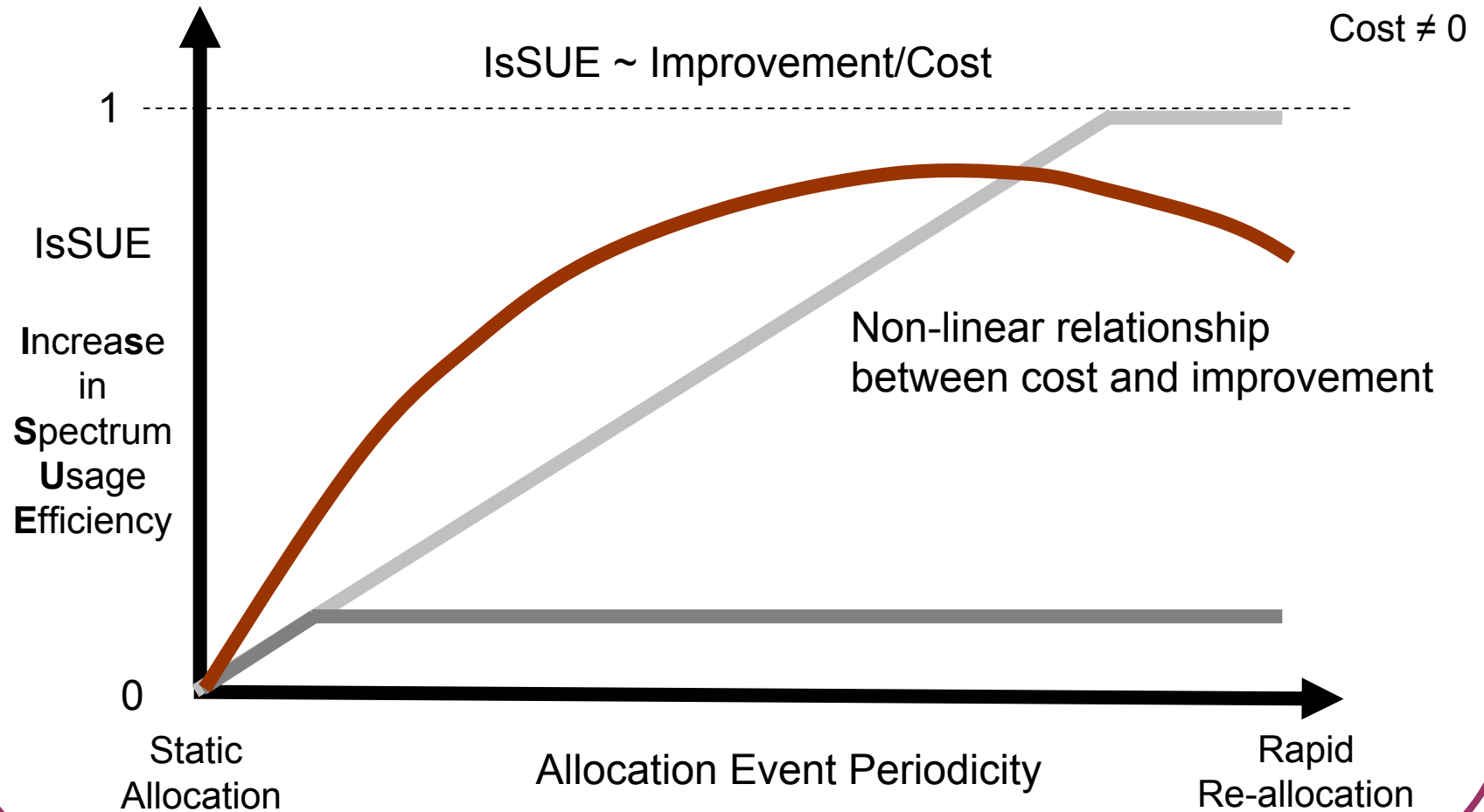
Big IsSUE with DSM



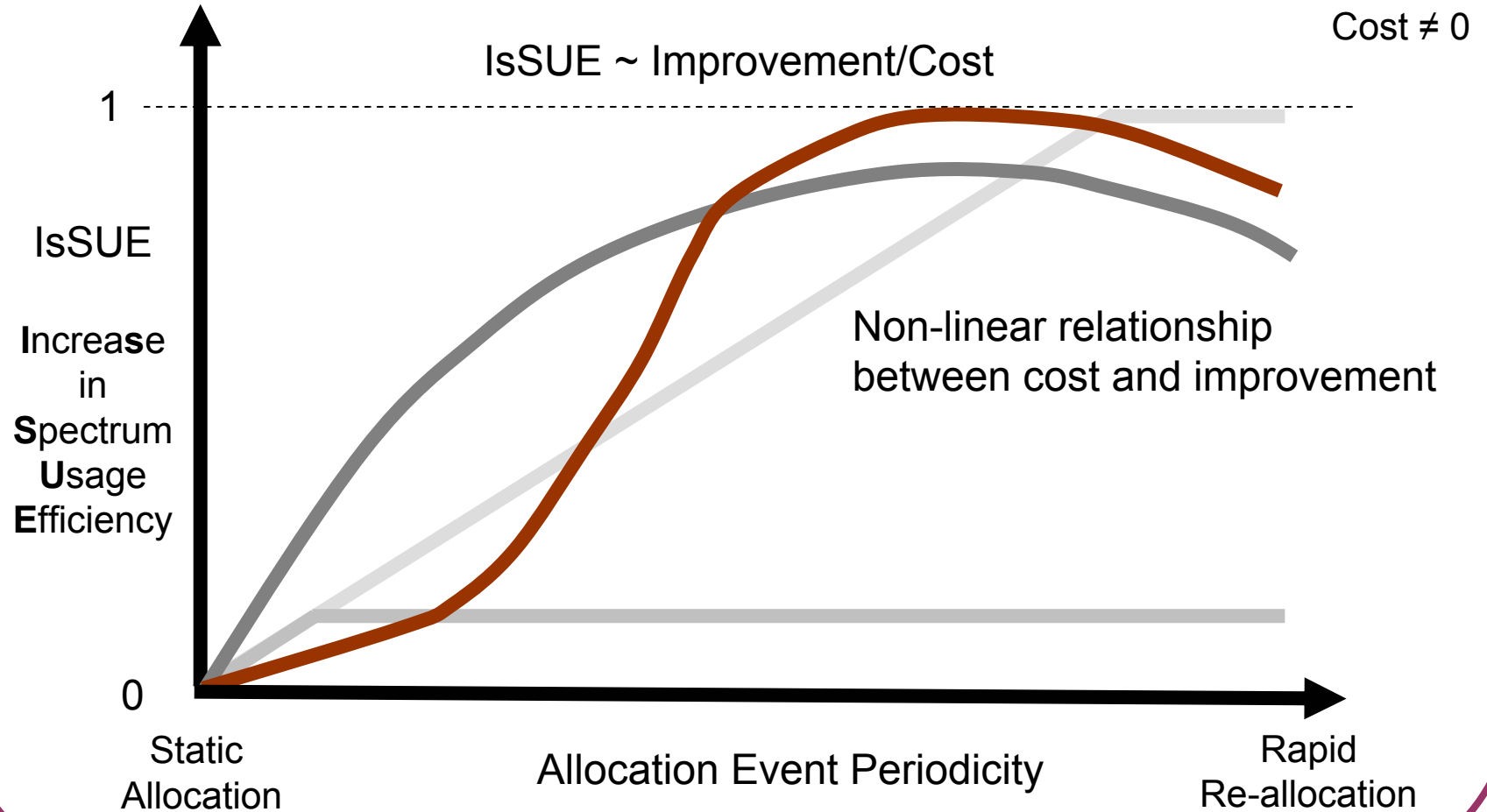
DSM Big IsSUE



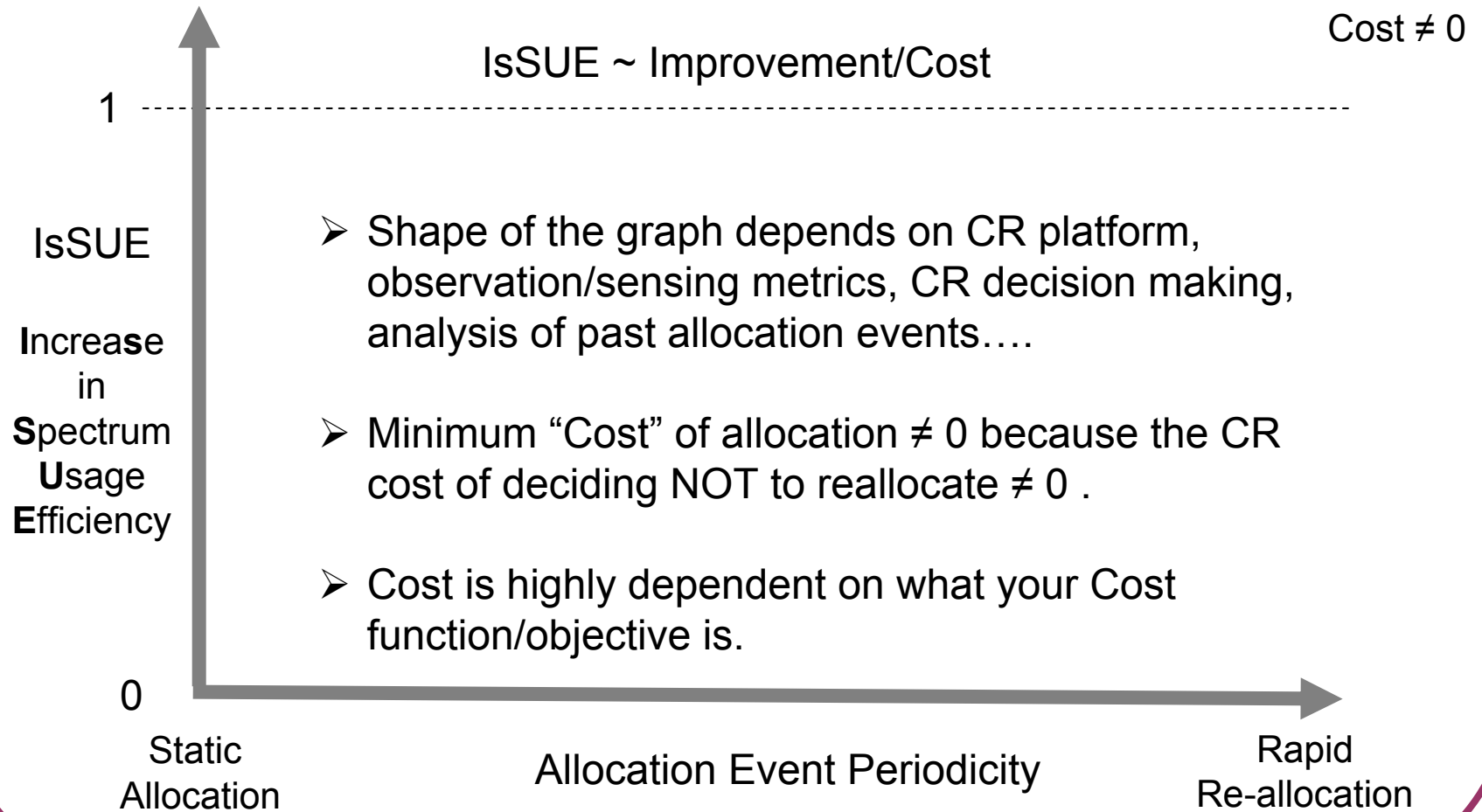
DSM Big IsSUE



DSM Big IsSUE



What is the expected trend?



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Summary – SDRF CR

- CRWG: Forming a general consensus of what CR and CR-related terms mean and imply.
- CA-SIG: Identifying wireless communication and control scenarios where CR and CR Apps could provide a better or optimal solution than traditional approaches.
 - What are these apps?
 - What are the requirements to create these apps
 - Are these requirements more focused on systems management, physical layer, sensing, security or multiple sectors?

Summary - DSM

- Dynamic Spectrum Management
 - Towards interference-free co-existence.
 - Moving spectrum regulation to device/base-station domain increases the attractiveness of 'greedy' and 'abusive' devices and users.
 - Ability to rapidly re-allocate spectrum does not necessarily imply that rapid re-allocation is always required.
Reconfiguration on a device-level may not be an onerous task as imagined.
- Increase economic attractiveness of DSM by actually trying it out.
- Irish Regulator (COMREG) is expected to permit test & trial of DSM.
- Yes, this presentation will be in the drop-box.

Cognitive Radio Working Group Contacts

- Conference Calls
 - Bi-weekly,
 - Wednesdays, 1600GMT, 1700 E-DT, 1100hrs EDT, 1000hrs CT,
 - 877-283-2663 passcode 0197232# (May change!)
- Contacts
 - John.grosspietsch@motorola.com (CRWG Chair)
 - john.polson@gd-decisionsystems.com
 - ohara@syrres.com
 - pkolodzy@kolodzy.com
- Web and Mailing List
 - <http://www.sdrforum.org/CognitiveRadioWG/>
 - cognitiveradio@sdrforum.org

CogAppsSIG Participation

- E-mail reflector
 - CogAppsSIG@sdrforum.org
 - E-mail sseidel@raytheon.com (Chair) to be added to the mailing list.
- Regular telecons held bi-weekly on Thursdays at 11 AM EDT (US Eastern Daylight Time)
 - 405-319-0674
 - PC: 818858
 - Next call Sept. 29 with inputs to table due
- SDRF Meetings
 - SDR'05: Anaheim – November 14-18, 2005
 - Miami – January 16-19, 2006

Thank you

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