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The fully networked human?
Innovations for future networks and services

Radio Resource Management in OFDMA-CRN Considering Primary User Activity and Detection Scenario

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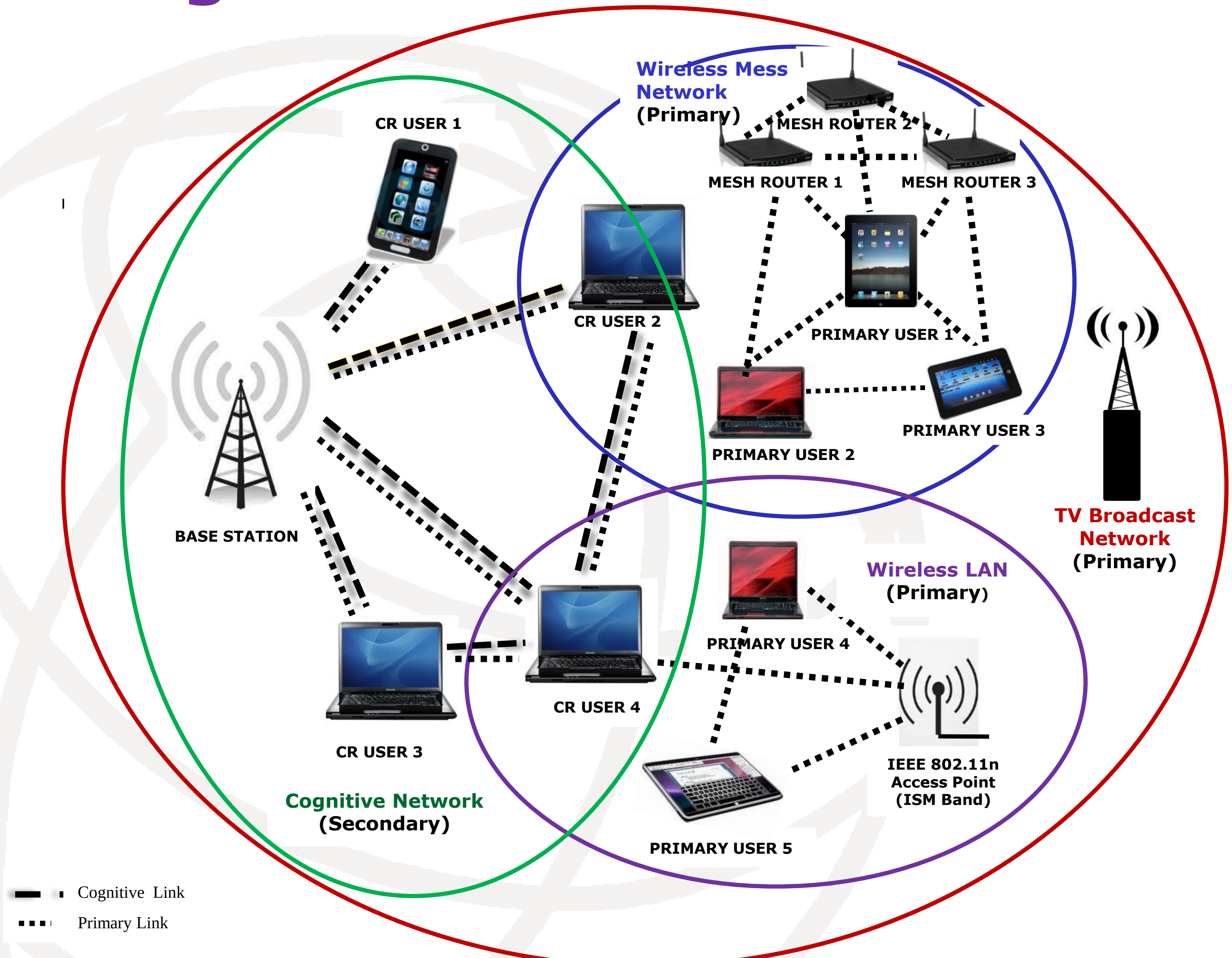
Outline

- Cognitive Radio Environment
- Real-time Observations & Requirement Analysis
- Learning in Cognitive Radio Networks
- Resource Allocation in Multi-carrier Systems
- Problem Formulation in OFDMA-CRN
- Simulation Results
- Conclusion & Future Works

Cognitive Radio Environment



Opportunity in 900 MHz Band

Measurements taken at Adyar, Chennai on 16th August, 2011

Fig.1. At 12:14:12 p.m.

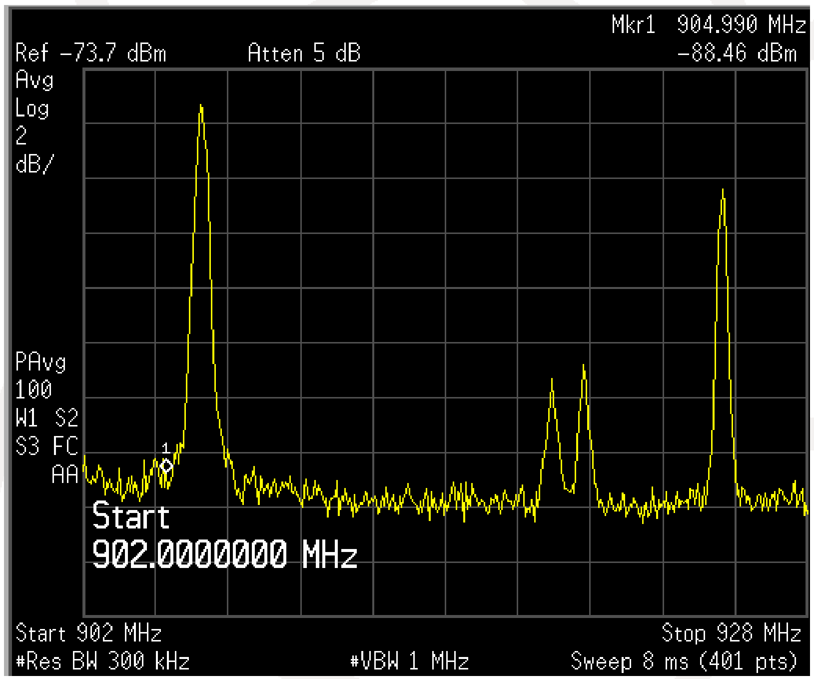
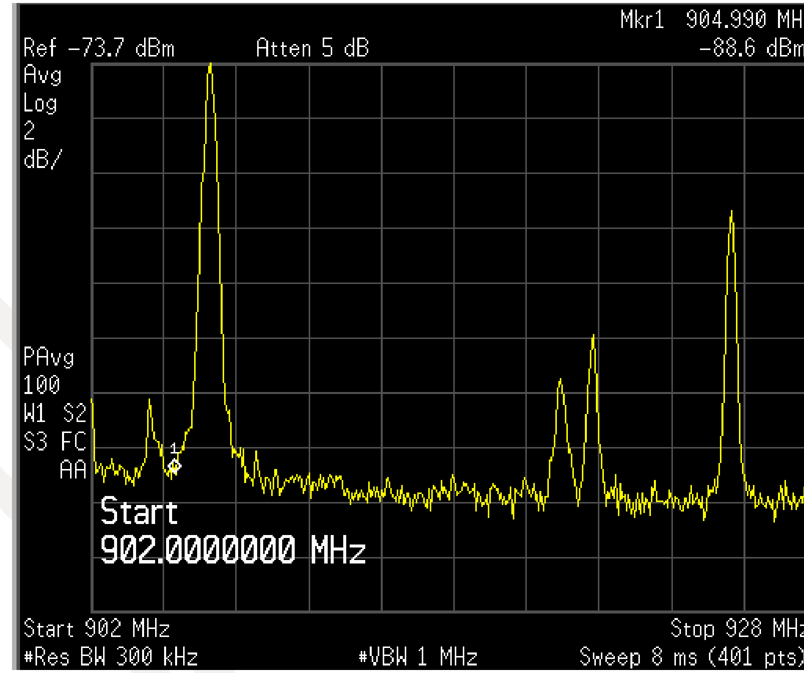


Fig.2. At 12:24:44 p.m.



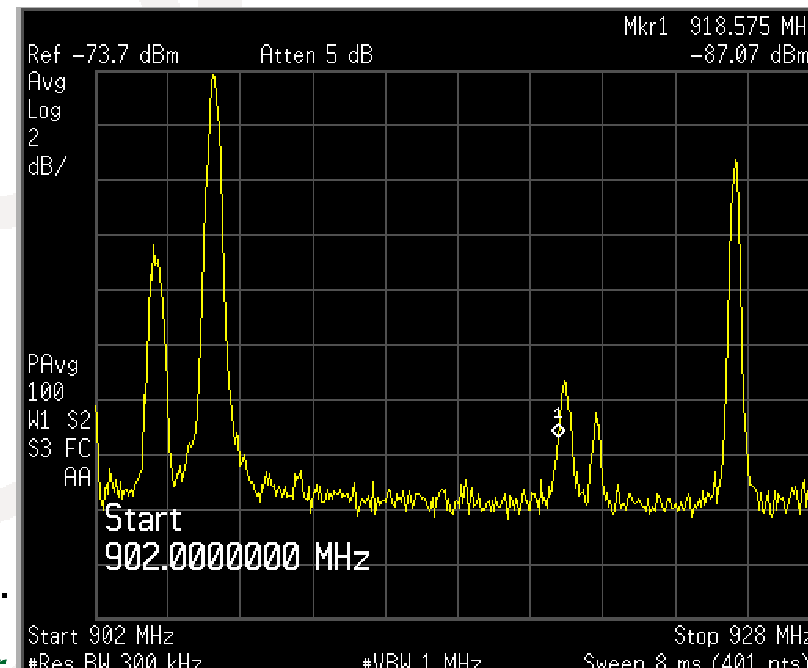


Fig.3. At 12:49:13 p.m.

Spectrum Usage in 2.4 GHz Band

On 24th August, 2011 (Adyar, Chennai)

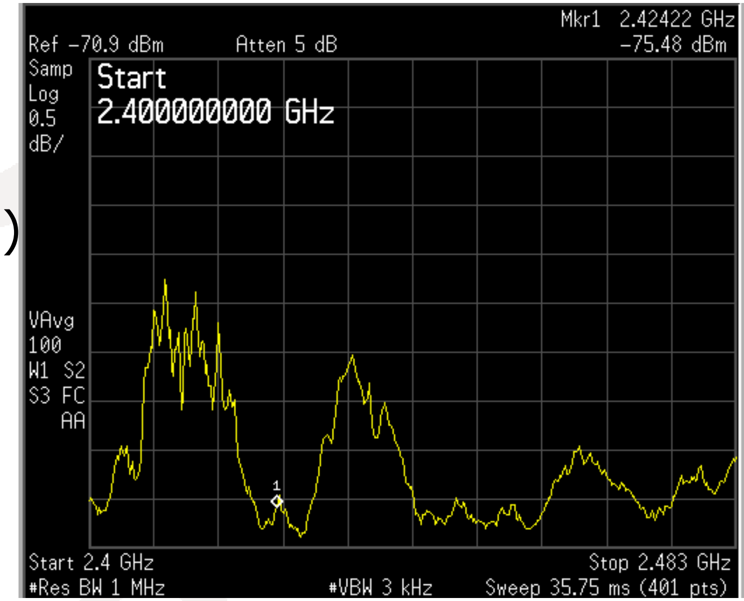


Fig.1. At 11:30:43 a.m.

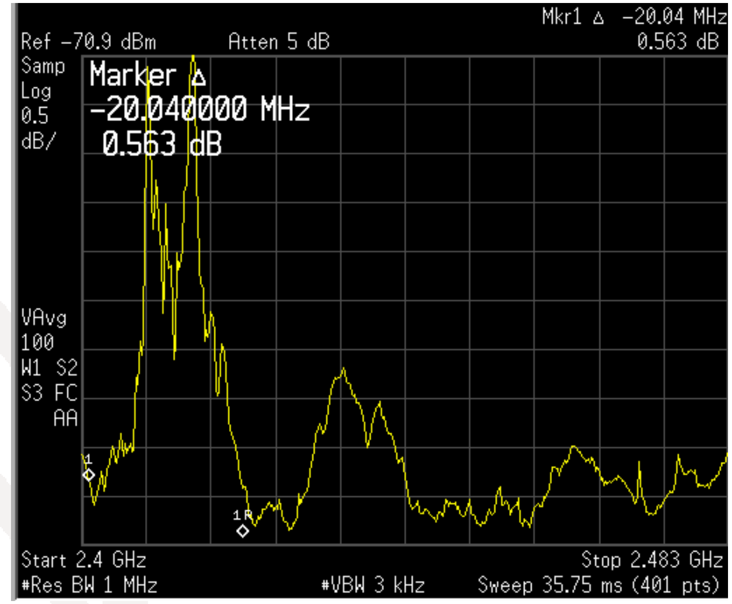


Fig.2. At 11:39:31 a.m.

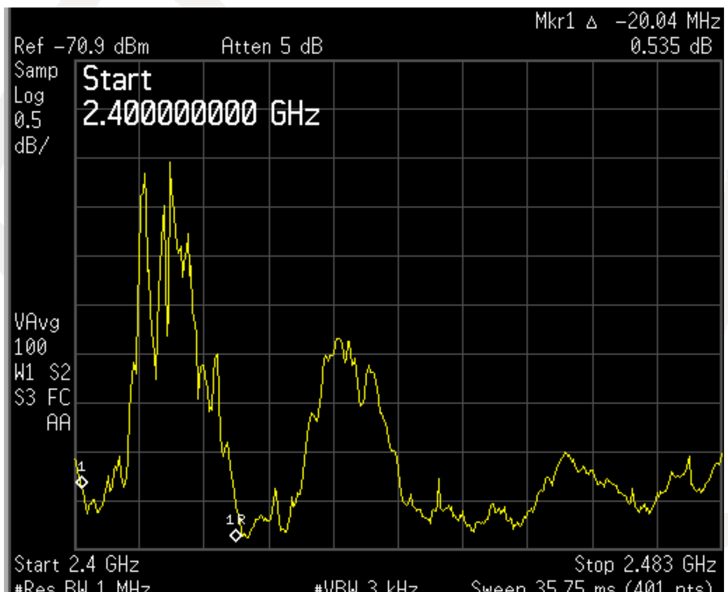
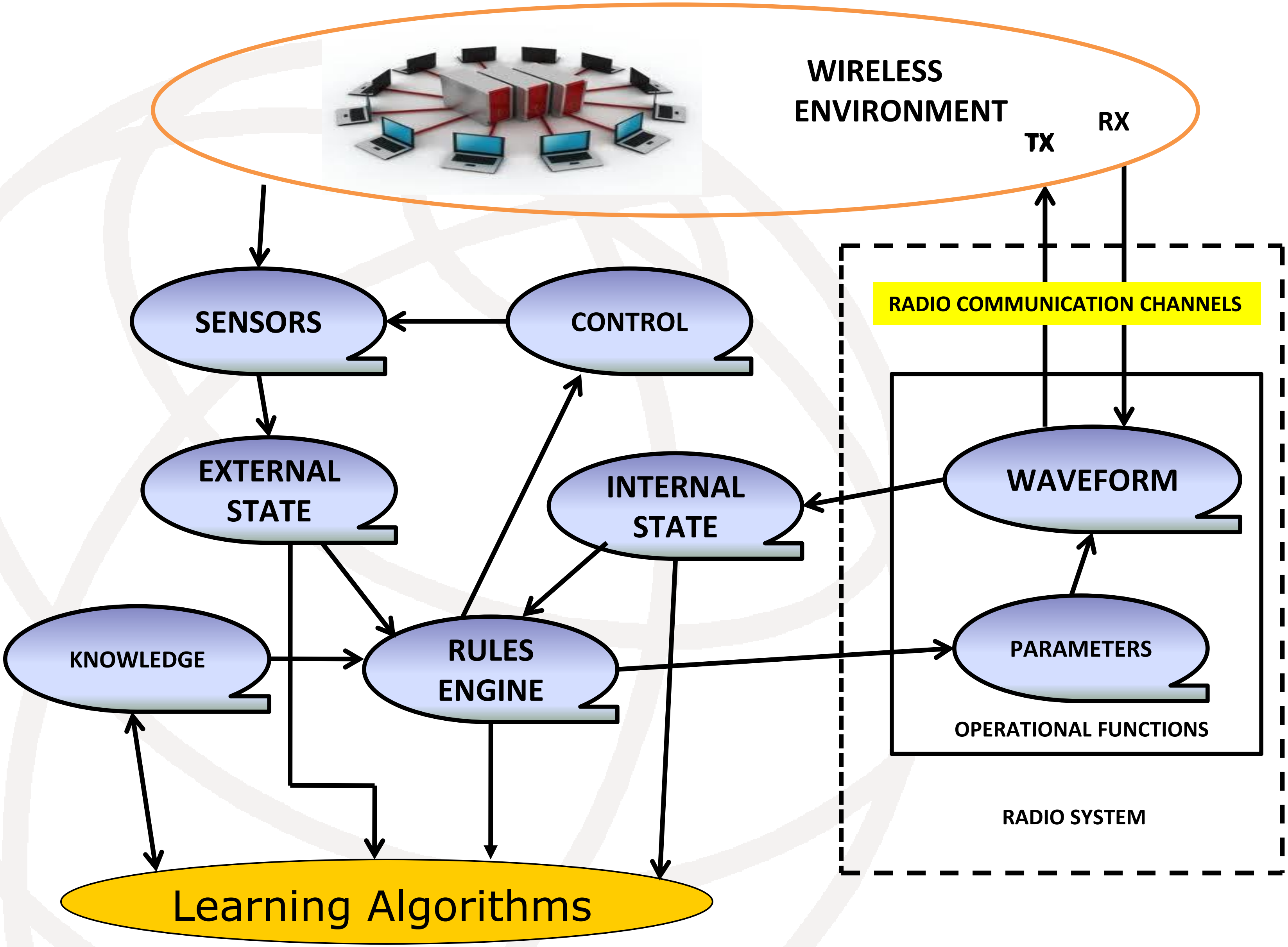


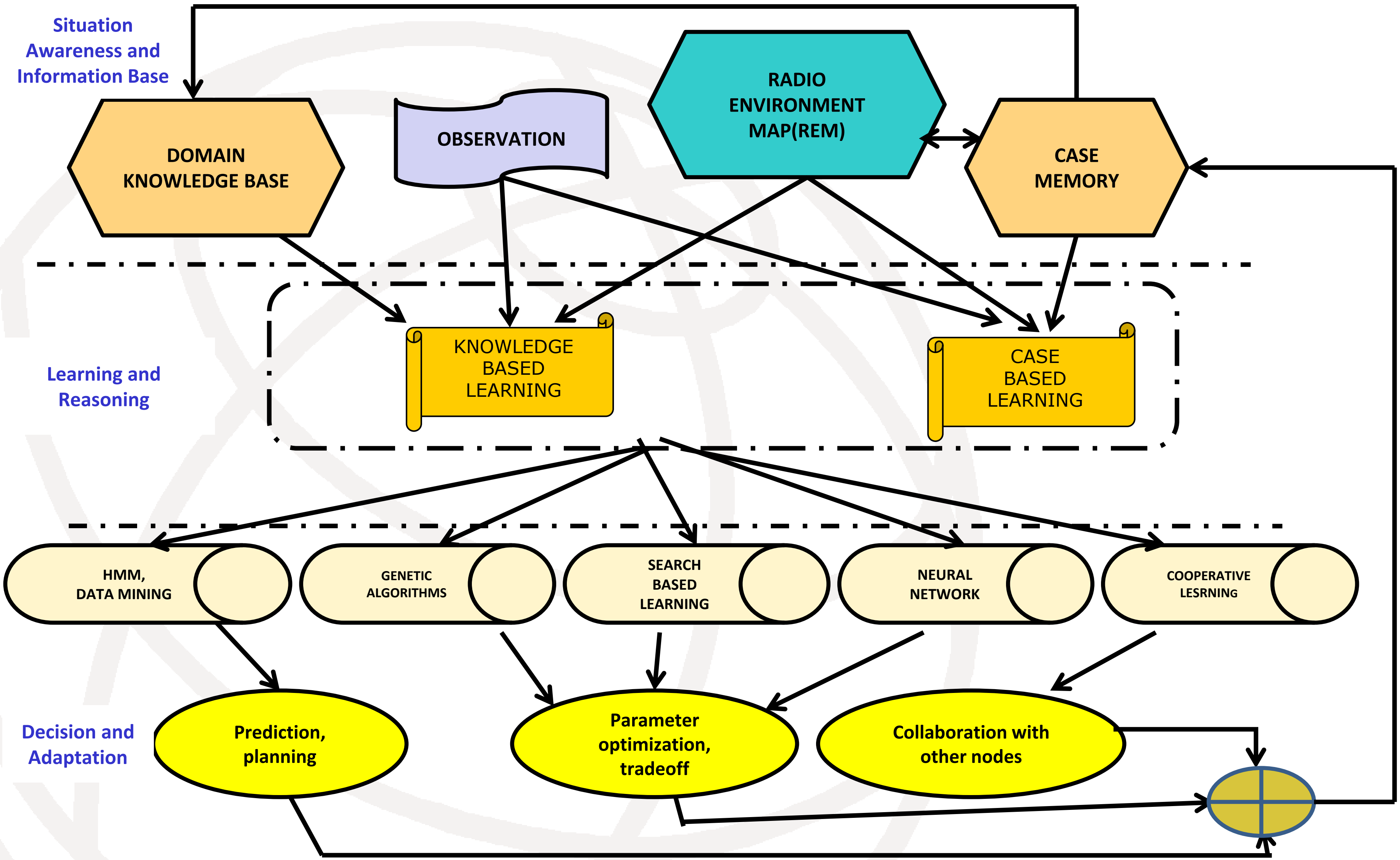
Fig.3. At 11:39:51 a.m.

Fig.4. At 11:40:39 a.m.

Learning in Cognitive Radio Network



Learning in a Broader Perspectives



Ref: Joseph Gaeddert et al., "Applying Artificial Intelligence to the Development of a Cognitive Radio Engine", http://wireless.vt.edu/archives/download/ApplyingArtificialIntelligence.pdf

Resource Allocation in Multi-carrier Base Cognitive Radio Networks

- Is situation-aware learning is enough in multi-carrier systems?
- Resource allocation
  - Sub-carrier selection
  - Power allocation
- Resource optimization

Resource Allocation in OFDMA-CRN: Problem Formulation

Objective Function:

$$\max_{P_{g,k}} \sum_{g=1}^{G} \sum_{k=1}^{K} \frac{\alpha_g |M_g| \log_2(1+\gamma_{g,k} P_{g,k})}{K} - \phi_k L(P_{g,k}) - \beta_k F(P_{g,k})$$

Subjected to

(i) $\sum_{g=1}^{G} \sum_{k=1}^{K} P_{g,k} I_k \leq I_{th}$

(ii) $P_{g,k} \geq 0, g = 1,2,\ldots,G \quad k = 1,2,\ldots,K$

(iii) $P_{g,k} P_{g',k} = 0 \ \forall \ g' \neq g$

(iv) $\sum_{g=1}^{G} \alpha_g = 1$

Optimization Methods

The overall objective defined can be assumed to be optimization of K independent functions:

$$D_k(\lambda) = \sum_{g=1}^{G} \left\{ \frac{\alpha_g |M_g| \log_2\left(1+\gamma_{g,k} P_{g,k}\right)}{K} - \left(\sum_{n=1}^{N} \lambda_n I_k^{(n)} P_{g,k} + \phi_k L\left(P_{g,k}\right) + \beta_k F\left(P_{g,k}\right) \right) \right\}$$

Applying Karush–Kuhn–Tucker (KKT) conditions for optimal power allocation,

$$\nabla_{P_{g,k}} D_k(\lambda) = \frac{\alpha_g |M_g| \gamma_{g,k}}{K(1+\gamma_{g,k} P_{g,k}^*) \log 2} - \sum_{n=1}^{N} \lambda_n I_k^{(n)} - \phi_k C_1 - \beta_k C_2 = 0$$

The KKT condition provides a basis for a closed-form solution, and $P^*_{g,k}$ can be derived as follows

$$P_{g,k}^* = \frac{\alpha_g |M_g|}{K[\sum_{n=1}^{N} \lambda_n I_k + \phi_k C_1 + \beta_k C_2] \log 2} - \frac{1}{\gamma_{g,k}}$$

Optimization Methods cont..

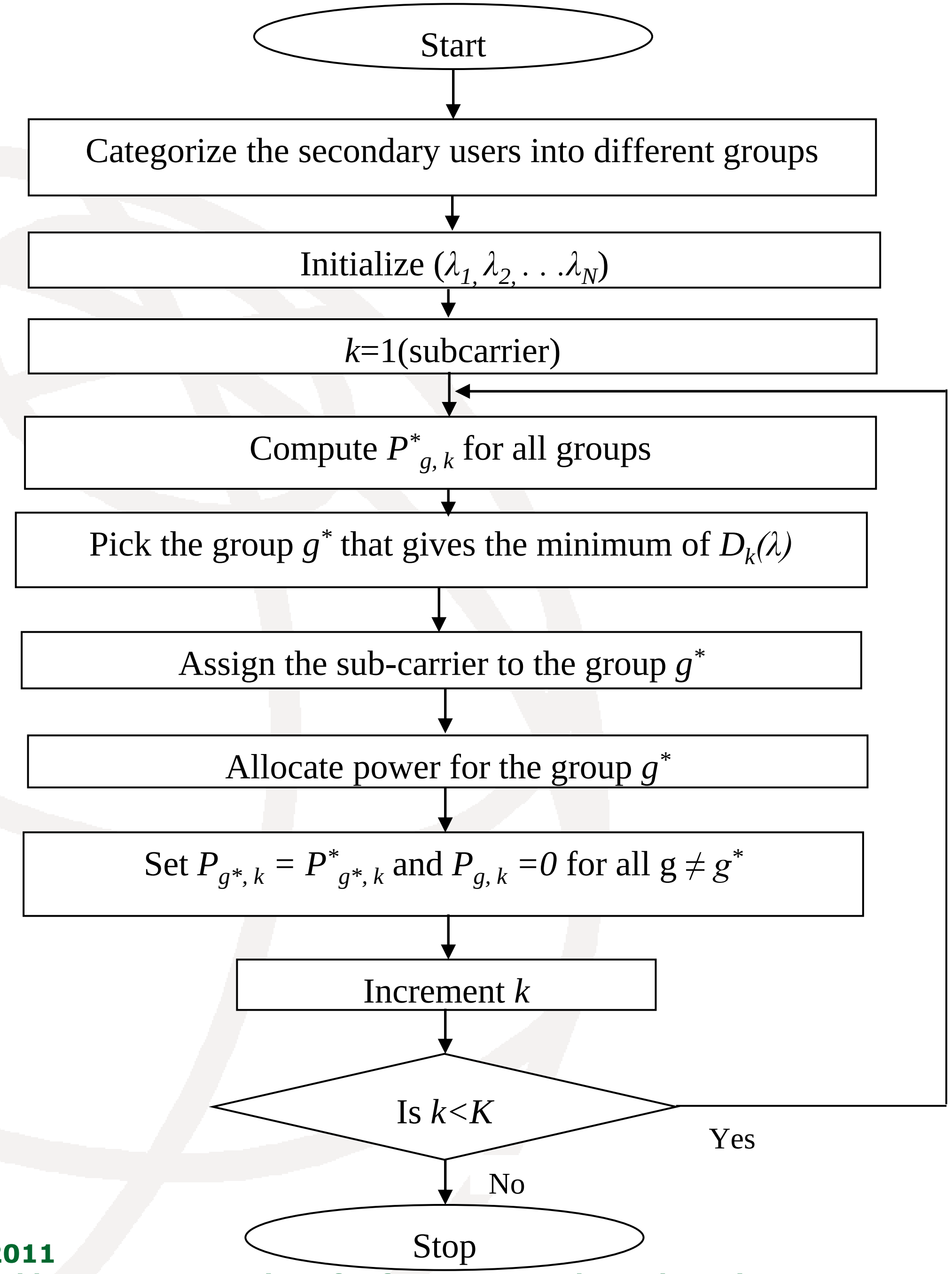
The optimal result can be obtained as

$$D_k^*(\lambda) = max_g \left\{ \frac{\alpha_g |M_g| \log_2(1+\gamma_{g,k} P_{g,k})}{K} - \left(\sum_{n=1}^{N} \lambda_n I_k \; P_{g,k}^* + \; \phi_k L(P_{g,k}^*) + \beta_k F(P_{g,k}^*) \right) \right\}$$

The λ is updated in step-size sequence given by

$$\lambda_n^{(t+1)} = \left(\lambda_n^{(t)} - \delta^{(t)} \left(I_{th}^{(n)} - \sum_{g=1}^{G} \sum_{k=1}^{K} P_{g,k} \, I_k^{(n)} \right) \right)^+$$

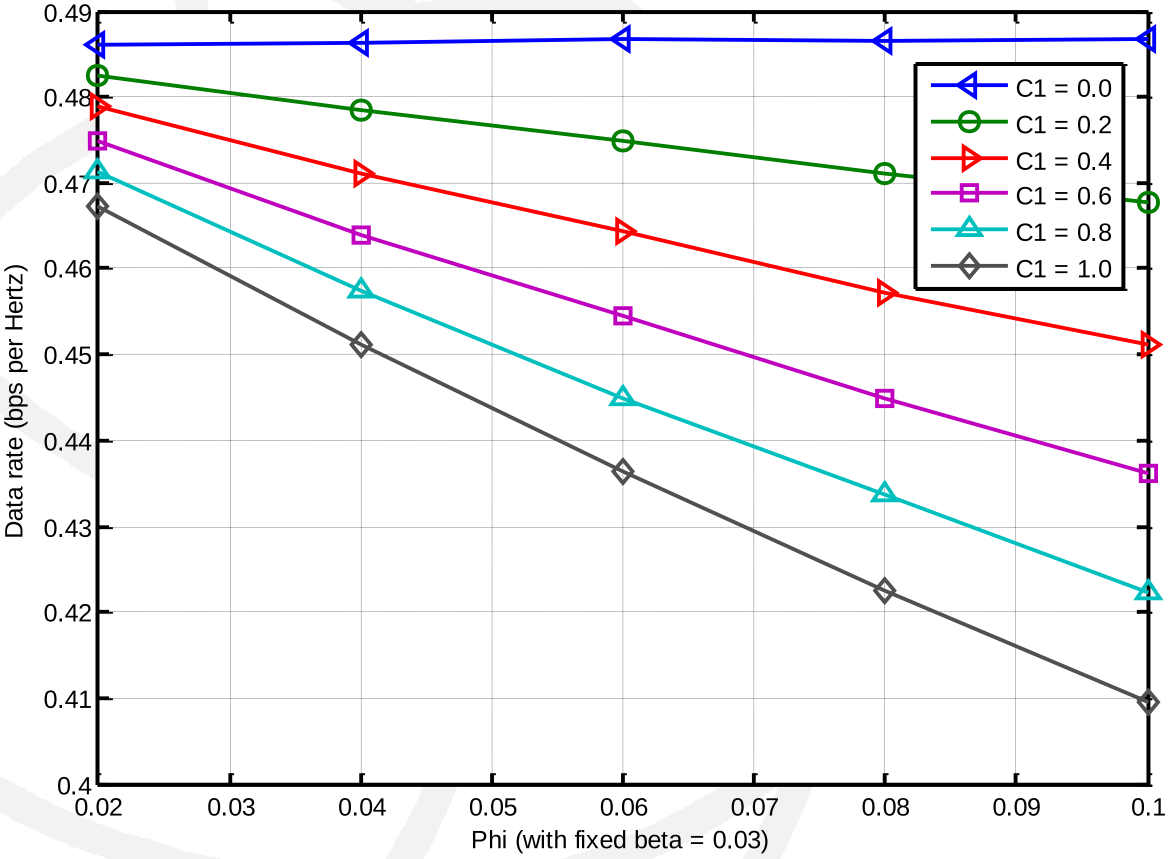
Sub-carrier and Power Allocation (SPA) Algorithm



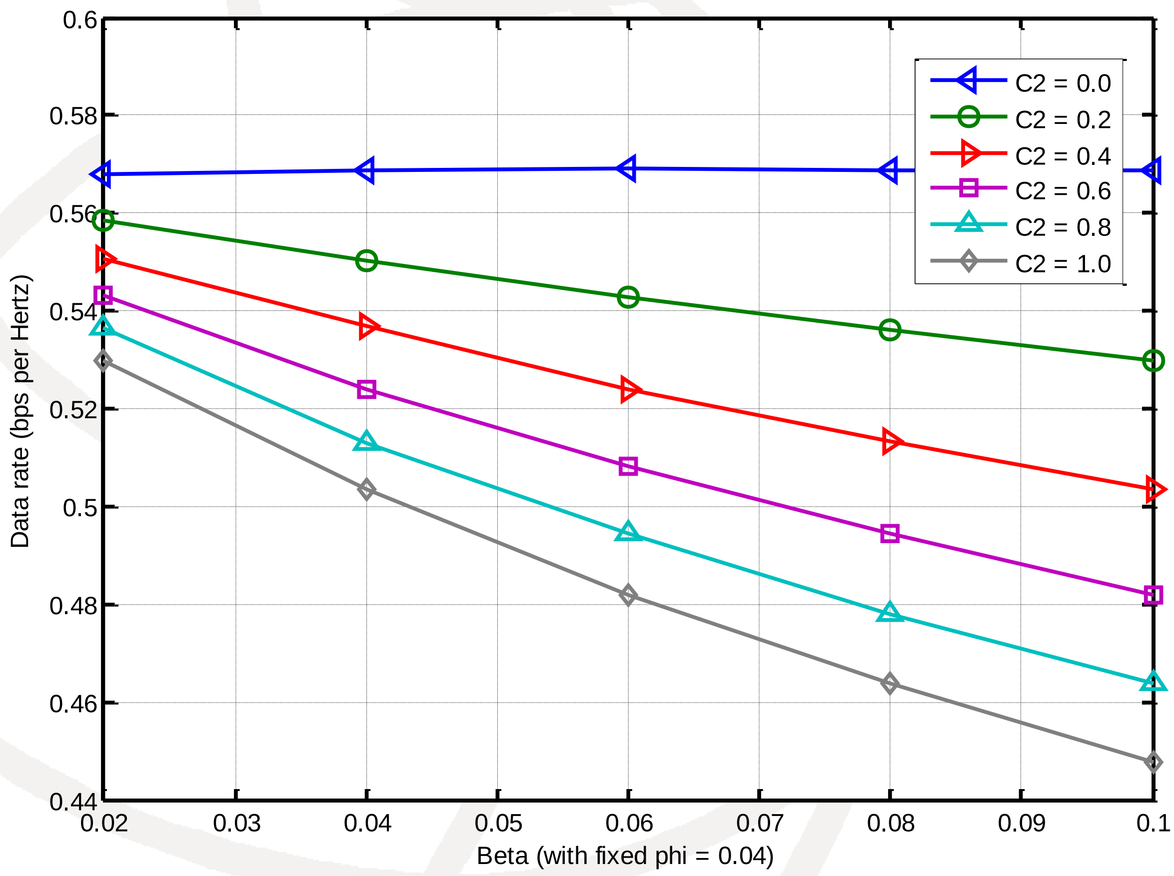
Main Simulation Parameters

Parameters	Description	Value
N	Number of primary users	2
K	Number of OFDM sub-carriers	128
B	Maximum spectrum hole	10MHz
G	Number of groups	10
$\|M_g\|$	Number of secondary users in each group *g*	4

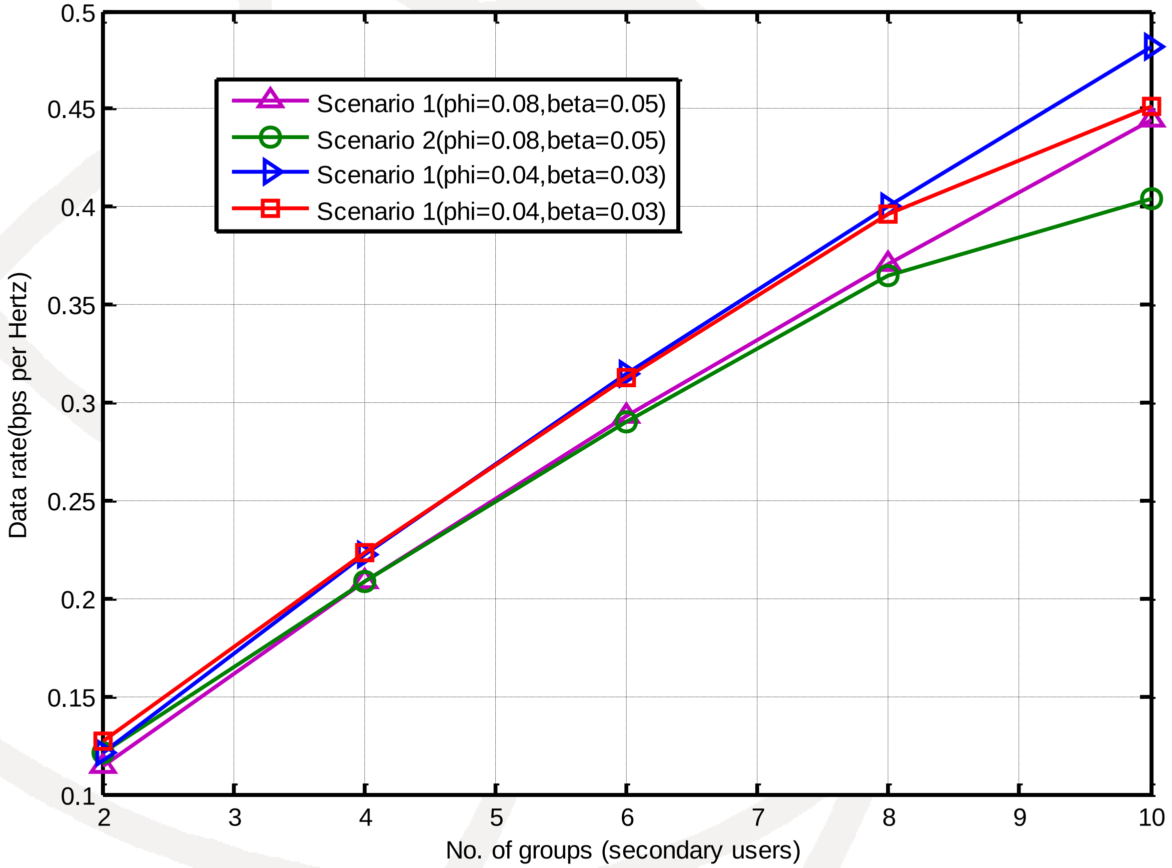
Effects of Varying Loss Parameters



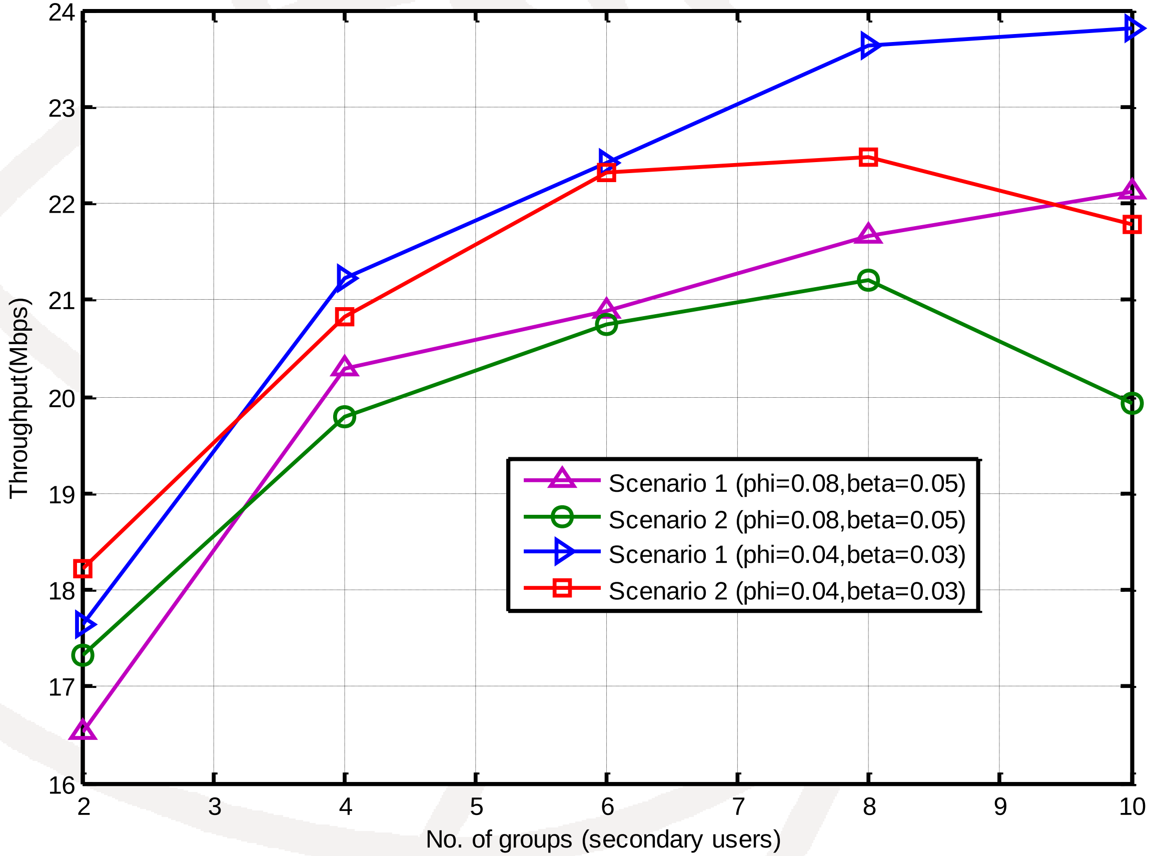
Effects of Varying Detection Parameters



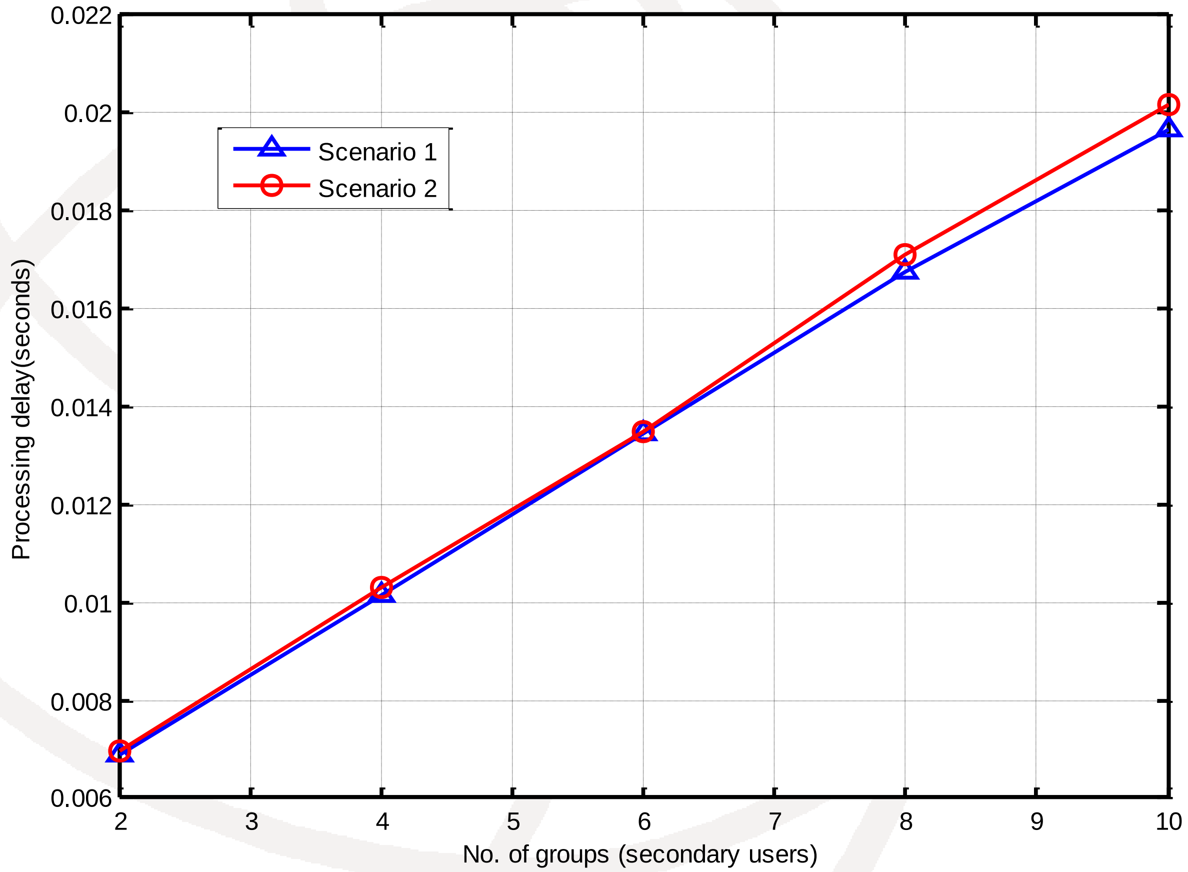
Sum Data Rates in Two Proposed Scenarios



Throughput Comparison



Assessment of Processing Delay



Conclusion & Future Work

- Analysed the spectrum availability based on real-time measurements.
- Discussed the learning scenarios
- Defined the objective function and optimized it analytically.
- Developed Sub-carrier and Power Allocation (SPA) Algorithm for OFDMA-CRN.
- Analysis & simulation of the effect of both issues i.e. primary user activity and detection
- Unification of learning algorithm with sub-carrier allocation in OFDMA-CRN is our future work.

Thank You