ITU Kaleidoscope 2013
Building Sustainable Communities

Harmonized Q-Learning for Radio Resource Management in LTE Based Networks

Dr. Dhananjay Kumar M.E., M.Tech., Ph.D.

Department of Information Technology
Anna University

MIT Campus, Chennai, India
dhananjay@annauniv.edu

Kyoto, Japan
22-24 April 2013

Outline

- Real Time Spectrum measurements
- System Architecture
- Q-Learning in Cognitive Radio
- Multi agent Q-Learning
- HQL based resource allocation in CR Based LTE Networks
- Simulation Results
- Conclusion and Future Works

Opportunity in 1.79GHz-1.84GHz

Measurement taken at Adyar, Chennai in wide band on 21st Sept 2012

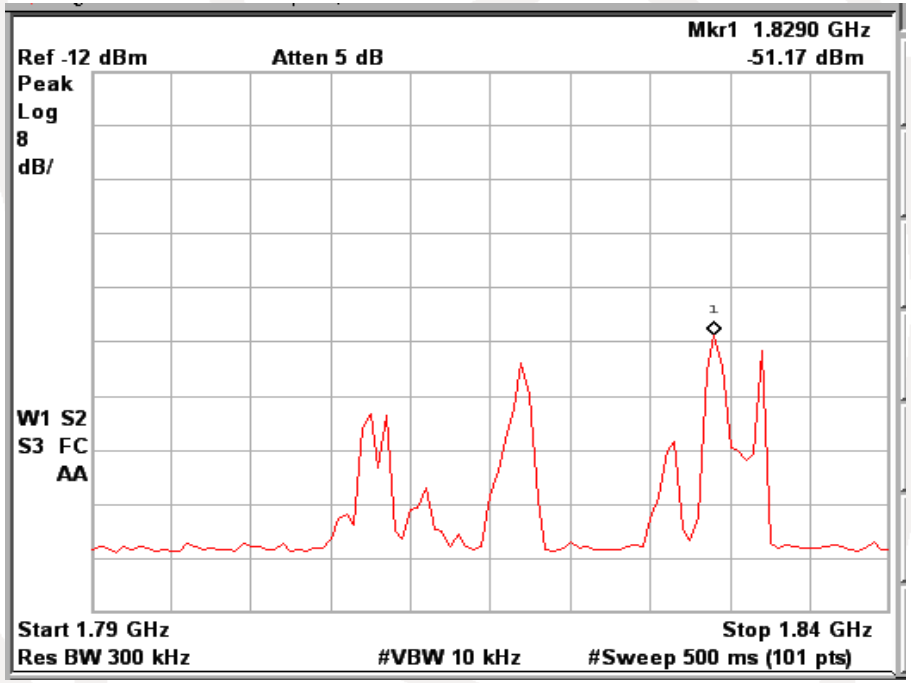


Fig.1. At 10:11:17 a.m

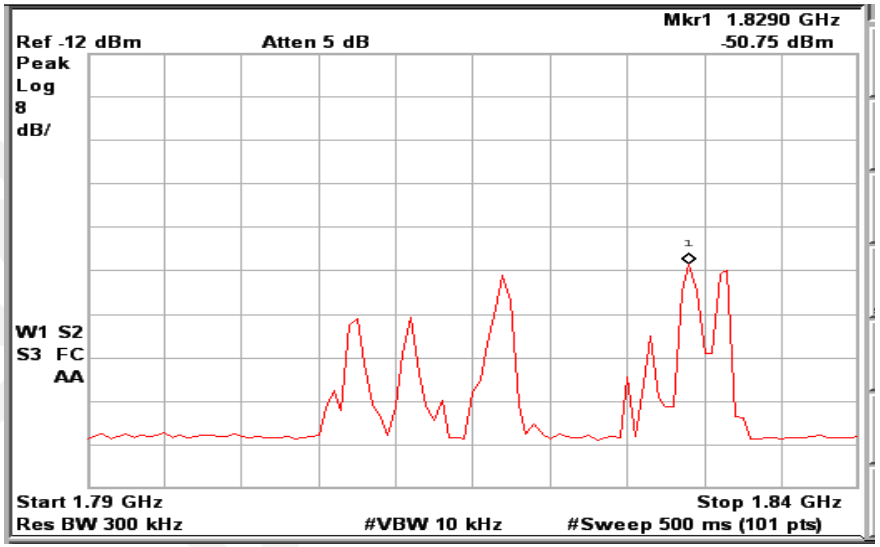


Fig.2. At 10:12:08 a.m

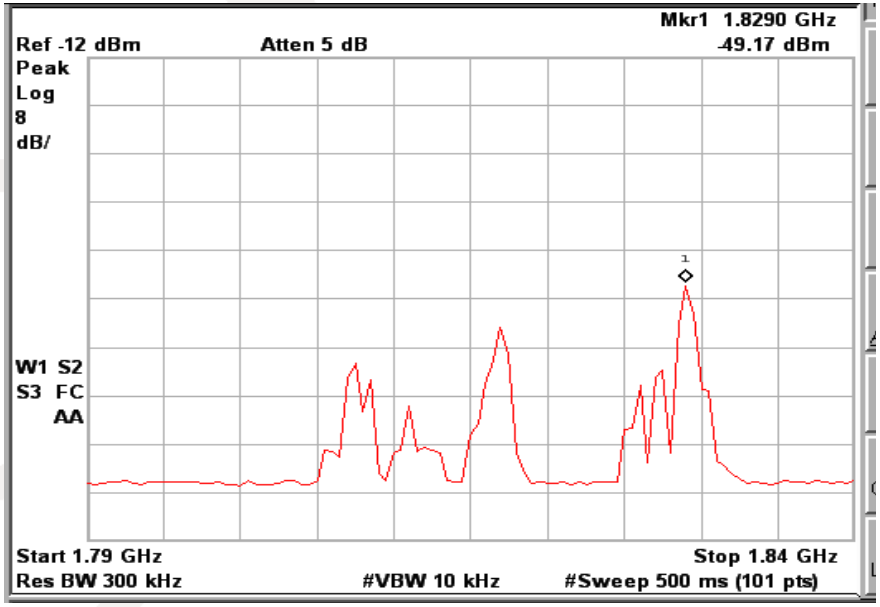


Fig.3. At 10:12:26 a.m

Cognitive Radio Network (CRN) Environment

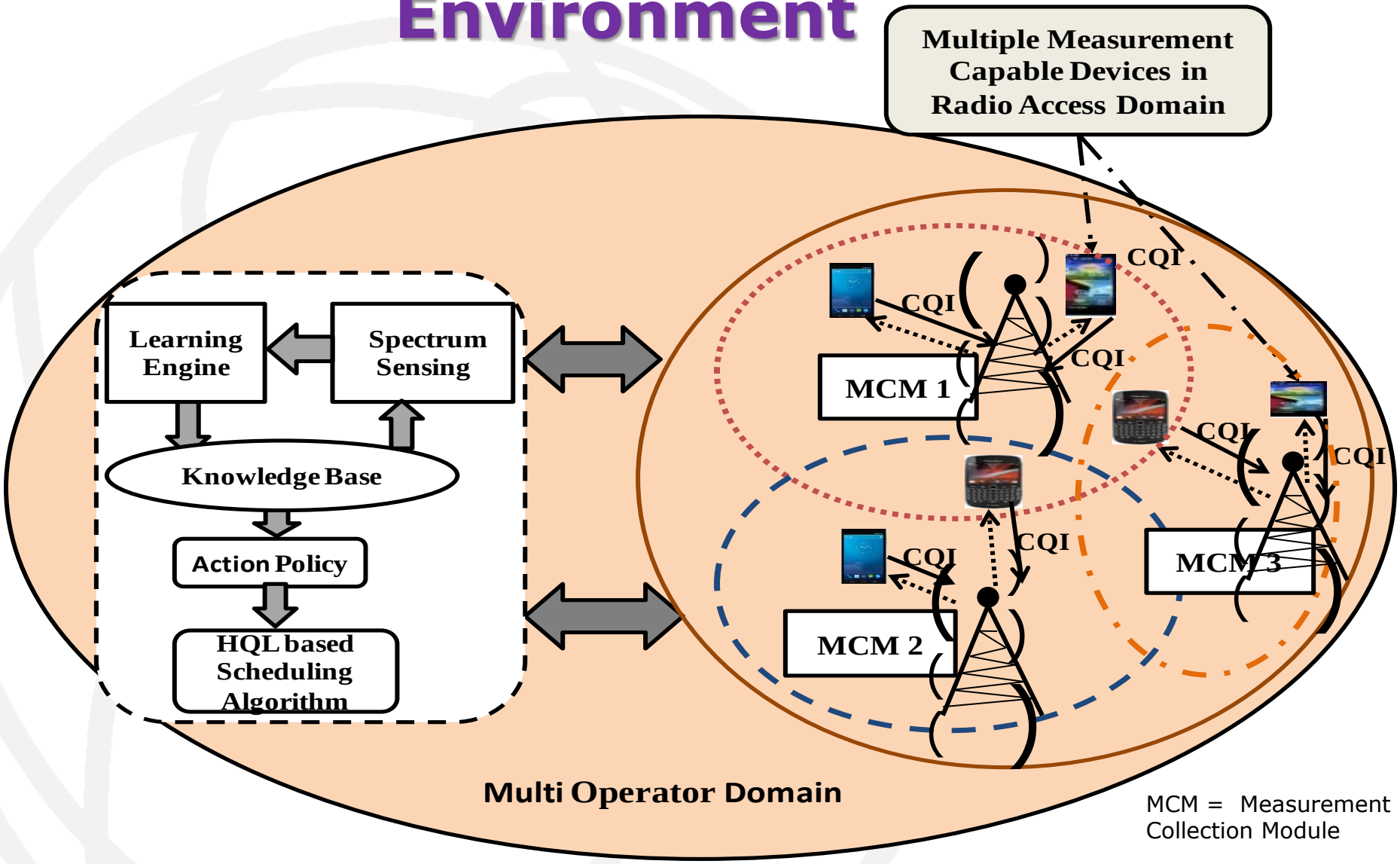


Fig.4. Learning in a Cellular Cognitive Radio Network

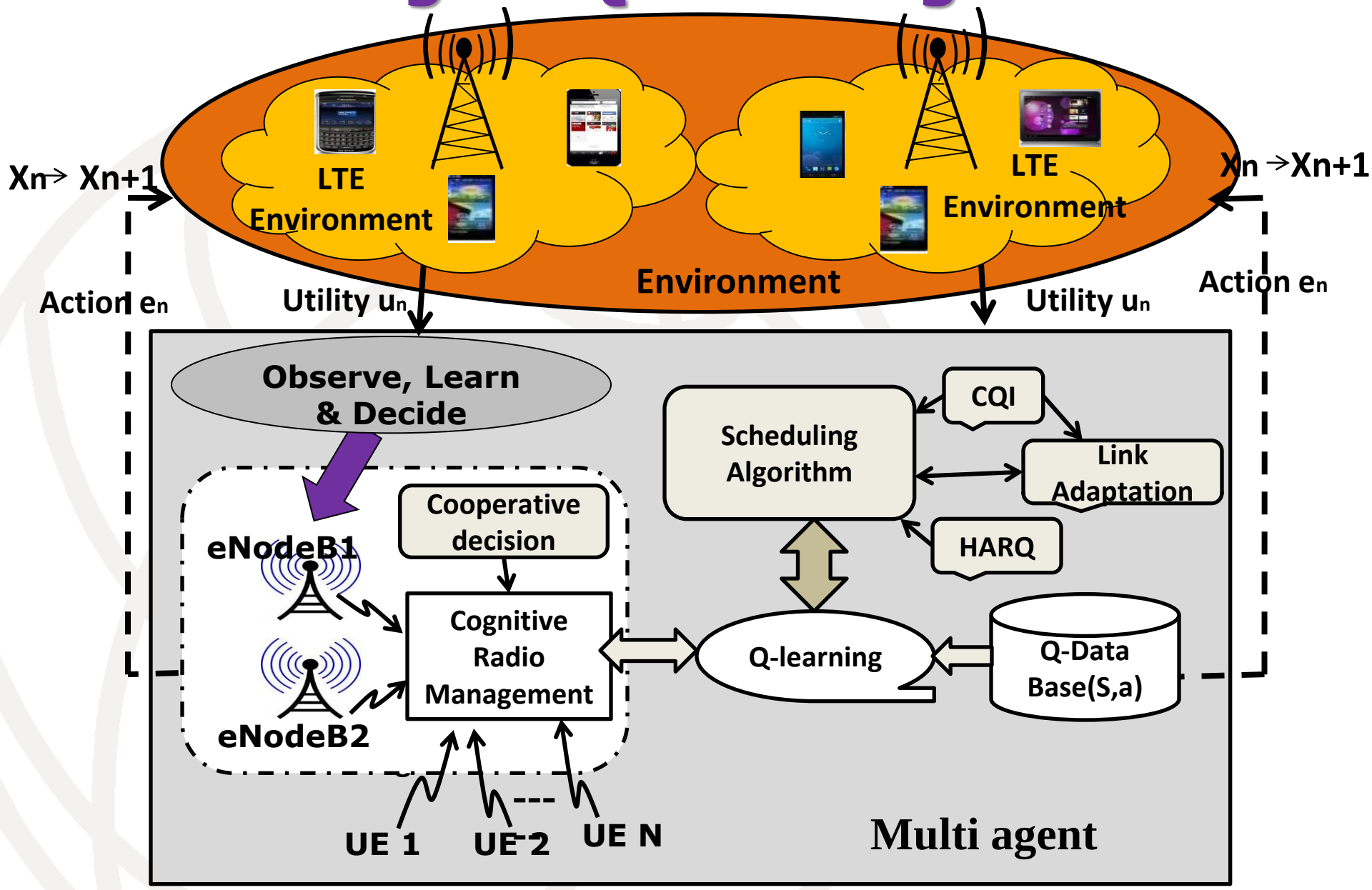
Q-Learning in Cognitive Radio

- Each access node (UE/BS) in the network is a learning agent
- The learning agent observes state, action and reward
- Q value for state-action pair is formulated as

$$Q_{n+1}(x_n, e_n) = (1-\beta)Q_n(x_n, e_n) + \beta\left[u_n + \rho \max_b Q_n(x', b)\right]$$

Where ***x*** *,* ***e*** *are state–action pair,* ***b*** *is Next state all actions,* ***ρ*** *is discount factor,* ***β*** *is Learning rate, and* $\boldsymbol{u_n}$ *is Reward value.*

Multi Agent Q-Learning in CRN



HQL Based Resource Allocation in CRN

Multi Agent(MA) Q-Learning

- Competition among agents is formulated using game theory

$$Q_*^i(x, e_1 \dots . e_n) = u_i(x, e_1 \dots . e_n) + \rho \sum_{x' \in X} p(x'|x, e_1 \dots . e_n) V^i(x', \sigma_1^* \dots \sigma_n^*)$$

Where ***x*** *,* ***e*** *are state–action pair,* ***ρ*** *is discount factor,* $\boldsymbol{u_n}$ *is Reward value ,* ***x'*** *is Next state, and* ***σ*** *is Strategy.*

Harmonized Q-Learning(HQL)

- Analyzed through Learning & Coordination
- Two approaches are used
  - Simultaneous Play Mode
  - Alternate Play Mode

Simulation Parameters

Parameter	Values
Frequency band	2.14 GHz
TTI length	1 ms
Sub carriers per RB	12
Sub carrier spacing	15 KHz
AMC levels	QPSK,16-QAM, 64QAM
Macroscopic path Loss	TS36942, Urban
Minimum Coupling loss	70
Transmit Mode	Closed Loop Special Multiplexing (CLSM)

Parameters	Values
FFT points	2048
Antenna azimuth offset	30
Shadowing	Log-normal distribution
Channel model	Winner model
Scheduler	Proportional fair
Number of eNodeB Sectors	19 x 3 = 57
UEs per Sector	10
Learning Rate (β)	0.8 ($0 \leq \beta \leq 1$)
Discount Rate (ρ)	0.7 ($0 \leq \rho \leq 1$)

eNodeB and UE Position

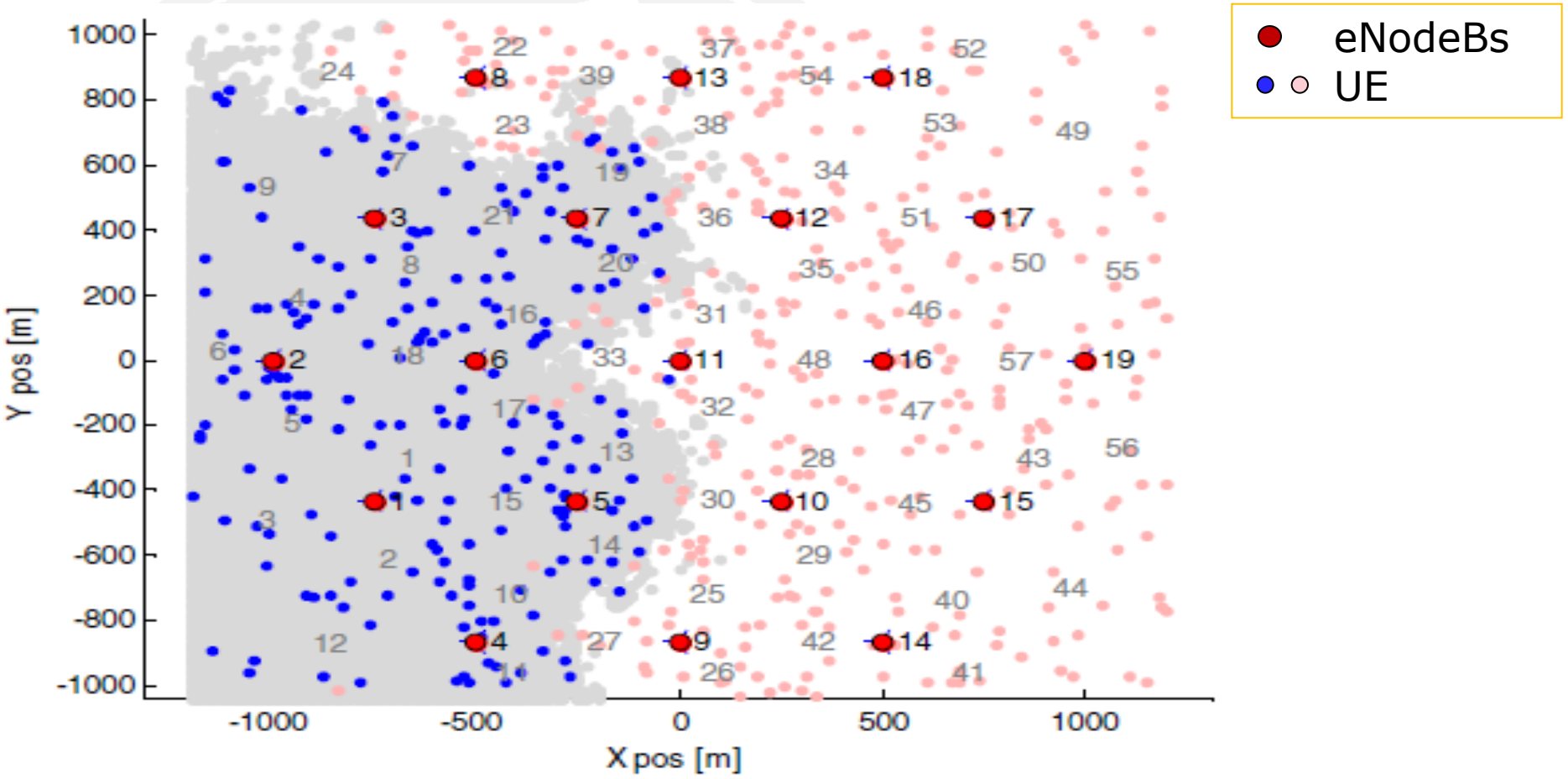


Fig.6. eNodeB & UE Location in Simulation Setup

Scatter Plot

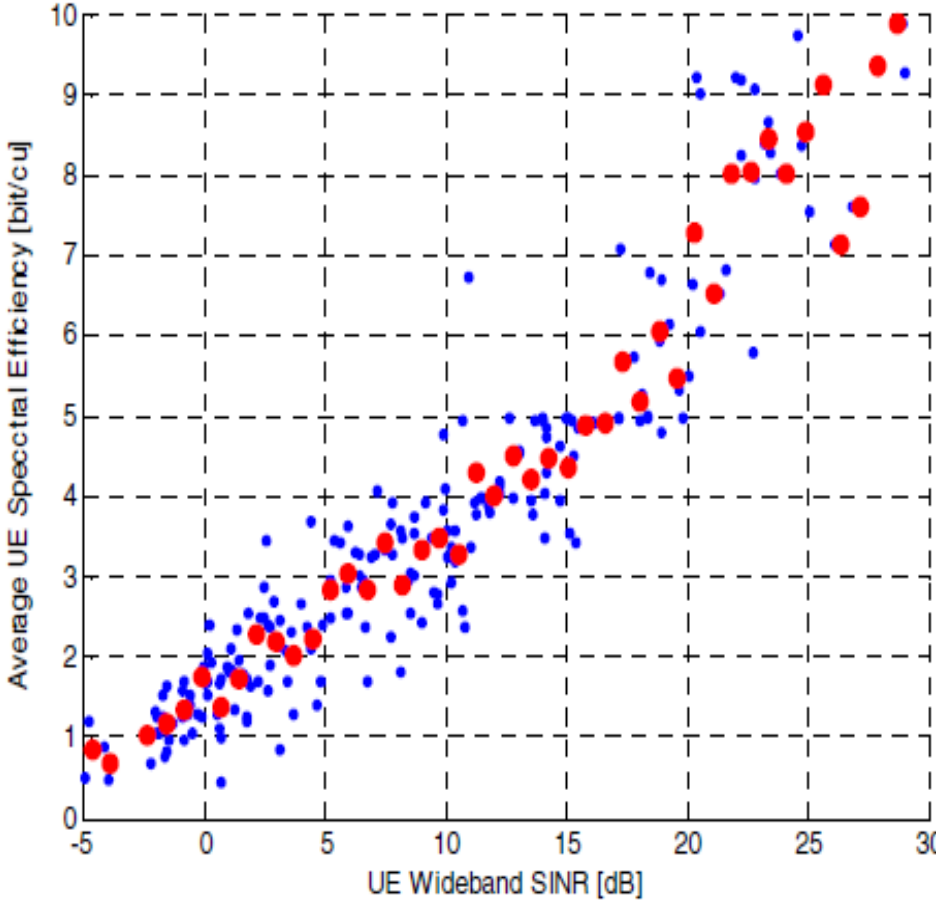


Fig.7. UE Wideband SINR Vs. Average UE Spectral Efficiency

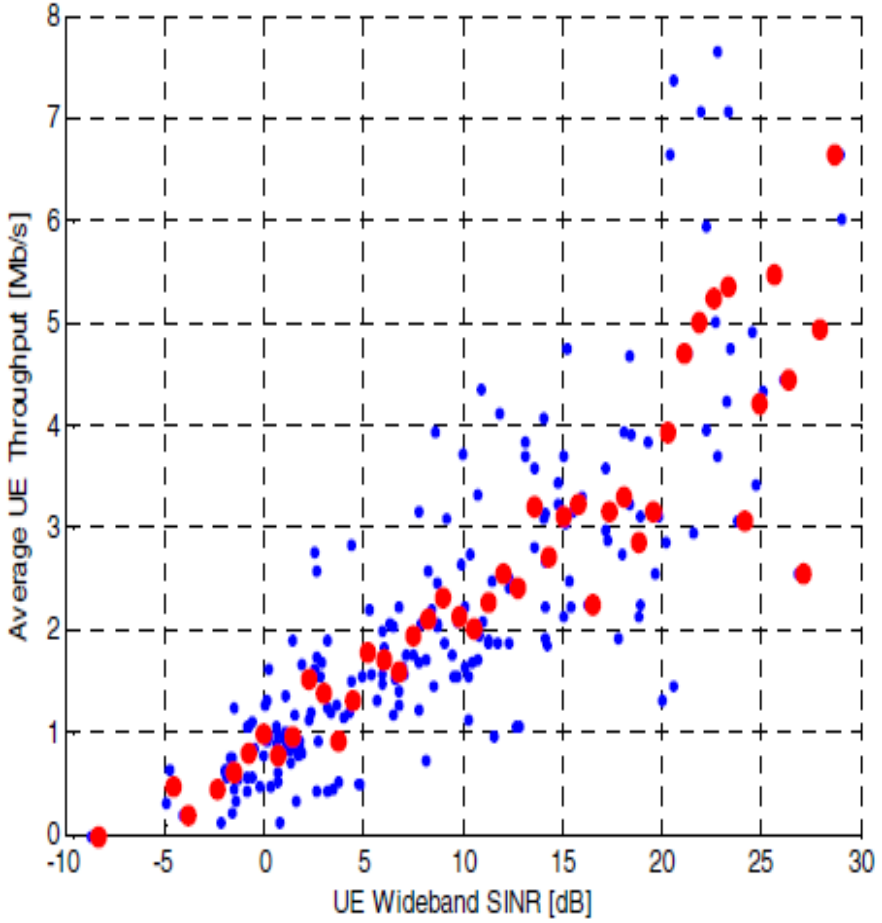


Fig.8. UE Wideband SINR Vs. Average Throughput

Empirical Cumulative Distribution Function(ECDF)

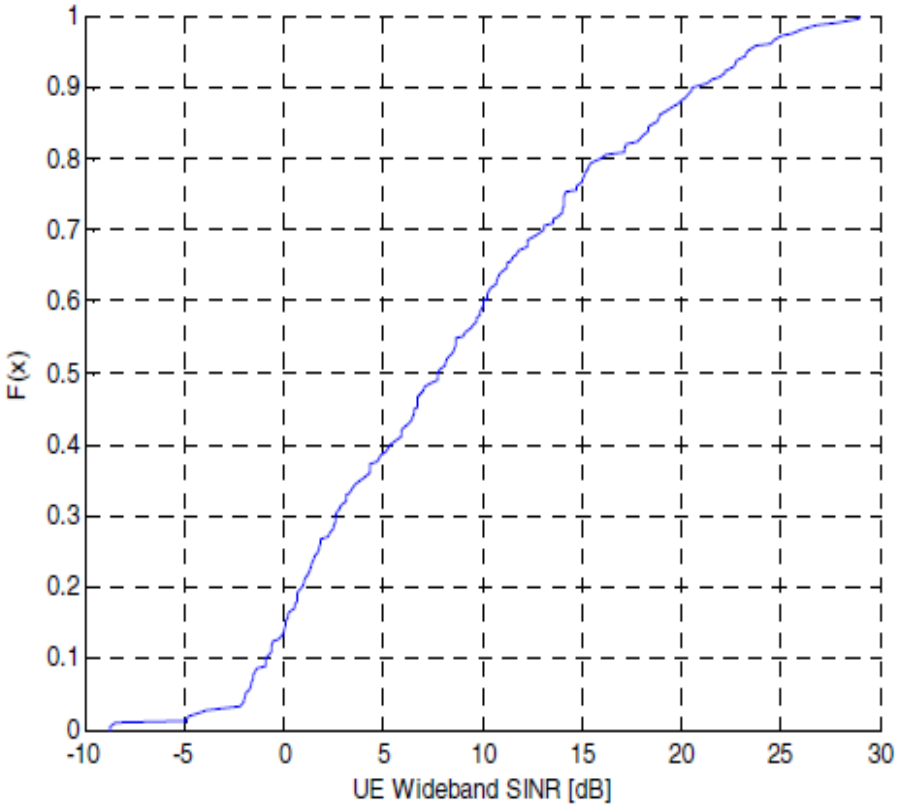


Fig.9. ECDF of UE Wideband SINR

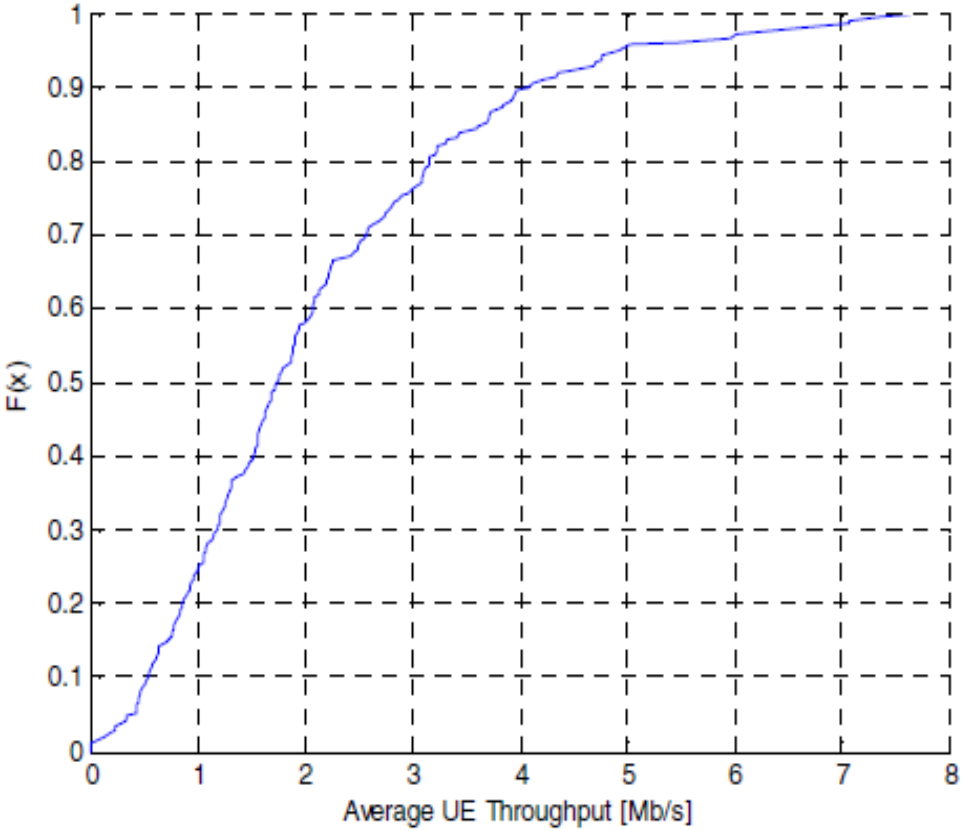


Fig.10. ECDF of Average UE Throughput

Throughput Observation

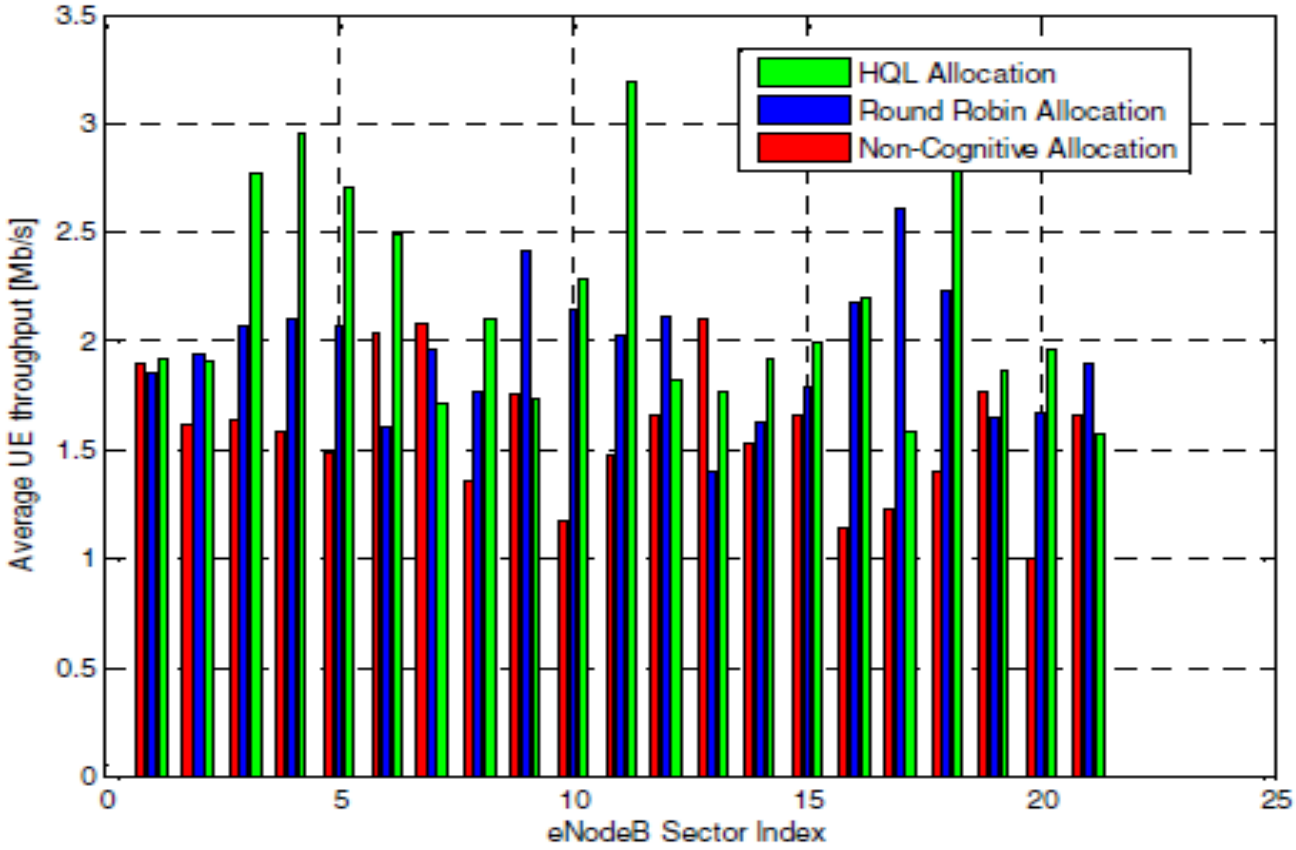


Fig.11. Average UE Throughput Observed in Various eNodeB Sectors

Conclusion & Future Work

- HQL algorithm is proposed for LTE based Cognitive Radio Networks.
- Resource allocation problem is formulated for multi agent scenario.
- The observed throughput using HQL algorithm is significantly high.
- Future work is to implement HQL algorithm in LTE-A simulation environment.
- Time complexity analysis is another future work.

Thank You