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Paving Way to Dynamic Spectrum Sharing: Understanding Spectrum Regulation and Enforcement Mechanics

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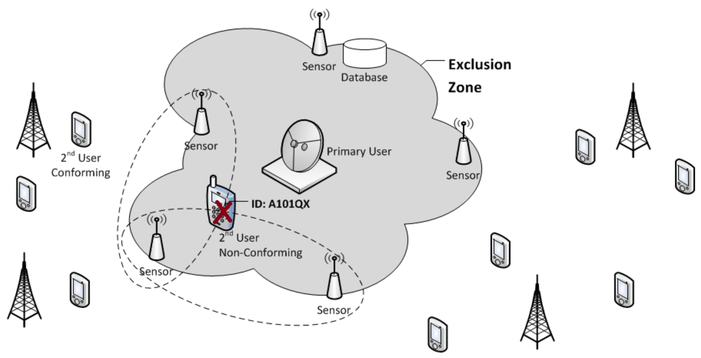
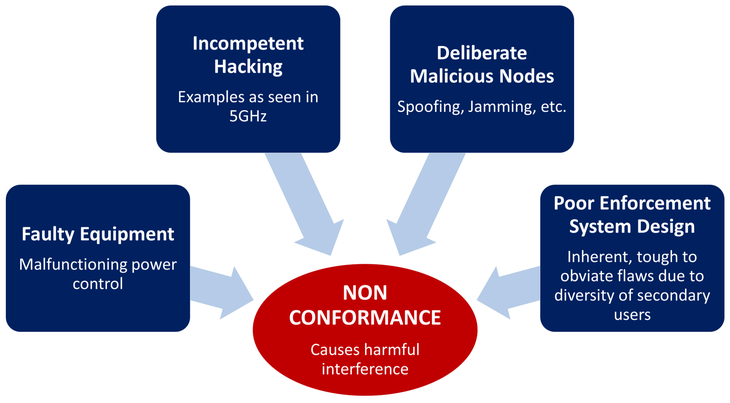
Spectrum Enforcement of DSA Radios

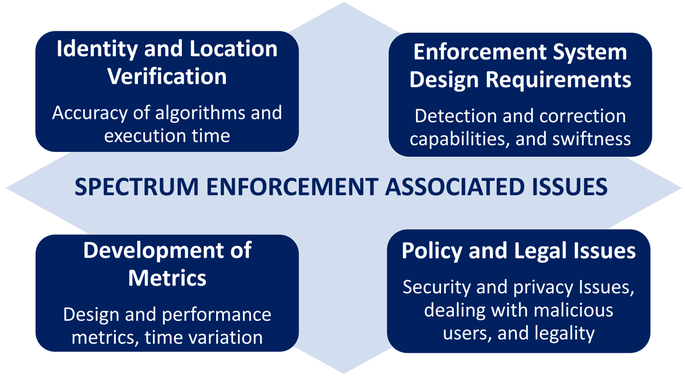


Can protection of incumbents from harmful interference be assured?

What Causes Harmful Interference?

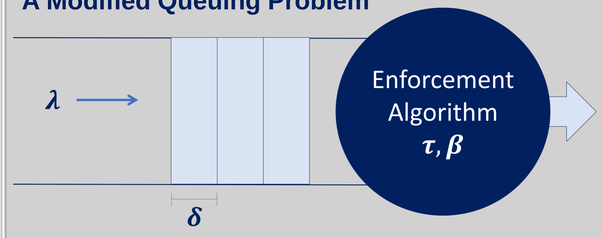


Enforcement System Design Considerations



Problem Formulation

A Modified Queuing Problem



- **What fraction of the unit time does it take to evict faulty users?**
- **Can probabilistic assurance be provided, given the following parameters?**

System Description

- Suspicious nodes are queued into the enforcement system for trial
- Enforcement system employs several identification and location verification algorithms to judge
- Depending on the node parameters, algorithm processing time varies

Initial Assumptions

- Level of Interference is binary
- Time to resolve and interference index are the metrics used
- All "arrests" made are independent
- All faulty nodes are arrested
- Arrest rate, λ > Rate of faulty node occurrence, ρ

N	Total number of nodes	n_t	Number of nodes in the queue at time instant t
λ	"Arrest" rate (Arrival rate)	m_t	Number of faulty nodes in the queue at time instant t
$p_T(\tau)$	PDF of algorithm processing time	β	Probability of missed detection
ρ	Rate of faulty node occurrence	δ	Smallest time interval

Probability density function of n_t, m_t is the standard Poisson

$$P_k = \frac{(\ell t)^k}{k!}\exp(-\ell t)$$

where $k, \ell = n_t, \lambda$ or m_t, ρ depending on the variable of interest

Algorithm processing time is a random variable assumed to be Gaussian $\mathcal{N}(\mu, \sigma)$

Thus, the statistics of the problem depend on the independent RVs: n_t, m_t, τ

Average time to resolution is,

$$T_{avg} = \frac{(\lambda+\rho)\mu}{2}(1-\beta)$$

Variance of time to resolution is,

$$T_{var} = \frac{(\lambda+\rho)\sigma}{2}(1-\beta)$$

Interference Index is a proposed metric to evaluate the mean success of the enforcement system. It gives a measure of the interference mitigated

$$I_{ind} = \frac{T_{avg} - \beta}{\lambda + \rho}$$

Enforcement System Strategies

Case 1	• Verify only upon complaints Least burden on system
Case 2	• Random node patrol and verification • Verify upon complaints Additional burden of patrolling
Case 3	• Verify with each update • Random node patrol and verification • Verify upon complaints Maximum burden on the system

Spectrum Enforcement Framework

Node Trial — System evaluates if the arrested node is guilty using algorithms → **Conviction** — The outcome of the evaluation is announced to the policy enforcer → **Punishment** — The node is punished if found guilty as per the policy

Time to Mitigate Harmful Interference

Delay in the Queue + System Processing Time + Enforcement Time

- Delay in the queue is dependent on system processing time
- Speed of algorithms decides the system processing time
- What are the constraints on system processing time for speedy enforcement?

The Path Ahead

- Derive confidence intervals and enhanced feasibility metrics based on the distributions
- Relax the several assumptions made
  - Arrests need not be independent
  - Co-operative misbehavior frameworks
  - Block arrivals instead of individual node arrival
- Extensive simulations to validate the theoretical models