Delay Analysis for Multi-radio Cognitive Radio Networks

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Background

- Licensed bands are highly (~85%) under-utilized [1]
- Cognitive Radio Networks (CRNs): Increase utilization of the licensed bands by learning corresponding spectrum occupancy
- Two types of users in a CRN [2]
  - Primary User (PU): Licensed users experiencing uninterrupted data tx
  - Secondary User (SU): Unlicensed users opportunistically using spectrum that is currently being free from PU's tx
- Applications: Military, emergency response, signature detection, etc. [3]

Motivation of Our Work

- Delay is an important performance measure for secondary users in cognitive radio networks
  - Several recent studies [4, 5, 6] have modeled delay in CRNs
    - Consider only single-radio SUs and single data channel
- We study delay in asynchronous data tx over *multi-radio* SUs
  - Transmission strategies
    - Fragmented: Data is fragmented over different channels
    - Back-up: Same data is transmitted over different channels
  - Our approach of study: Analytical formulation and simulation

Analytical Model for Total Transmission Delay

$$T_{pu\_idle} = \frac{T_{ms}}{1-p_{busy}} + \frac{(m+1)xT_{ms}}{2} + E[T_n] + T_{data}$$

$$p_{busy} = \frac{\lambda_{pu}}{\mu_{pu}} + \frac{(m-1)x\lambda_{su}}{(n-x+1)\mu_{su}}$$

$$E[T_{us}] = \frac{1}{\lambda_{pu}}\left(1-e^{-\lambda_{pu}T_{pu\_idle}}\right) - T_{pu\_idle}e^{-\lambda_{pu}T_{pu\_idle}}$$

$$p_{pu\_idle} = e^{-\lambda_{pu}T_{pu\_idle}}$$

$$E[T_{total}] = T_{pu\_idle} + \frac{(1-p_{pu\_idle})}{p_{pu\_idle}}E[T_{us}]$$

•Notations: n→ number of PUs, m→ number of SUs, T_{ms}→ mini-slot time, T_{us}→ unsuccessful data tx time, λ→ arrival rate, μ→ service rate, x→ number of radios used in data transmission

•Analysis of the model: Through numerical simulation

- Parametric values for numerical simulation
  - λ_{pu} = 40Hz, μ_{pu} = 200Hz, λ_{su} = 0.8Hz, μ_{su} = 20Hz

Simulation Results for Fragmented Data Transmission

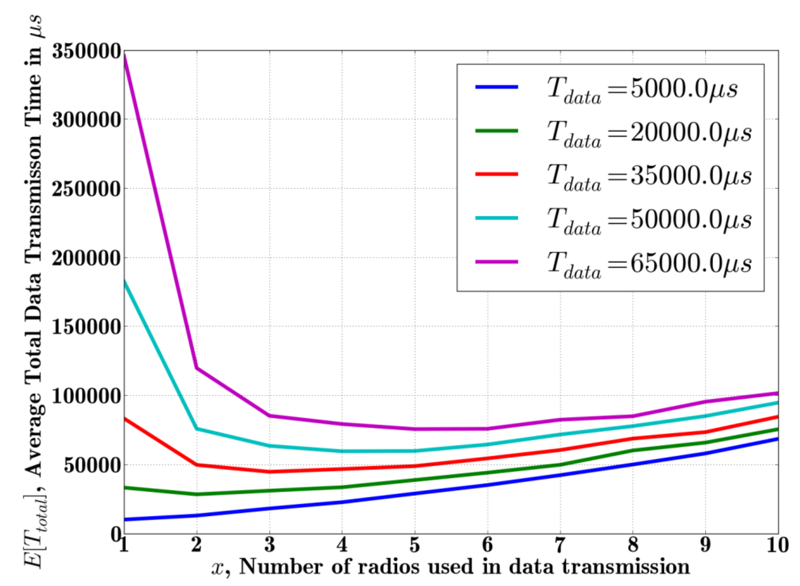

Fig: Total transmission delay for fragmented data transmission

Simulation Results for Back-up Data Transmission

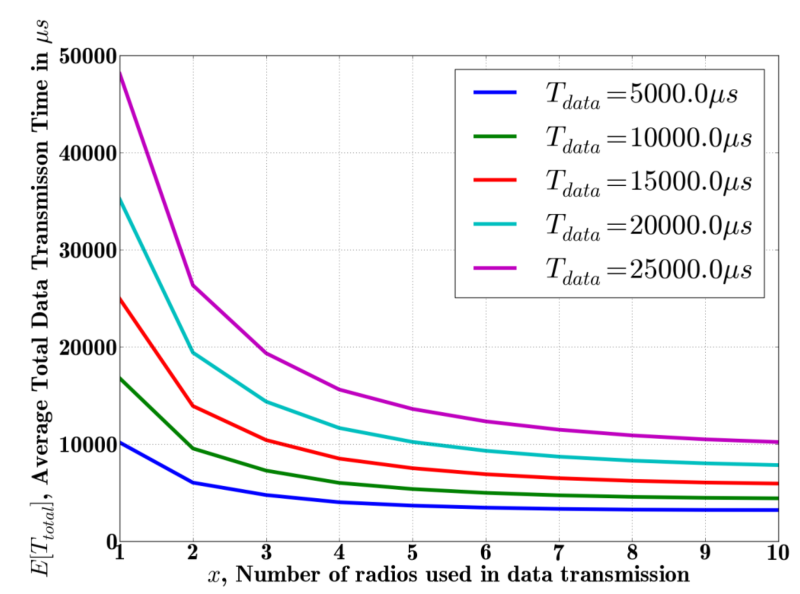

Fig: Total transmission delay for back-up data transmission

Delay Comparison between Two Approaches

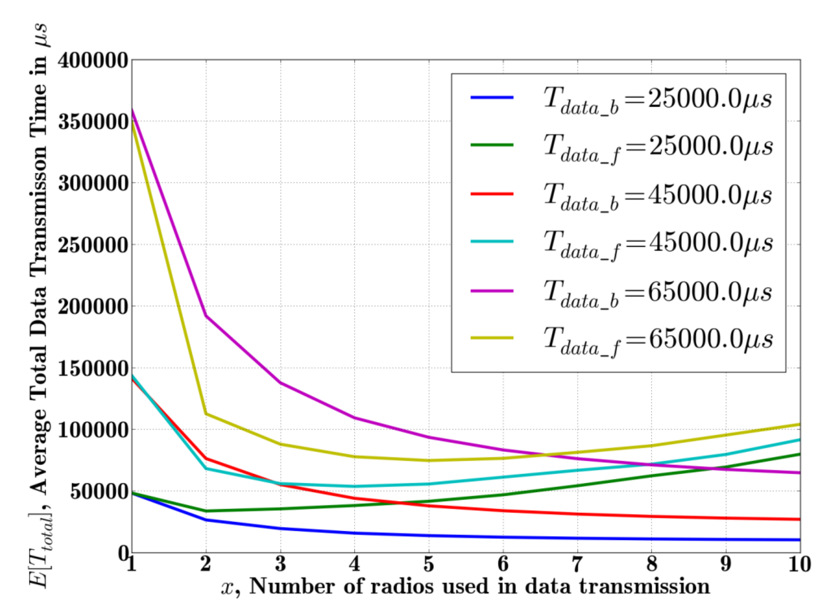

Fig: Total transmission delay comparison between two approaches

Findings from Simulation Results

- Data transmission delay substantially decreases with the increase in the number of radios used in a SU
  - Fragmented data packet tx: Better for large data packets
  - Back-up data tx: Better results in case of smaller data packets
- However, delay rapidly reaches the optimal value and for fragmented data packets it starts rising after that point
- Total delay non-linearly increases with an increase in data packet size
- SUs experience minimum overhead due to PUs' sudden arrival

Conclusion and Future Work

- In this study, we introduce a model for asynchronous cognitive radio networks and formulate a closed form for point-to-point data transmission delay over multi-radio SUs
  - Our numerical results reveal that delay performance can be significantly improved through using multi-radio SUs
- Delay performance degrades if PU's channel utilization gets significantly high
- Future work: Multi-radio secondary users' performance in case of high data traffic from PUs

References

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