A Novel Channel Handover Strategy to Improve the Throughput in Cognitive Radio Networks

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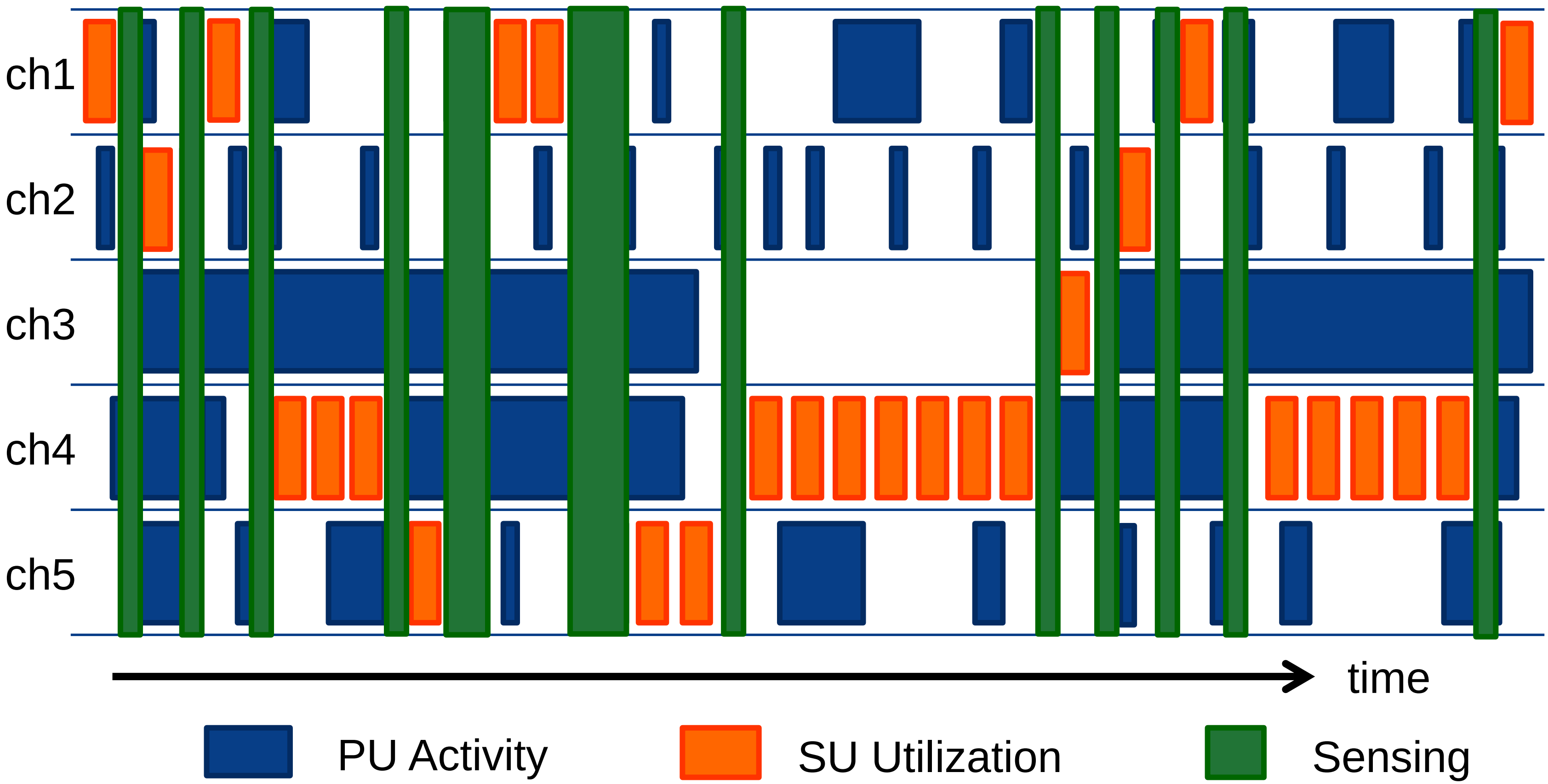
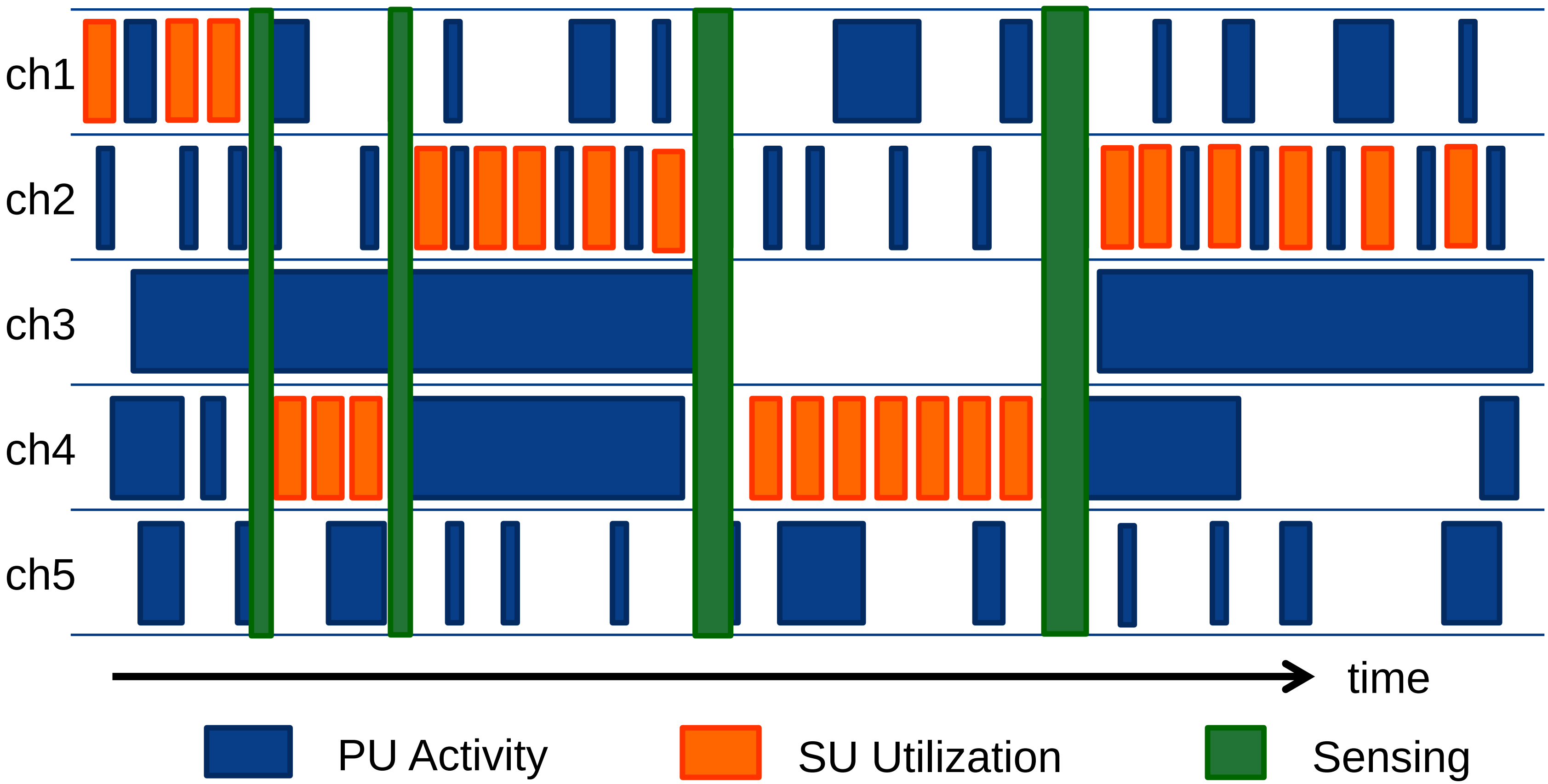
MOTIVATION

- Different Data Channels



MOTIVATION

- Another Solution for Secondary Access

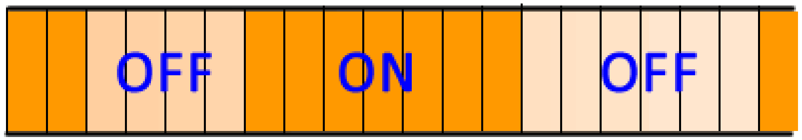


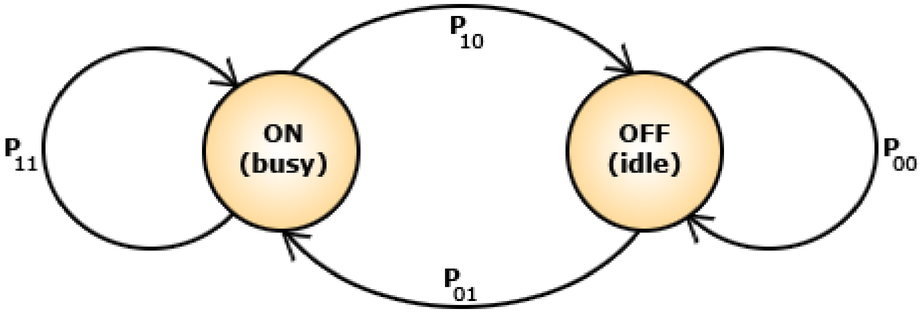
MOTIVATION

- **When SU detects PU activity**
- **Analyze the tradeoff between**
  - Initiating channel handover process (CHP)
    - Cost: average duration of CHP
  - Waiting for the end of PU activity
    - Cost: average duration of PU activity

SYSTEM MODEL

- **PU Activity Model**
  - Slotted Exponential ON/OFF Model

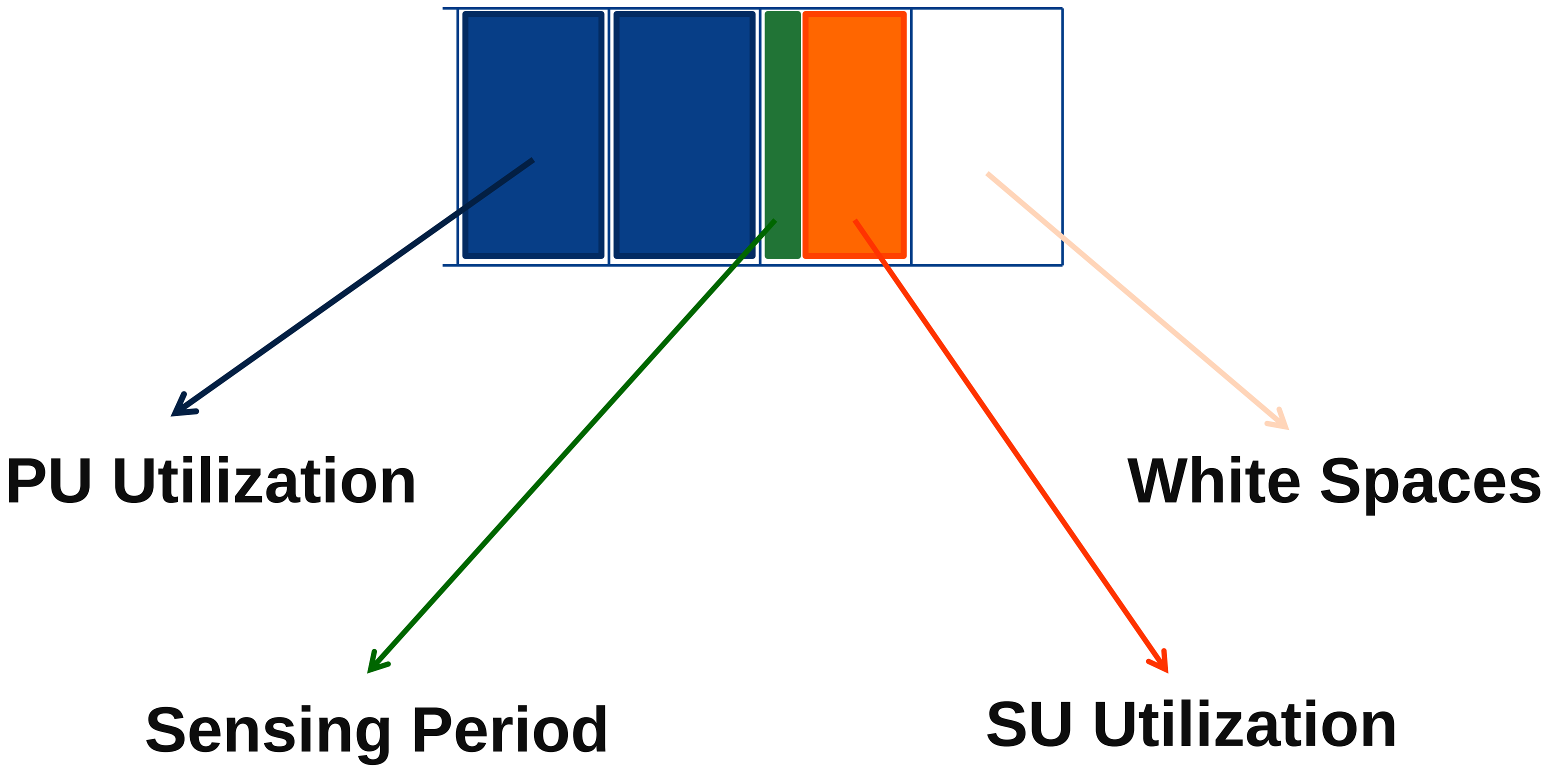




$$\begin{bmatrix} P_{00} & P_{01} \\ P_{10} & P_{11} \end{bmatrix} = \frac{1}{\lambda + \mu} \begin{bmatrix} \mu + \lambda e^{-(\lambda+\mu)t} & \lambda - \lambda e^{-(\lambda+\mu)t} \\ \mu - \mu e^{-(\lambda+\mu)t} & \lambda + \mu e^{-(\lambda+\mu)t} \end{bmatrix}$$ [Xiao]

SYSTEM MODEL

- SU Access



CHANNEL HANDOVER PROCESS (CHP)

- **A simple two-way handshaking scheme**
  - Cost of CHP (γ)

$$\gamma = t_{sense}^{t} + \delta + t_{sense}^{r} + \delta + Max\left(t_{adapt}^{t}, t_{adapt}^{r}\right)$$

  - t_{sense}^{t}: Cost of sensing on transmitter side
  - δ: Cost of negotiation through common control channel (CCC)
  - t_{sense}^{r}: Cost of sensing on receiver side
  - t_{adapt}: Cost of adjusting frequency and modulation settings

CHANNEL HANDOVER PROCESS (CHP)

- **State-of-the-art**
  - Slot length: 1 ms - 200 ms [Yang, Hoyhtya, Xu, …]
    - PUs may not tolerate over 20 ms
  - Slot length = 20 ms
  - 100 ms frame, SNR of -20dB at RSU, optimum sensing duration is 5 ms – 15 ms (%90 detection probability) [Liang]
  - 5 ms fast sensing, 25 ms fine sensing [Cordeiro]
  - Sensing duration (in slot) = 5 ms

CHANNEL HANDOVER PROCESS (CHP)

- **State-of-the-art**
  - CHP of MadWifi driver up to 100 ms
    - Bypassing re-association process 5 ms
  - Larger for distant frequency bands [Yang]
  - Sensing Available Channels
    - Transmitter Side (4-8 channels) = 40 ms
    - Receiver Side (lower) = 20 ms
  - Frequency and modulation settings = 10 ms

CHANNEL HANDOVER PROCESS (CHP)

- **State-of-the-art**
  - CSMA based channel access on CCC
  - Negotiation = 5 ms

$$\gamma = t_{sense}^{t} + \delta + t_{sense}^{r} + \delta + Max\left(t_{adapt}^{t}, t_{adapt}^{r}\right)$$

- t_{sense}^{t} = 40 ms
- t_{sense}^{r} = 20 ms
- γ = 80 ms
- $s_{\gamma} \approx$ 4 slots

t_{adapt} = 10 ms

δ = 5 ms

t_{slot} = 20 ms

CHANNEL HANDOVER STRATEGIES (CHS)

- **Available CHS (ACHS)**
  - Usual channel handover decision
  - For each detected PU activity (PUA) Initiate channel handover process (CHP)
  - Cost: Average duration of CHP
    - For each detected PU activity
    - Even for false alarm!
  - Congestion in CCC

PROPOSED LINEAR CHS

- **TSU calculates a linear model**
  - Channel state variable U
  - $U = U_{init}^{(i)}$ for new channels

$$U(k) = \alpha^{(i)}.C_s(k) + \left(1 - \alpha^{(i)}\right)U(k-1)$$

  - For each step k
  - $\alpha^{(i)} \in [0,1]$: linear model parameter for channel i
  - $C_s(k) \in \{idle \equiv 0,\ busy \equiv\ 1\}$: k^{th} slot state
  - If $U(k) > U_{Limit}^{(i)}$ for channel i, initiate CHP

SIMULATION RESULTS

- **One SU pair**
  - Ignore collisions between SUs
  - Focus on success of LCHS
- **K = 5 channels**
- $U_{init}^{(i)}$ **= 0.5** $U_{Limit}^{(i)}$ **= 0.8**
- $\alpha^{(i)}$ **= 1 / 8**
- t_{slot} = 20 ms, t_{obs} = 5 ms (75% SU in slot utilization)

SIMULATION RESULTS

- **Parameters**
  - Utilization for channel i $S_{(i)} = 0.3$

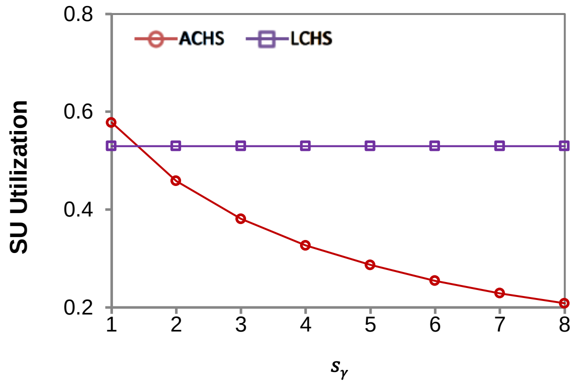
$$S_{(i)} = \frac{\lambda_{(i)}^{-1}}{\lambda_{(i)}^{-1} + \mu_{(i)}^{-1}}$$

$$\lambda_{(i)}^{-1} = 6 \quad \rightarrow \quad \mu_{(i)}^{-1} = 14$$

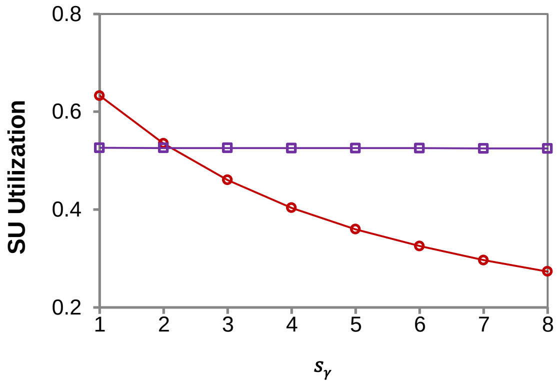
  - Simulations for different $s_\gamma (\approx 4)$
    - $s_\gamma \in \{1, 2, 3, \ldots, 8\}$

SIMULATION RESULTS

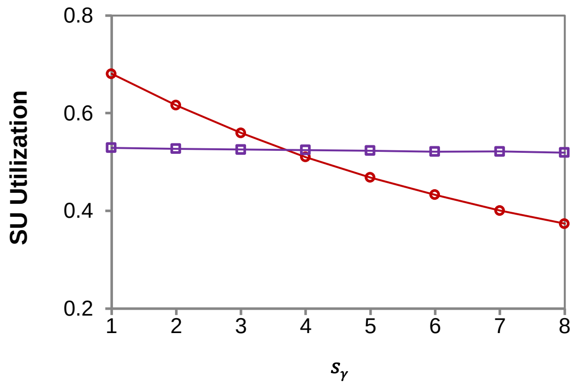
- **SU Utilization vs. Cost of CHP (s_γ)**



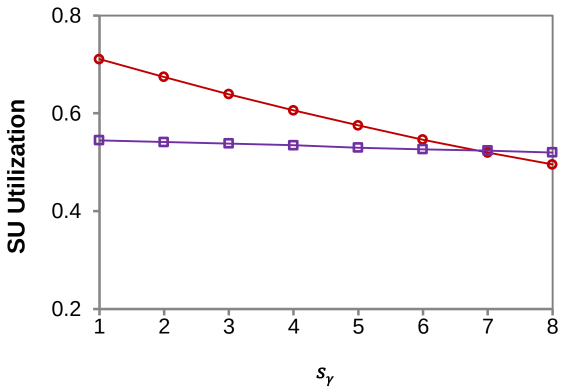
$(a)\ \lambda^{-1} = 1$



$(b)\ \lambda^{-1} = 2$



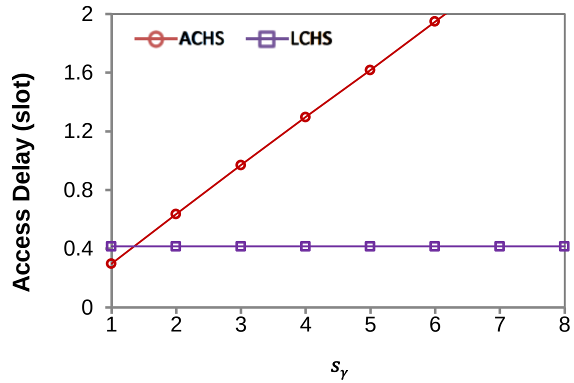
$(c)\ \lambda^{-1} = 4$



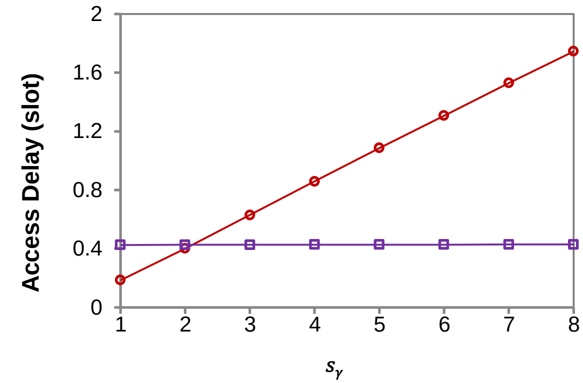
$(d)\ \lambda^{-1} = 8$

SIMULATION RESULTS

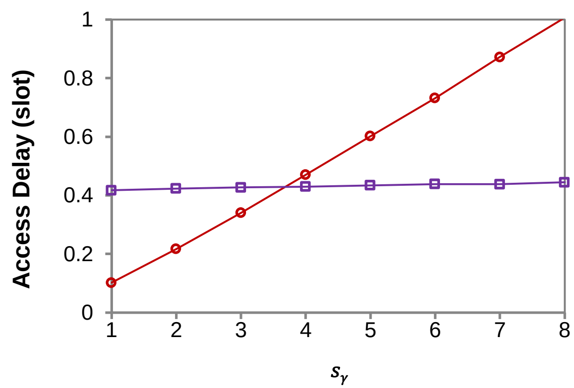
- **Avg. Access Delay vs. Cost of CHP (s_γ)**



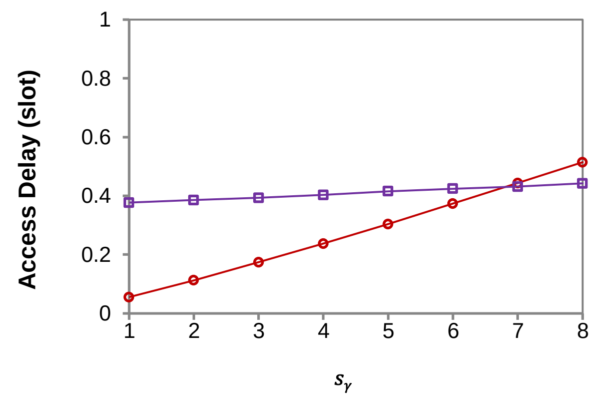
$(a)\ \lambda^{-1} = 1$



$(b)\ \lambda^{-1} = 2$



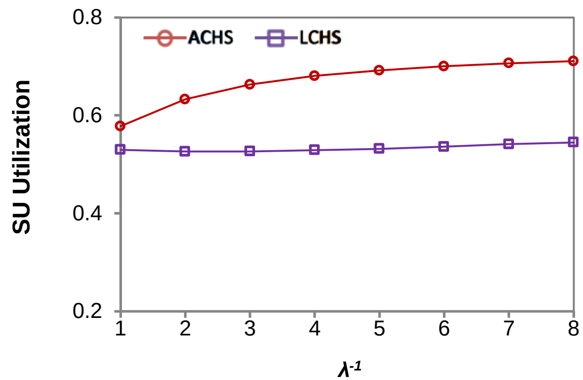
$(c)\ \lambda^{-1} = 4$



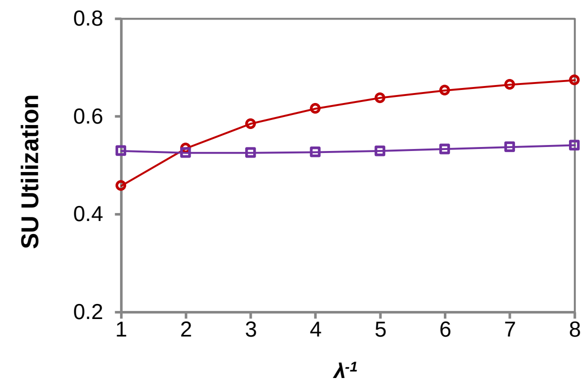
$(d)\ \lambda^{-1} = 8$

SIMULATION RESULTS

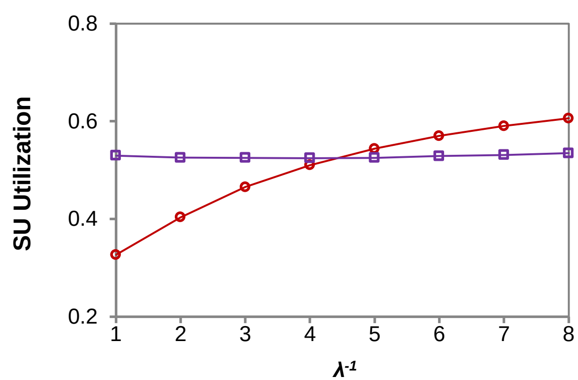
- **SU Utilization vs. Avg. Duration of PU Activity**



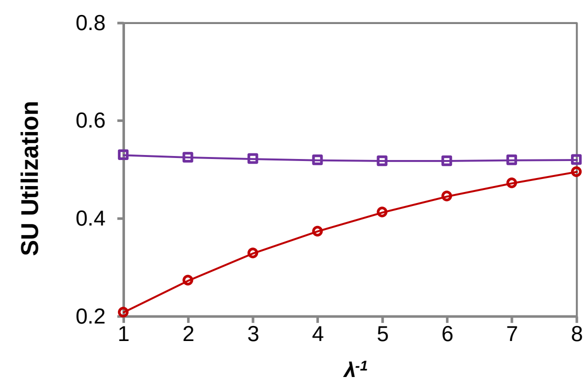
$(a)\ s_\gamma = 1$



$(b)\ s_\gamma = 2$



$(c)\ s_\gamma = 4$



$(d)\ s_\gamma = 8$

SIMULATION RESULTS

- **Average Access Delay (AD) – Max. AD ($\lambda^{-1} = 3$)**

	AAD: Average Access Delay (slot)		MAD: Maximum Access Delay (slot)	
s_γ	ACHS	LCHS	ACHS	LCHS
1	**0.074**	0.168	**7**	25
2	**0.154**	0.170	**16**	28
3	0.235	**0.170**	**27**	32
4	0.319	**0.175**	40	**38**
5	0.403	**0.169**	45	**36**
6	0.480	**0.175**	42	**40**
7	0.566	**0.177**	56	**42**
8	0.652	**0.177**	64	**42**

- **Std. Dev. Of AD – Total # of Handovers**

	SAD: Standard Deviation of AD (slot)		TNoH: Total Number of Handovers	
s_γ	ACHS	LCHS	ACHS	LCHS
1	**0.303**	0.990	116190	**2507**
2	**0.653**	1.010	109961	**2512**
3	1.023	**1.023**	102532	**2542**
4	1.407	**1.050**	94829	**2549**
5	1.791	**1.043**	87777	**2588**
6	2.146	**1.081**	80895	**2536**
7	2.529	**1.103**	75545	**2544**
8	2.936	**1.118**	70513	**2535**

CONCLUSION

- **Channel handover is a time consuming process**
- **Tradeoff between**
  - Cost of channel handover
  - Cost of PU activity
- **Propose a novel channel handover strategy to balance this tradeoff**
  - Local observations to give desicion

CONCLUSION

- **Decrease frequency of handovers**
  - Also load in CCC!
- **May increase throughput**
- **Study continues on**
  - Multiple SU groups
  - Dynamic environment

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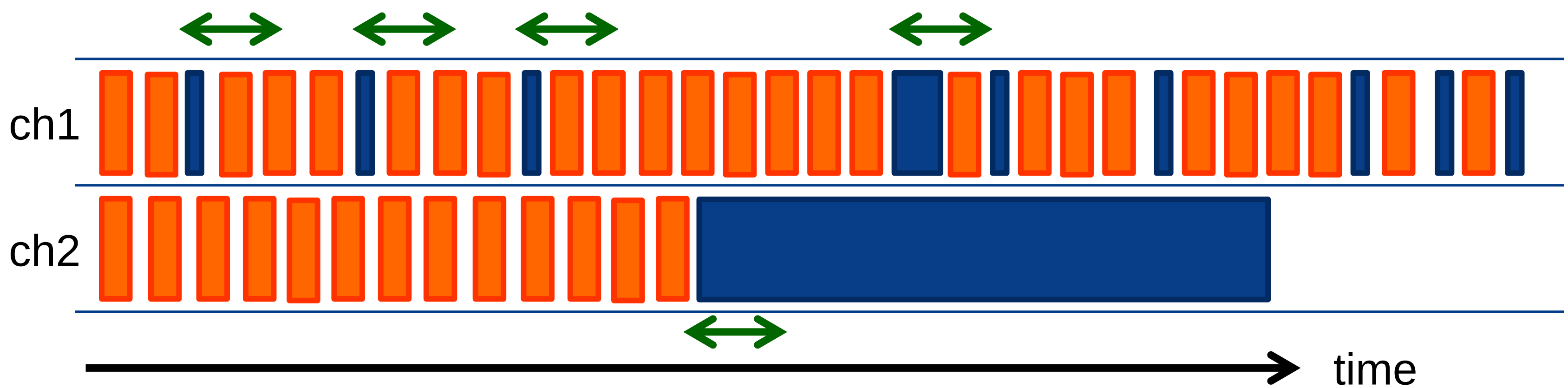
QUESTION

- **Optimize Model Parameters**

$$U = \alpha . C + (1 - \alpha)U$$

$\alpha = 0$ means DO NOT UPDATE *U*!

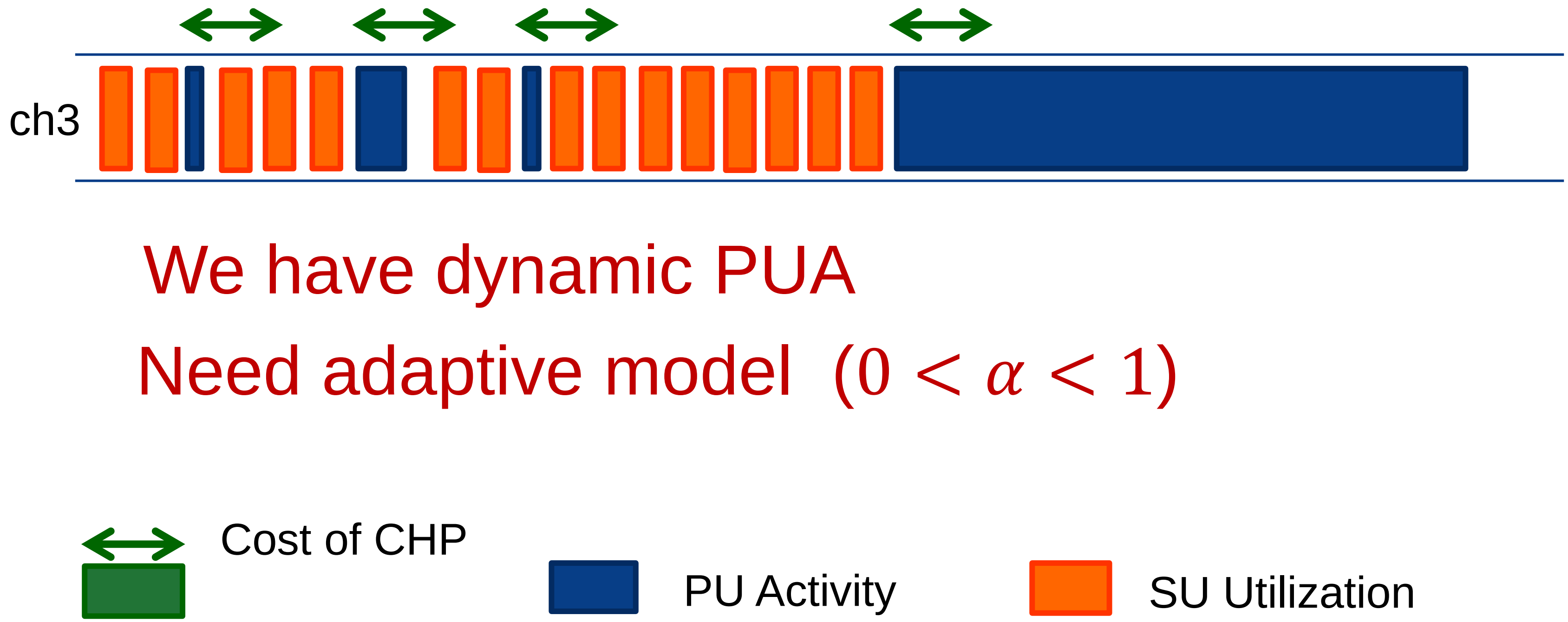


$\alpha = 1$ ADAPT LAST RESULT ≡ ACHS

QUESTION

- **Optimize Model Parameters**

$$U = \alpha . C + (1 - \alpha) U$$



We have dynamic PUA

Need adaptive model $(0 < \alpha < 1)$