



Enable Flexible Spectrum Access with Spectrum Virtualization

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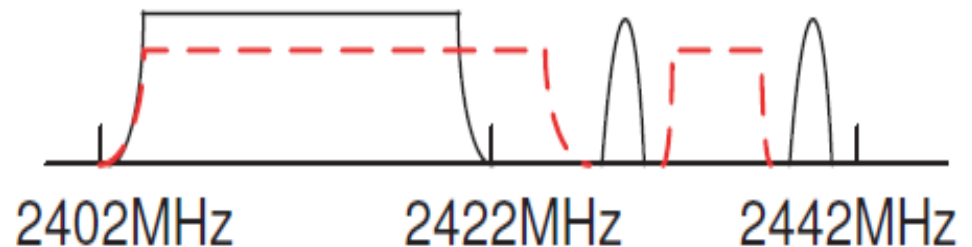
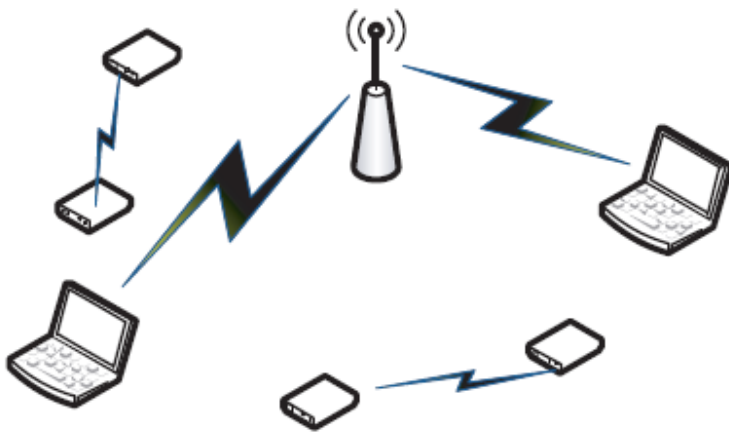
WNG, MSR Asia

*Joint work with (Haichen Shen, Jiansong
Zhang, and Yongguang Zhang)*



Flexible Spectrum Access

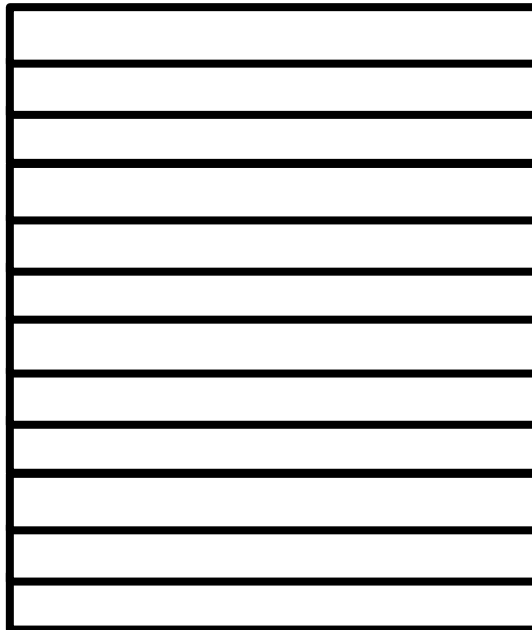
- Fixed channel allocation is inefficient when multiple heterogeneous wireless coexists
 - Narrow-band interfering with wide-band wireless





NC-OFDM Approach

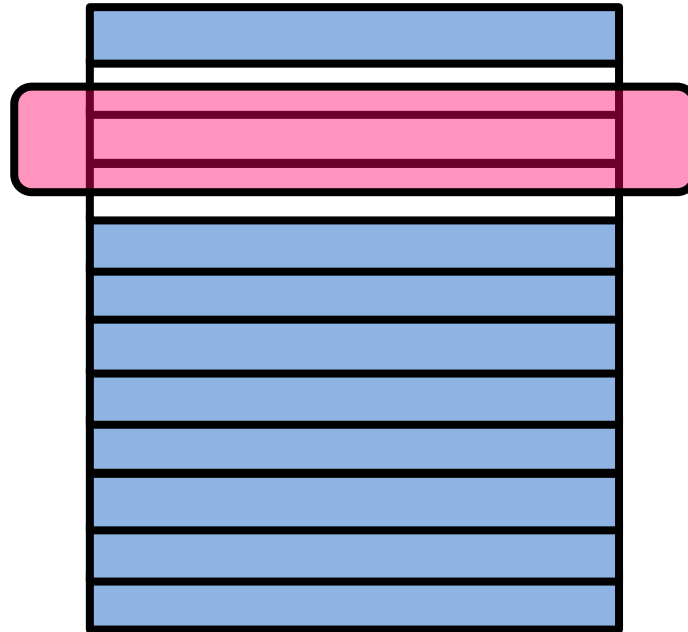
- Divide the channel into tiny subcarriers





NC-OFDM Approach

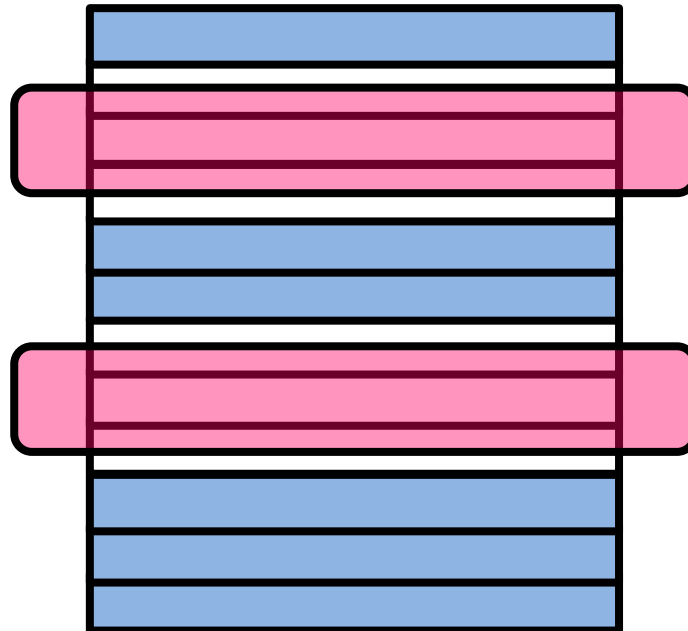
- Divide the channel into tiny subcarriers
- Turn off subcarriers with interference





NC-OFDM Approach

- Divide the channel into tiny subcarriers
- Turn off subcarriers with interference





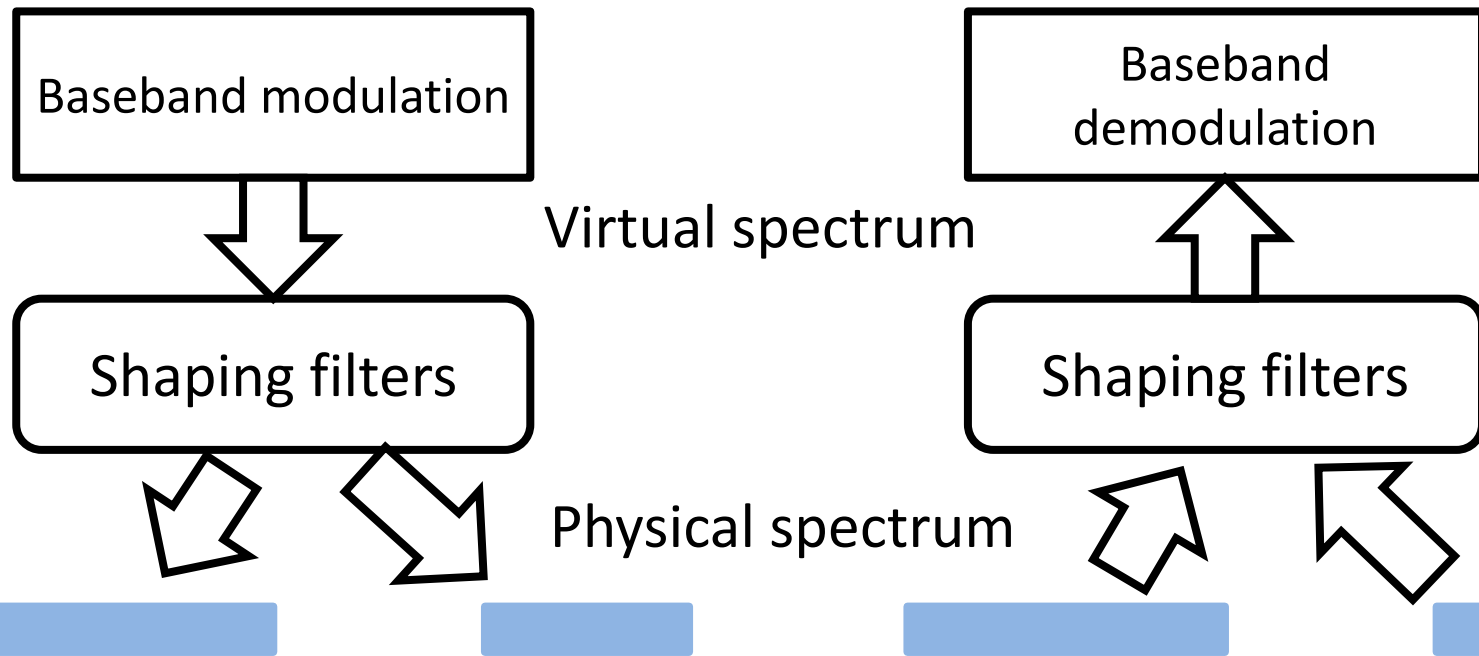
NC-OFDM Approach

- Divide the channel into tiny subcarriers
- Turn off subcarriers with interference
- Issue: Complexity
 - Each interference pattern may result in a different subcarrier allocation, and a *unique mode* to PHY
 - Each mode requires special treatment
 - Preamble type, pilot placement, etc.



Spectrum Virtualization

- Can we separate the baseband from real spectrum allocation?
- So we can program spectrum usage without changing the PHY





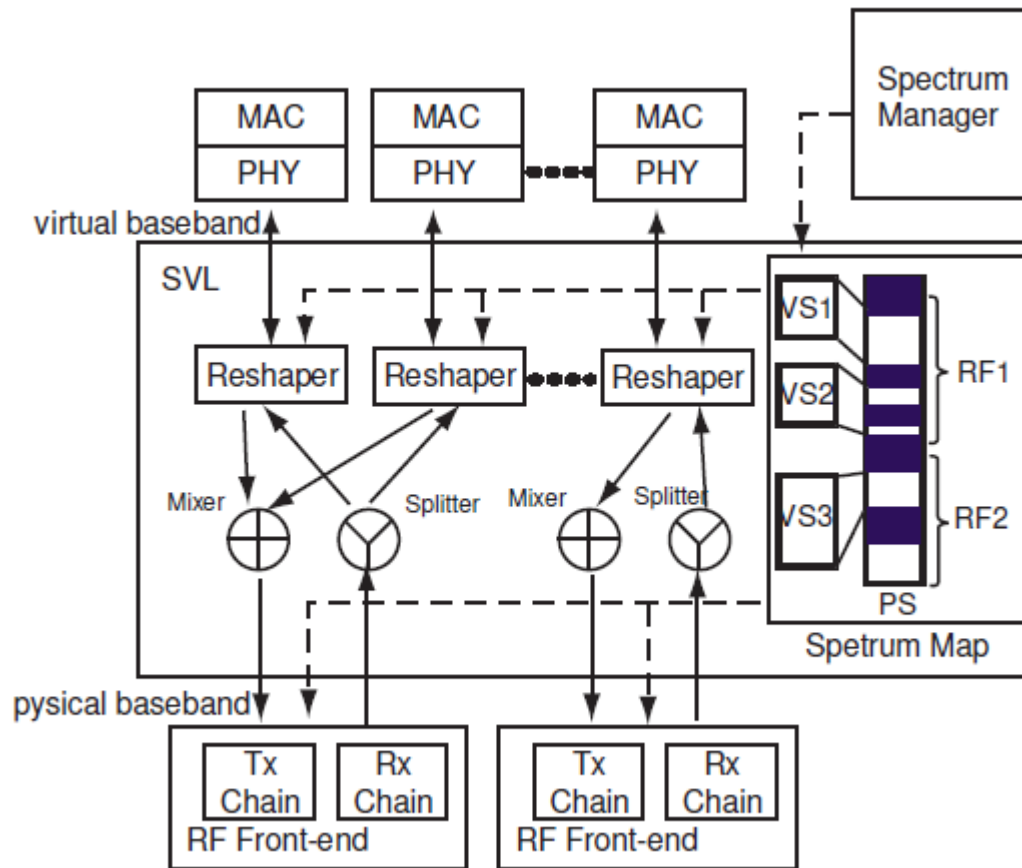
Spectrum Virtualization Layer

- *Spectrum programmability* at Layer 0.5

Layer 2
Layer 1

Layer 0.5

Layer 0



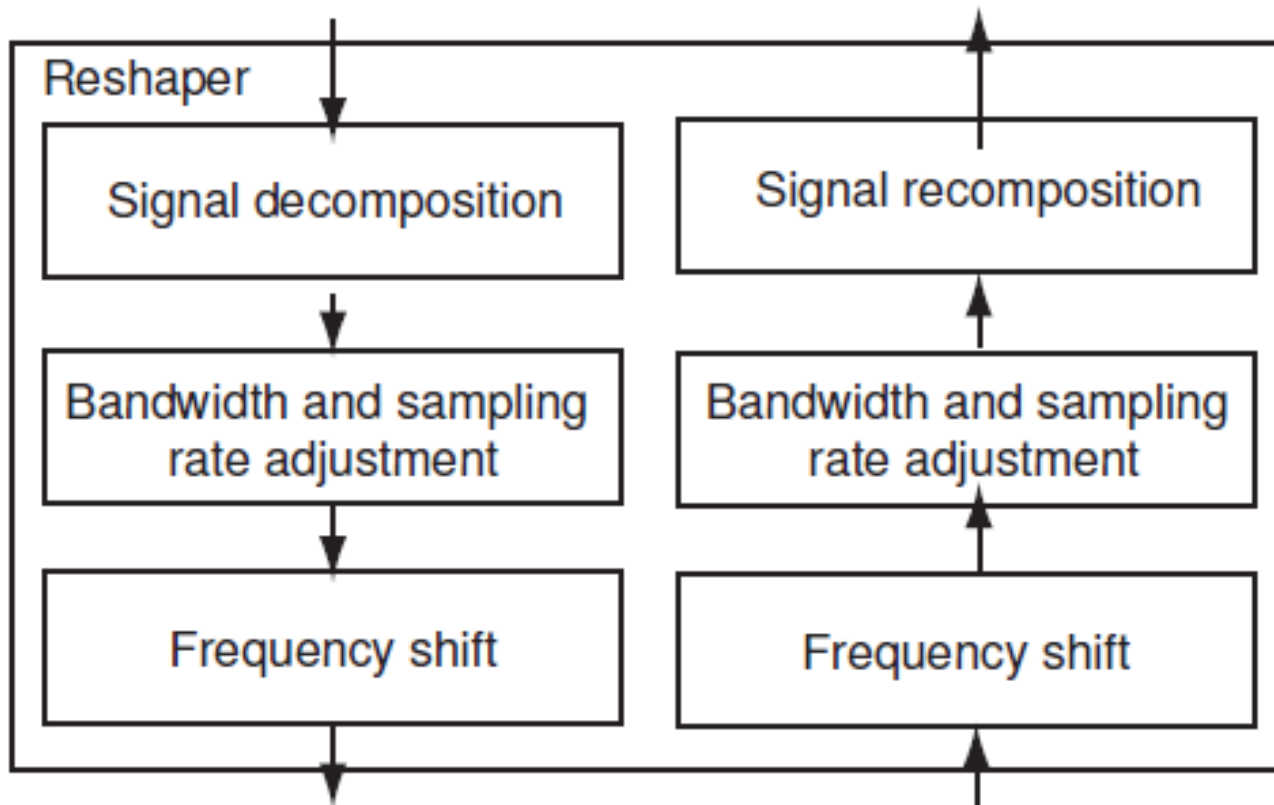


Design of Signal Shaping Functions

- Goal: Translate baseband signal to waveform matching the physical channel allocation, without losing the modulated information
- Design principles
 - PHY agnostic
 - Transparent
 - Simple and best effort

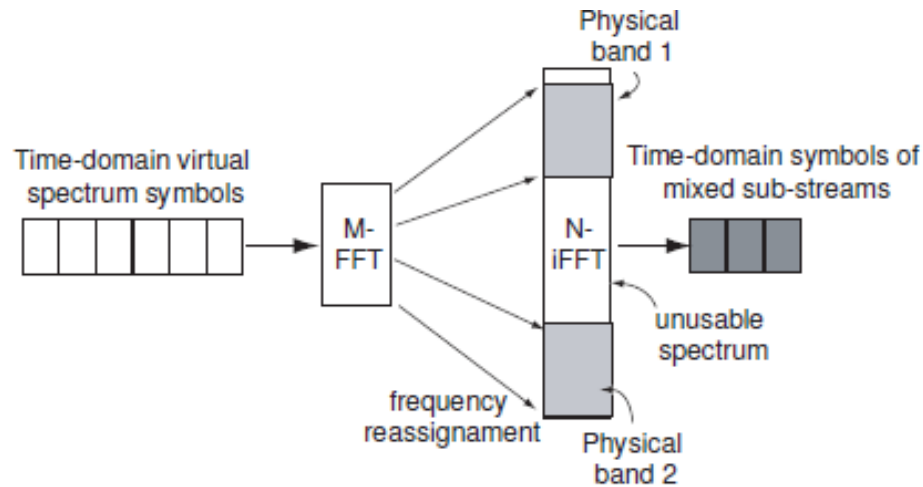


Shaping Operations



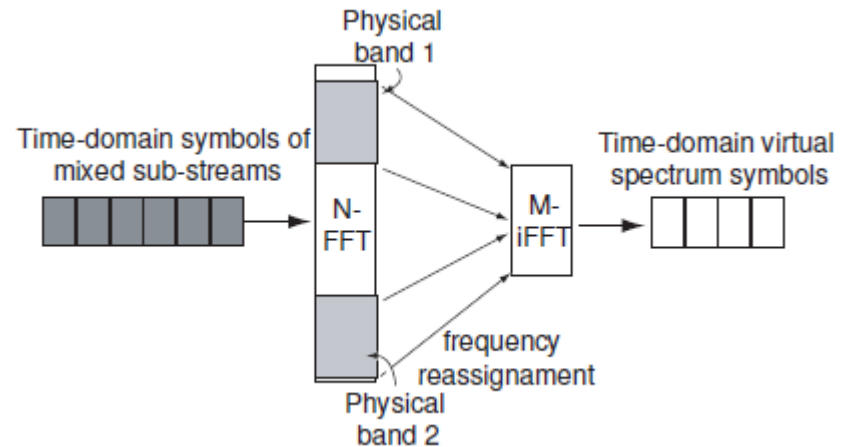


FFT-based Signal Decomposition/Composition



Decomposition

Composition





Bandwidth Adjustment

- Manipulate sampling rate to change signal bandwidth
- Reduce bandwidth by α
 - Adding α times more samples with interpolation

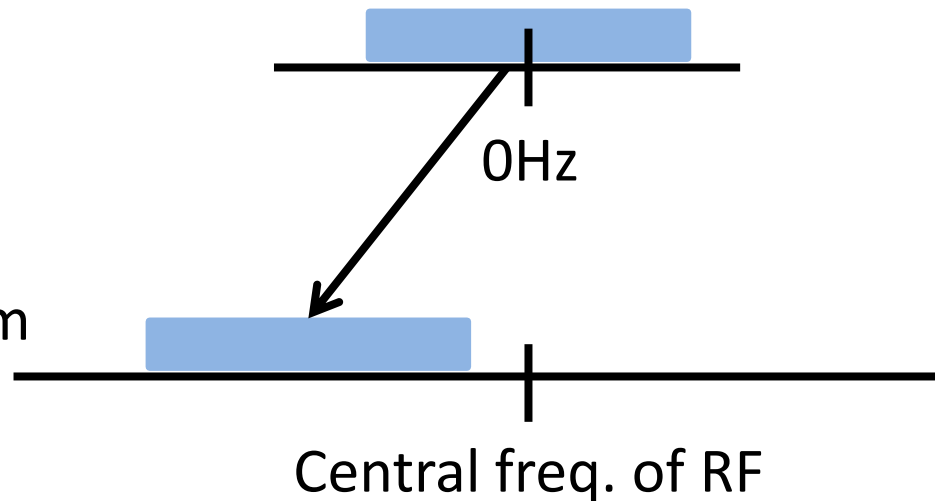


Frequency Band Shifting

- Adjust the central frequency of the signal to match the allocation spectrum band

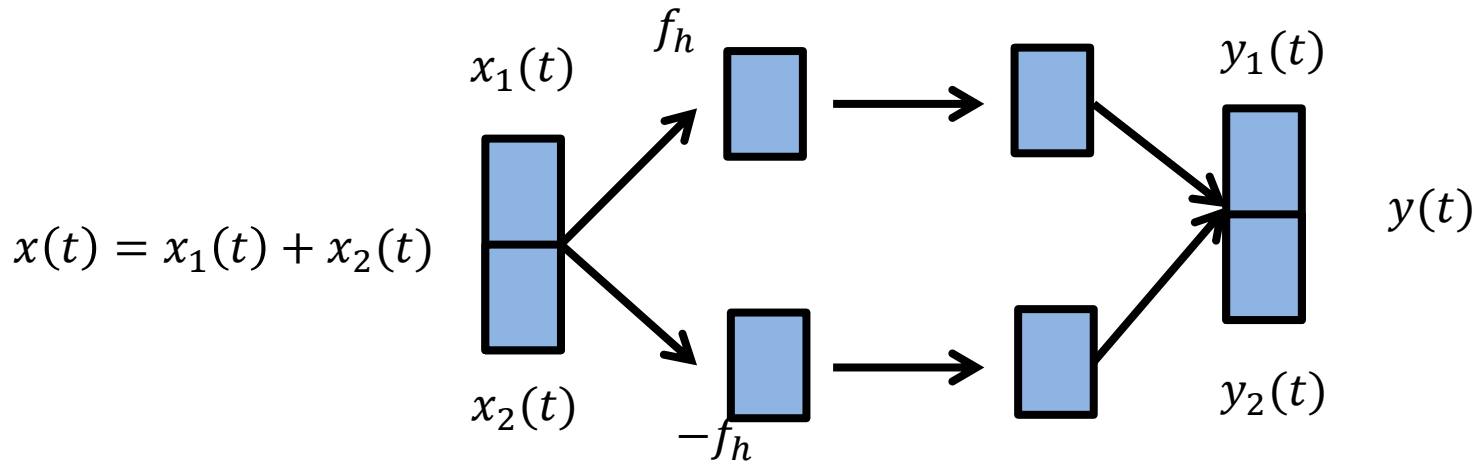
Virtual spectrum

Physical spectrum





Understand Reshaping



$$y(t) = h * x'(t - t_0) e^{j2\pi f \delta t} \quad \text{where}$$

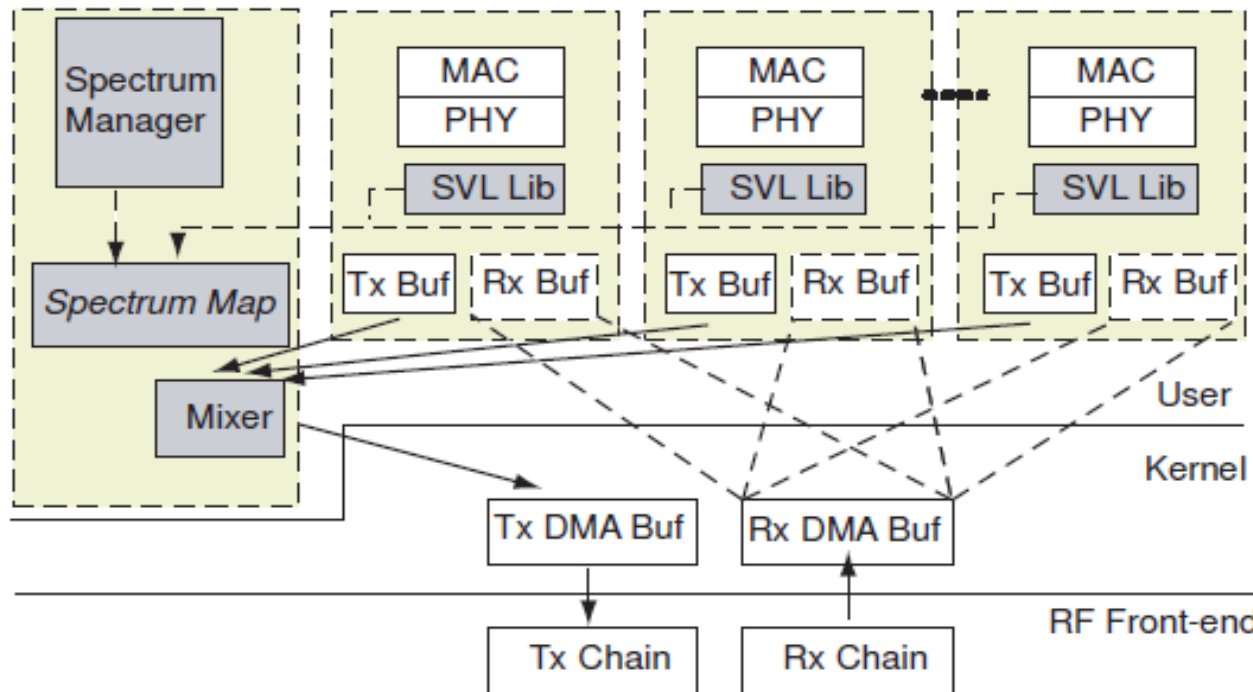
$$x'(t - t_0) = x_1(t - t_0) e^{-j2\pi f_h t_0} + x_2(t - t_0) e^{j2\pi f_h t_0}$$

- Recovered signal contains a multi-path version of the original signal
 - Require accurate timing synchronization



Implementation

- Prototype based on Sora platform

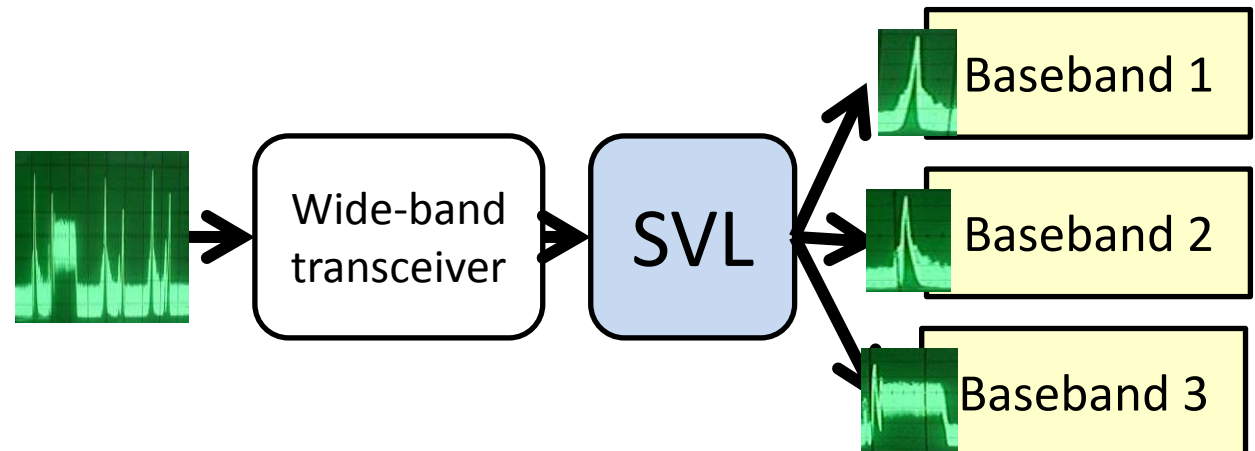


- Hardware implement is also possible



SVL Applications

- Whitespace networking with unmodified 802.11g
 - Support various TV channels (6/7/8MHz)
 - Support contiguous/non-contiguous spectrum bonding
- Multi-purpose access point (*Radio Virtualization*)
 - Consolidate multiple wireless device into single hardware



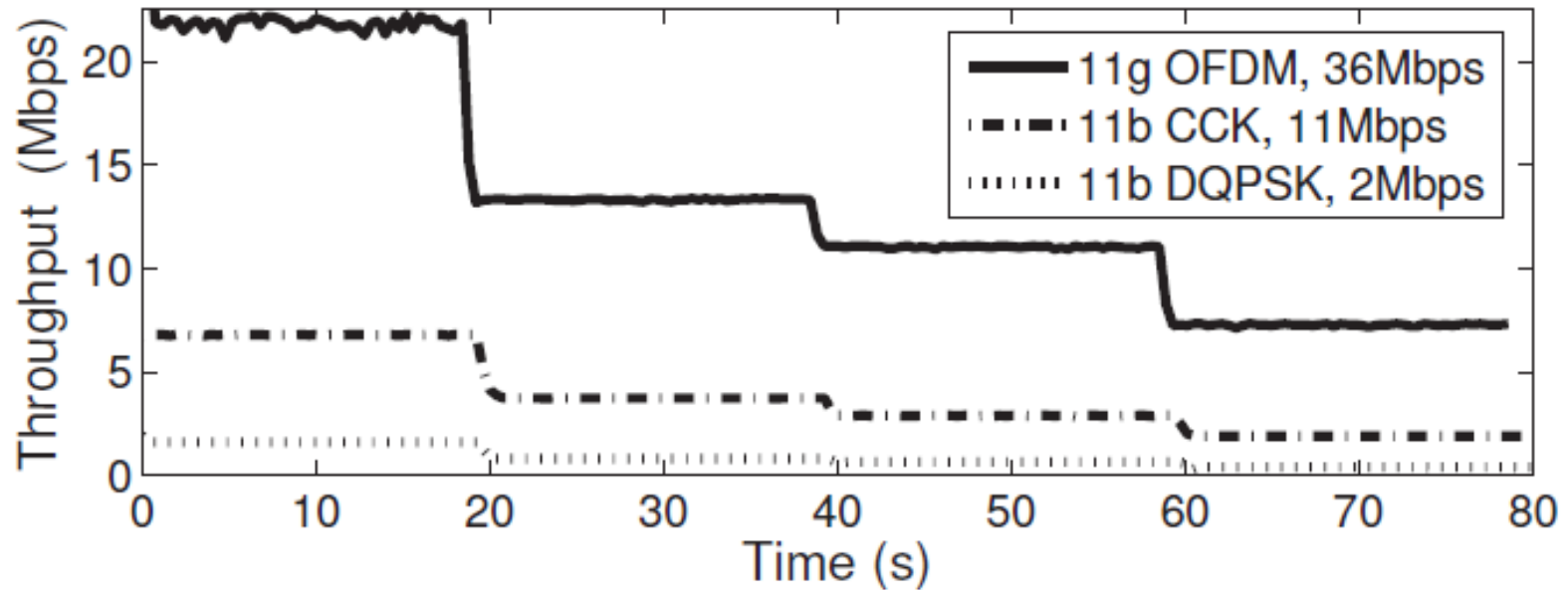


Evaluation

- Single link spectrum bonding
- DSA networking
- Reshaping precision

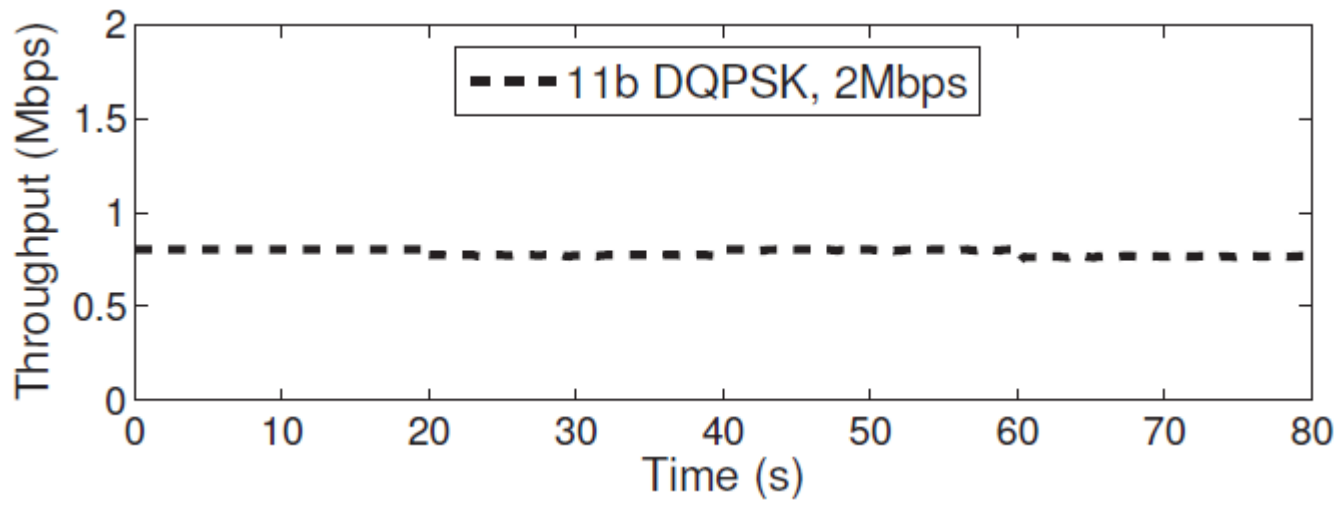
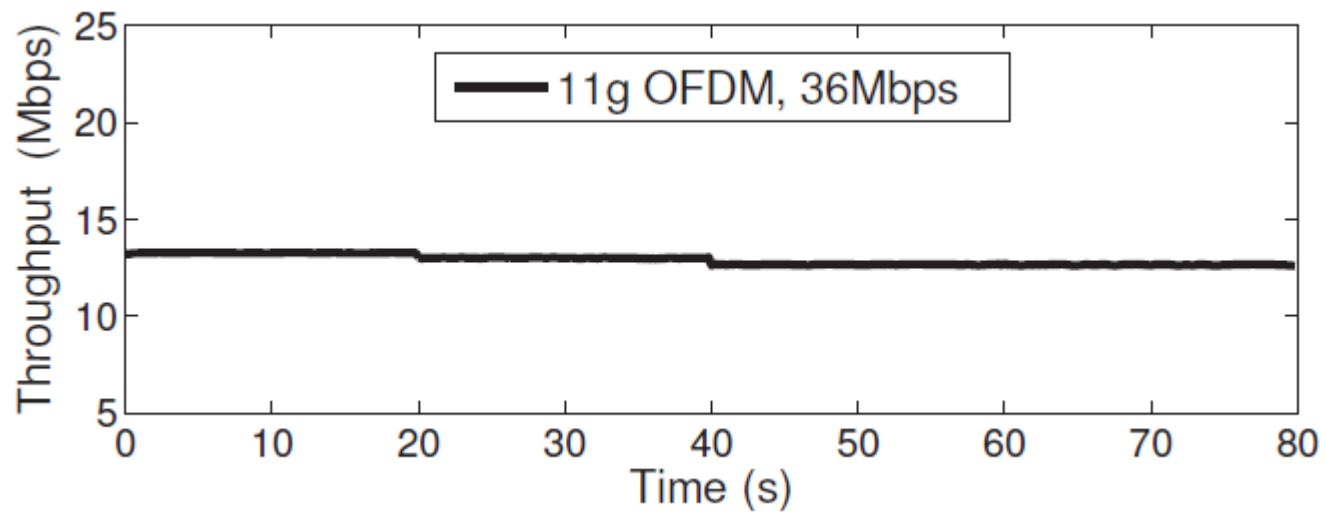


Results: Single Link with Variable Bandwidth



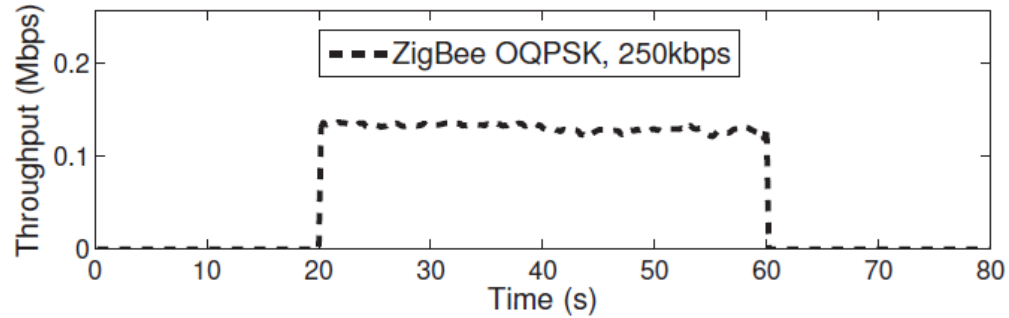
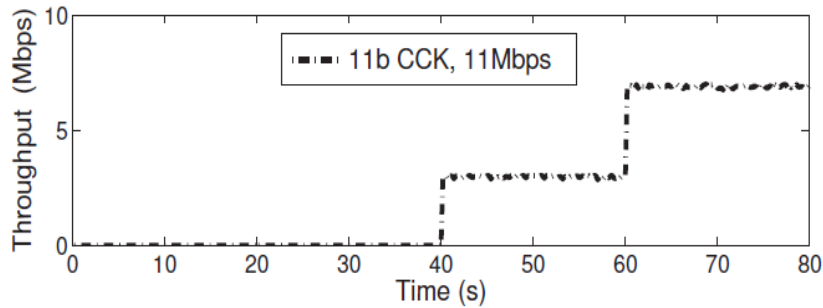
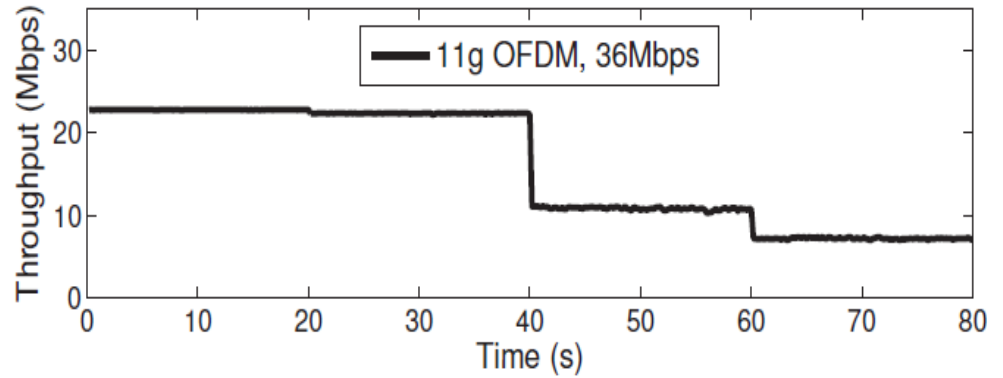
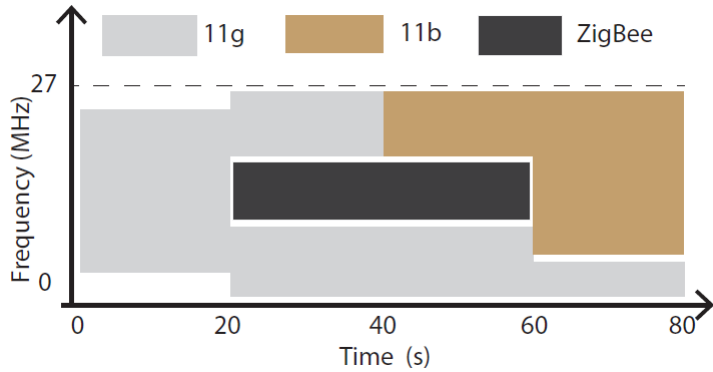


Results: Single Link with NC bonding





Results: DSA Networking





Results: Reshaping Precision

ERROR INTRODUCED BY SVL DSP OPERATIONS (dB).

Int-Width	PHY	<i>N</i> -Point			
		128	256	512	1024
16b	11g	-17	-15.2	-13.3	-8.3
	11b	-17.8	-15.9	-13.6	-10.7
32b	11g	-46.4	-43.9	-41	-38.1
	11b	-48	-45.4	-42.6	-39.8



Conclusion

- A new *Spectrum Virtualization Layer* to support **Spectrum Programmability** without PHY changes (*Demoed in SIGCOMM'10, TR in Jan 2011*)
 - Virtual spectrum abstraction to PHY (static, contiguous)
 - Dynamic shape virtual baseband to physical baseband using signal reshaping
 - Extensible to *Radio Virtualization* that allows multiple PHYs share the same RF front-ends.



Thanks!
Questions?



Backup