



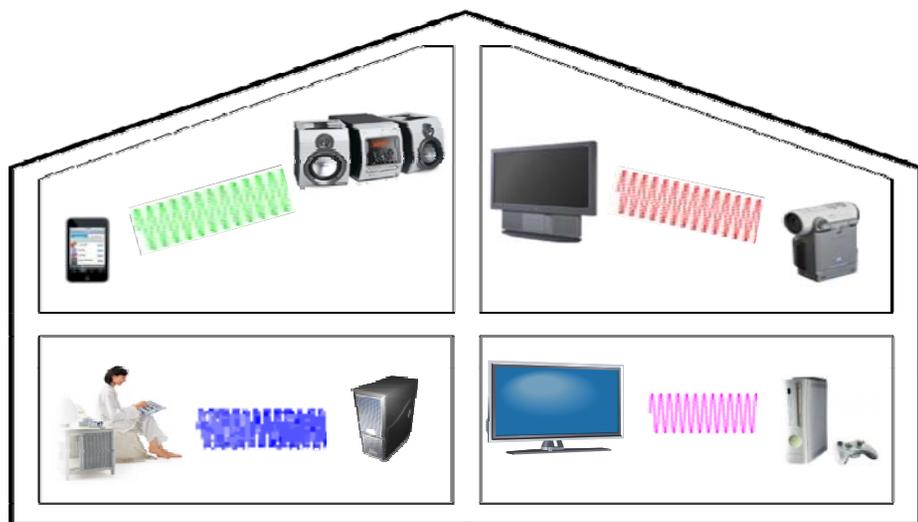
Dynamic Spectrum Sharing for Demanding Wireless Applications

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Supporting Wireless Media Sessions



WiFi ??

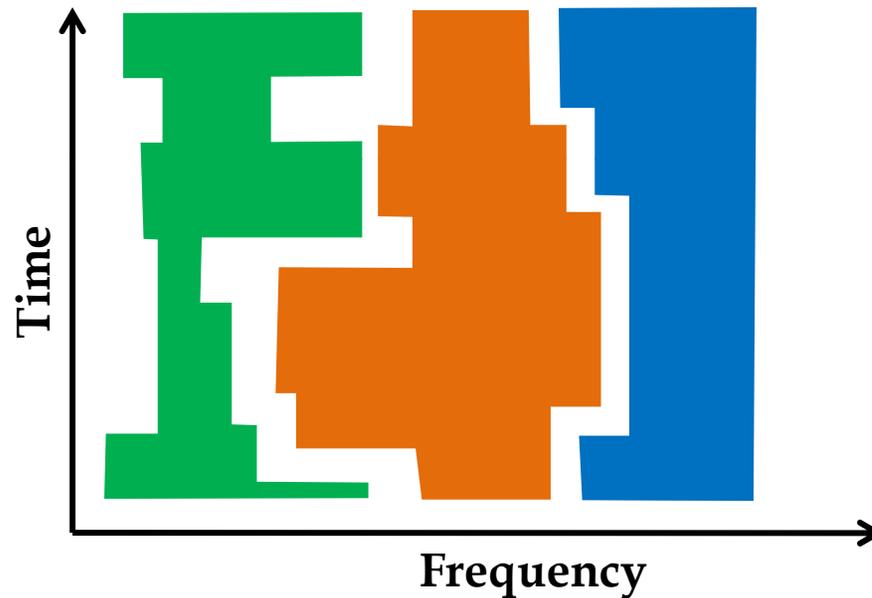


- The band is highly crowded
- Per-packet contention → unpredictable disruptions

- Desired properties
 - **Continuous access** to radio spectrum, high-bandwidth transmissions
 - Support multiple **concurrent** flows
 - **Adapt** to time-varying traffic demands

Per-session Dynamic Spectrum Sharing

- Simultaneous media sessions work in **parallel** on **isolated** frequencies



No interference



Continuous spectrum access in time

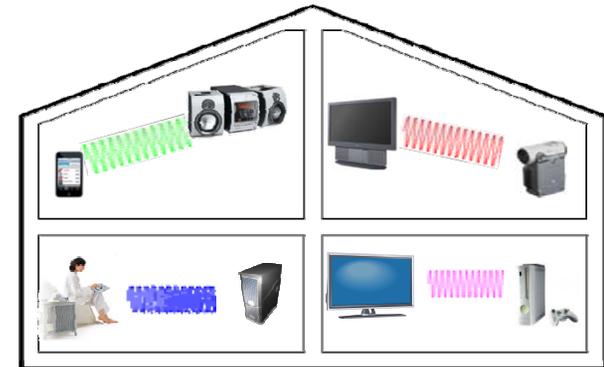


On-demand frequency usage

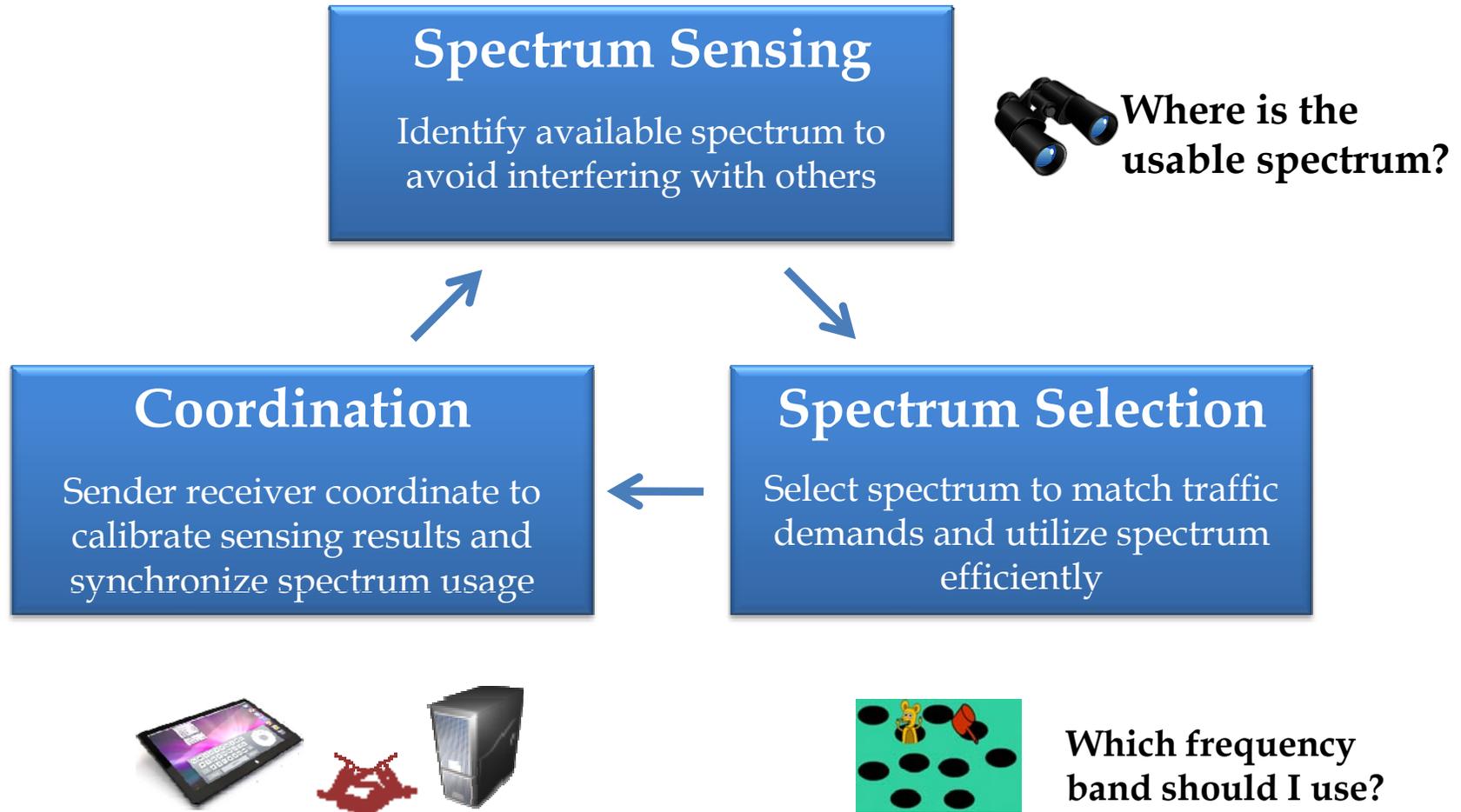
Jello: Decentralized Home Media System



- **Decentralized**
 - Flexible
 - Support different types of device
 - Self-configuring, self repairing
 - Low cost
 - No extra control radio
 - No central controller
- Utilizing **frequency-agile** radios
 - Flexible, reprogrammable

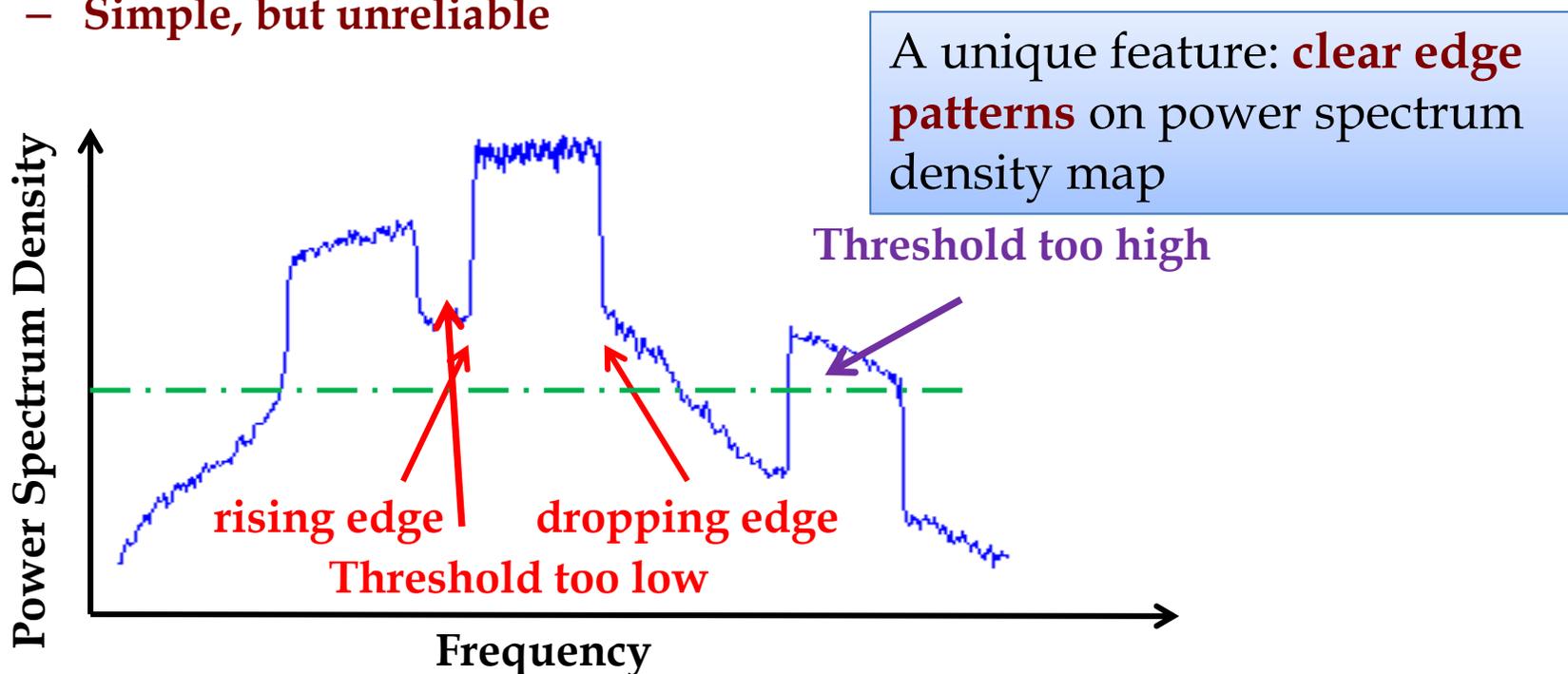


Jello's Key Components



How to Identify Free Spectrum?

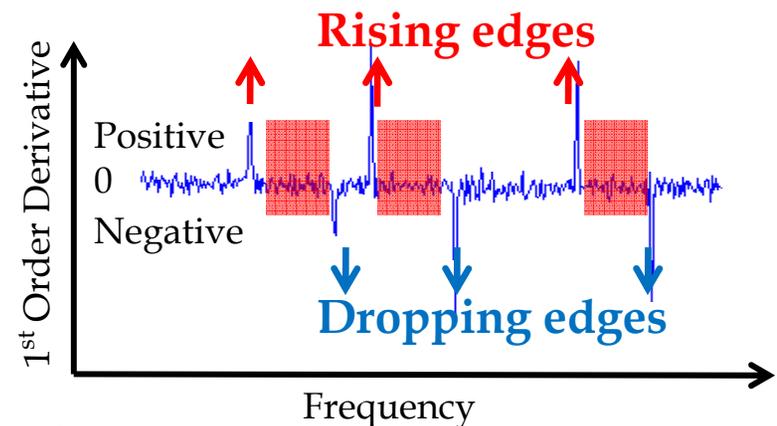
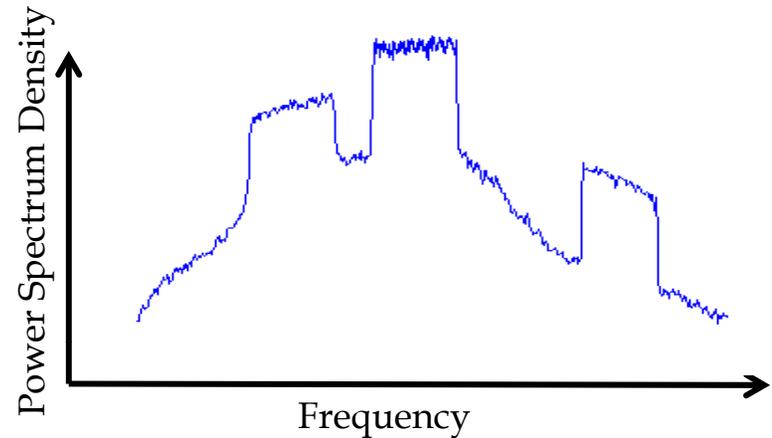
- Conventional sensing: energy detection
 - **Simple, but unreliable**



Jello devices identify and use such **edge patterns** to get better sensing!

Sensing via Edge Detection

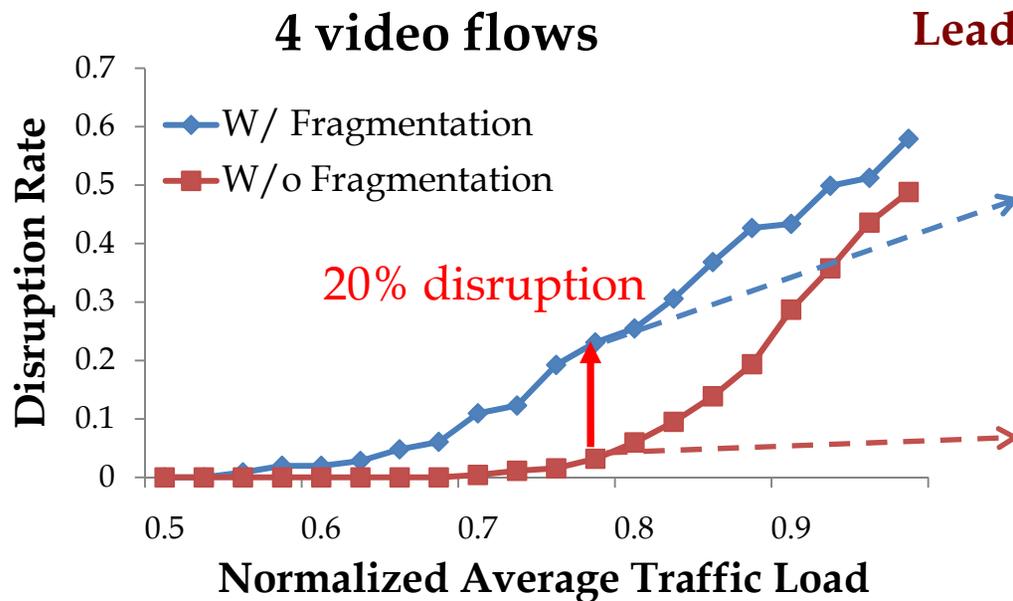
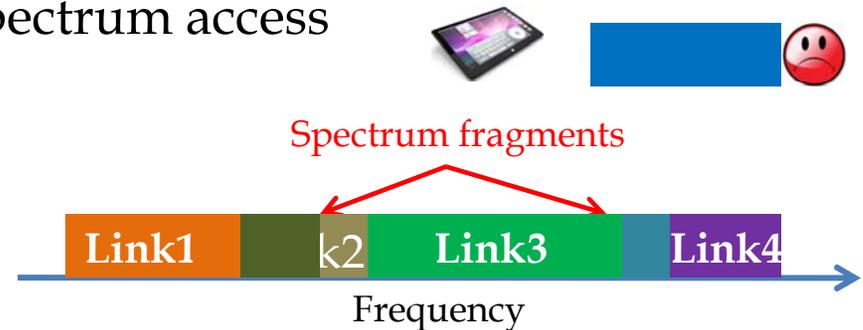
- **Step 1: Preprocessing**
 - Smoothing by averaging over multiple observations
- **Step 2: Detecting edges**
 - Calculate 1st order derivative of the power spectrum map
 - Identify rising/dropping edges



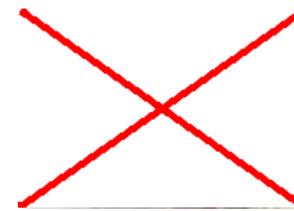
😊 **Much more robust than energy detection!**

Spectrum Selection & Defragmentation

- Like disks and memory, dynamic spectrum access creates **spectrum fragmentation**
 - Link comes and leaves
 - Link changes spectrum usage



Lead to significant media disruptions!



W/ Fragmentation



W/o Fragmentation

Solution 1: Defragmentation

- Rearrange global spectrum usage



No, cannot stop all transmissions



- Our solution: **individual online defragmentation**

- Voluntarily change spectrum usage to reduce fragmentation



😊 Stays transparent to other links

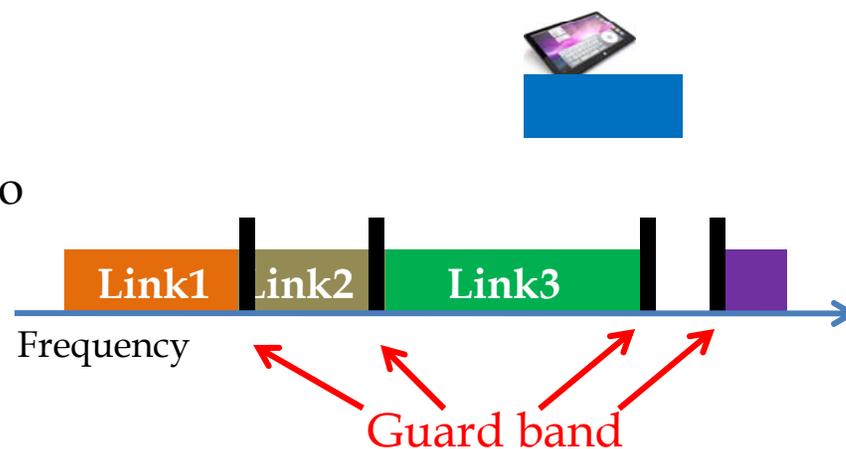
☹ Self-disruption → Defrag occurs infrequently

**Cannot eliminate fragmentation entirely,
low levels of fragmentation may still exist**



Solution 2: Non-Contiguous Spectrum Access

- Frequency-agile radios → redesign PHY to support non-contiguous spectrum access
 - Combine multiple spectrum slices to form a single transmission
 - Decentralized OFDMA
- 😊 Fragmentation is no longer harmful
- ☹️ Additional costs
 - Increased frequency overhead

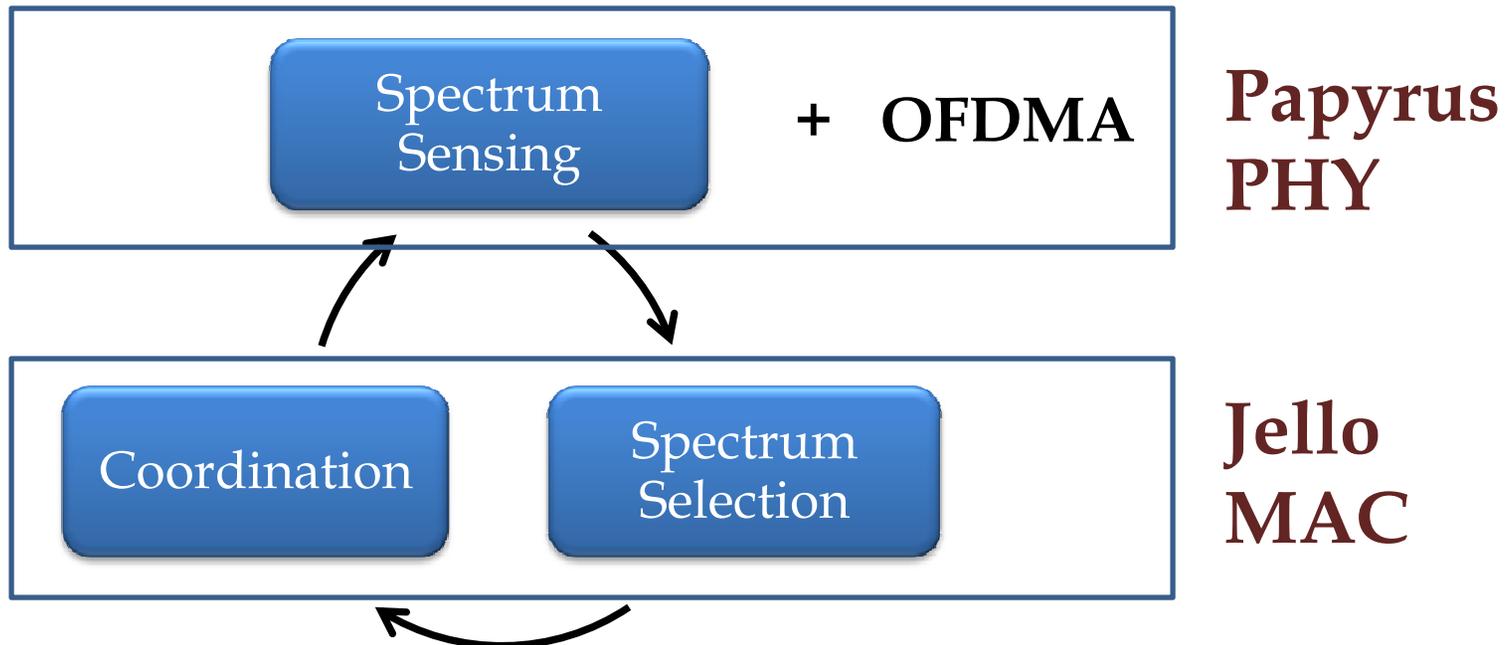


Non-contiguous frequency access reduces the impact of fragmentation, but at additional costs

Jello combines both solutions

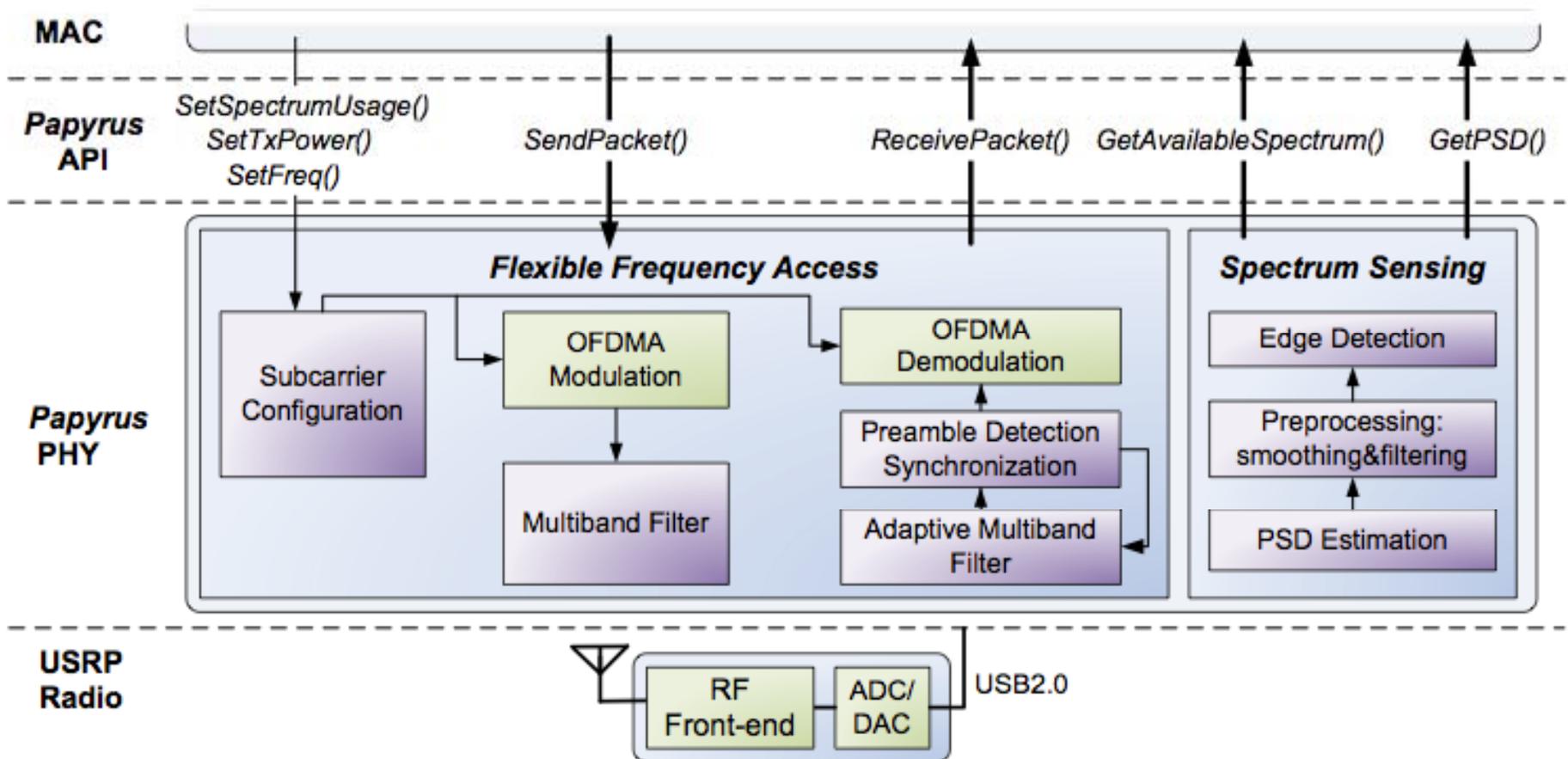
Jello Implementation

- USRP GNU Radio at 2.4G band
 - Widely available, inexpensive, flexible



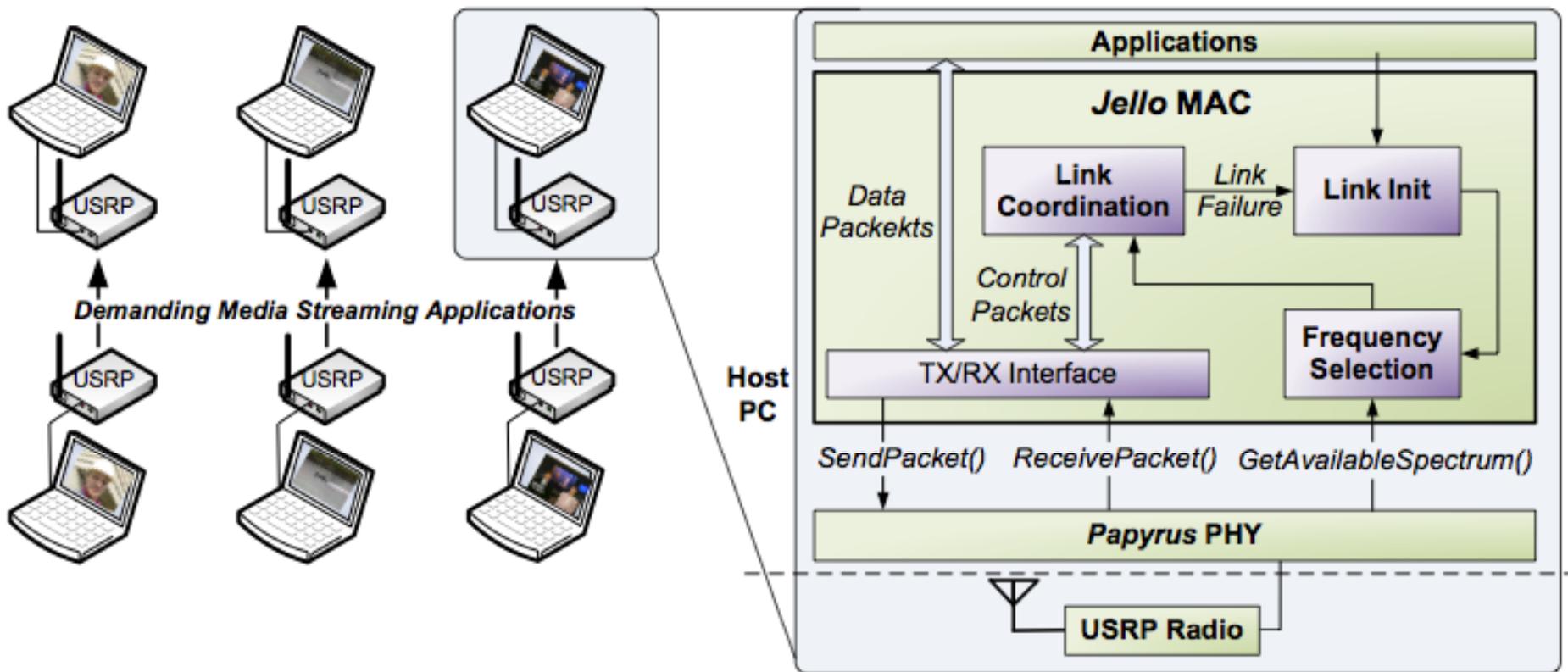
USRP GNU Radio Implementation (1)

- **Papyrus** PHY API: flexible frequency access + spectrum sensing



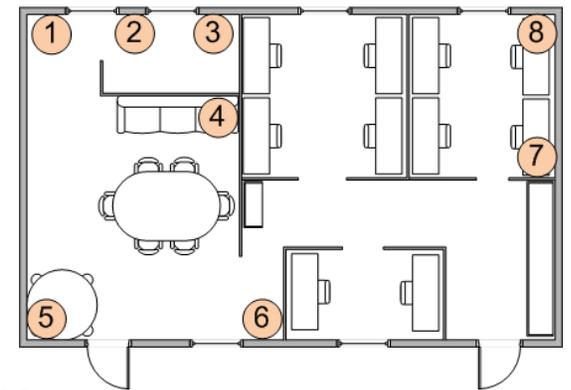
USRP GNU Radio Implementation (2)

- **Jello** MAC overlay (Frequency selection + defragmentation + coordination)



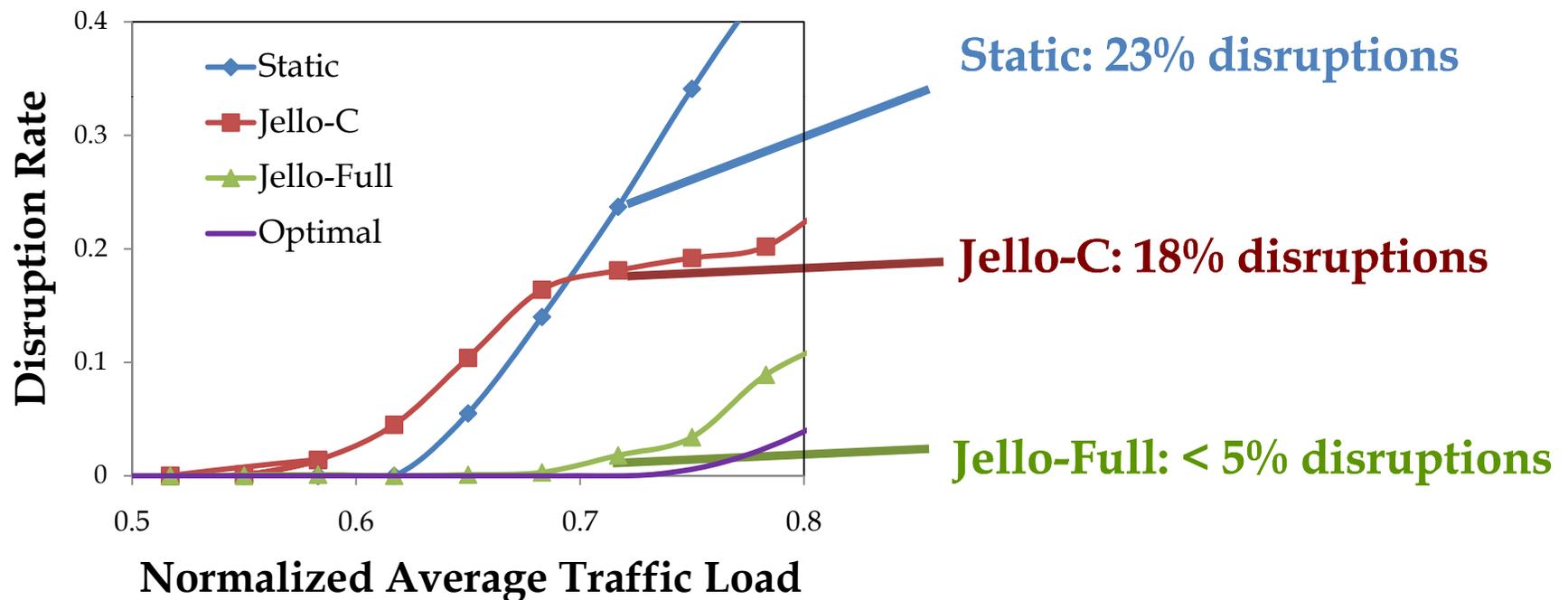
Initial Deployments

- 8-node GNU Radio testbed
 - 4 concurrent flows
 - 12m x 7m room with various furniture and walls
- Traffic load
 - Video and synthetic traces
- Evaluated 4 systems
 - **Static**: Partition spectrum equally, WiFi-like
 - **Jello-C**: Jello with contiguous frequency access
 - **Jello-Full**: Full version of Jello
 - **Optimal**: Oracle solution w/o fragmentation and overhead



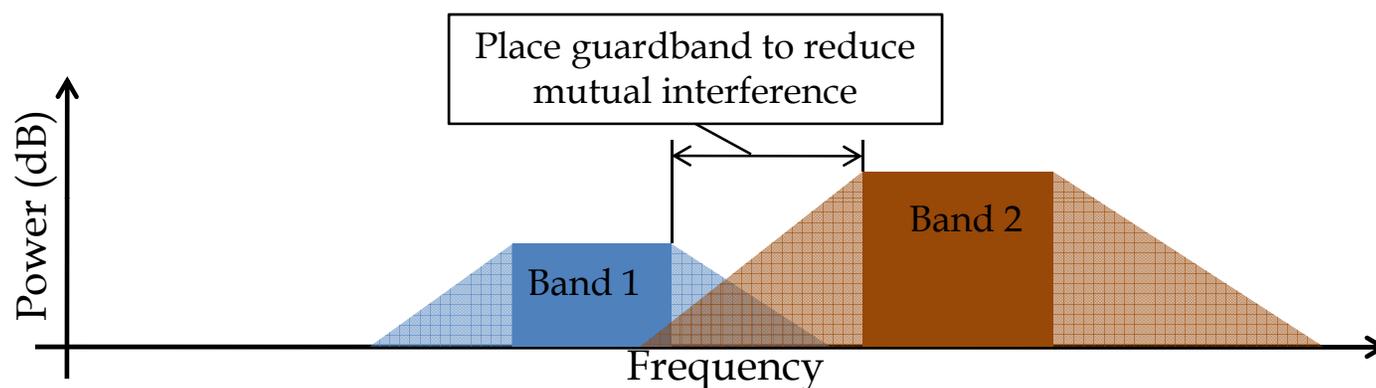
Results: Media Quality

Video Disruption Rate: percentage of time video is disrupted



The Problem of Cross-band Interference

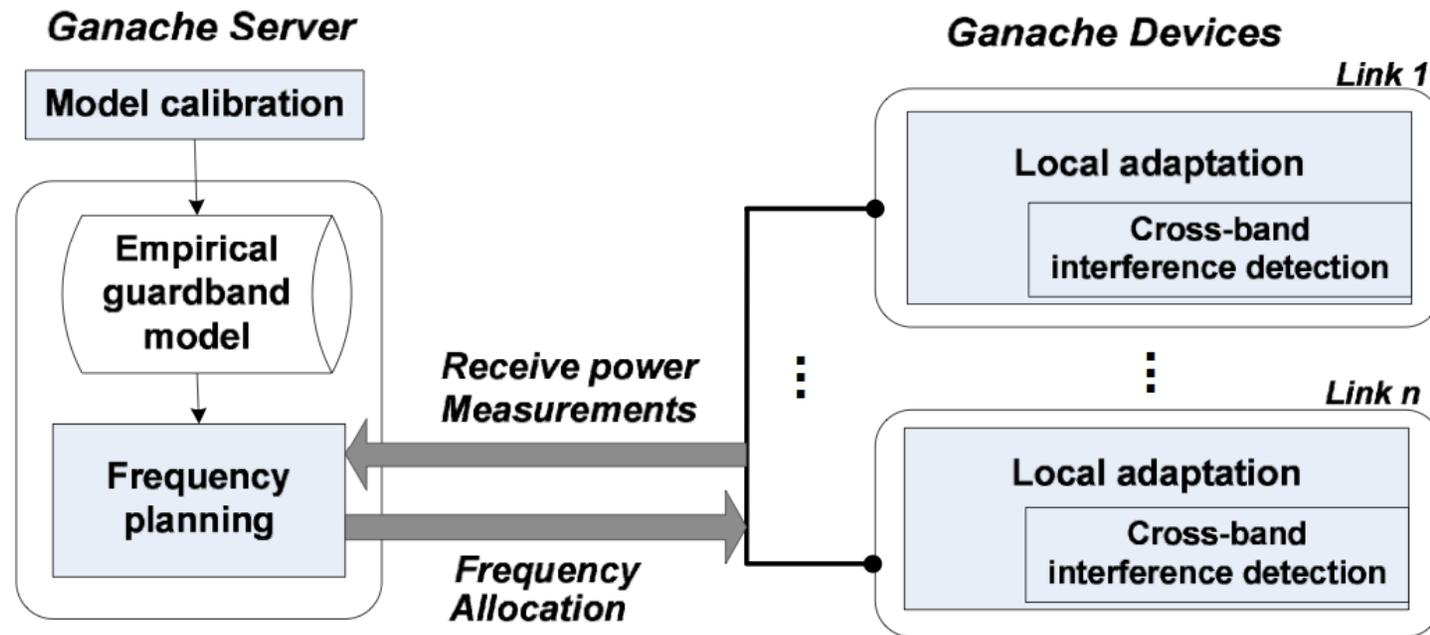
- Cross-band interference is harmful with **heterogeneous links**



- Traditional “one-size-fits-all” guardband configuration leads to severe performance degradation. (up to 80% in WiFi experiments)
- Links’ frequency placement is critical

We need to configure frequency placement and guardband usage based on network conditions

Ganache: Dynamic Guardband Configuration



- *The Spaces Between Us: Setting and Maintaining Boundaries in Wireless Spectrum Access. To Appear in MobiCom 2010*

Additional information from our NSDI 2010 and MobiCom 2010 paper Full Jello/Papyrus Implementation available @

- <http://link.cs.ucsb.edu/papyrus/>

Jello Demo available @

- <http://www.cs.ucsb.edu/~htzheng/papyrus/detail/demo.html>
- <http://www.youtube.com/watch?v=-BcycTXh4uc>

Papyrus: A Software Radio Platform for Dynamic Spectrum Sharing

Overview

Design

Papyrus --> Jello

Prototype

Download

Demo

Team

Related Publications

Supporting Demanding Wireless Applications with Frequency-Agile Radios, NSDI 2010 [PDF]

Jello: Dynamic Spectrum Sharing in Digital Homes, Demo, Infocom 2010 [PDF] [Photo]

The Impact of Frequency-Agility on Dynamic Spectrum Sharing, DySPAN 2010 [PDF]

Papyrus

Proliferation and innovation of wireless technologies require significant amounts of radio spectrum. Recent government policy reforms by the FCC are paving the way by freeing up spectrum for a new generation of frequency-agile wireless devices based on software defined radios (SDRs). Despite recent advances in experimental SDR platforms, further research into SDR MAC protocols or applications requires an experimental platform for managing physical spectrum access.

We have developed Papyrus, a software platform for wireless researchers to develop and experiment dynamic spectrum systems using currently available SDR hardware. Papyrus manages the complexities of spectrum access at the physical layer, exporting a clean, manageable abstraction to the MAC layer. Papyrus provides **no fundamental building blocks** at the physical layer: flexible non-contiguous frequency access and robust usable frequency detection. Researchers can deploy and experiment new MAC protocols and applications on Papyrus, which is available on the USRP GNU Radios, but can be adapted to run on all current SDR platforms. We demonstrated the use of Papyrus as an experimental platform using **Jello**, a distributed MAC overlay for high-bandwidth media streaming applications.

You can download the USRP GNU Radio implementation of Papyrus and Jello [here](#).

The following figure shows our demo at Infocom 2010. It includes 3 pairs of USRP GNU radio links, demonstrating fully decentralized spectrum sharing. We also use 1 USRP as the spectrum analyzer. Click [here](#) to watch our Demo video.



Questions?