Dynamic Spectrum Sharing for Demanding Wireless Applications

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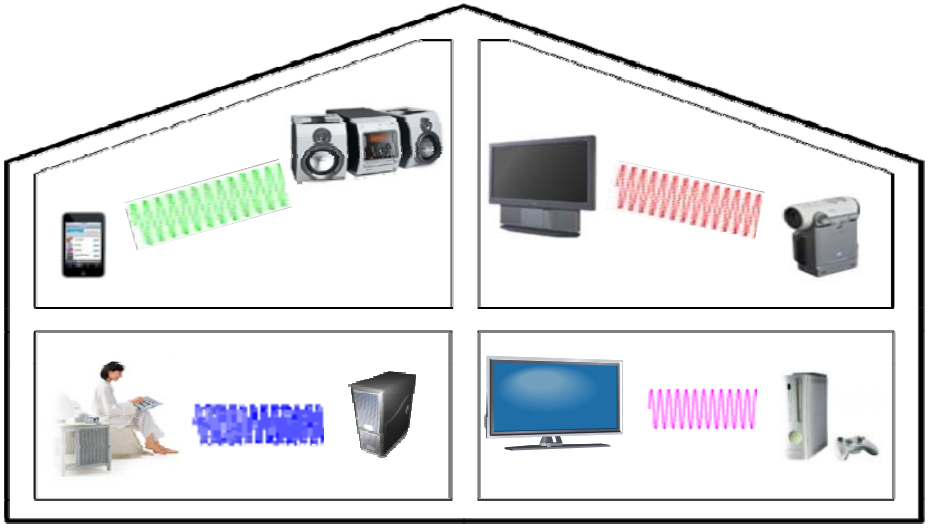
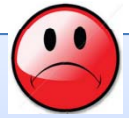
Supporting Wireless Media Sessions



WiFi ??

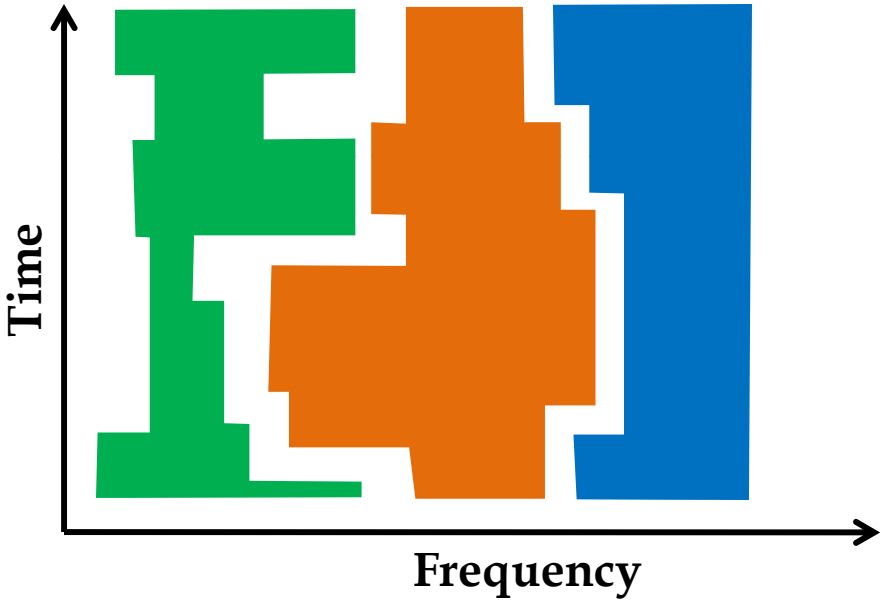


- The band is highly crowded
- Per-packet contention → unpredictable disruptions

- 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



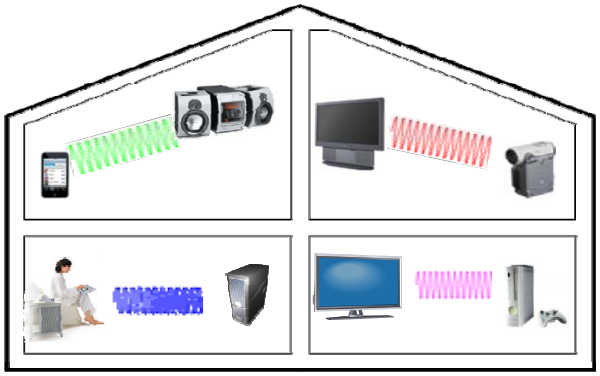
No interference

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

GNU Radio

SORA

AirBlue

WARP RICE UNIVERSITY WIRELESS OPEN-ACCESS RESEARCH PLATFORM

Jello's Key Components

Spectrum Sensing

Identify available spectrum to avoid interfering with others

Where is the usable spectrum?

Spectrum Selection

Select spectrum to match traffic demands and utilize spectrum efficiently

Coordination

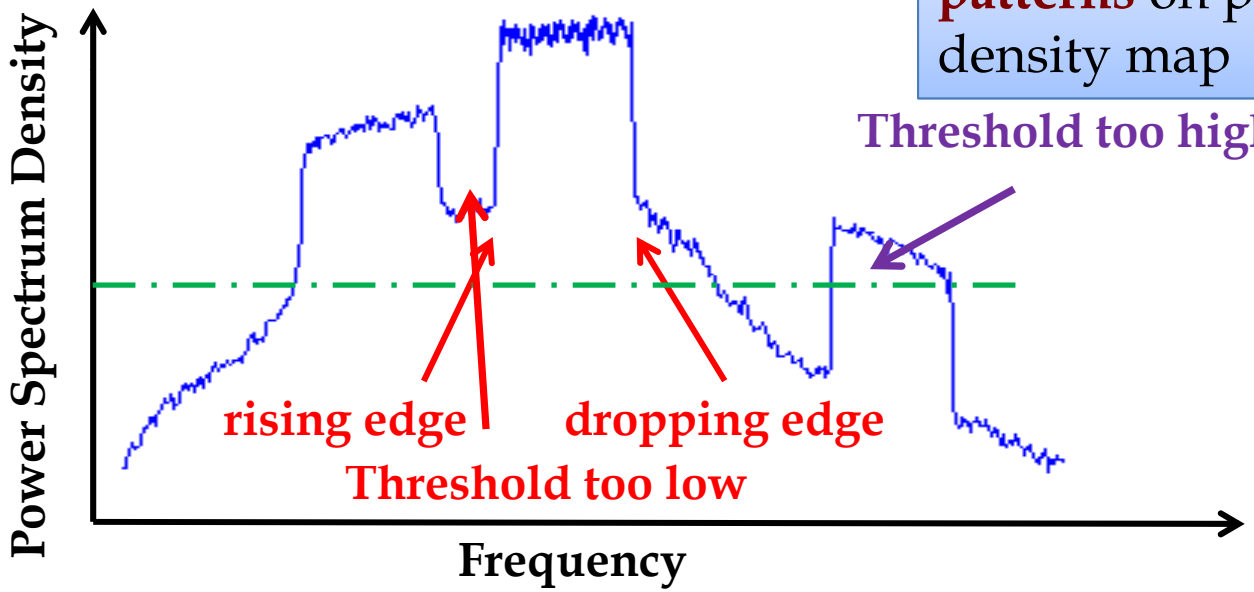
Sender receiver coordinate to calibrate sensing results and synchronize spectrum usage

Which frequency band should I use?

How to Identify Free Spectrum?

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

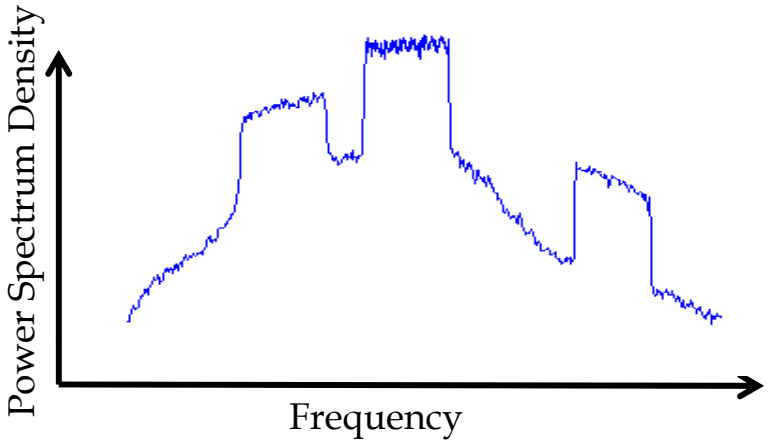
A unique feature: **clear edge patterns** on power spectrum density map



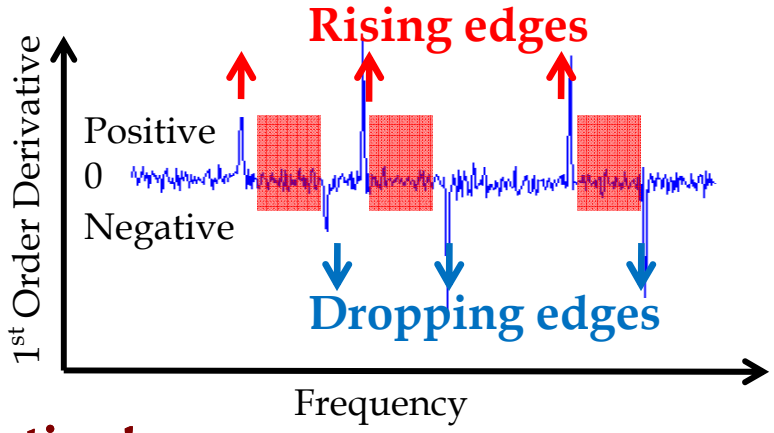
Jello devices identify and use such edge patterns to get better sensing!

Sensing via Edge Detection

- **Step 1: Preprocessing**
  - Smoothing by averaging over multiple observations



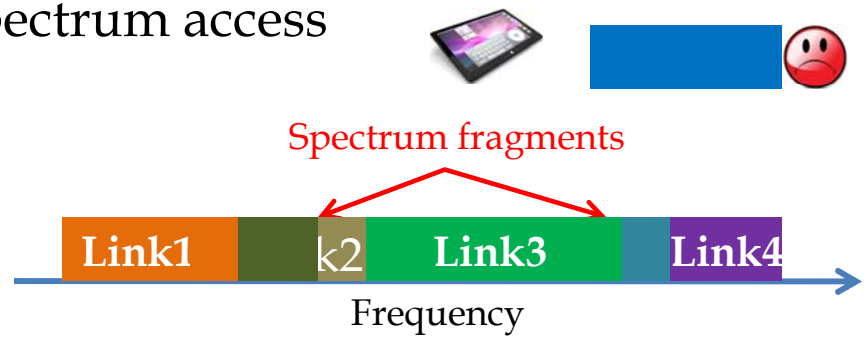
- **Step 2: Detecting edges**
  - Calculate 1st order derivative of the power spectrum map
  - Identify rising/dropping edges

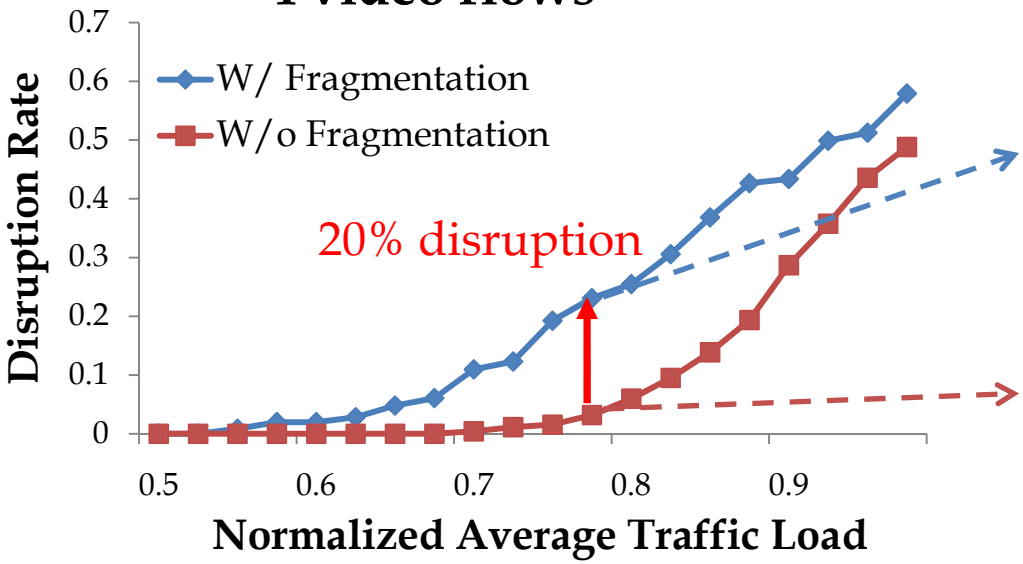


Much more robust than energy detection!

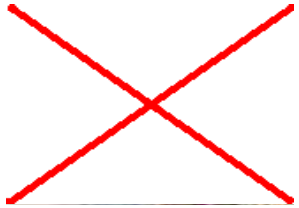
Spectrum Selection & Defragmentation

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





Lead to significant media disruptions!

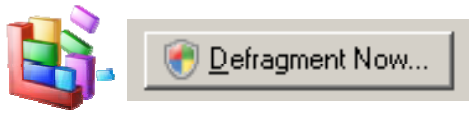


W/ Fragmentation

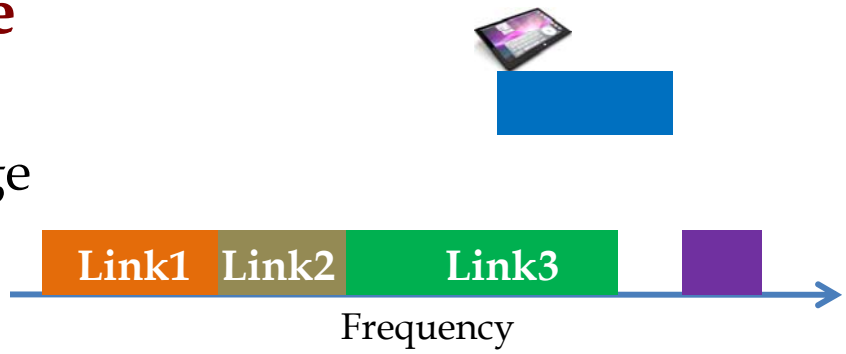
W/o Fragmentation

Solution 1: Defragmentation

- Rearrange global spectrum usage
  - **No, cannot stop all transmissions**



- Our solution: **individual online defragmentation**
  - Voluntarily change spectrum usage to reduce fragmentation

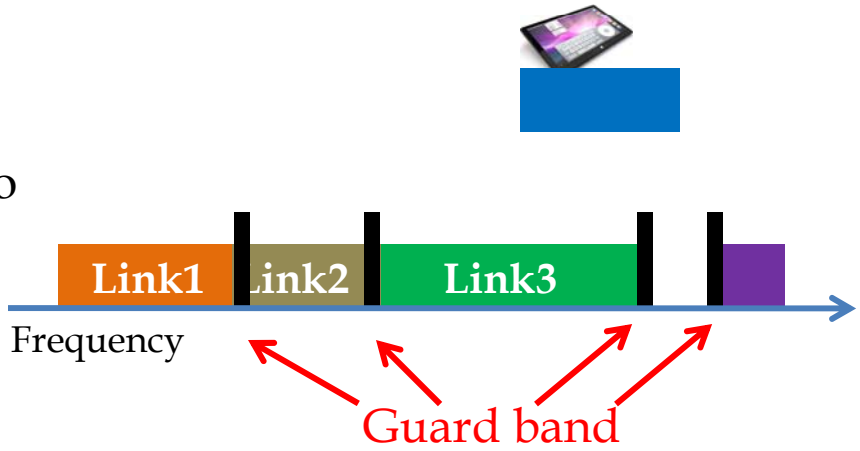


  - **Stays transparent to other links**
  - **Self-disruption →Defrag occurs infrequently**

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



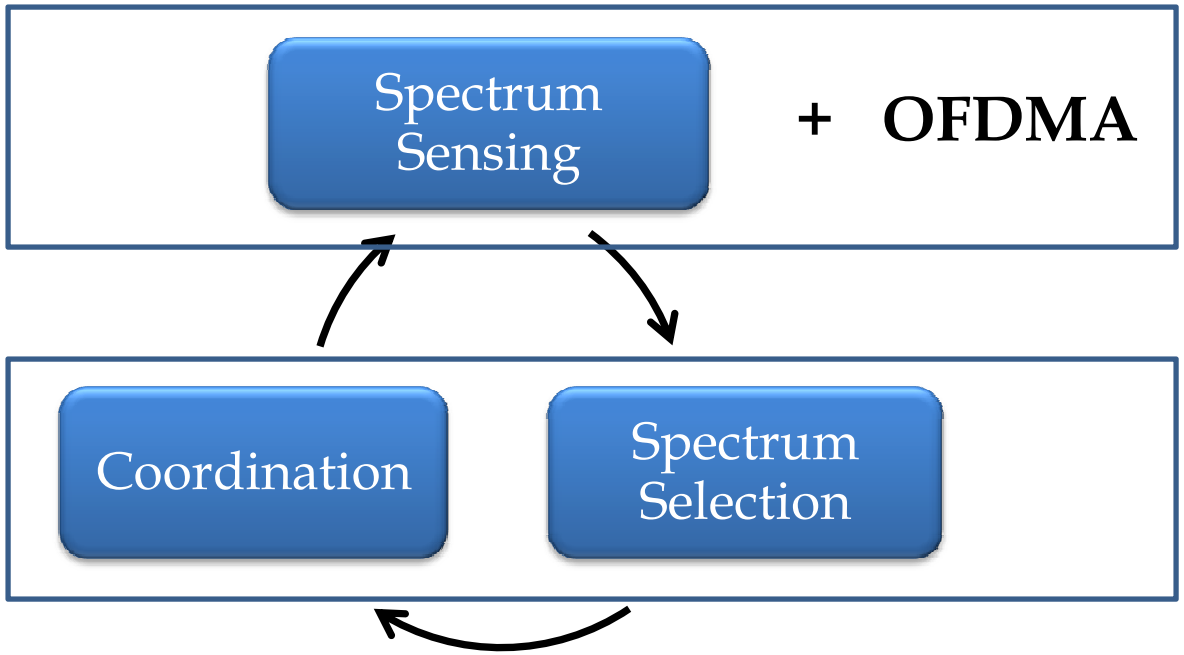
- Fragmentation is no longer harmful
- Additional costs
  - Increased frequency overhead

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

Jello combines both solutions

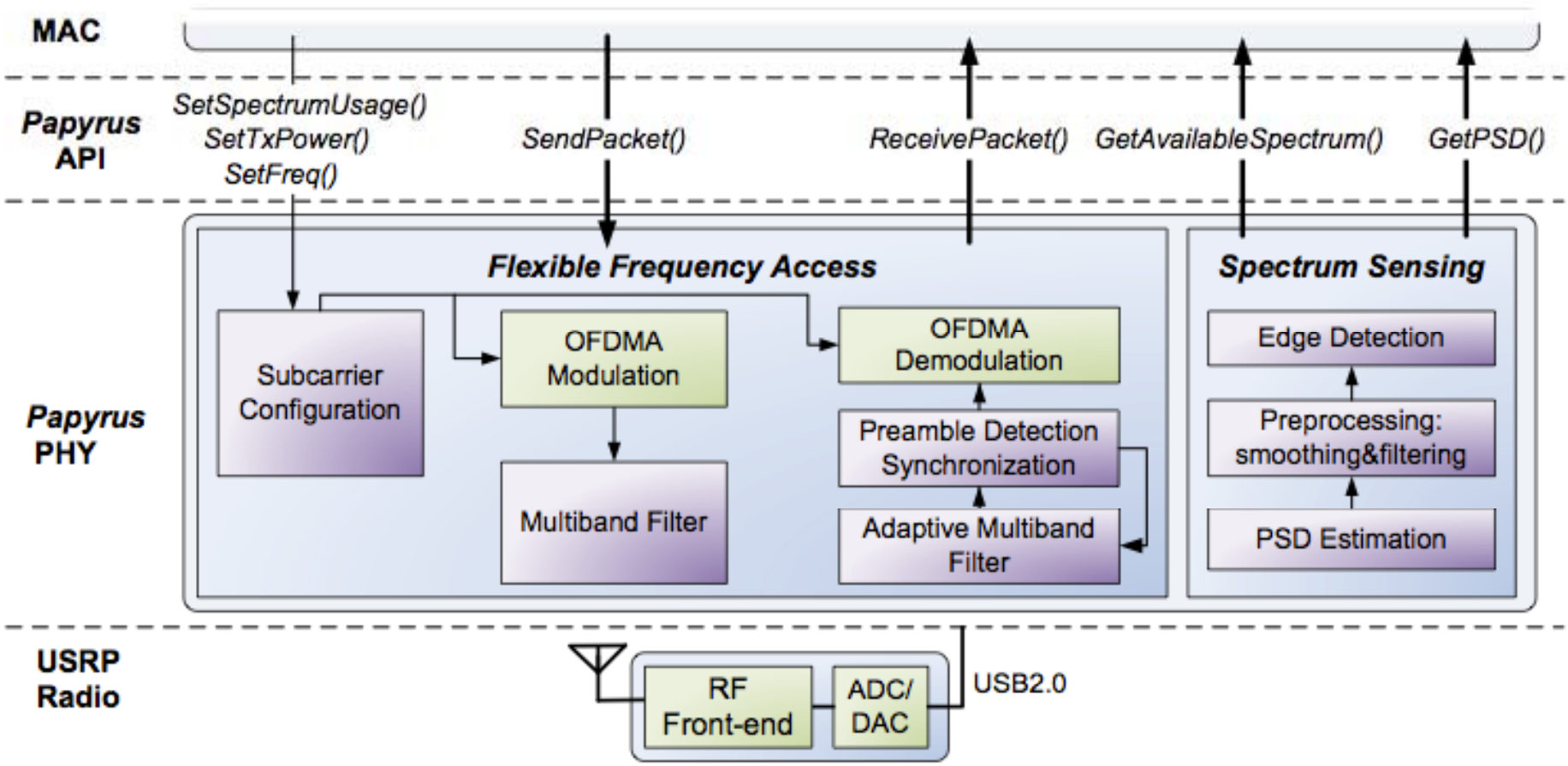
Jello Implementation

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



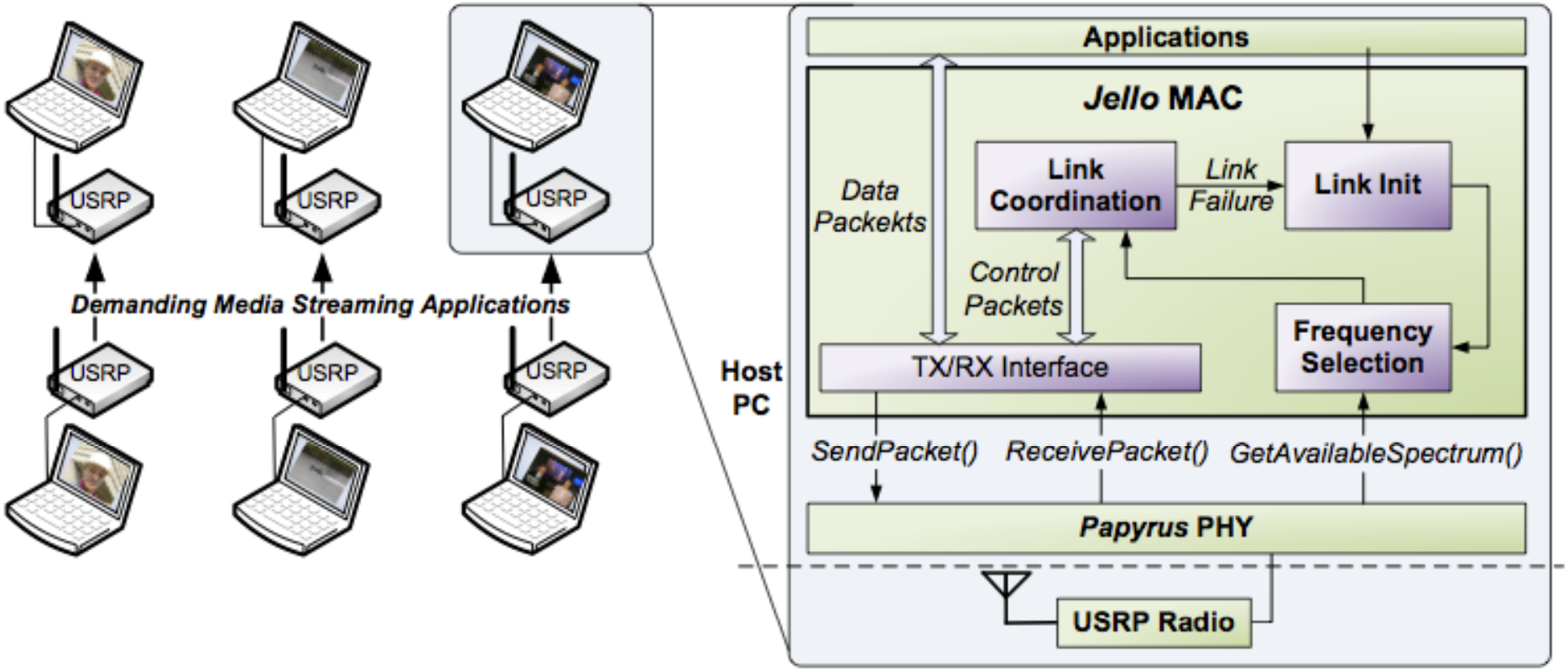
USRP GNU Radio Implementation (1)

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



USRP GNU Radio Implementation (2)

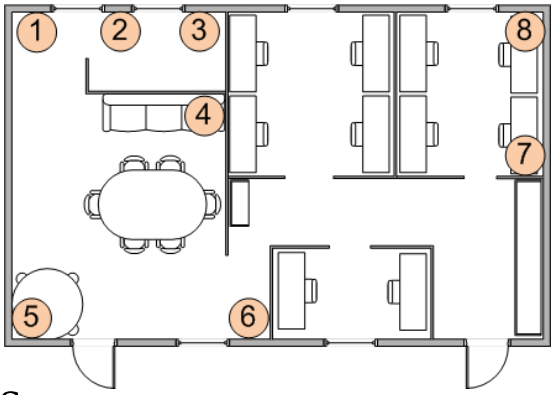
- **Jello** MAC overlay (Frequency selection +defragmentation + coordination)



Initial Deployments

- 8-node GNU Radio testbed
  - 4 concurrent flows
  - 12m x 7m room with various furniture and walls

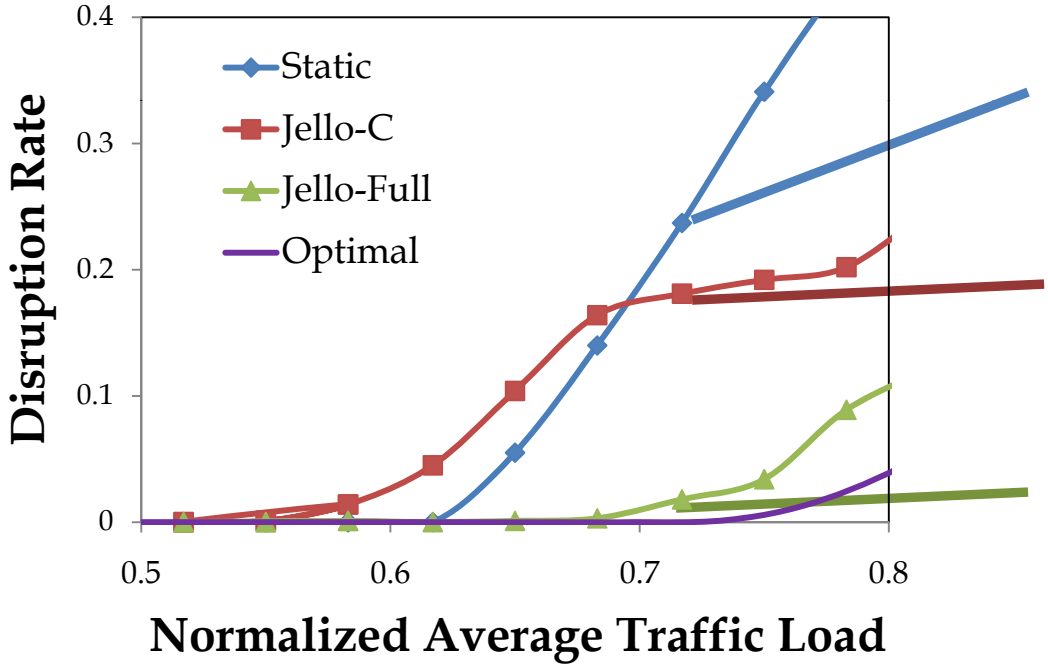
- Traffic load
  - Video and synthetic traces



- 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



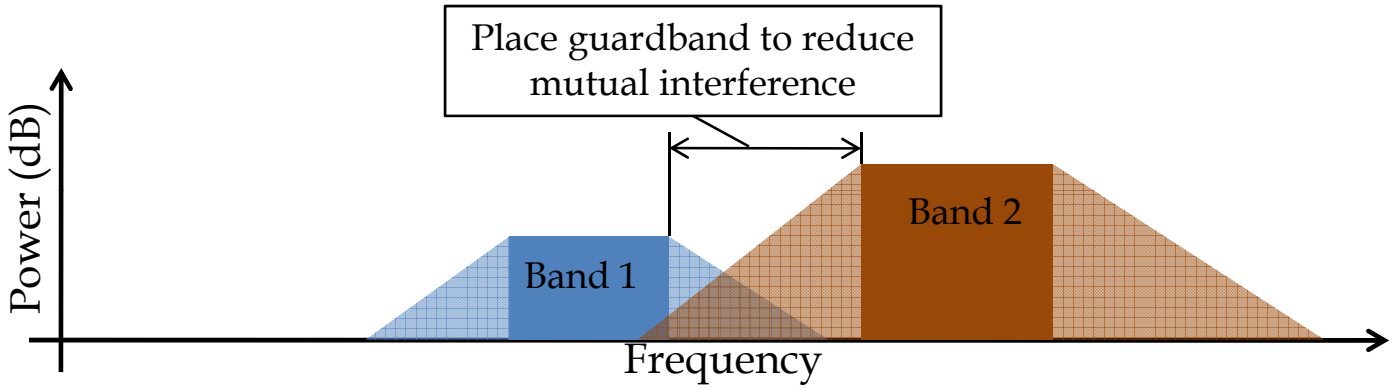
Static: 23% disruptions

Jello-C: 18% disruptions

Jello-Full: < 5% disruptions

The Problem of Cross-band Interference

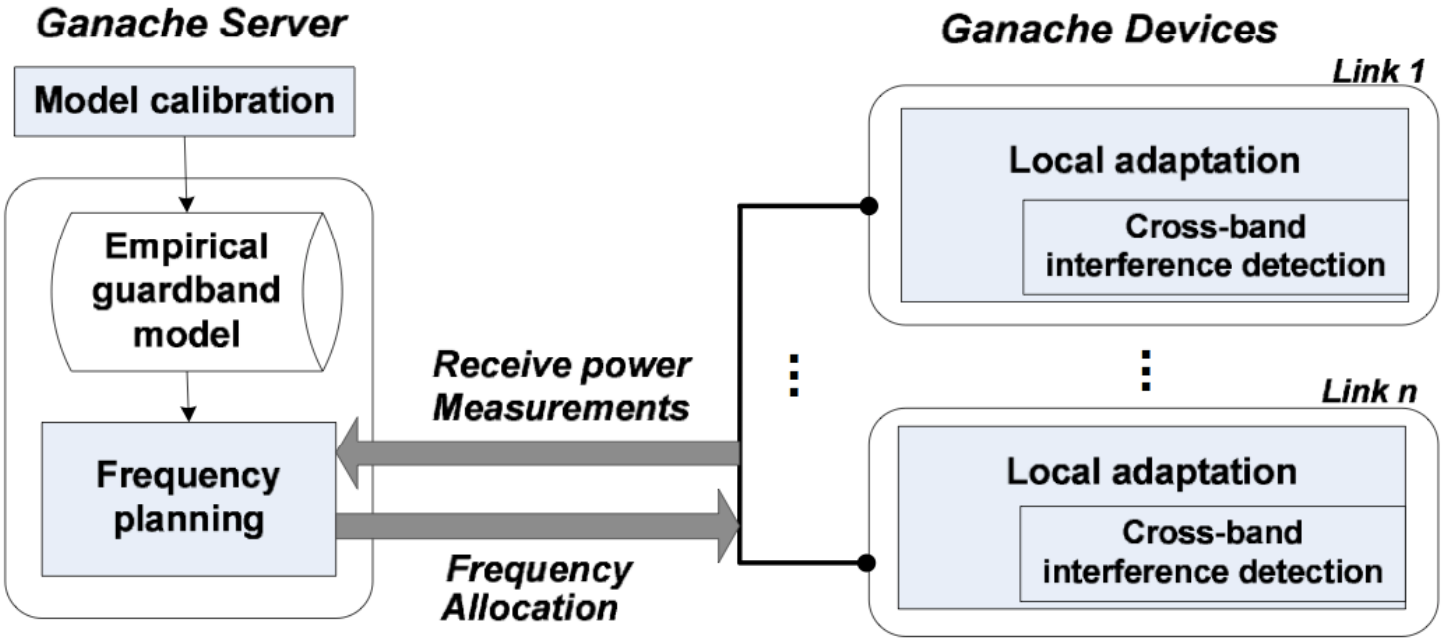
- Cross-band interference is harmful with **heterogeneous links**



- 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**

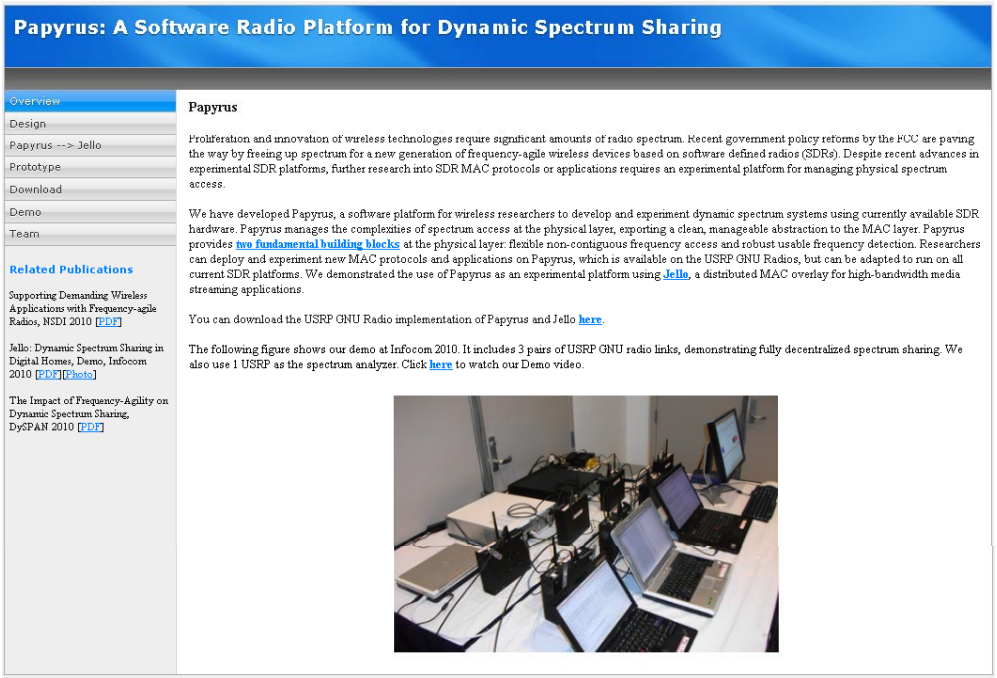
Additional information from our NSDI 2010 and MobiCom 2010 paper

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**



Questions?