

# Jello: Dynamic Spectrum Sharing in Digital Homes

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## ABSTRACT

Wireless devices are being increasingly deployed in digital homes to deliver demanding applications such as high-quality streaming media. To avoid costly interference, they can use frequency-agile hardware to detect and utilize unoccupied wireless spectrum ranges. The challenge is how to manage spectrum among a variety of heterogeneous consumer devices efficiently without expensive control hardware or disrupting ongoing transmissions. We develop Jello, a distributed dynamic spectrum access system based on non-contiguous OFDMA to provide robust, high-bandwidth communication for consumer wireless devices. We implement a Jello prototype on a 7-node GNU Radio testbed. In this Jello demo, we will run three parallel transmissions with time-varying loads. We show that Jello can significantly increase spectrum utilization while reducing media disruption.

## 1. MOTIVATION

Wireless technologies are an increasing part of our daily lives. Today’s digital home uses a wide range of wireless devices to replace messy and cumbersome audio, video, telephone and data cables. Future wireless technologies are expected to deliver multiple high-quality streaming media sessions simultaneously across rooms (see Figure 1). While mom or dad streams a cooking video from the office PC to the kitchen counter, kids in the den are watching an HD movie streamed from the Digital Video Recorder (DVR) in the living room.

Unlike best-effort traffic applications, these multimedia flows require dedicated spectrum access to minimize disruptions to their transmissions and to maintain the expected quality of user experience. At the same time, these flows often occur simultaneously and thus must share the medium with each other. Therefore, we must carefully manage wireless spectrum, in digital homes, and many other high density environments.

In this respect, new hardware in the form of frequency-agile radios can be extremely useful. With these radios, devices can share and obtain prolonged access to wireless spectrum in the frequency domain. At the start of each network connection, the device examines the usage of wireless spectrum in the local area, and directs its radio (and that of its peer receiver) to a frequency range that not only matches its traffic demands, but also lies orthogonal to existing transmissions. Thus si-

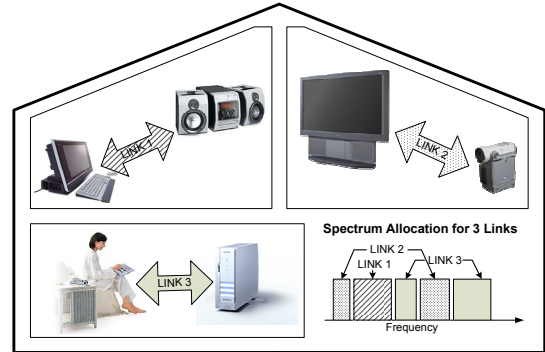


Figure 1: Home networking devices using non-contiguous frequency blocks to provide high-quality media streaming.

multaneous transmissions work in parallel on isolated frequencies, and avoid costly wireless interference that traditionally leads to contention and network communication delays. As its traffic volume varies, the device can grab and release spectrum as necessary without being confined by fixed channel configurations in 802.11.

Realizing dynamic spectrum sharing across a variety of home consumer devices requires a fully decentralized, plug-in-play network design. Conventional solutions for dynamic spectrum access either rely on a central controller to periodically reallocate spectrum for the entire network, or require devices to coordinate on a dedicated control channel or radio. This works well in infrastructure networks across groups of similar and well-synchronized devices, but enforcing such coordination and cooperation across a variety of home consumer networking devices is unrealistic.

## 2. JELLO

In this demo, we present Jello [3], a fully distributed system design where devices access and share spectrum dynamically to support demanding wireless media applications. Jello implements a fully decentralized OFDMA system allowing consumer wireless devices to sense, identify, occupy and adapt their frequency access independently on-the-fly. Jello requires neither centralized spectrum controllers nor dedicated control radios. In addition, Jello offers several unique properties. First, Jello suppresses the impact of spectrum fragmentation by enabling non-contiguous spectrum access. Using OFDMA,

a Jello radio can combine multiple spectrum ranges to support a single high-speed transmission. Second, Jello allows wireless devices to access spectrum contiguously in time using frequency-domain spectrum sharing, avoiding frequent time contention and its overhead. In these respects, Jello differs from prior work on dynamic spectrum access [1] by enabling non-contiguous spectrum access and using in-band signaling rather than control radios. Jello also differs from SWIFT [2] by exploiting frequency domain sharing to avoid frequent contention and ensure that traffic flows continuously.

The key to our Jello design is a fully decentralized OFDMA mechanism that allows home consumer devices to adapt their frequency access. To eliminate cross frequency interference, we place “frequency guard bands” between allocated frequency boundaries, and we take significant efforts to reduce the size of guard bands, including adding receiver filters. We also leverage the “wide-band sensing” capability provided by OFDM, and apply an “edge detection” technique to accurately and quickly identify free spectrum. Using a number of techniques, we ensure that our scheme only impacts a transmission when it changes its own frequencies. The frequency change is nearly instantaneous, and stays completely transparent to other ongoing sessions. We have implemented a Jello prototype on USRP GNU radios, operating on a 500kHz frequency band at 2.38GHz and using 256 sub-carriers.

### 3. DEMO SETUP

In this demo, we demonstrate our Jello prototype using a USRP/GNU Radio testbed (see Fig. 2). We present detailed measurements to demonstrate Jello’s performance and overhead, its robustness, as well as its individual design elements.

As shown in Fig. 2, our demo consists of seven USRP nodes. Six of them will form three parallel transmissions that carry time-varying media loads, and one will serve as a software spectrum analyzer. The analyzer will display in real time the spectrum usage map of the three parallel links in terms of the power spectrum density. A sample snapshot is shown in Figure 3. We will provide a real time trace window to illustrate the detailed spectrum usage, the application-level disruption rate, the spectrum sensing result, and the sender-receiver coordination process. We will also change each node’s traffic demand and disable/enable nodes to demonstrate Jello’s resilience to network and environmental changes.

Specifically, we examine Jello from three aspects:

- **Overall efficiency.** With three parallel transmissions, we show that Jello provides good link quality and can utilize spectrum effectively while keeping application outage rate below 10%.
- **Robustness to conflicts and link failures.** We disconnect the antenna from one device which causes

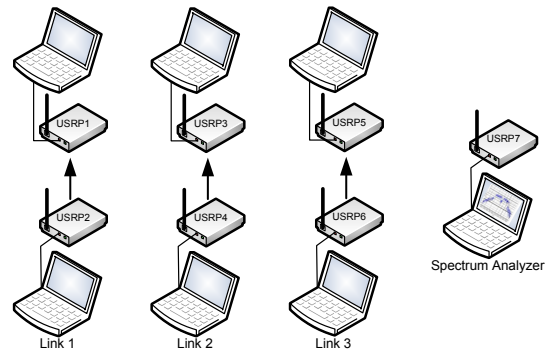


Figure 2: Demo scenario: we set three variable bitrate transmissions using six USRP nodes, and one software spectrum analyzer using one USRP node.

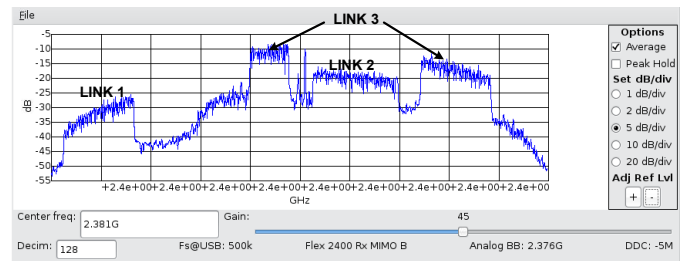


Figure 3: Snapshot of the spectrum analyzer, showing three links with non-contiguous spectrum blocks.

a link failure, and after the antenna is attached to the device again, we show that the failed link can restore connection by itself.

- **Jello’s underlying mechanisms.** We use trace files to show the effectiveness of spectrum sensing and adaptive filtering, and their robustness against heterogeneous receiver power levels and frequency offsets.

### 4. REFERENCES

- [1] CHANDRA, R., MAHAJAN, R., MOSCIBRODA, T., RAGHAVENDRA, R., AND BAHL, P. A case for adapting channel width in wireless networks. In *Proc. of SIGCOMM* (2008).
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