

# When WiFi Packets Miss a Beat

Why Irregular Timing Matters for WiFi Sensing

## Why timing matters

WiFi sensing uses changes in wireless signals to recognize human activity without cameras or wearable devices [1]. This work uses Channel State Information (CSI): packet-by-packet measurements of how the WiFi channel changes over time. Many sensing models assume CSI packets arrive at a stable rate, so packet index  $\approx$  time. In real WiFi traffic, packets may be delayed, dropped, or arrive in bursts.

Result: motion patterns can be stretched, compressed, or partially missing.

**Regular:** 

**Irregular:** 

**SAME ACTIVITY, DIFFERENT TIMING**  
→ DIFFERENT MODEL INPUT

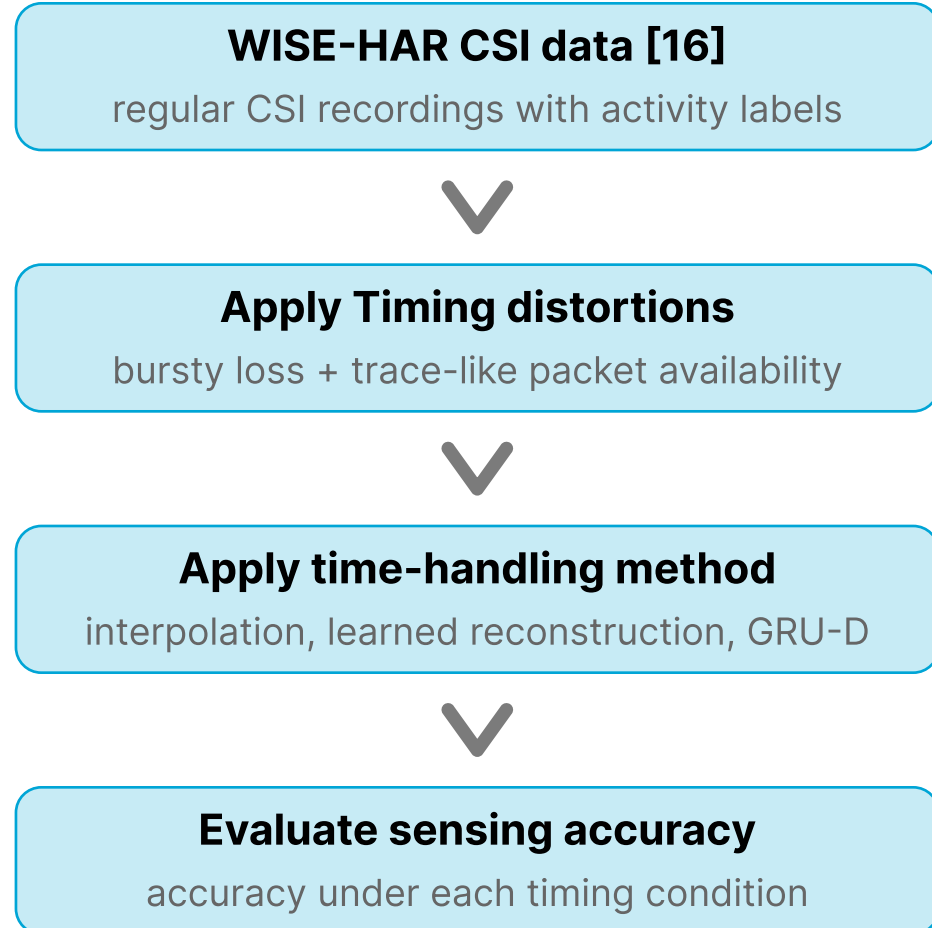
## Research question

- How does irregular CSI packet timing affect WiFi-based activity recognition?
- When is simple reconstruction enough, and when is time-aware modeling needed?

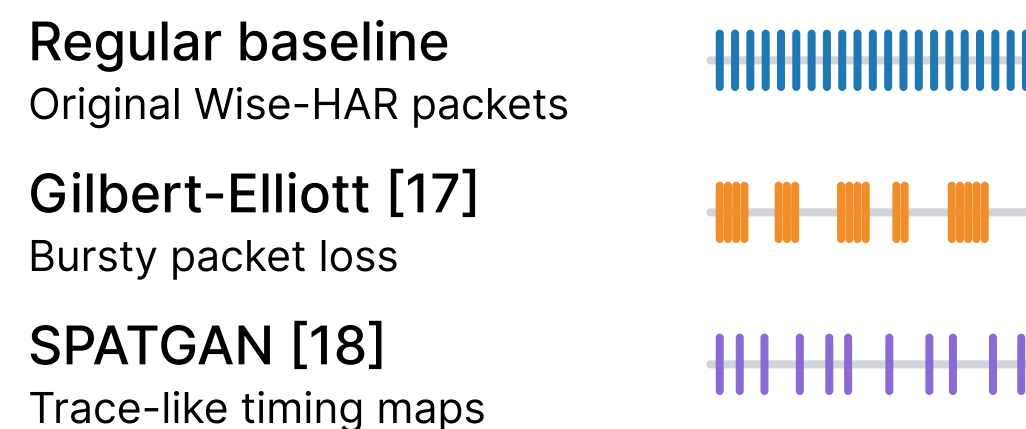
## Contribution

We isolate timing effects by changing packet availability while keeping the CSI values, labels, preprocessing, and evaluation procedure fixed.

## How we tested timing irregularity



## Timing distortions

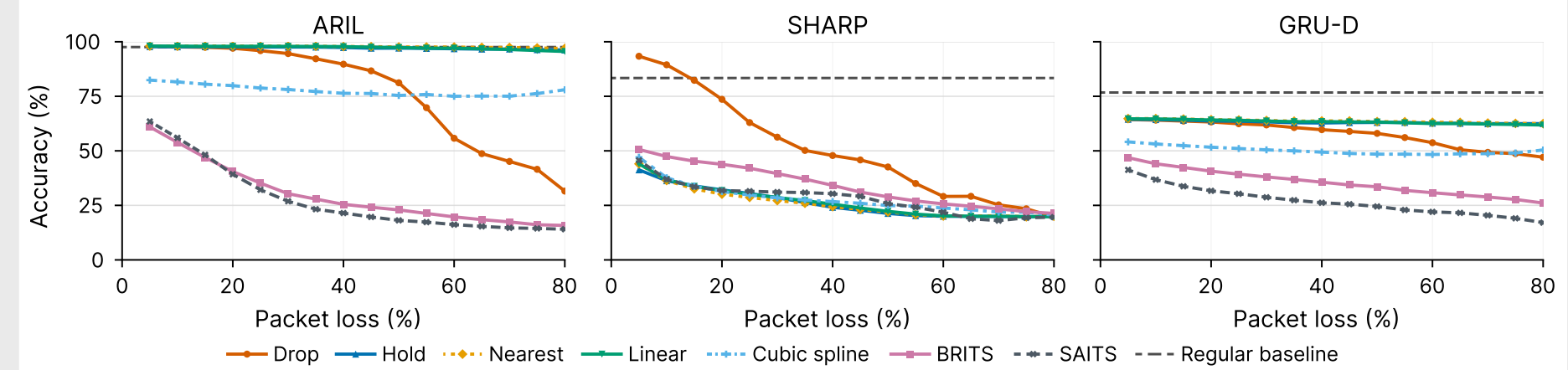


## Models compared

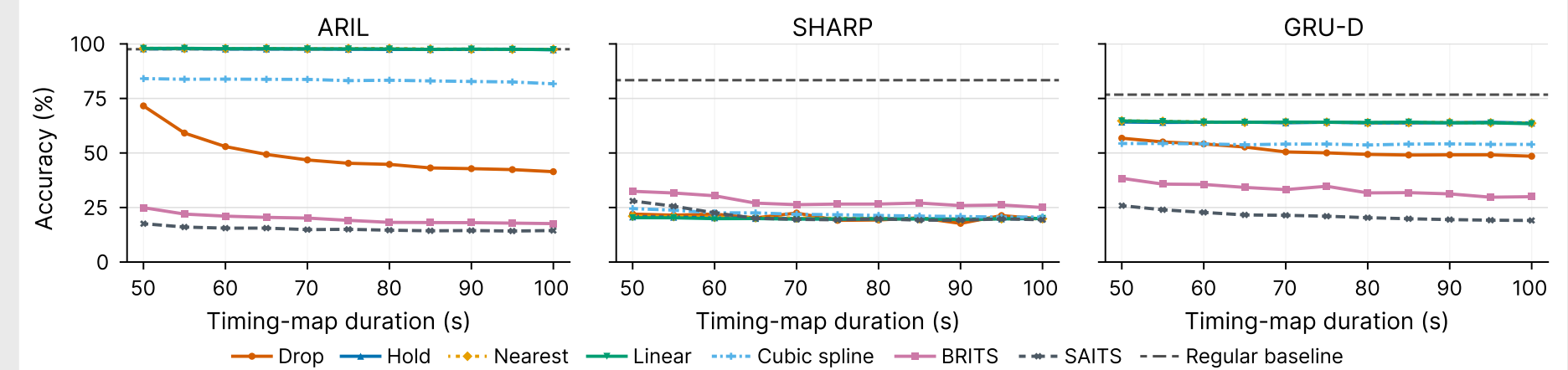
- ARIL [12] (Amplitude-based)**  
Uses CSI amplitude windows directly
- SHARP [14] (Doppler-based)**  
Uses Doppler / motion-frequency features
- GRU-D [15] (Time-aware)**  
Uses CSI values, masks, and time gaps

## Main results

### Gilbert-Elliott results



### SPATGAN results



Robustness depends more on the sensing pipeline than on the timing condition.

## Key findings

**Amplitude: simple interpolation works**  
Restores the fixed-rate CSI structure ARIL expects.

**Doppler: interpolation is not enough**  
Timing artifacts distort motion-frequency features.

**Time-aware: more stable, not fully recovered**  
Time gaps help, but lost packets still remove information.

## Takeaway

Irregular packet timing is not just missing data. Lightweight reconstruction can work for amplitude-based CSI sensing, but it is not a general solution. Timing-handling methods should be evaluated relative to the sensing pipeline.