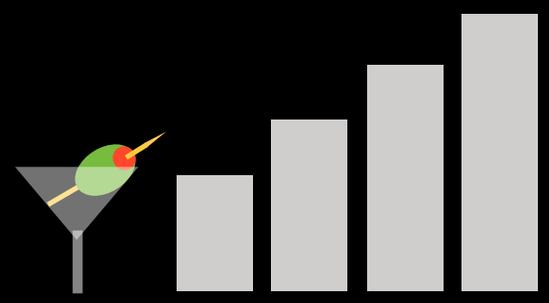


Bartendr: A Practical Approach to Energy-aware Cellular Data Scheduling

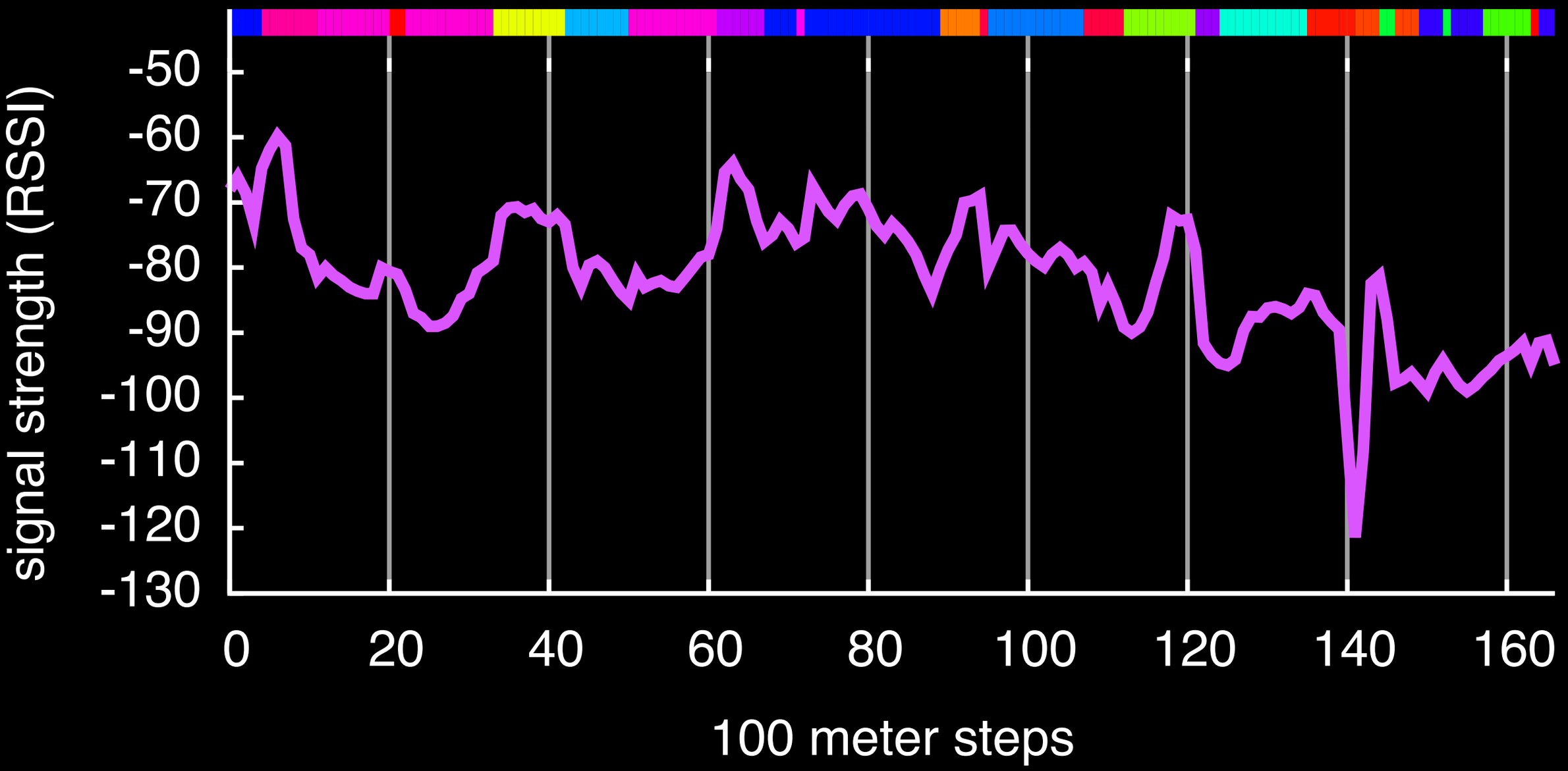
Aaron Schulman
Neil Spring
Calvin Grunewald
University of Maryland

Vishnu Navda
Ramachandran Ramjee
Venkata N. Padmanabhan
Microsoft Research India

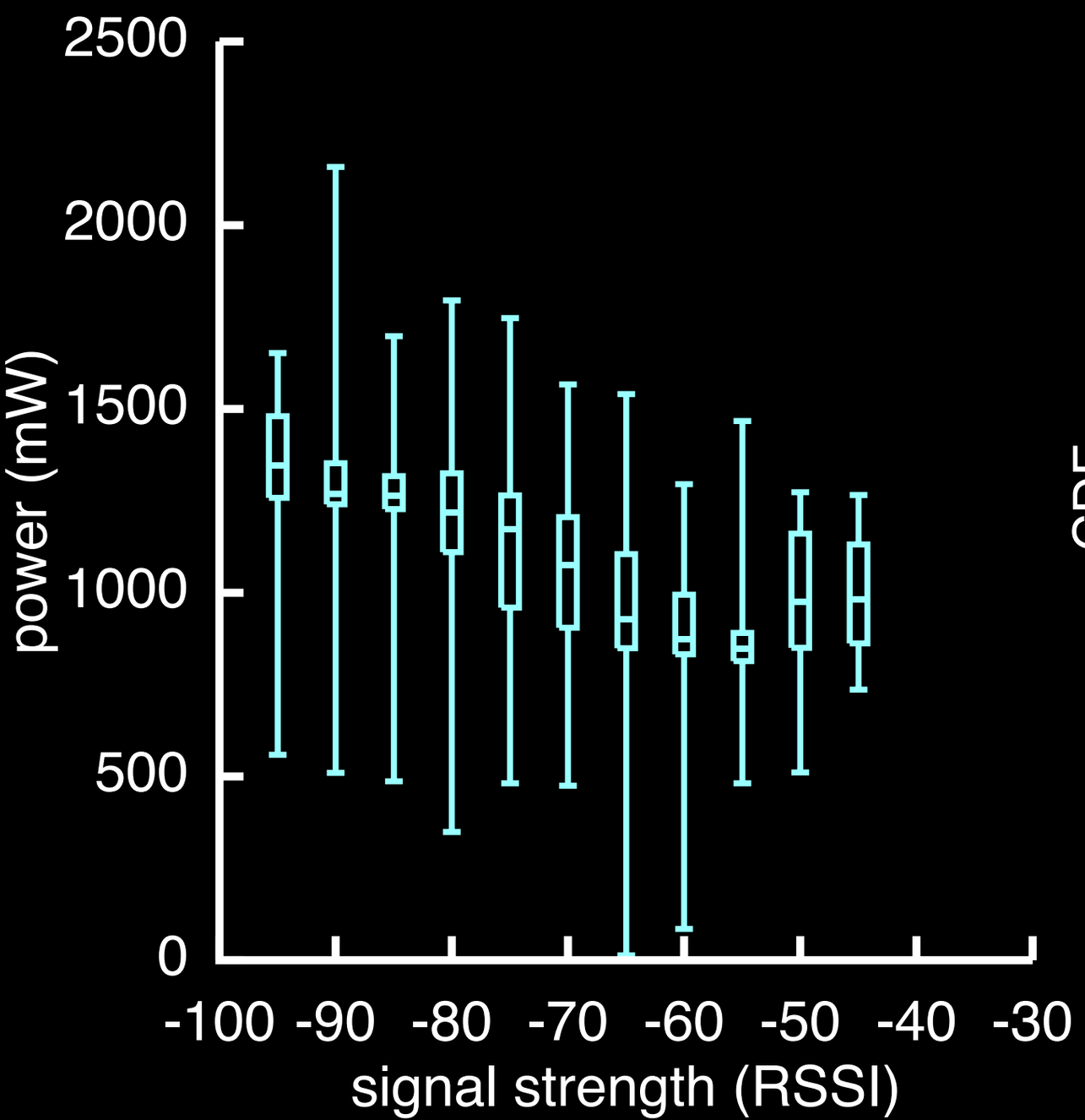
Pralhad Deshpande
Stony Brook University

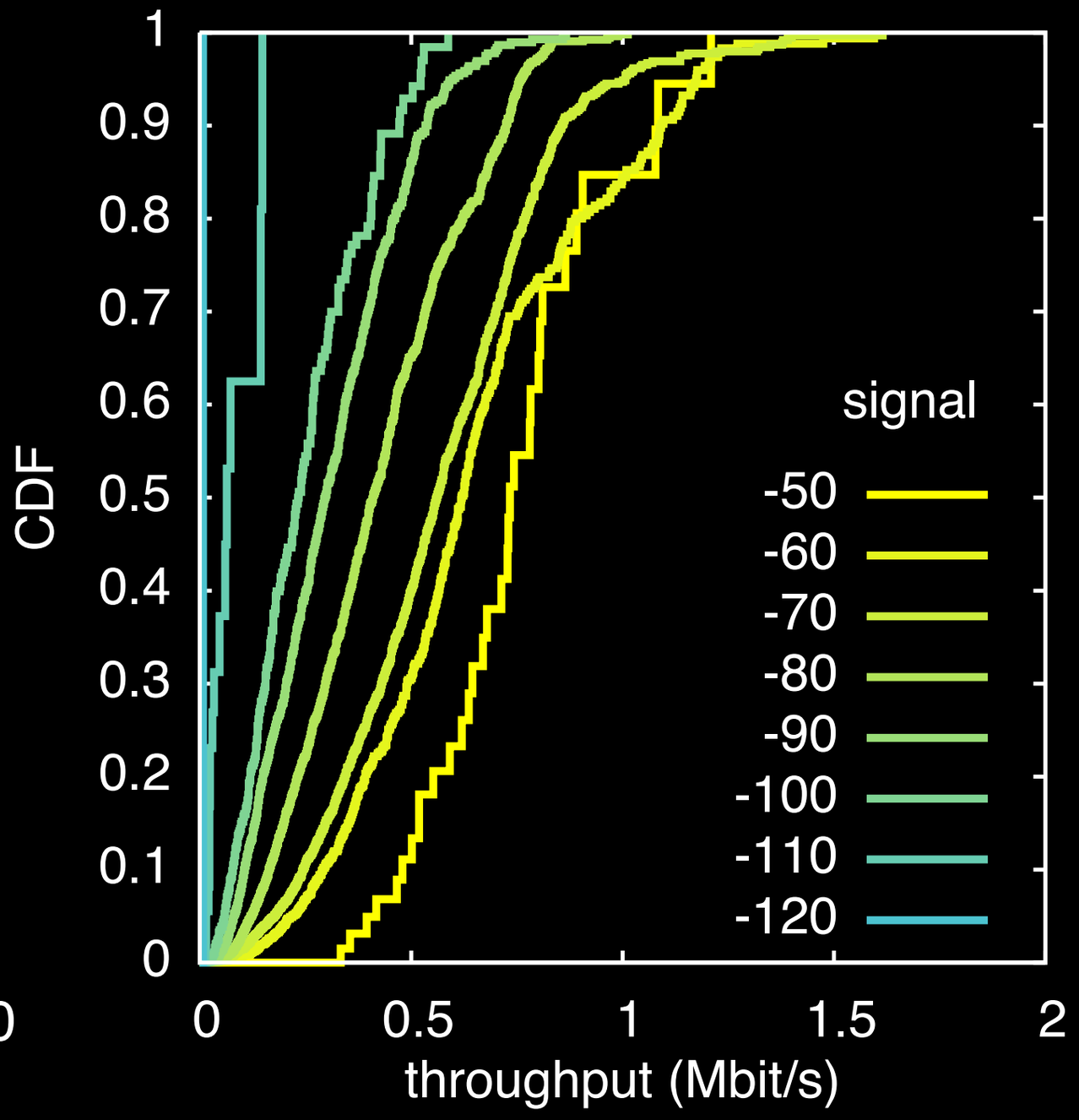
Kamal Jain
Microsoft Research Redmond

A moving phone experiences signal strength variations



Signal strength affects radio power and throughput





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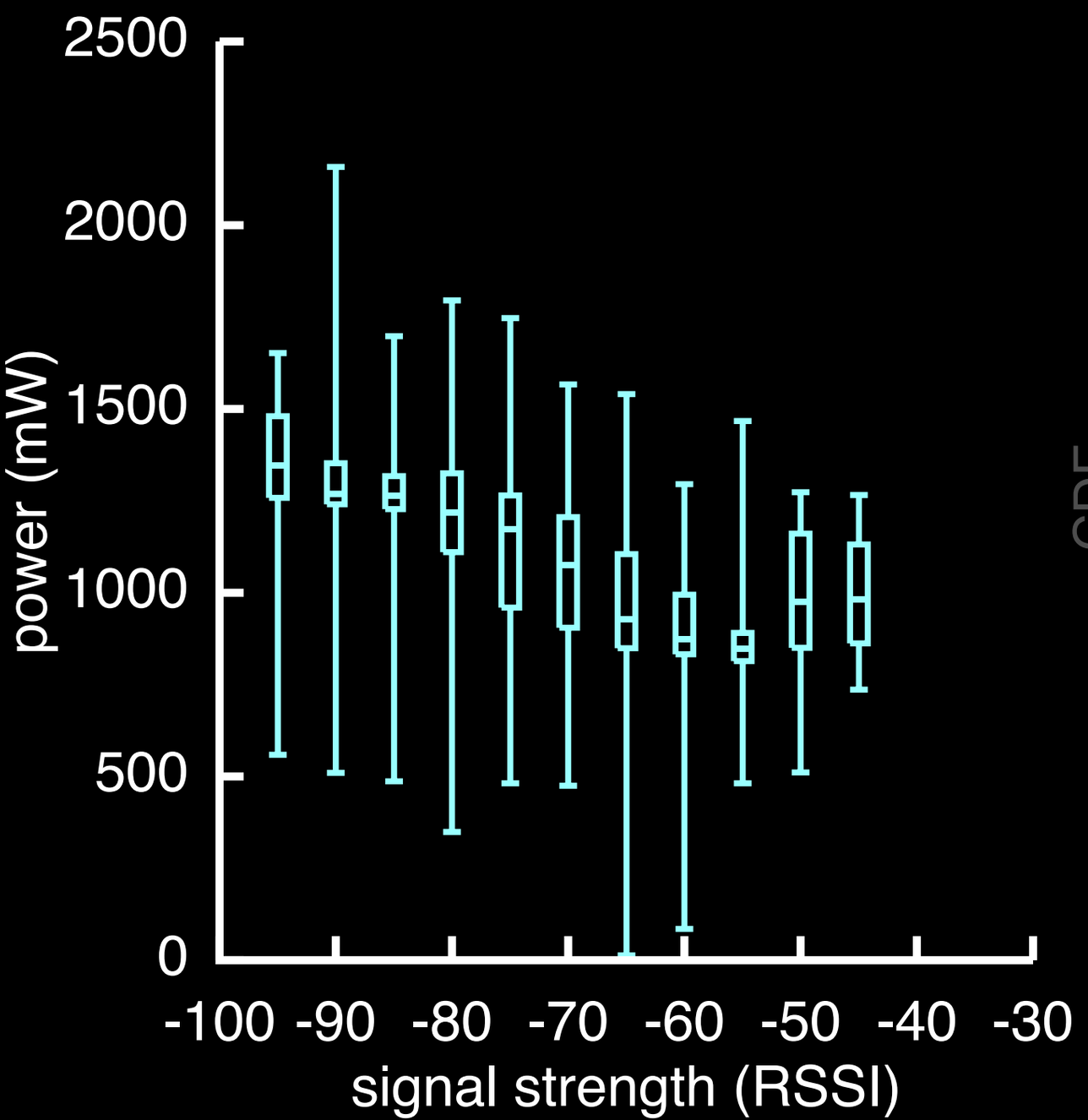

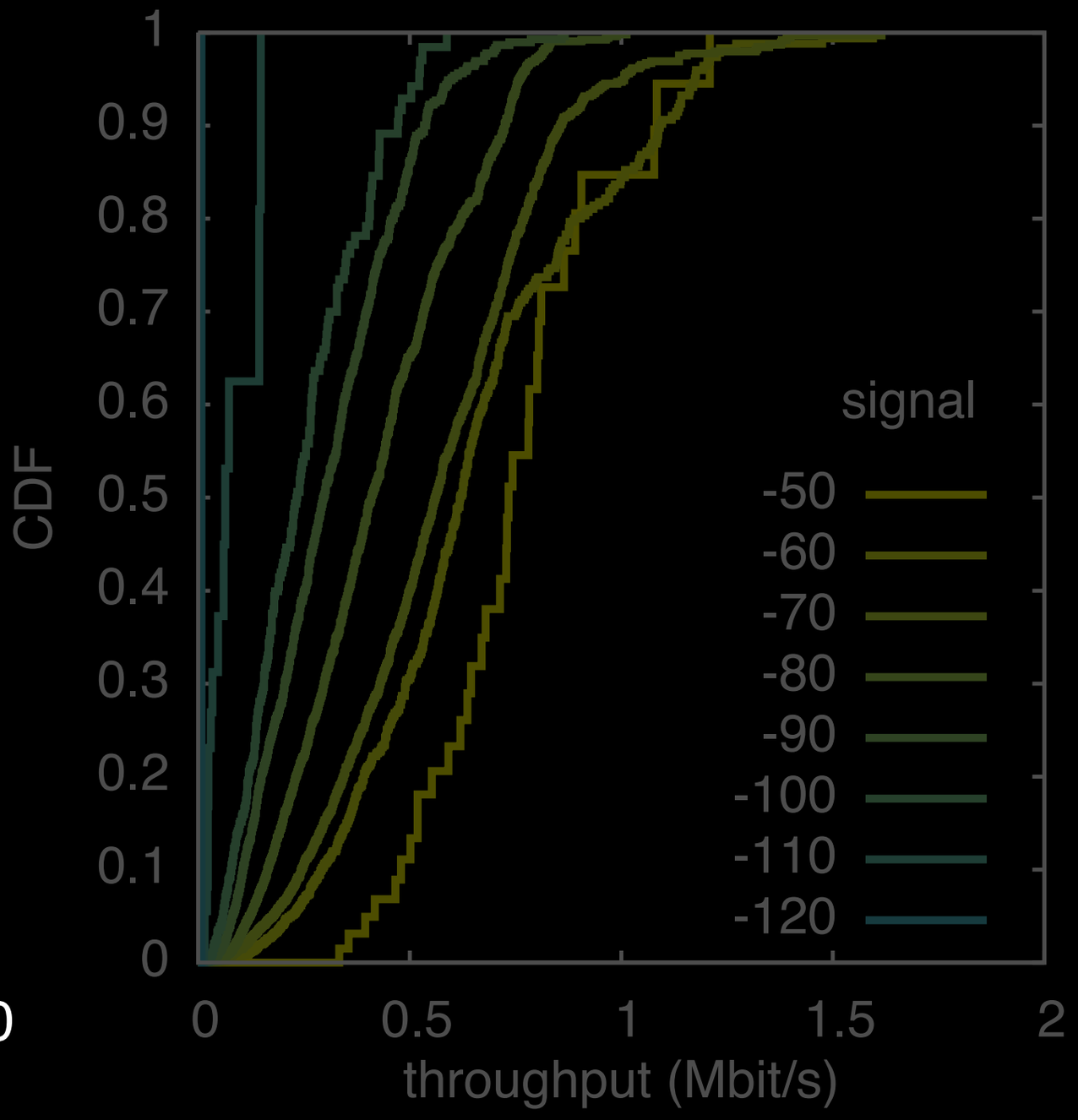

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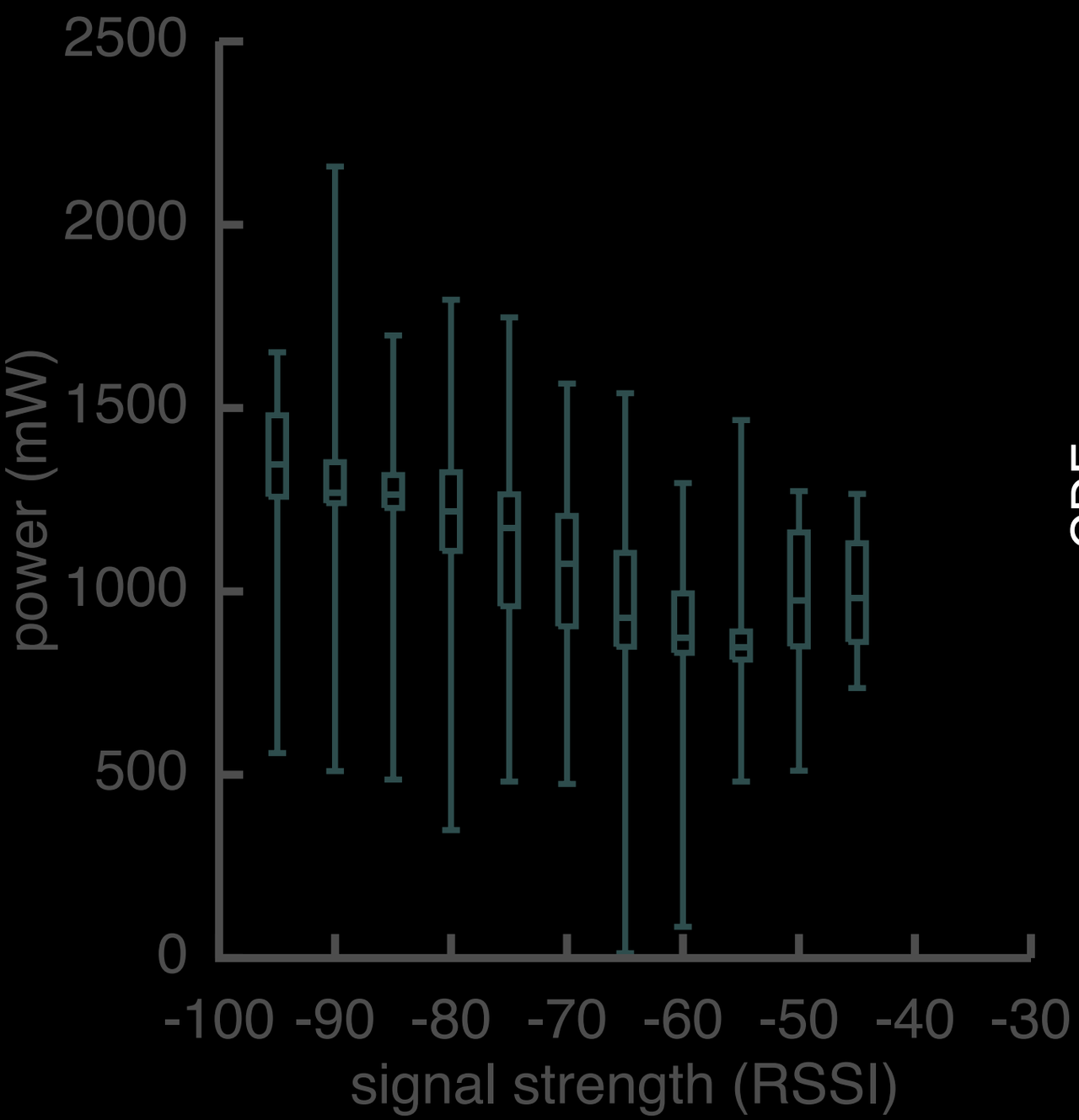

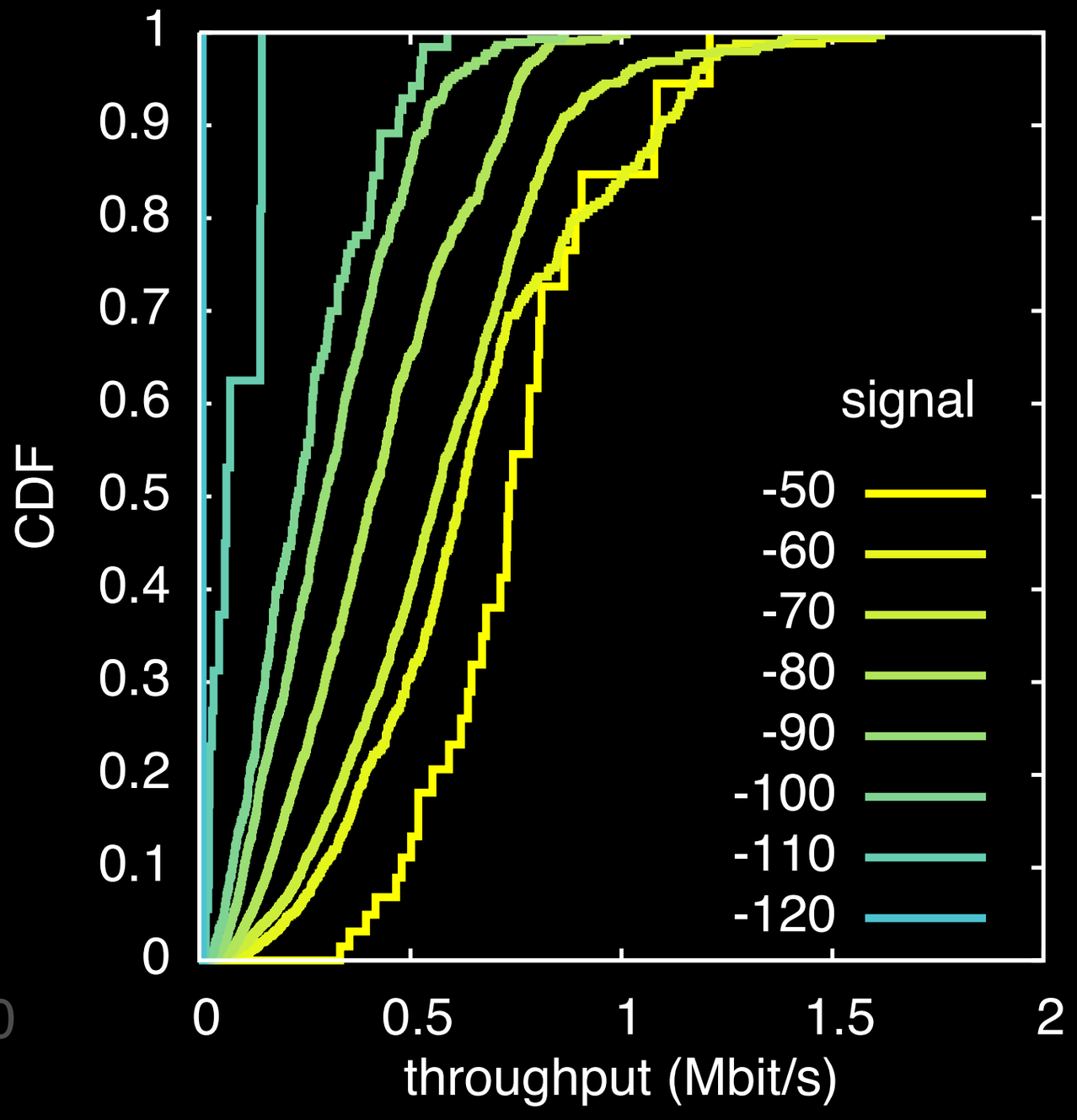

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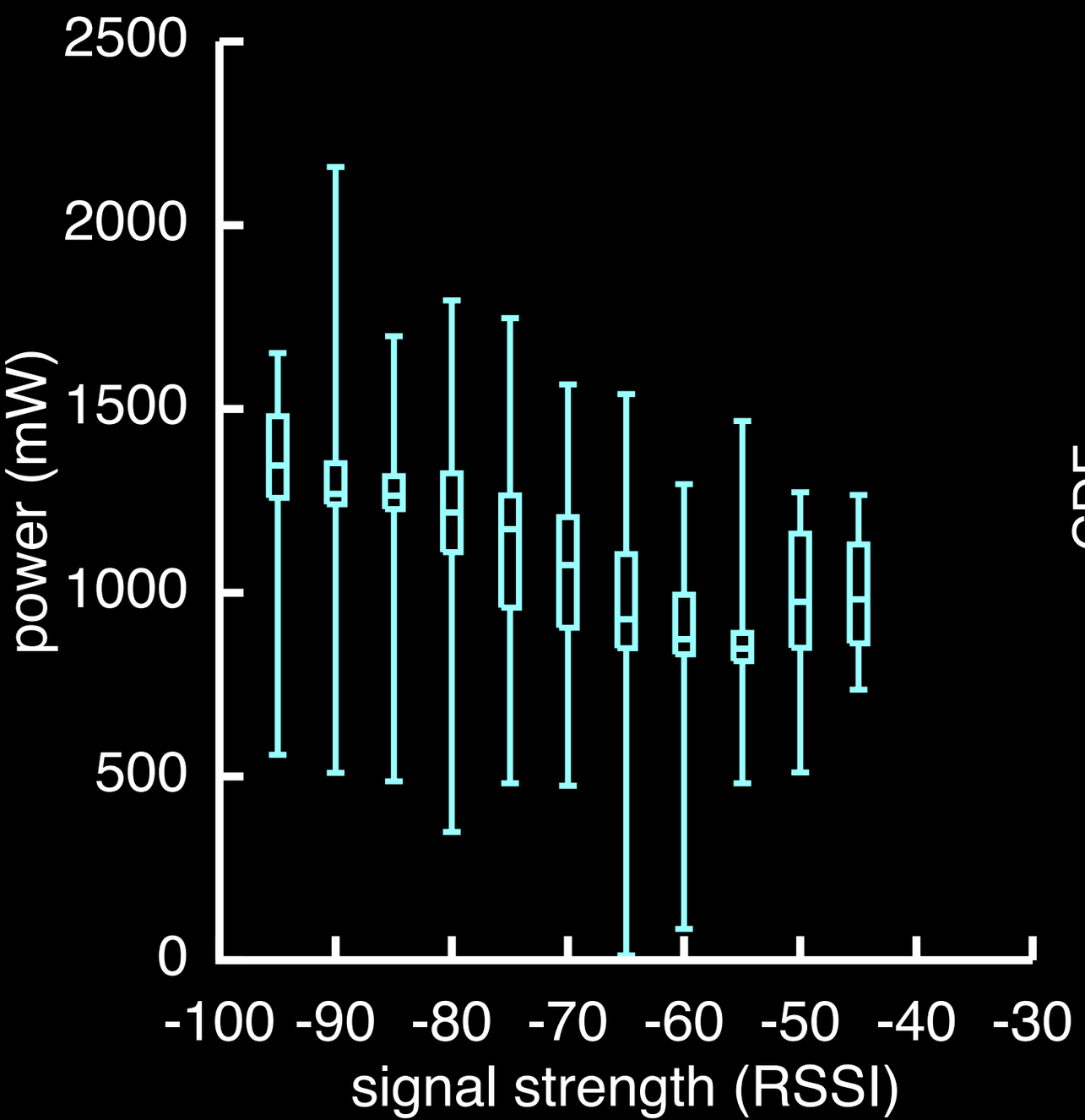
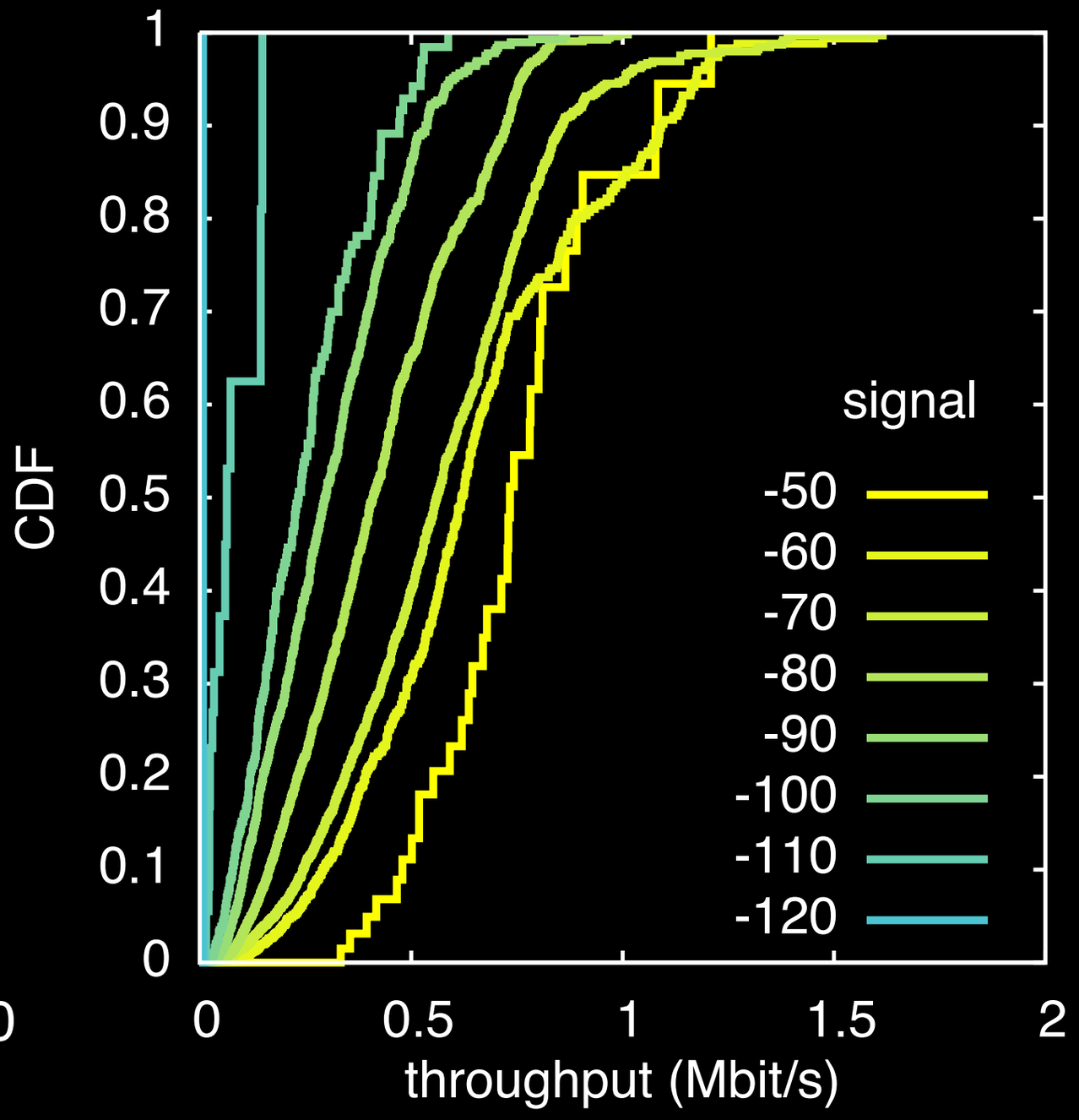




Energy efficiency can be improved

A moving phone experiences signal strength variations.

Signal strength affects communication energy.

Applications can hold off until signal increases and prefetch while signal is strong.

Energy efficiency can be improved

A moving phone experiences signal strength variations.

Signal strength affects communication energy.

Applications can hold off until signal increases and prefetch while signal is strong.

Applications can receive when signal is strong

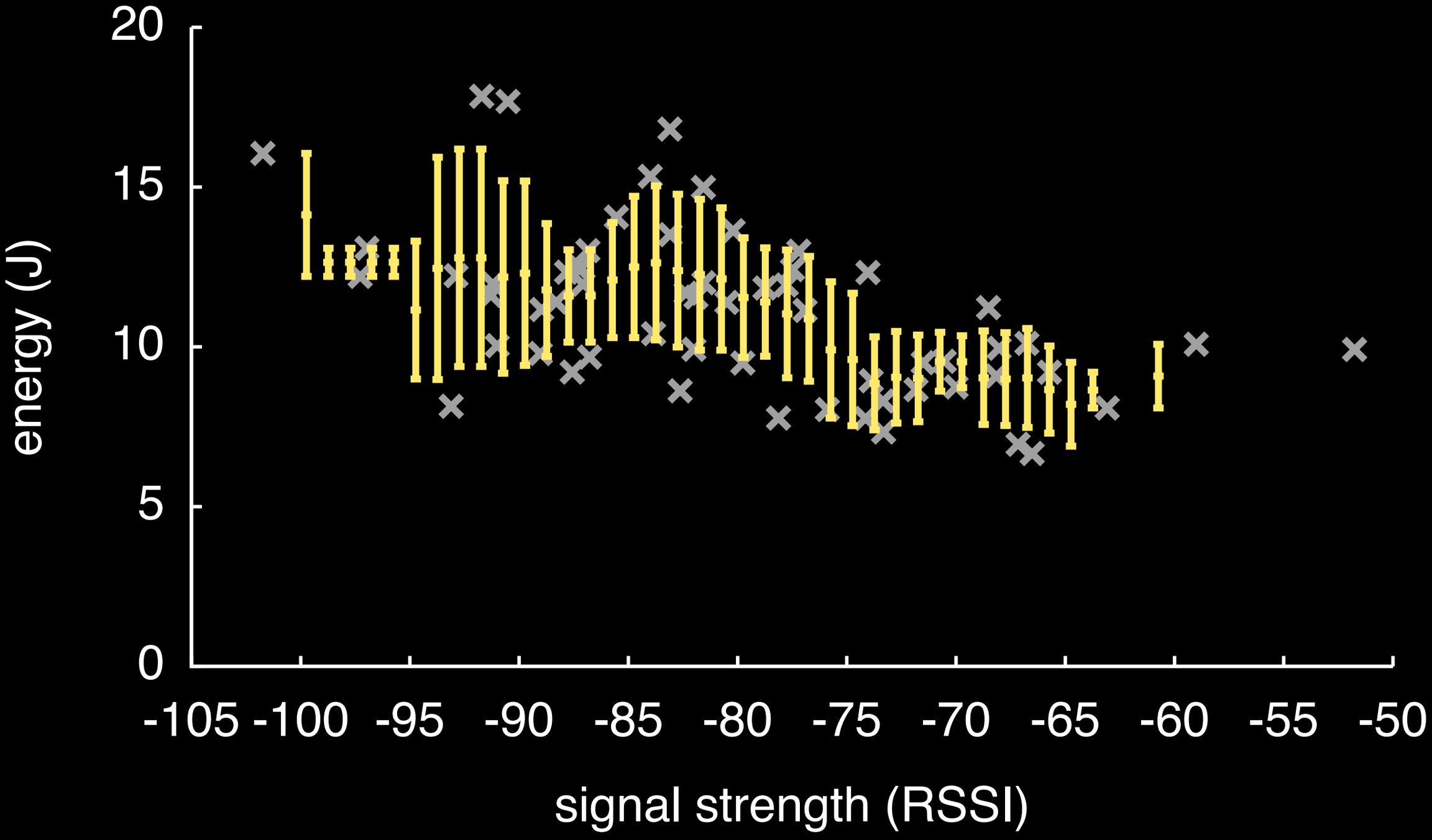
Background sync - 5 min interval sync could be more efficient if done sometime between 4 to 6 min

Streaming media - Consume buffer when the signal is weak, prefetch when the signal is strong

Application energy measurements

Drove with a mobile power monitor connected to a Palm Pre

Email sync energy consumption



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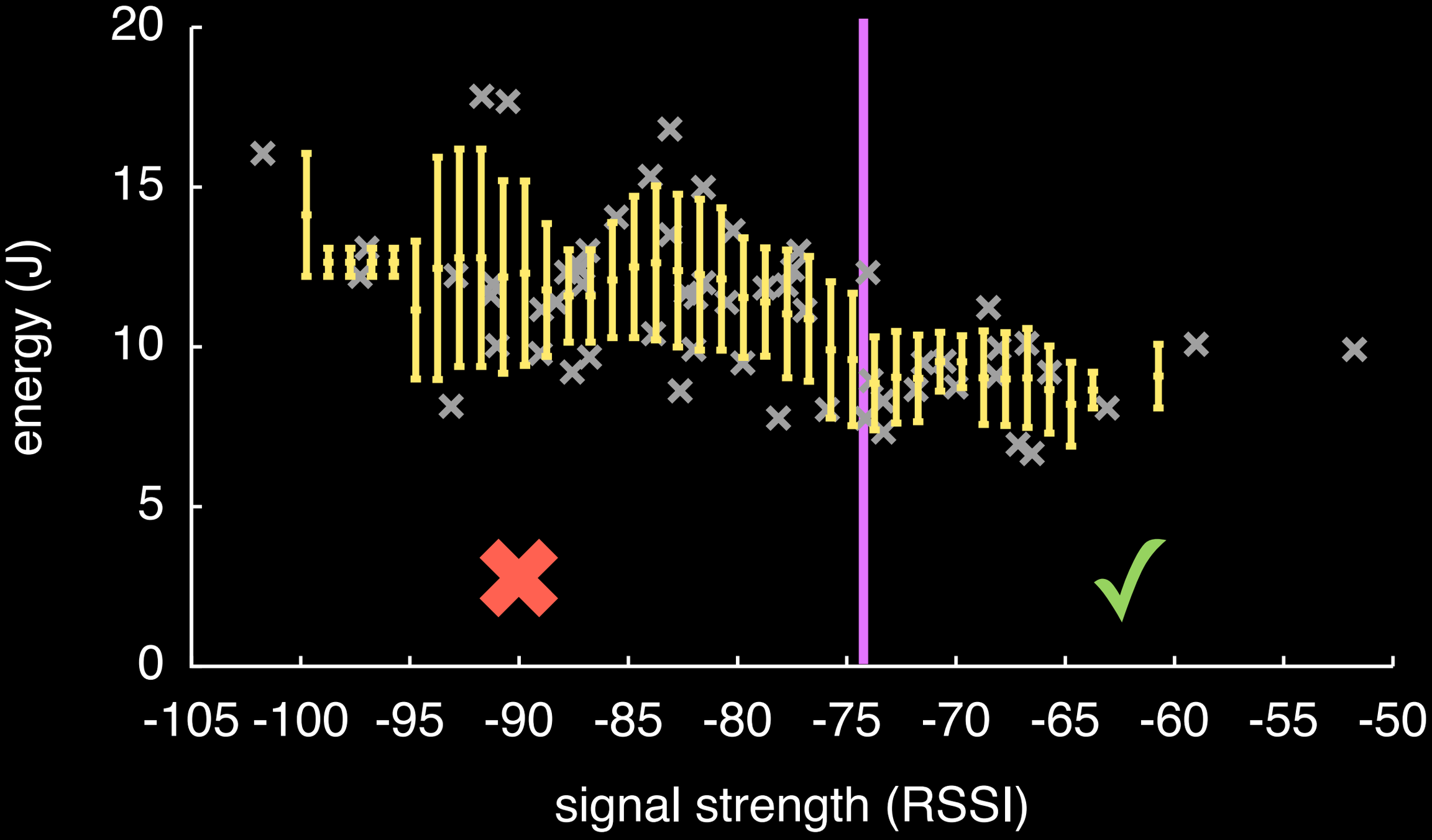
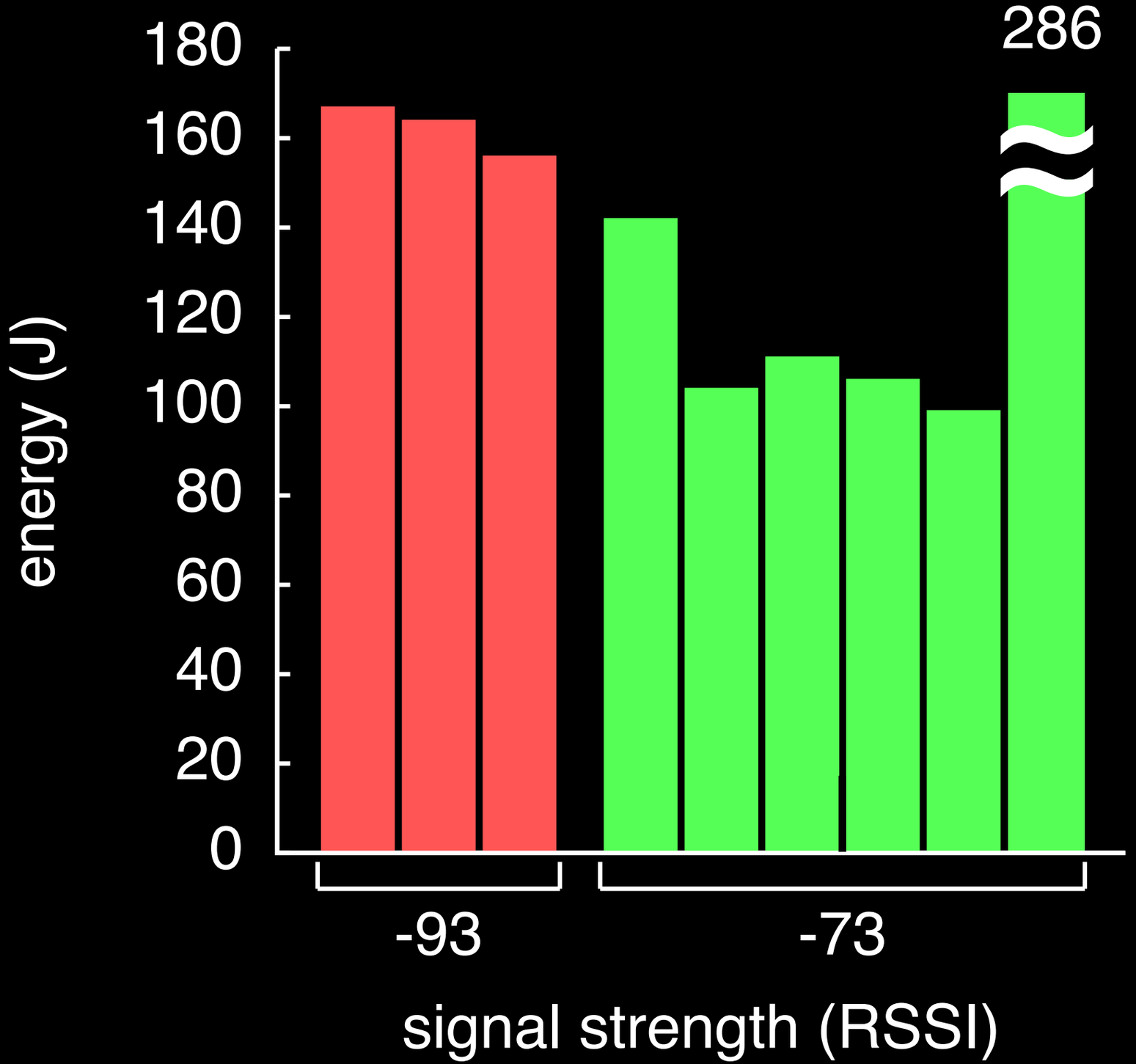


YouTube energy consumption



Applications must schedule communication

Sync	Streaming
Schedule wakeup	Fill the buffer efficiently

Problem

When to schedule communication to save energy?

Predict signal strength

- Schedule syncs
- Schedule streaming

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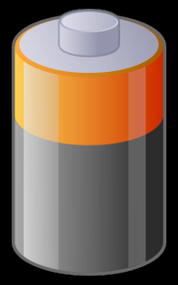


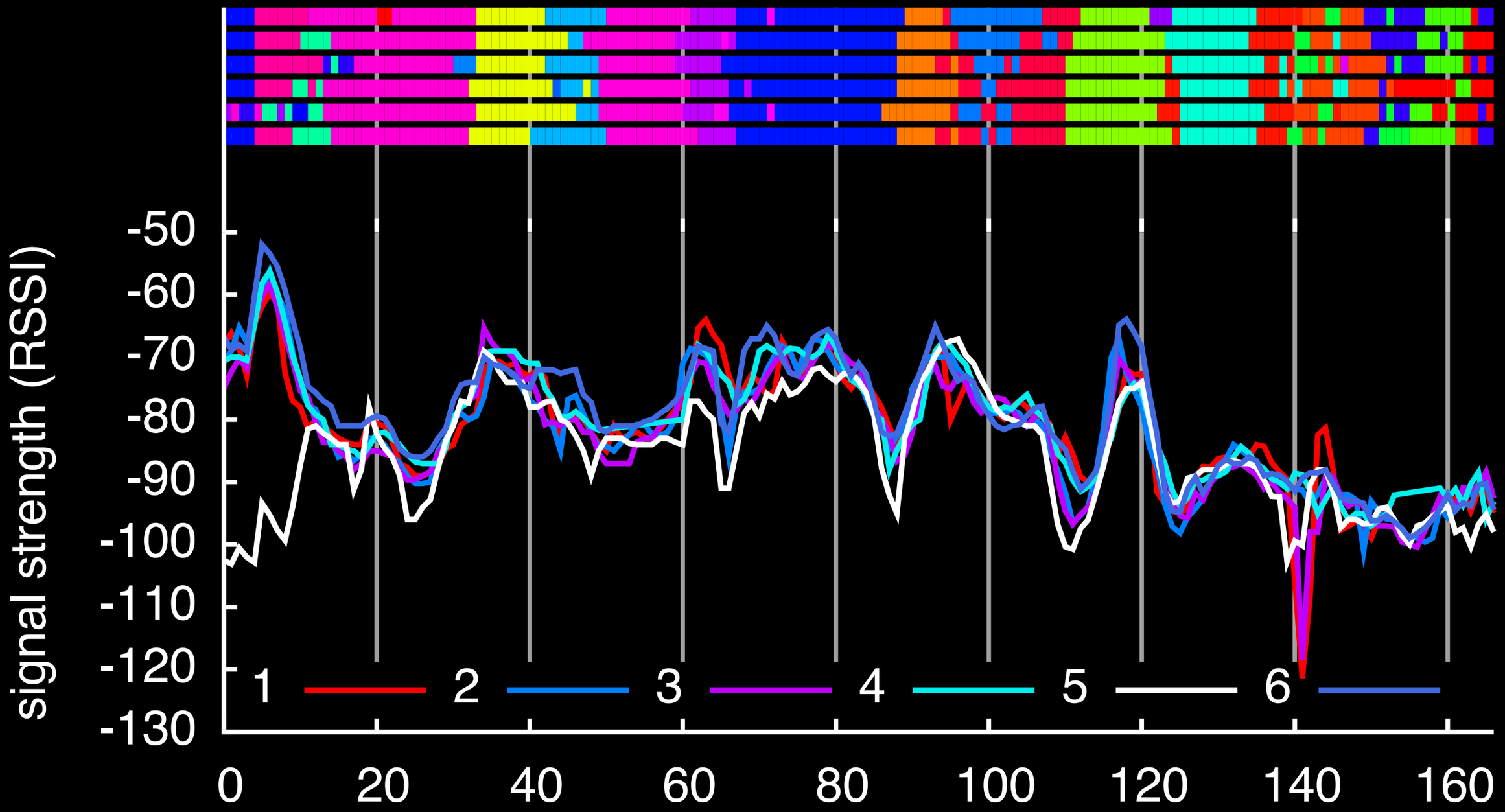
Challenge

Scheduling must save more energy than it consumes.

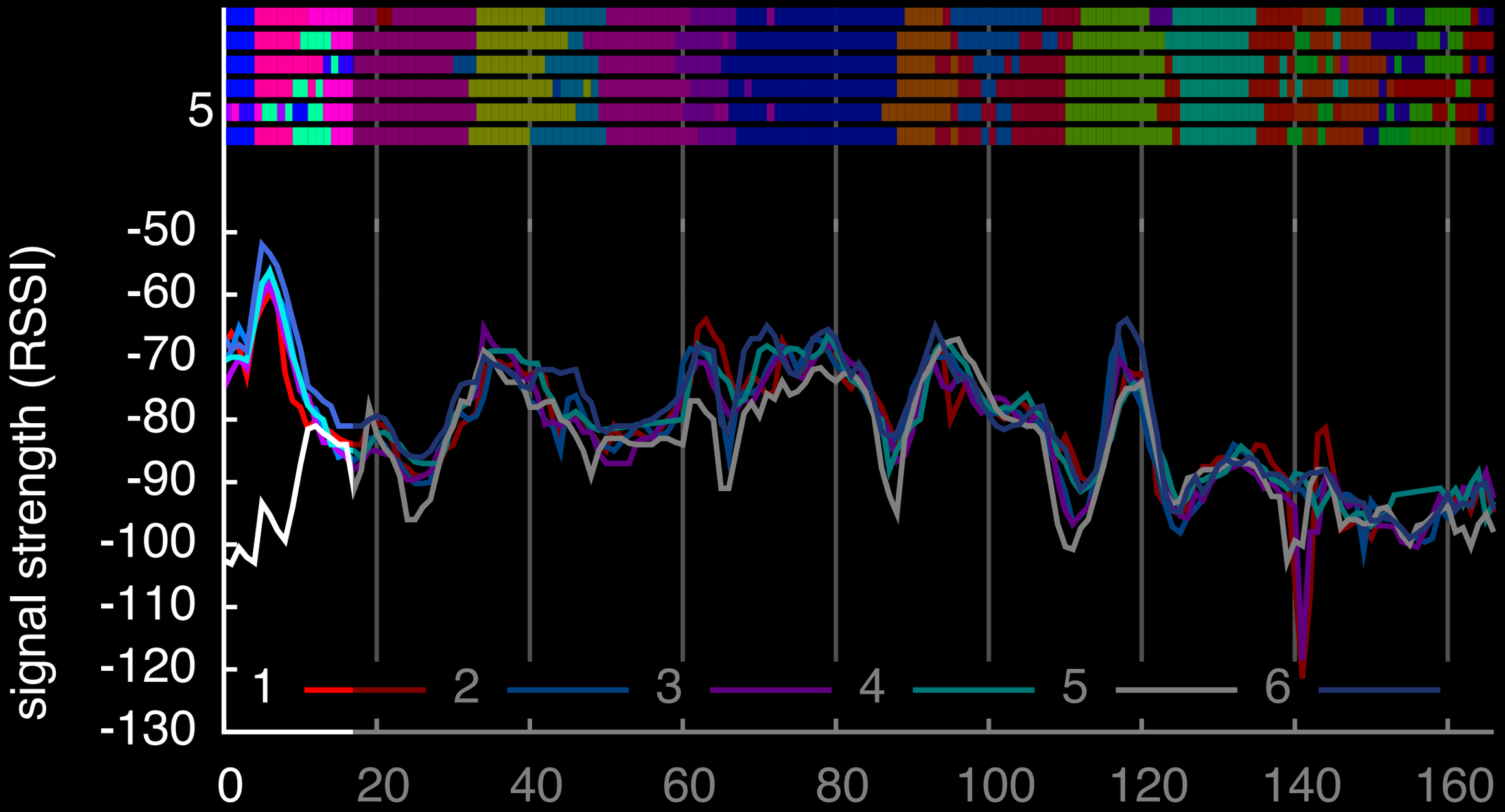
Obstacles to energy efficient scheduling

energy consumer	consumption	Bartendr
Signal prediction locating the phone on a path (1D not 2 or 3D)	GPS is 400 mW and slow to fix, WiFi must be in receive mode	phone already maintains signal strength, cell id, and neighbor cells
Sync scheduler wakeup and sleep	1 J to wake up 0.5 J to sleep	schedule syncs minutes into the future
Streaming scheduler radio energy tail	3 - 10 s of radio power after communication (at least 400 mW)	consider the radio's power state when scheduling a stream

Signal strength variation on a path



Signal strength variation on a path



Predicting signal strength with previous drives

1. Find location in a previous drive
   Signal strength, cell id, neighbor list
2. Look ahead for future signal strength

seconds in the future

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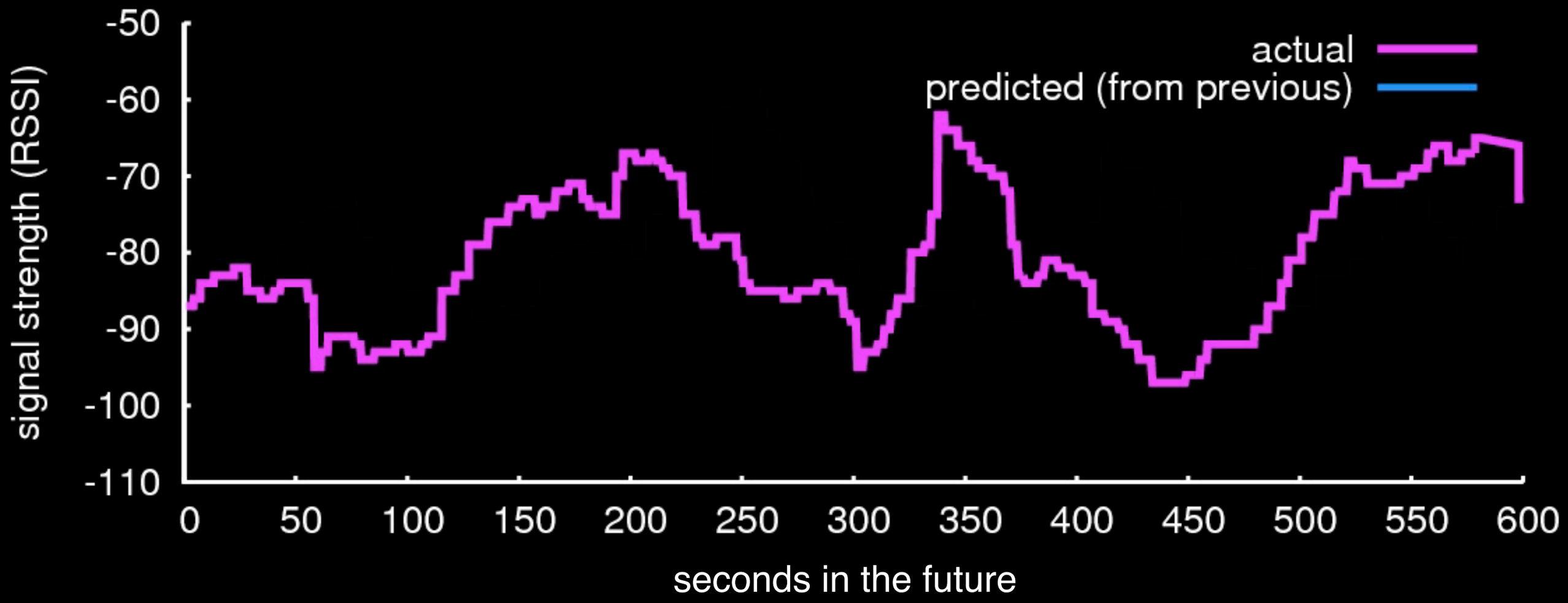
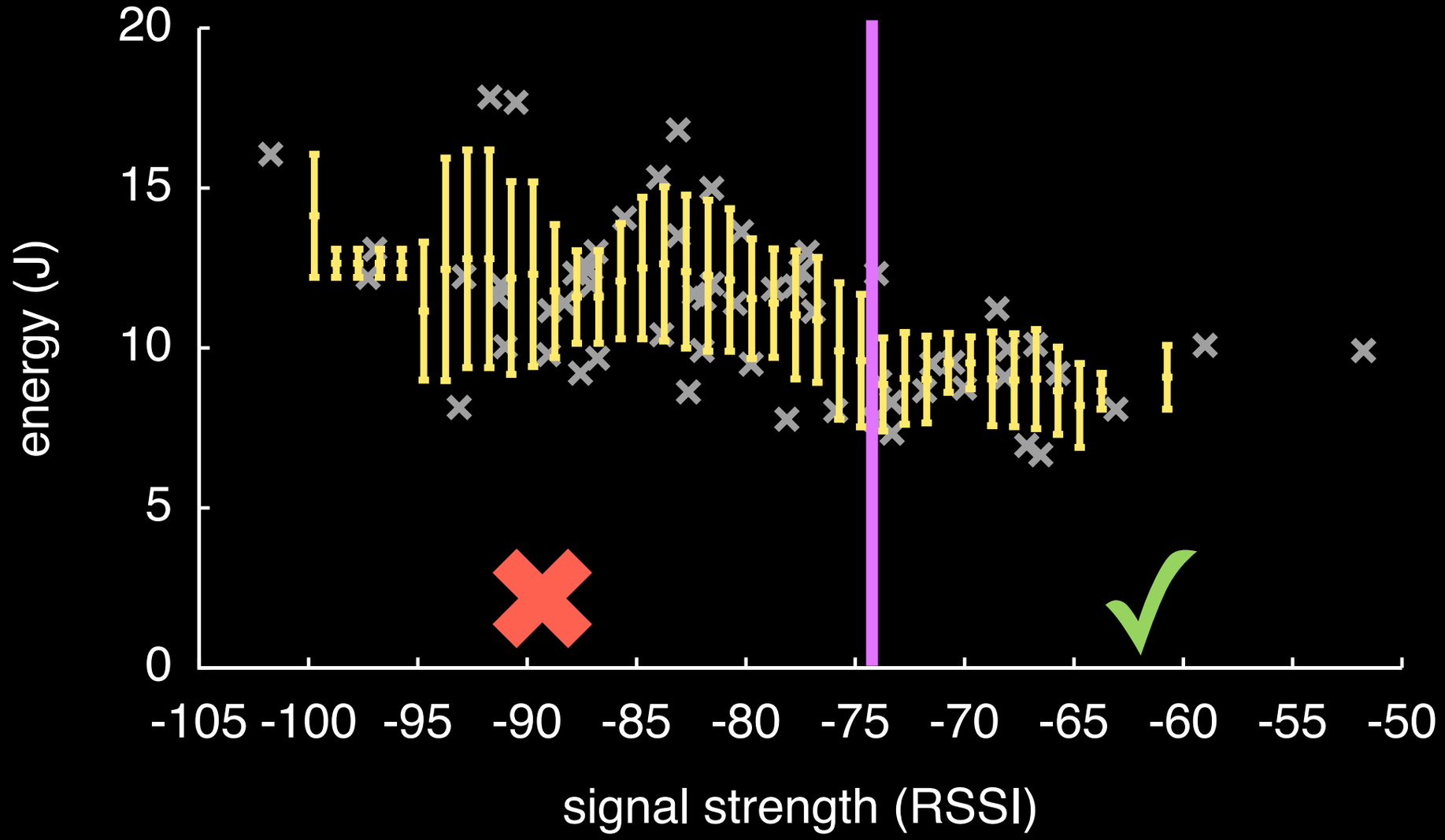


Scheduling when to sync

Wake-up, sync, schedule, sleep

Uses threshold for efficient sync

Schedules for either first or widest signal



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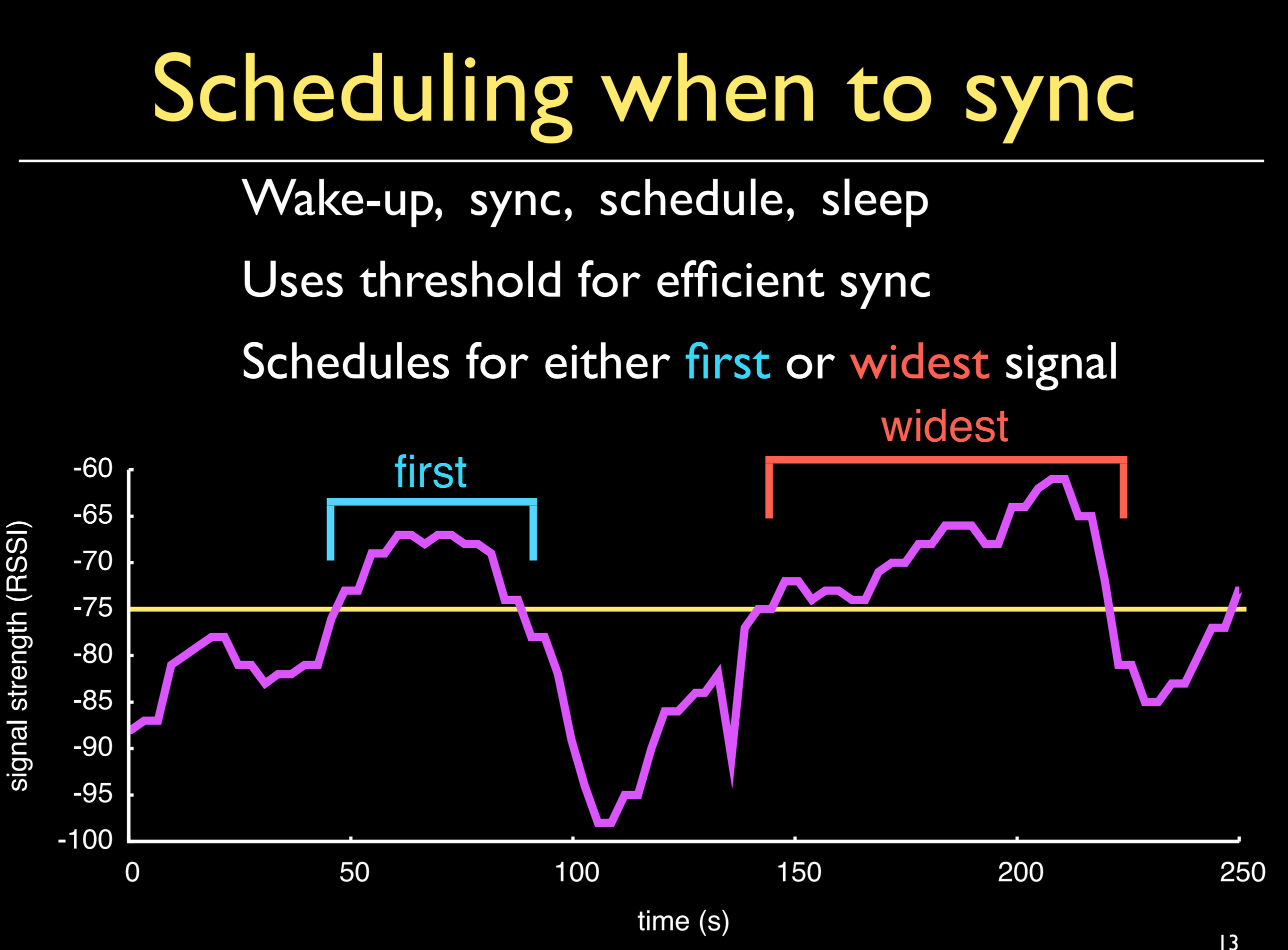


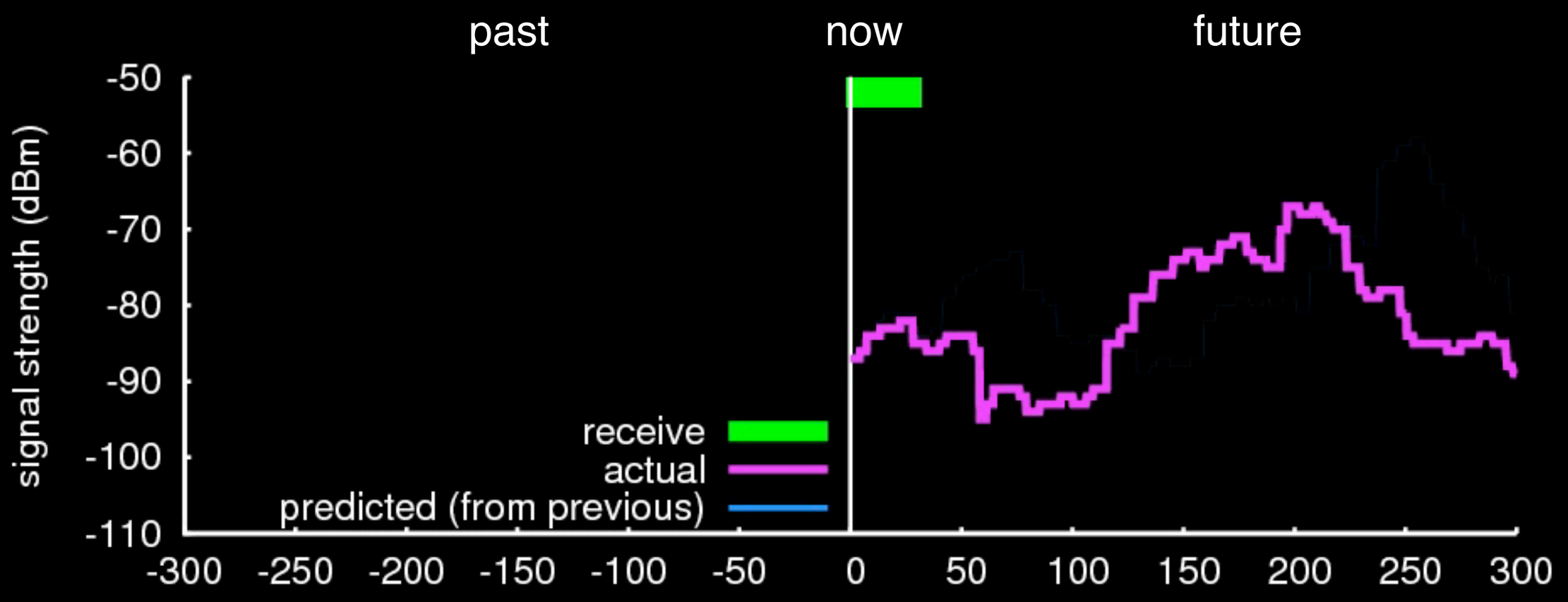
Scheduling when to receive a stream

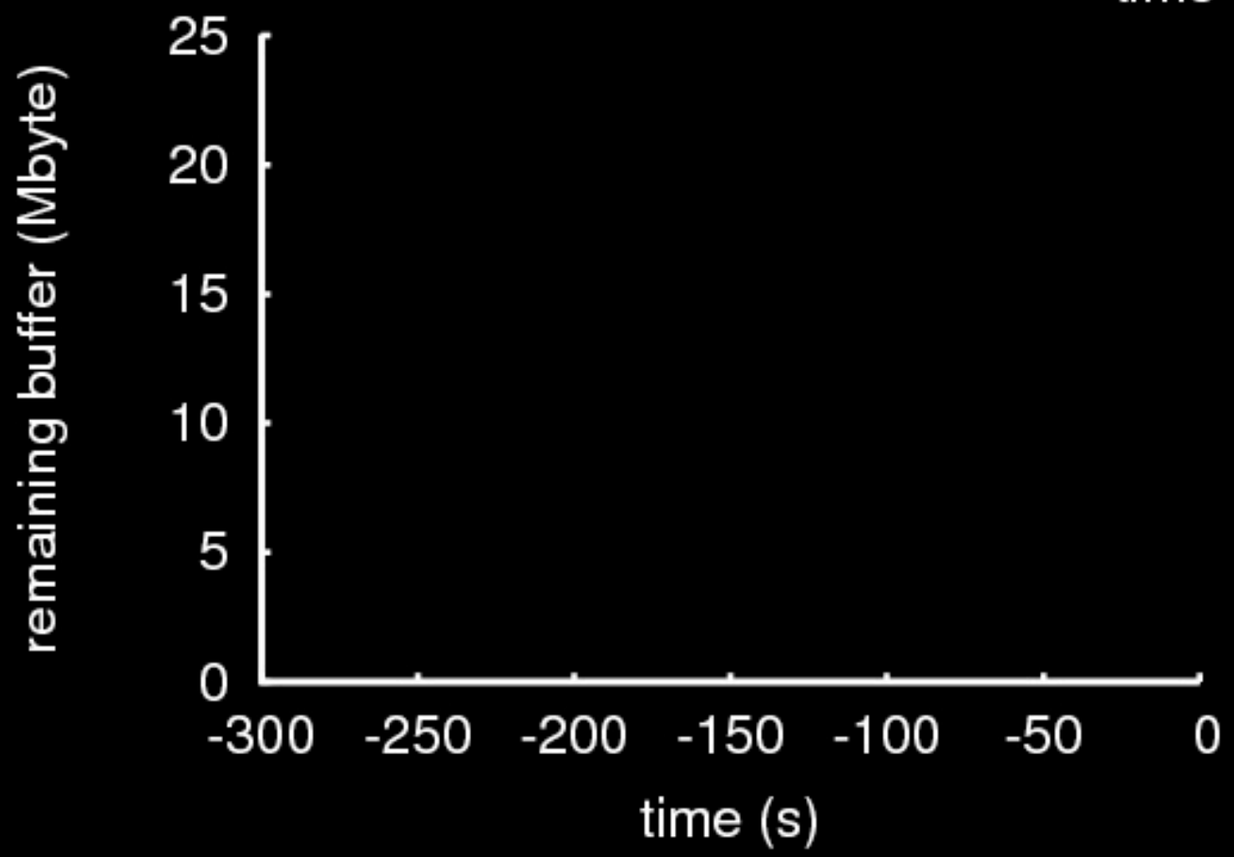
Challenge

1. Tradeoff between strong signal and radio tail energy
2. Signal prediction error due to speed variations
3. Throughput prediction error due to congestion

Approach

1. Minimize predicted energy - dynamic programming algorithm
2. Update schedule with latest signal prediction
3. Schedule based on remaining buffer


past
now
future
signal strength (dBm)
-50
-60
-70
-80
-90
-100
-110
receive
actual
predicted (from previous)
-300
-250
-200
-150
-100
-50
0
50
100
150
200
250
300
time (s)


remaining buffer (Mbyte)
25
20
15
10
5
0
-300
-250
-200
-150
-100
-50
0
time (s)

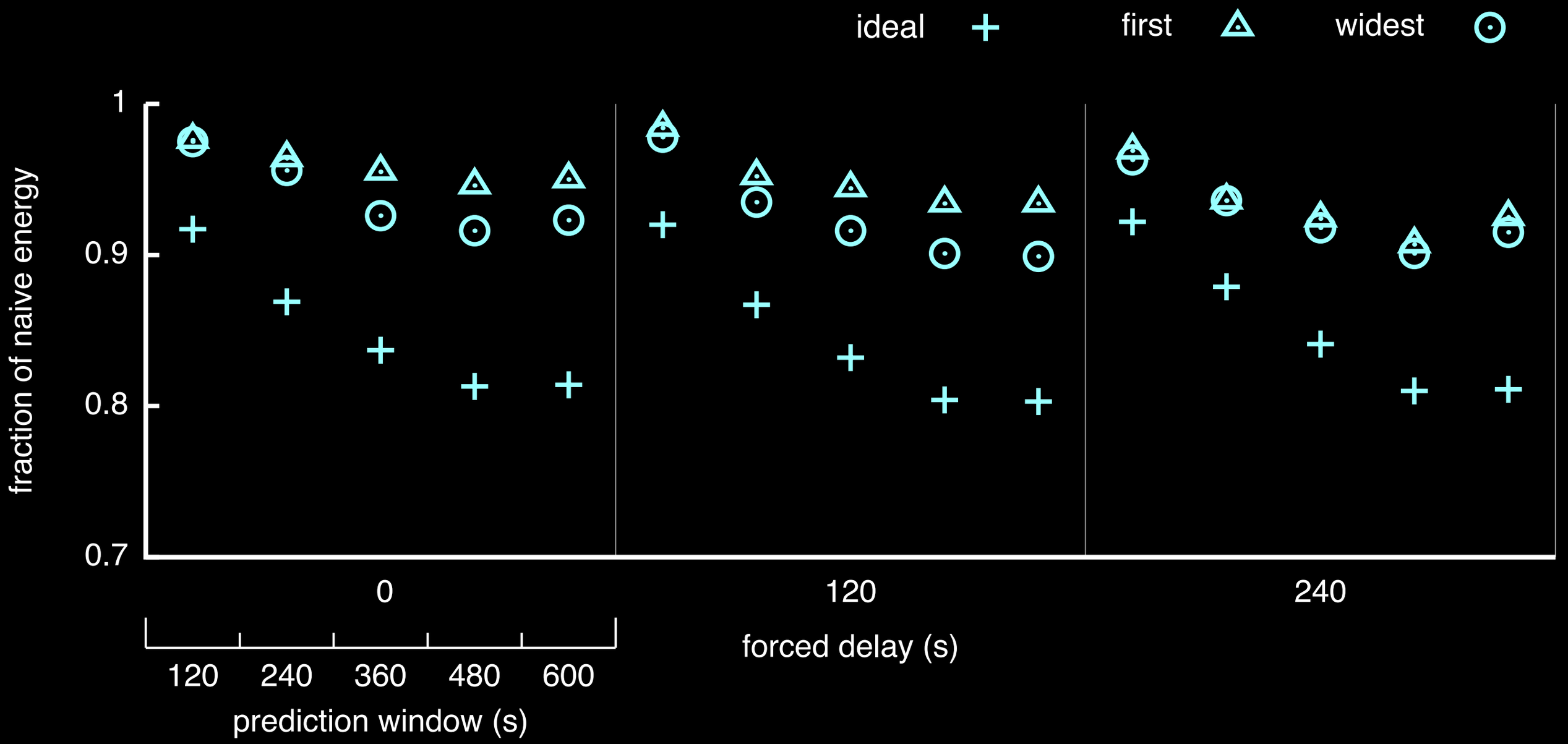
Evaluation methodology

Simulated energy consumption of naive and scheduled syncs and streaming

Several 17 km drives of throughput and signal for prediction and simulation of energy consumption

Started at many points in the drive

Syncing simulation



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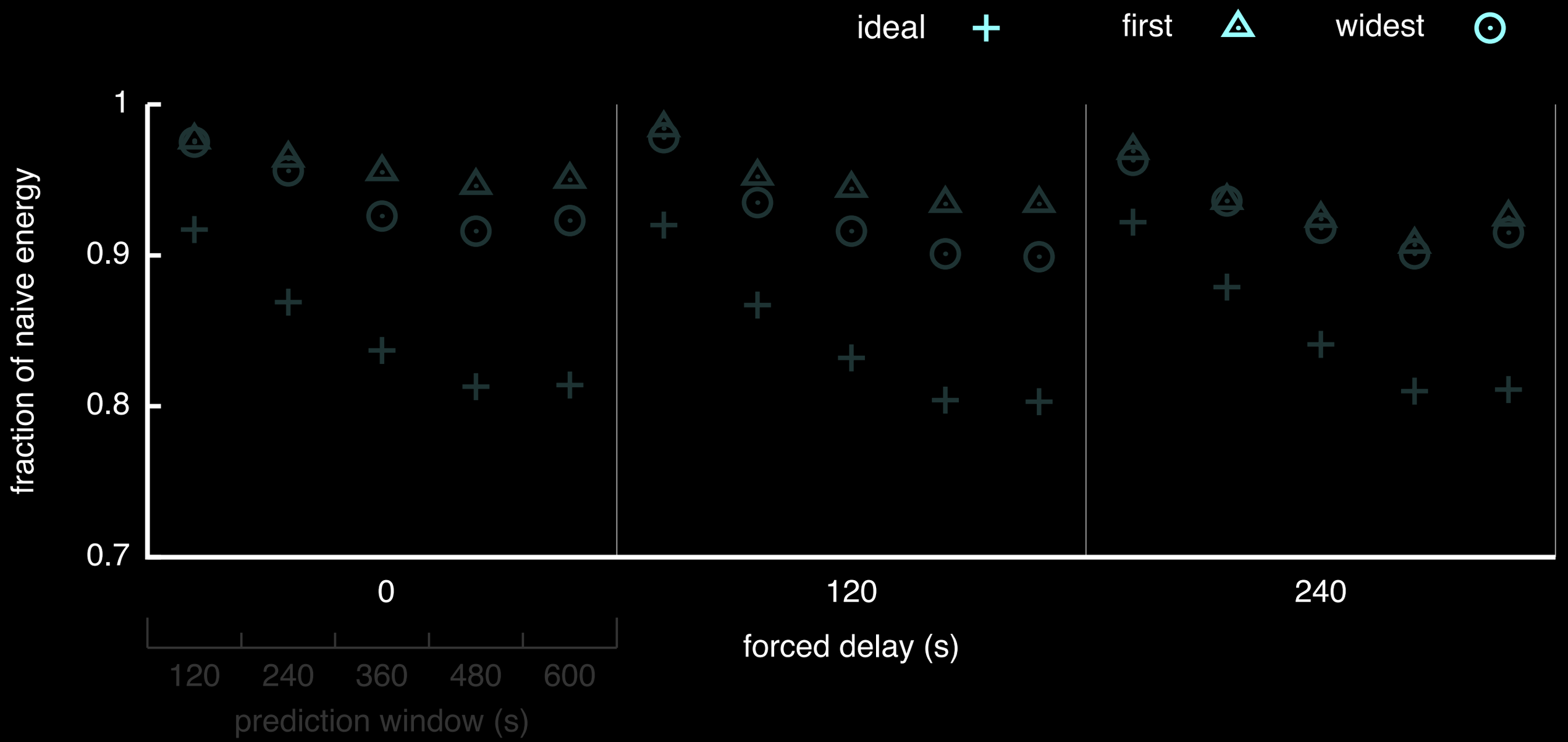

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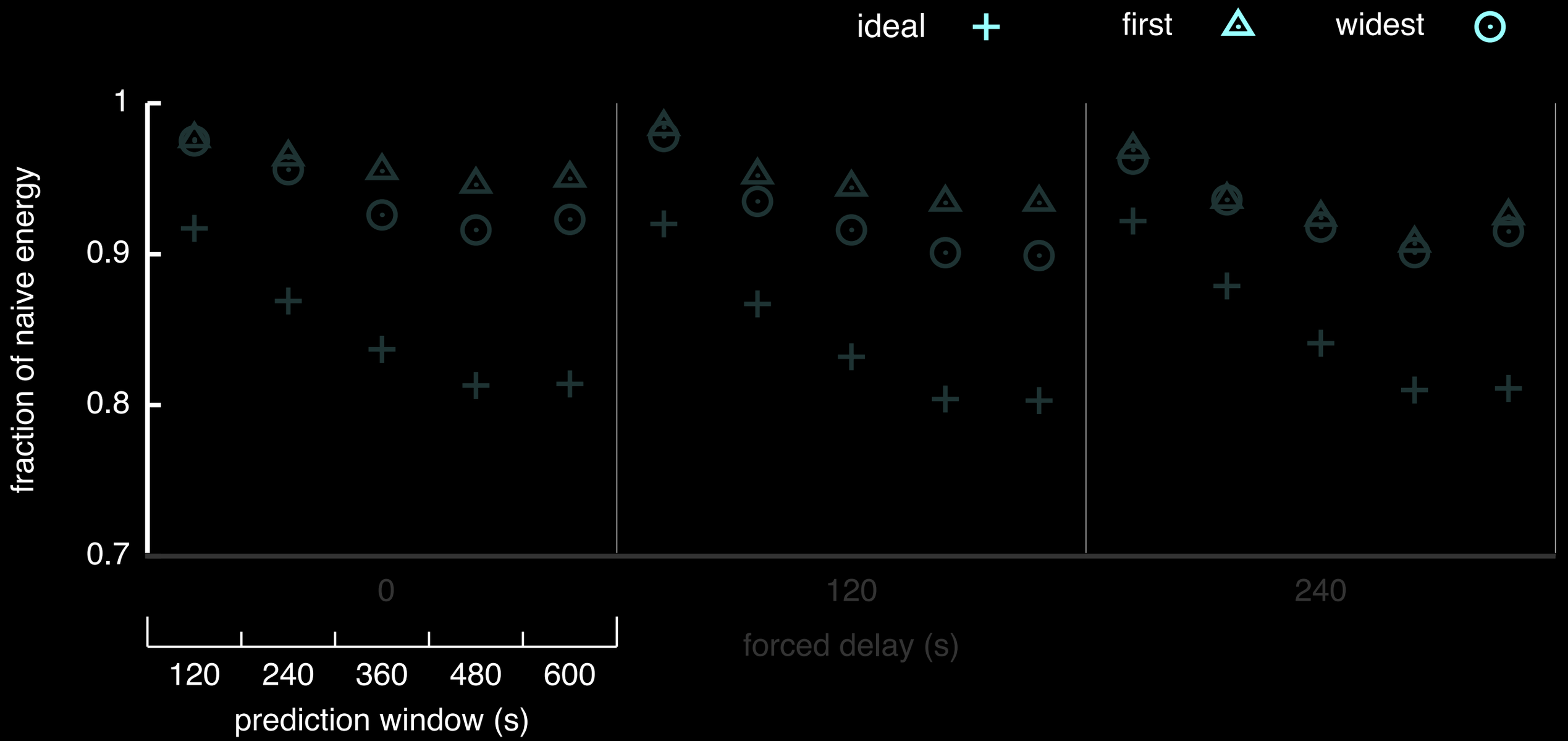

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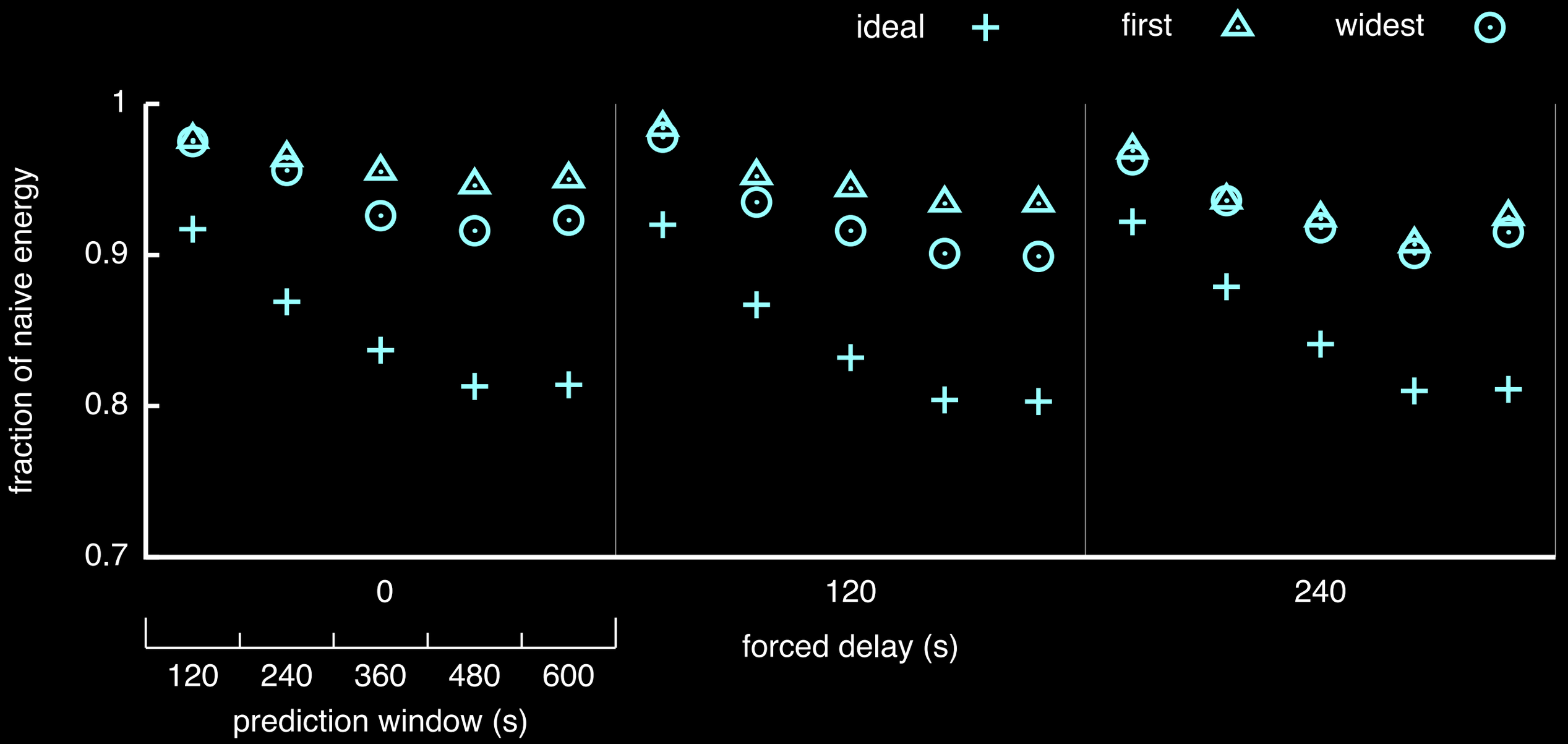

Streaming simulation

Related work

Breadcrumbs (A. J. Nicholson et al.)
Predicts WiFi network quality for a mobile device

Experiences in a 3G Network (Liu et al.) and
An empirical study on 3G network capacity and performance (Tan et al.)
Long term throughput at a location varies

TailEnder (N. Balasubramanian et al.) and
Cool-Tether (A. Sharma et al.)
Batching and prefetching reduce radio energy tail

Last call

Signal strength affects energy consumption

Applications like sync and streaming can improve energy efficiency by deferring and prefetching

Previous drives can predict signal strength without breaking the energy bank

Scheduling can reduce energy consumption by up to 50% for large workloads and 10% for small