Using Cooperation for Low Power Low Latency Cellular Connectivity

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trilogy 2
UE FP7 Project

UEFISCDI Romania

“mobile kibbutz”

GOALS

- lower power
- lower RTT
- higher throughput

Mobile connectivity

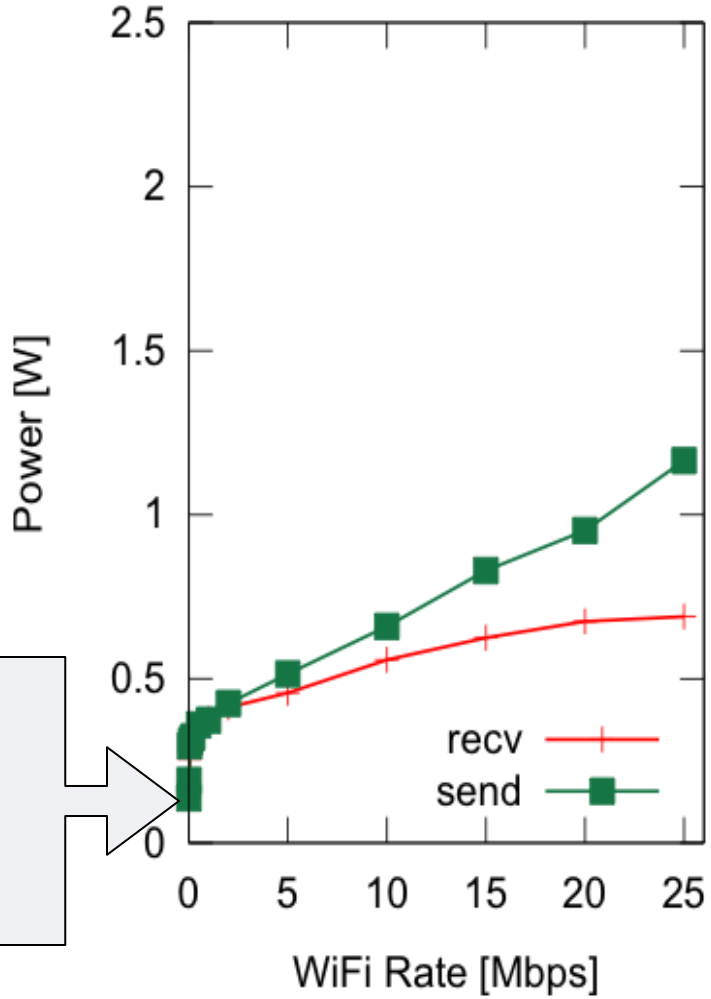
- **WiFi**
  - Good bandwidth (20Mbps), low latency (1-5ms)
  - Restricted distance (hundreds of meters), patchy coverage
  - **Proportional energy usage, power save**
- **3G/4G**
  - Low bandwidth (2-5Mbps), large latency (100-200ms)
  - Long distance (kilometers), good coverage
  - **Tail energy**

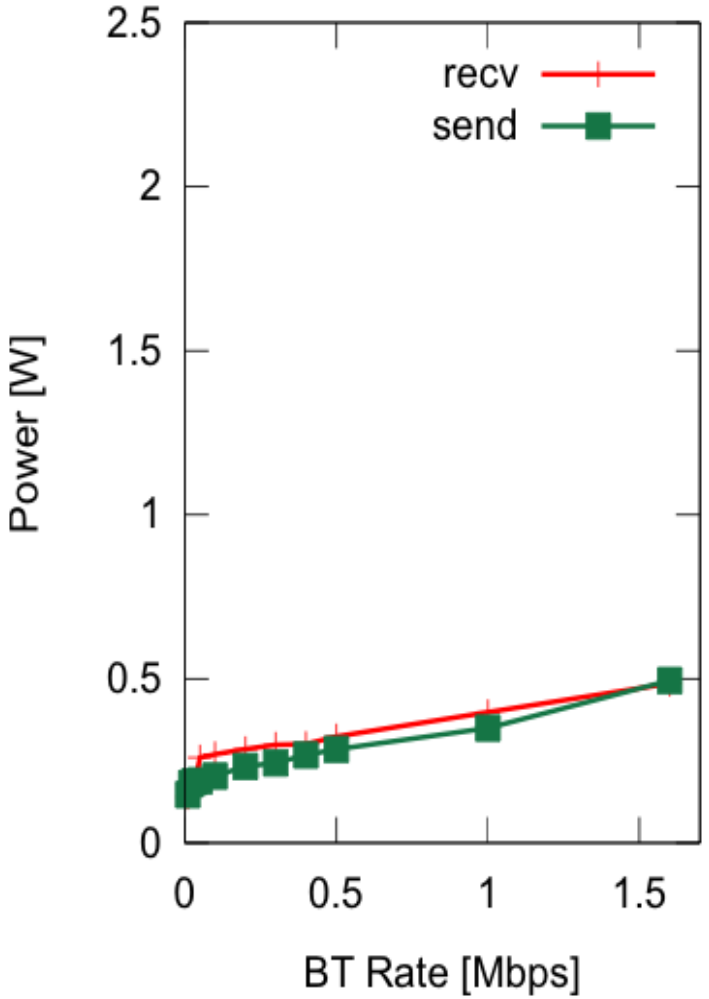
Mobile connectivity

- **On smartphones we have: WiFi, Bluetooth, 3G, 4G**
  - What to use? when? how?

- **Tradeoffs**
  - coverage – capacity - cost
  - power - RTT

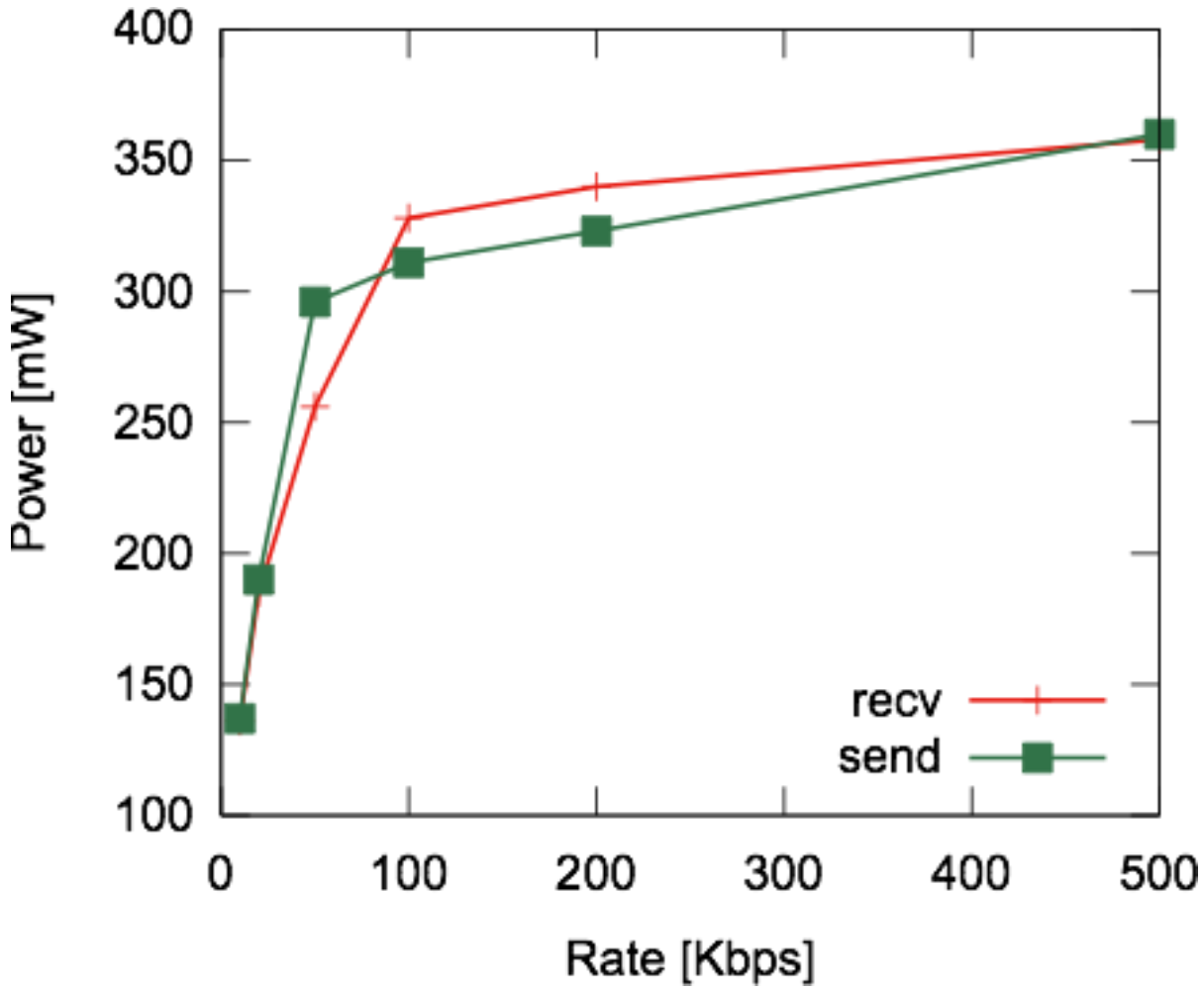
WiFi/Bluetooth are power proportional



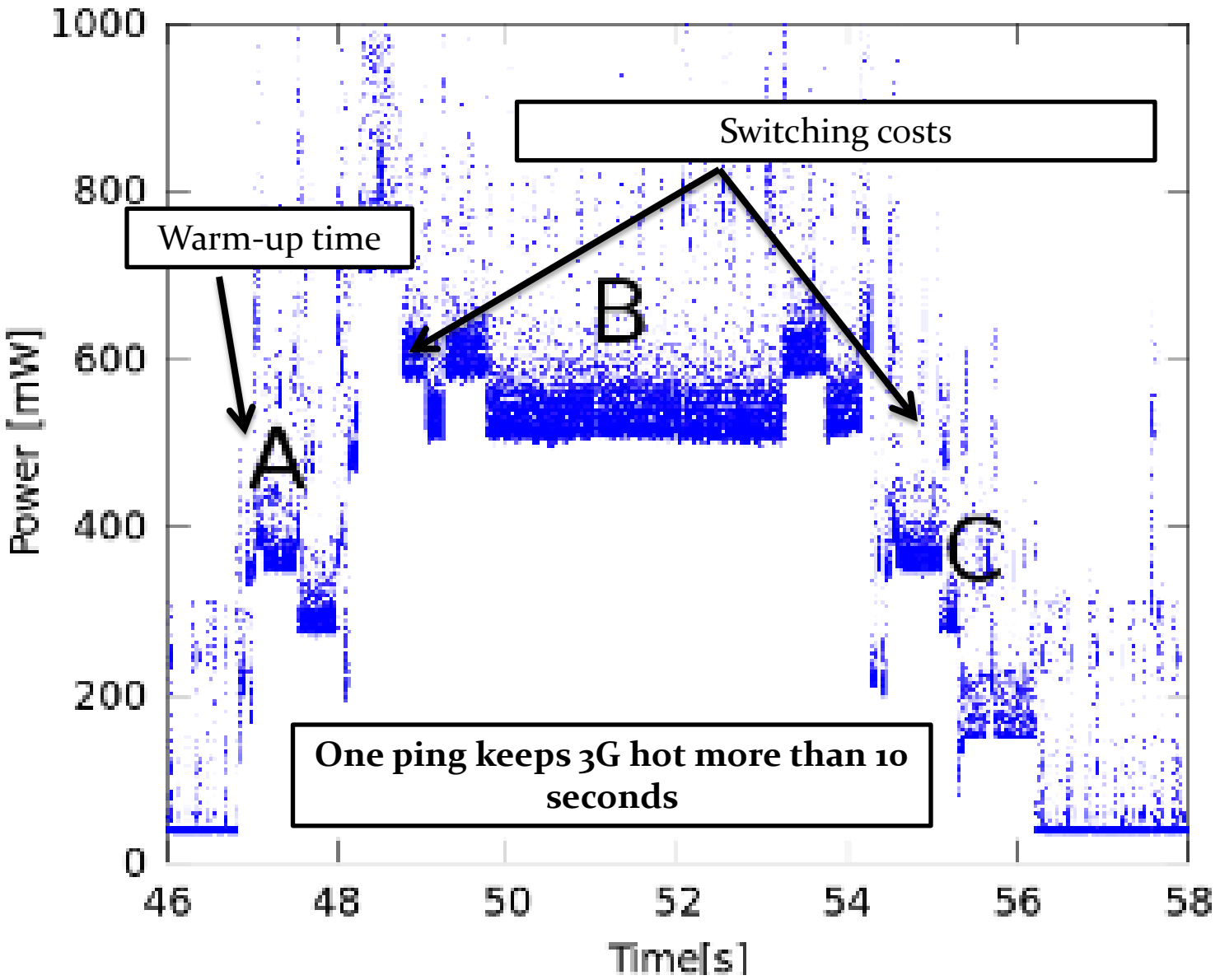


WiFi Power Save Mode

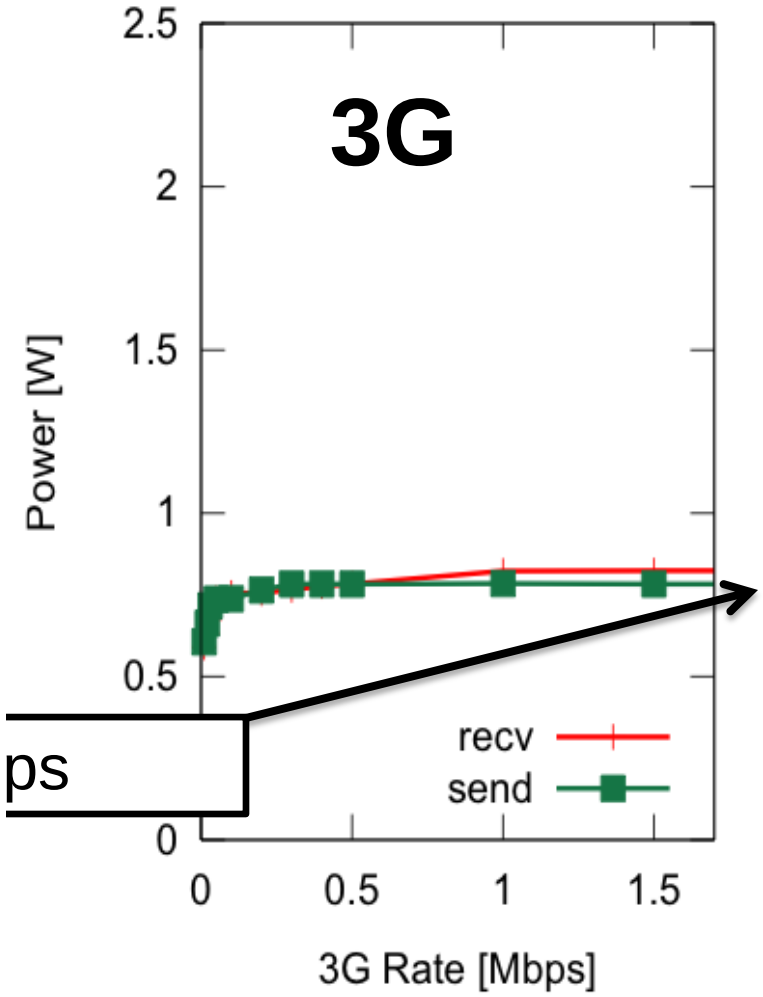
WiFi power save behavior



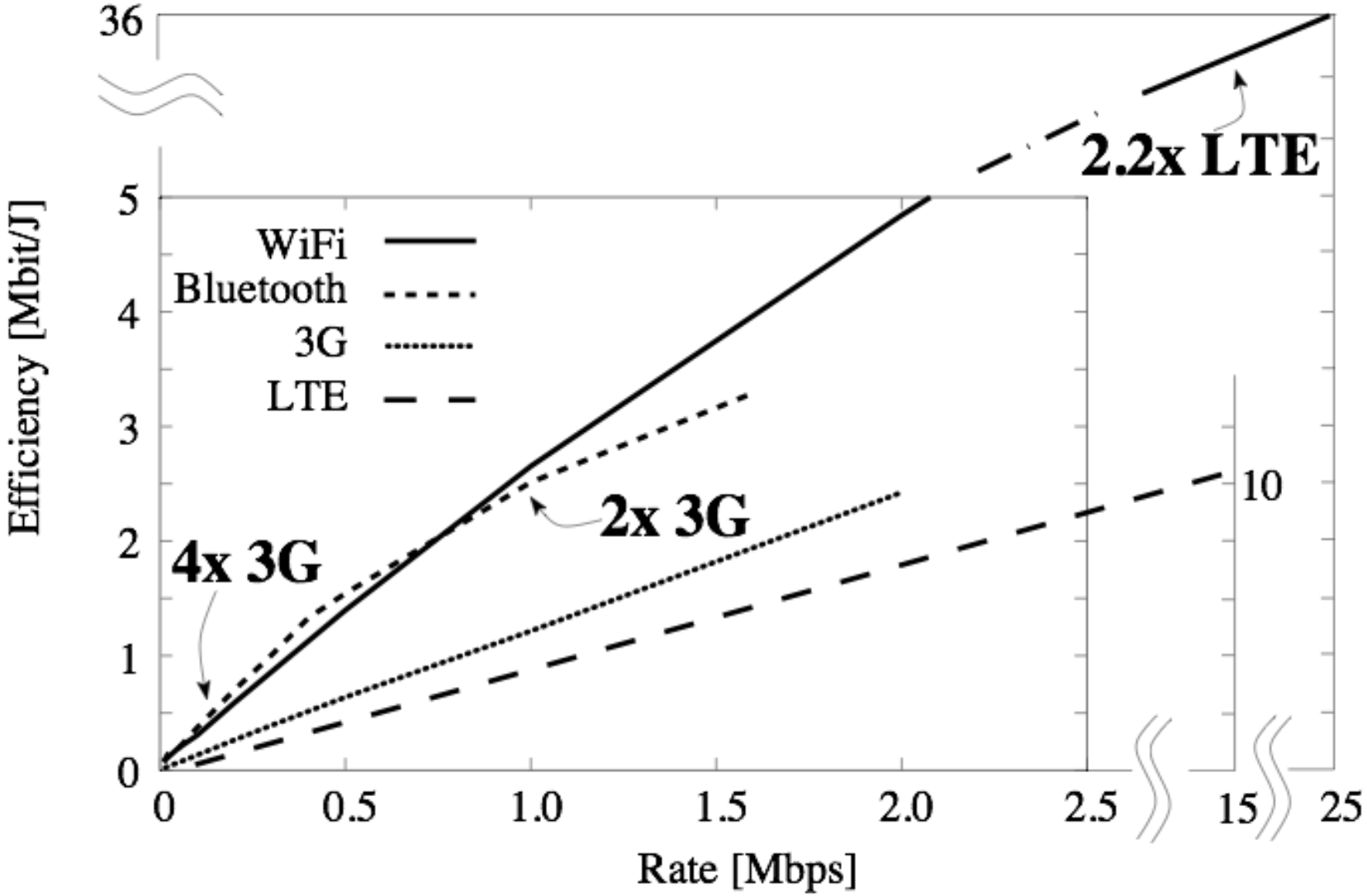
3G power consumption



Cellular links are not power proportional



Efficiency of a link



Browsing: tradeoff latency for energy

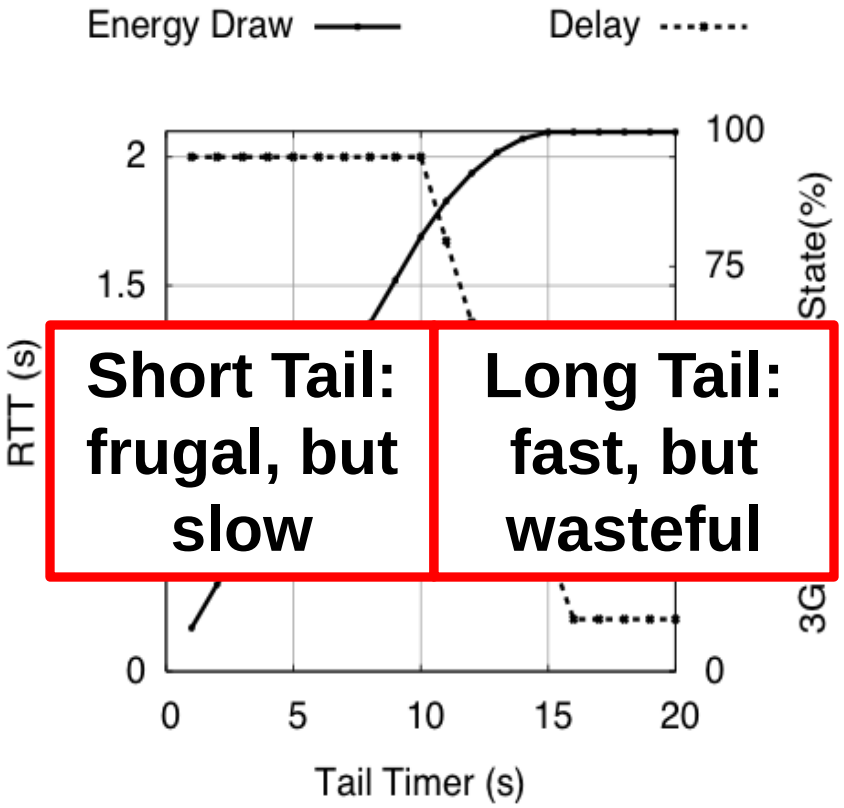
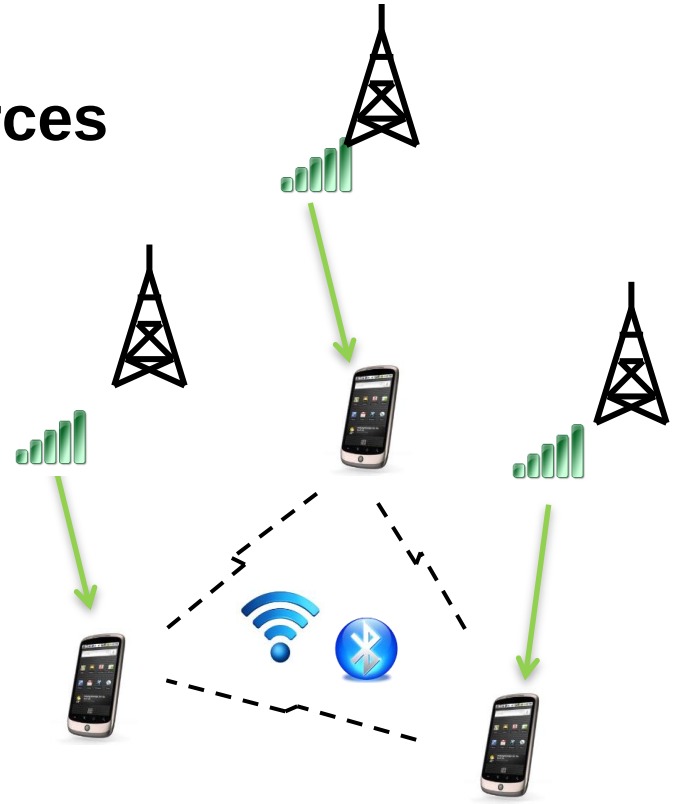


Figure 1: Cellular links offer a tradeoff between energy consumption and latency after idle

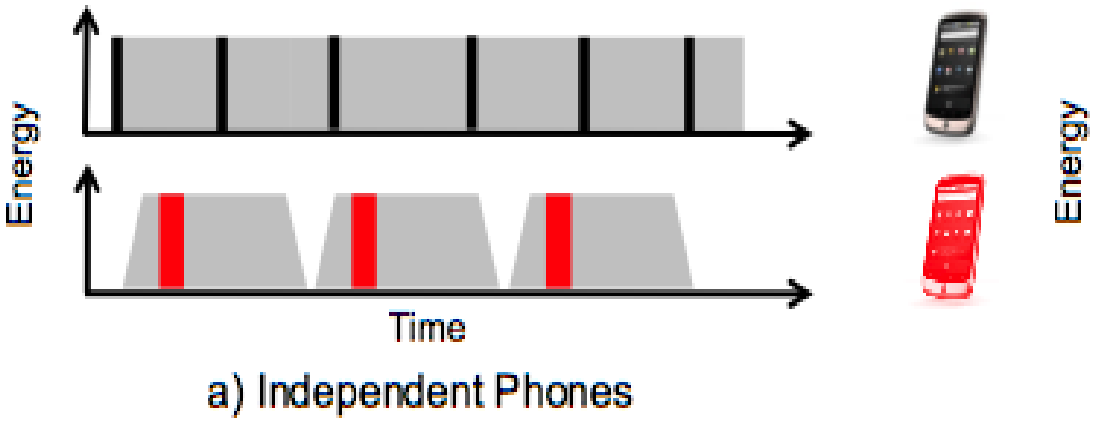
Key insights

- Cellular links work well only in the high power state
  - cellular link draws the same power, regardless of load
- Most users under-utilize cellular links

- **Users fare better by pooling resources**



Traffic consolidation

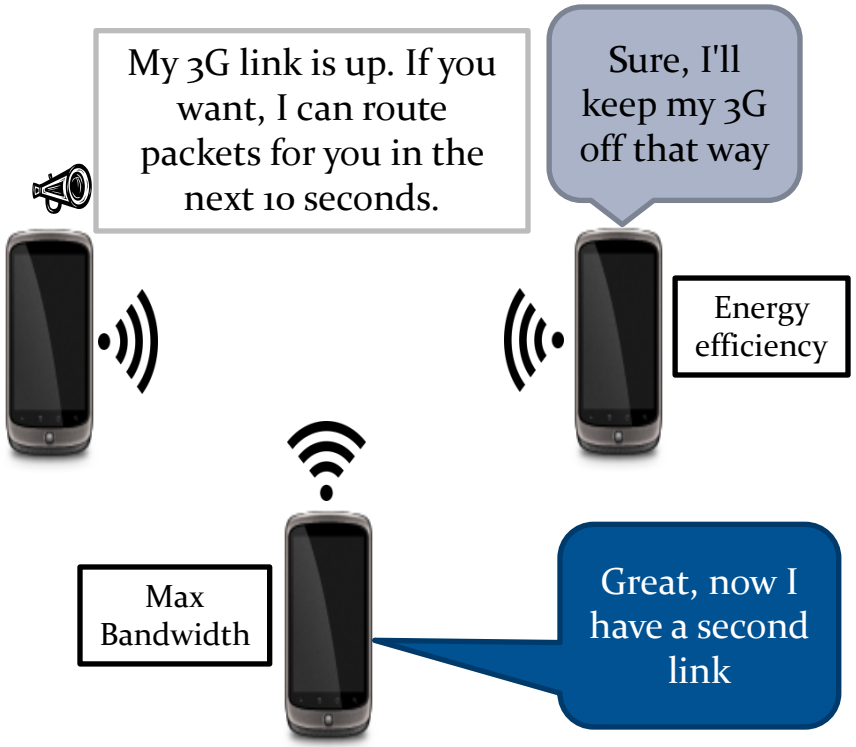


- black user listens to Internet radio
- red user browses the Web
- gray portion = wasted energy

Consolidation allows for more efficient energy usage

High level overview

- When the cellular link is hot the device advertises to neighbors "*will route for you for X seconds* "
- Neighboring devices choose whether to use offer or not

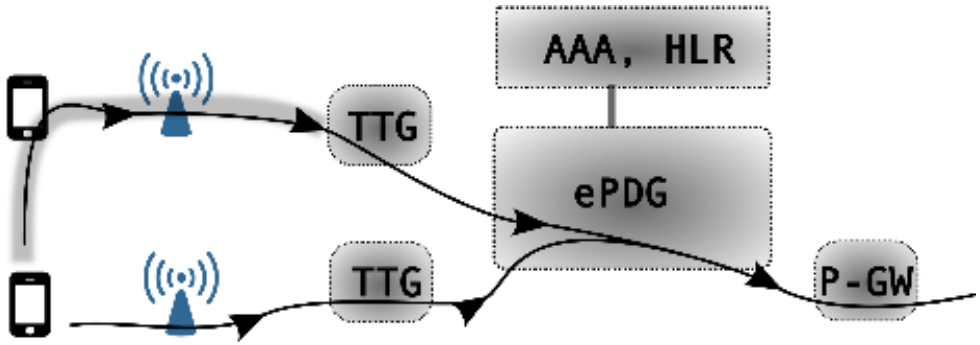


Fairness

- **This mechanism is inherently unfair:**
  - All traffic is consolidated on one link, one user pays the bill
  - Maximum efficiency and zero fairness
- **Short-term fairness: Tit-for-tat**
  - Each device holds a counter for every neighbor
  - Keep track if we routed for / via a neighbor in a certain time slot
  - Allow neighbors to use link as long as counter > 0
  - Initial counter value: trade fairness vs efficiency

Billing & security

- **Neighbor = untrusted => use existing WiFi offload solutions**
  - Many standardized protocols (3GPP, AnyFi)
  - All traffic encrypted
  - Appropriate billing support

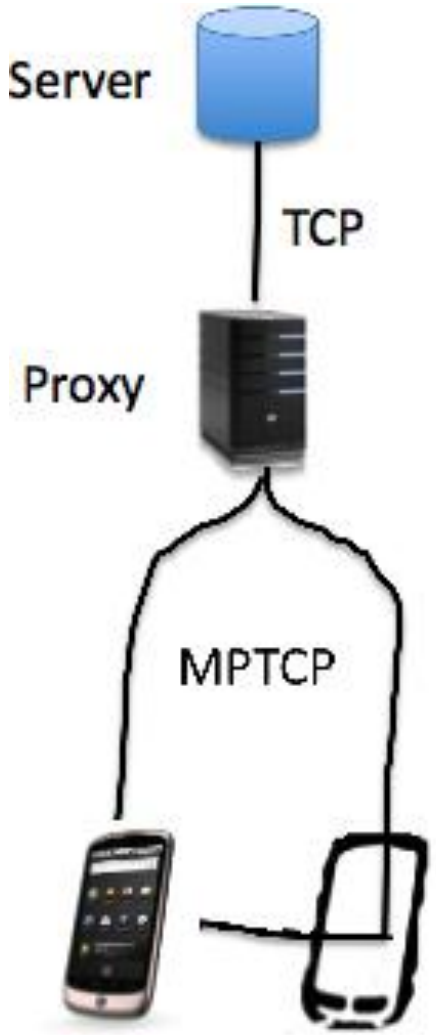


- **Kibbutz goal: everyone pays for their own traffic**

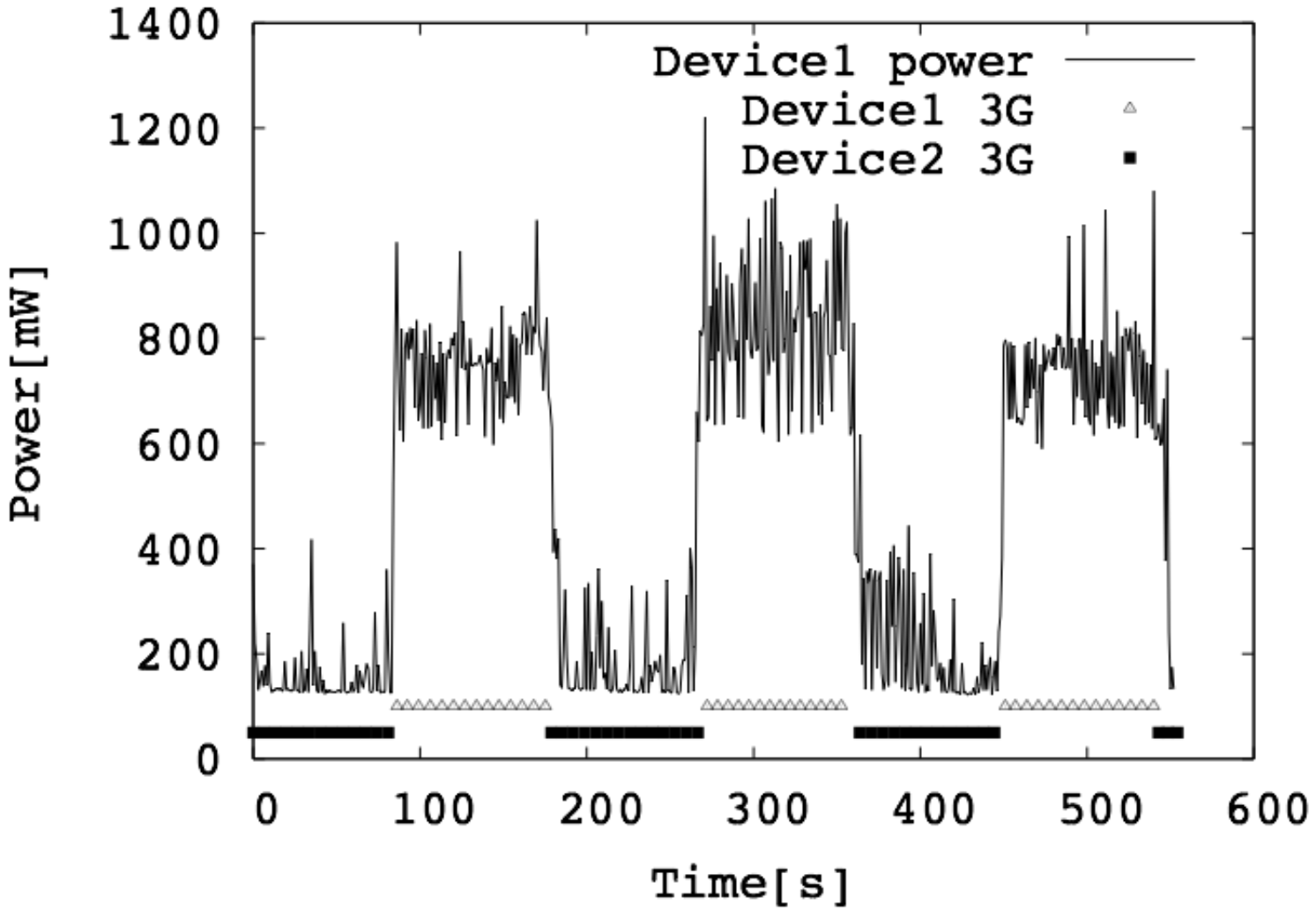
Implementing the kibbutz

- **Use MPTCP to steer traffic onto the right link**
  - Neighbor link if available or
  - Own link otherwise
  - MPTCP MP_PRIO
- Prototype running for Samsung Galaxy Nexus
- Can use WiFi or Bluetooth as local link

Experimental setup



Simple TCP “ping-pong”



2 packets per second, 31% power saving

How much energy can we save?

- **Depends on combination of cellular and local link**
  - 3G + BT (previous graph) ~ 31%
  - LTE + WiFi ~ 29%
  - LTE + BT ~ 35%

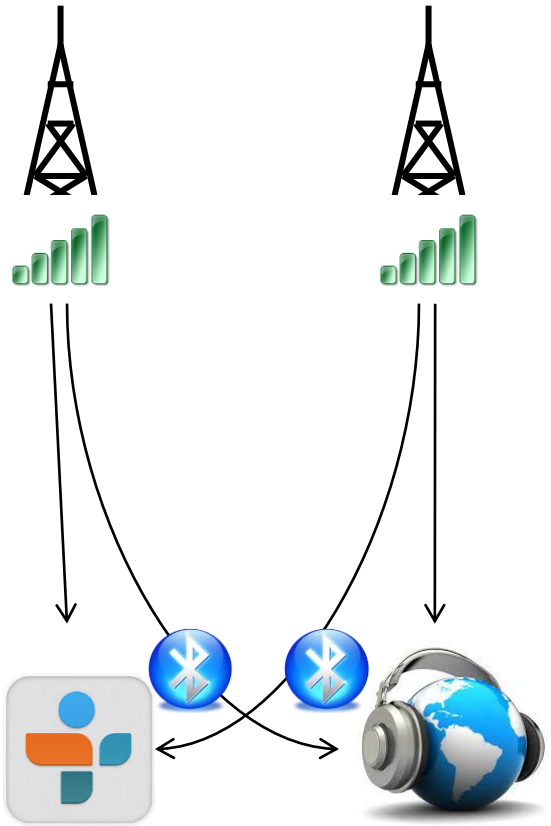
How much energy can we save?

- Depends on combination of cellular and local link

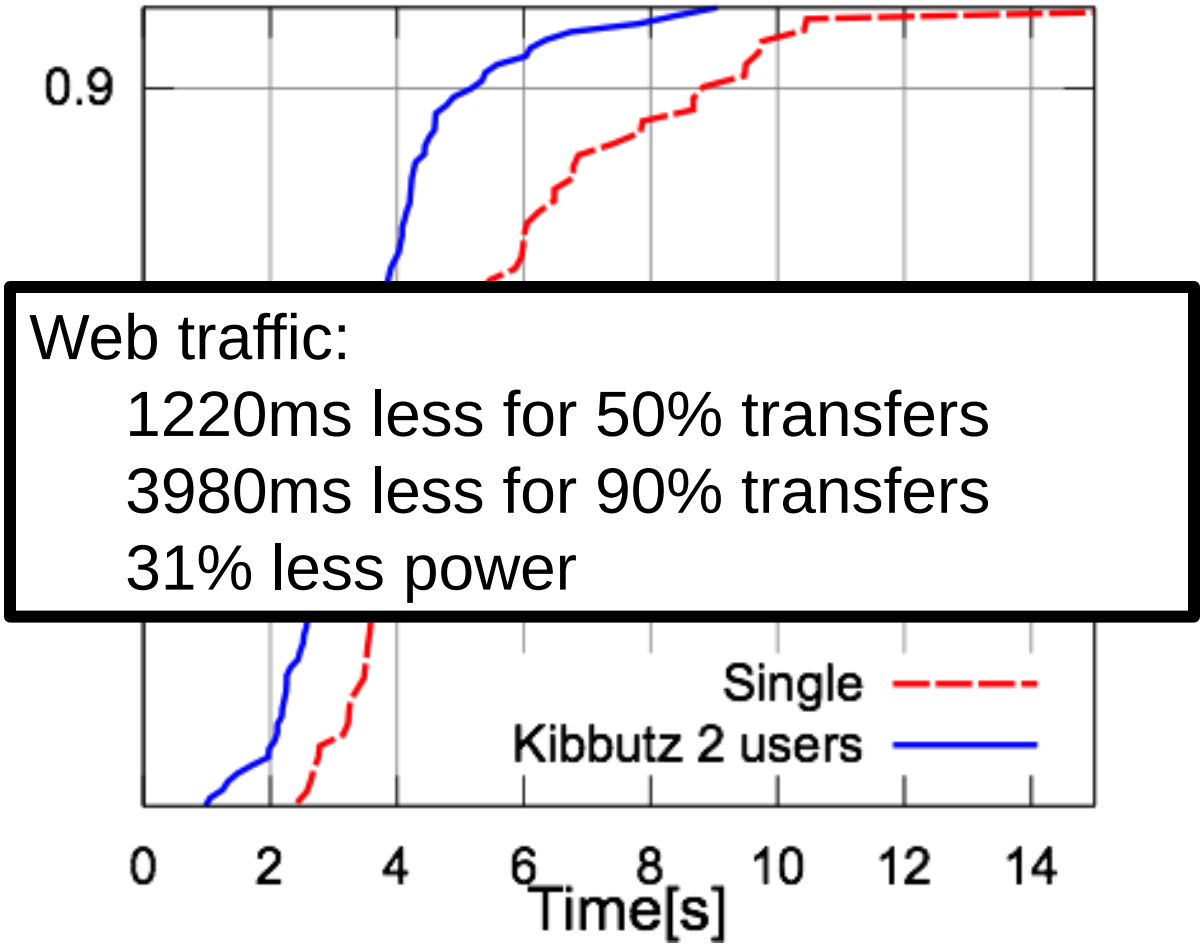
Link type vertical + horizontal	*kibbutz* Router [mW]	*kibbutz* Consumer [mW]	Stand alone [mW]	Power Savings
LTE + BT	1095	220	1020	35.5%
LTE + WiFi	1316 / 1080	170 / 320	1020	27.1% / 31.4%
3G + BT	740	191	675	31.0%
3G + WiFi	866 / 630	113 / 323	680	28.0% / 29.9%

How about real apps?

- **Internet radio (MP3) streaming 48Kbps**
  - 25% less than standalone consumption
- **YouTube**
  - 15% less than standalone consumption

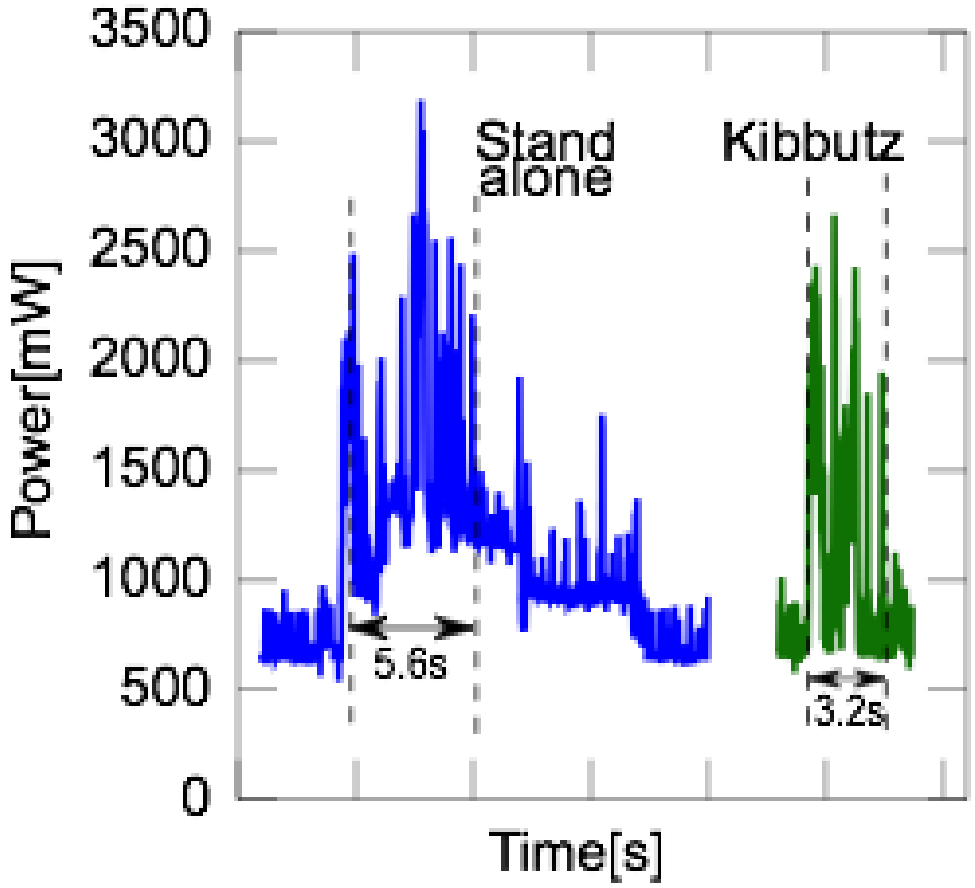


Web traffic RTT



Time taken to load a mobile page

Google search mobile



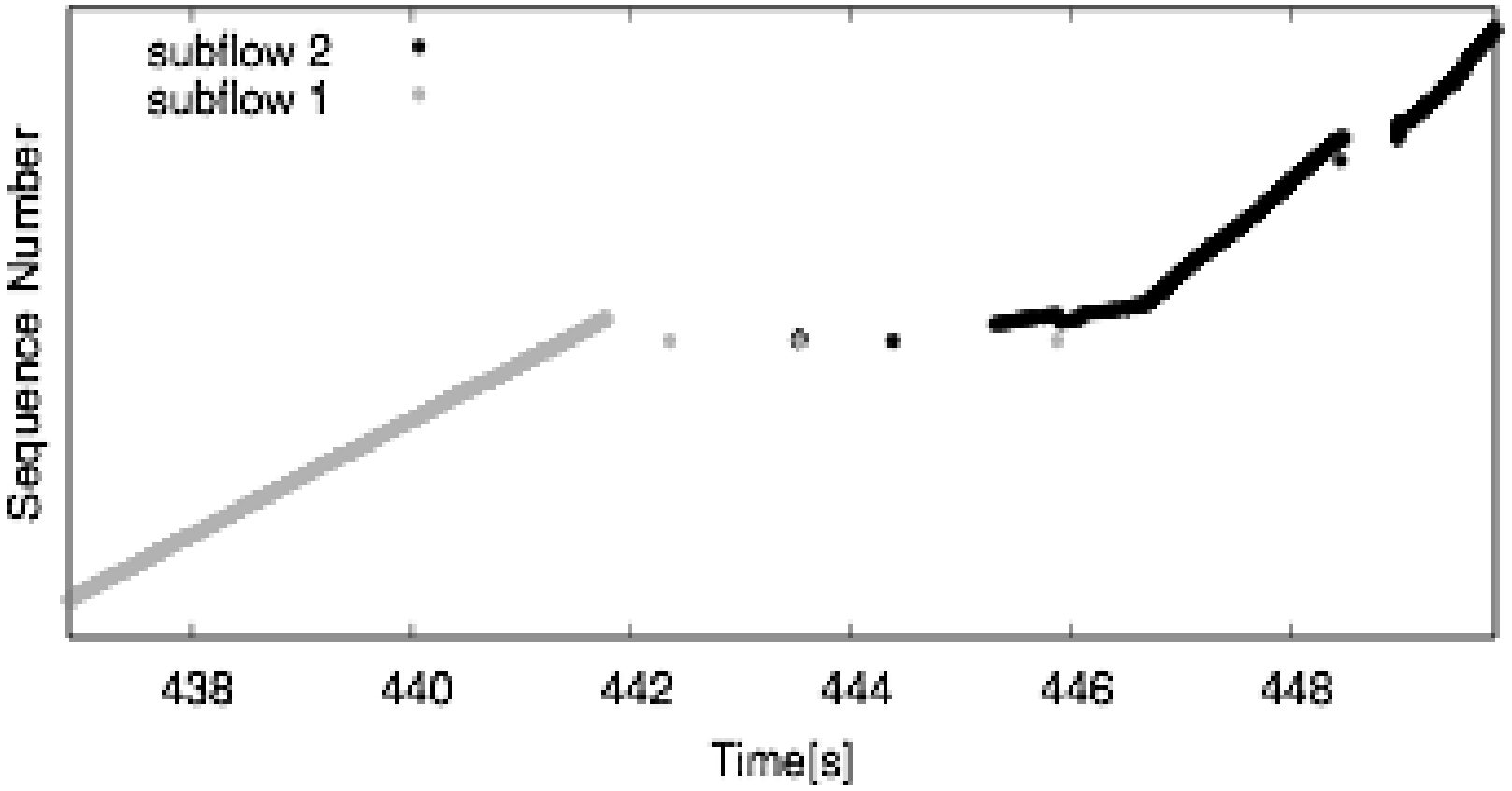
Searching using 3G link vs using local Bluetooth link

What about bandwidth intensive apps?

- **App download, (6MB) using max bandwidth strategy**
  - Isolated download time: 31 ± 8 seconds, 41 Joules
  - Kibbutz (different carriers) : 21 ± 5 seconds, 31 Jou
  - Using two interfaces saves energy!
  - Screen is ON

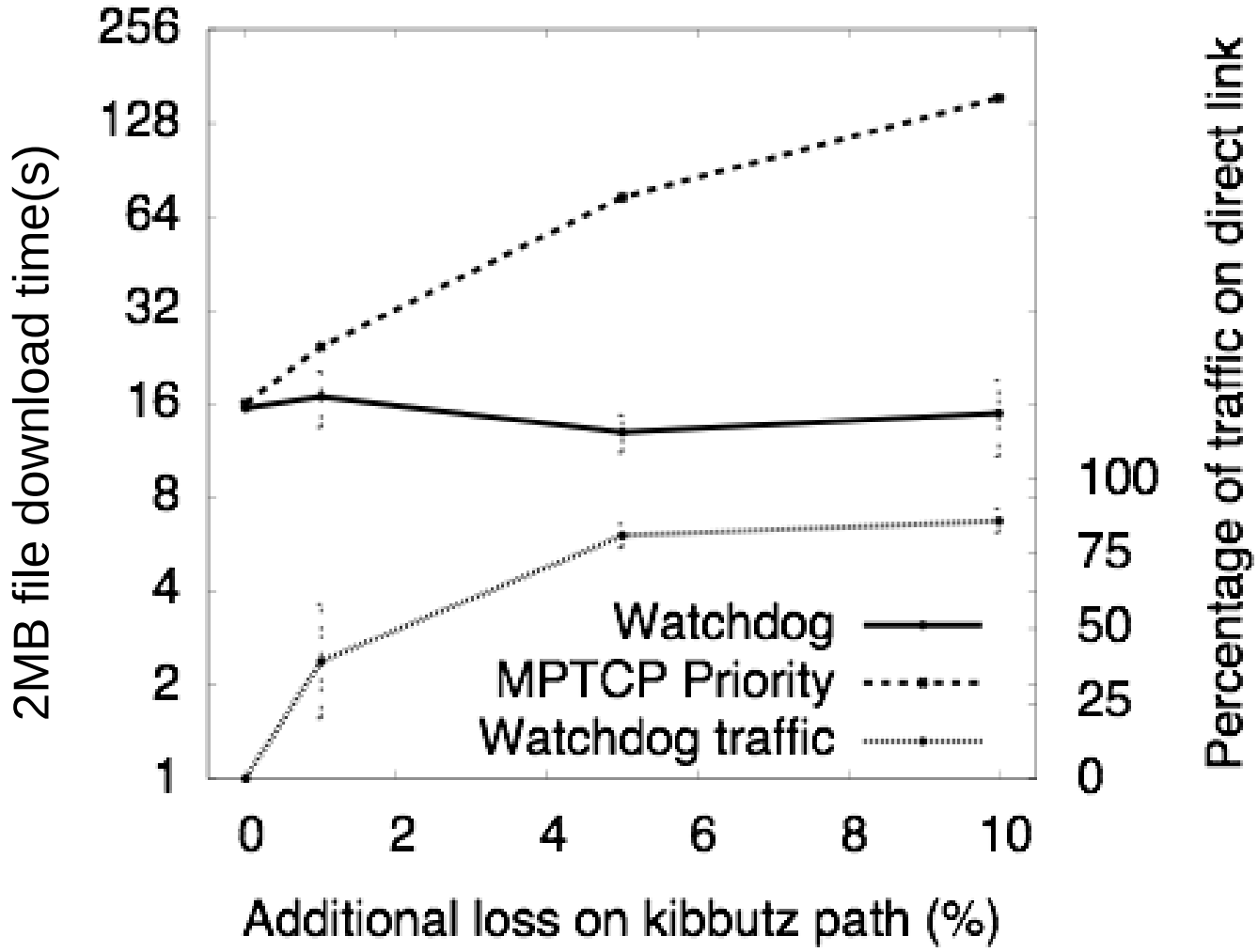
Robustness

- What happens if the Kibbutz peer suddenly leaves?

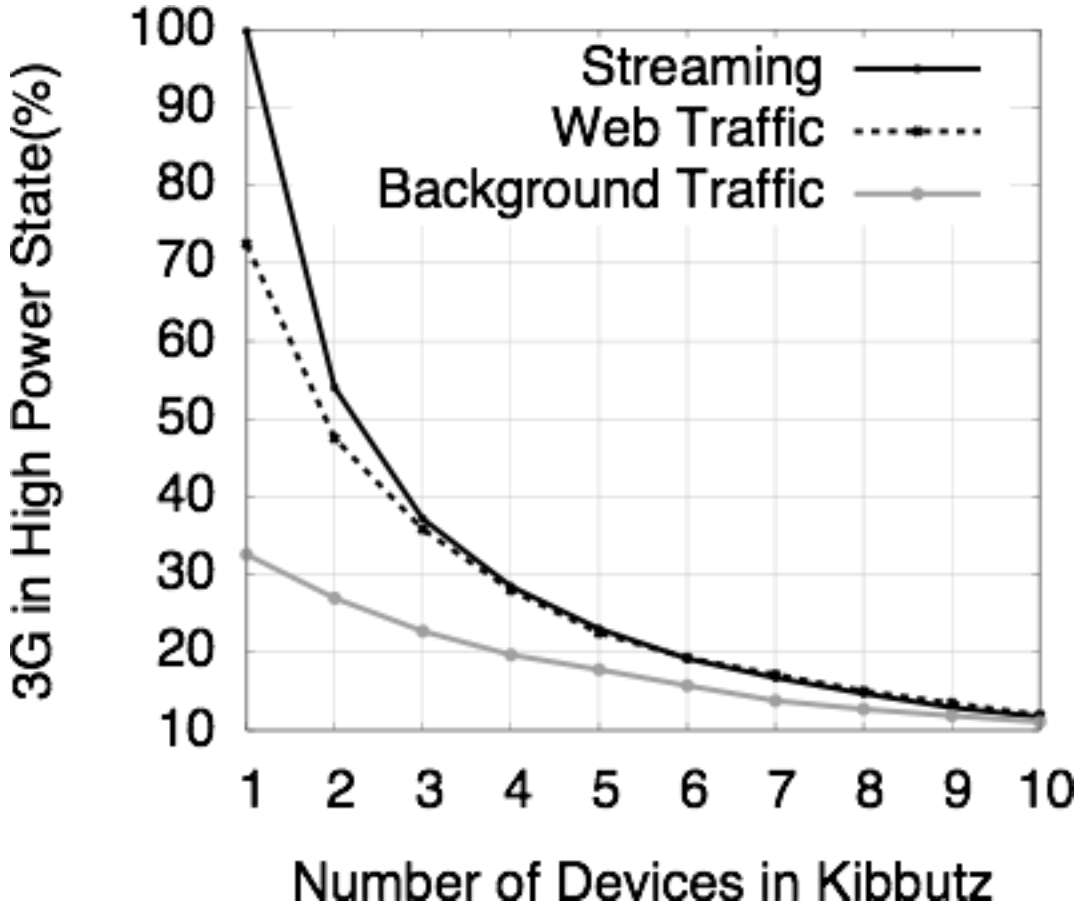


Robustness

- What if the connection is bad?

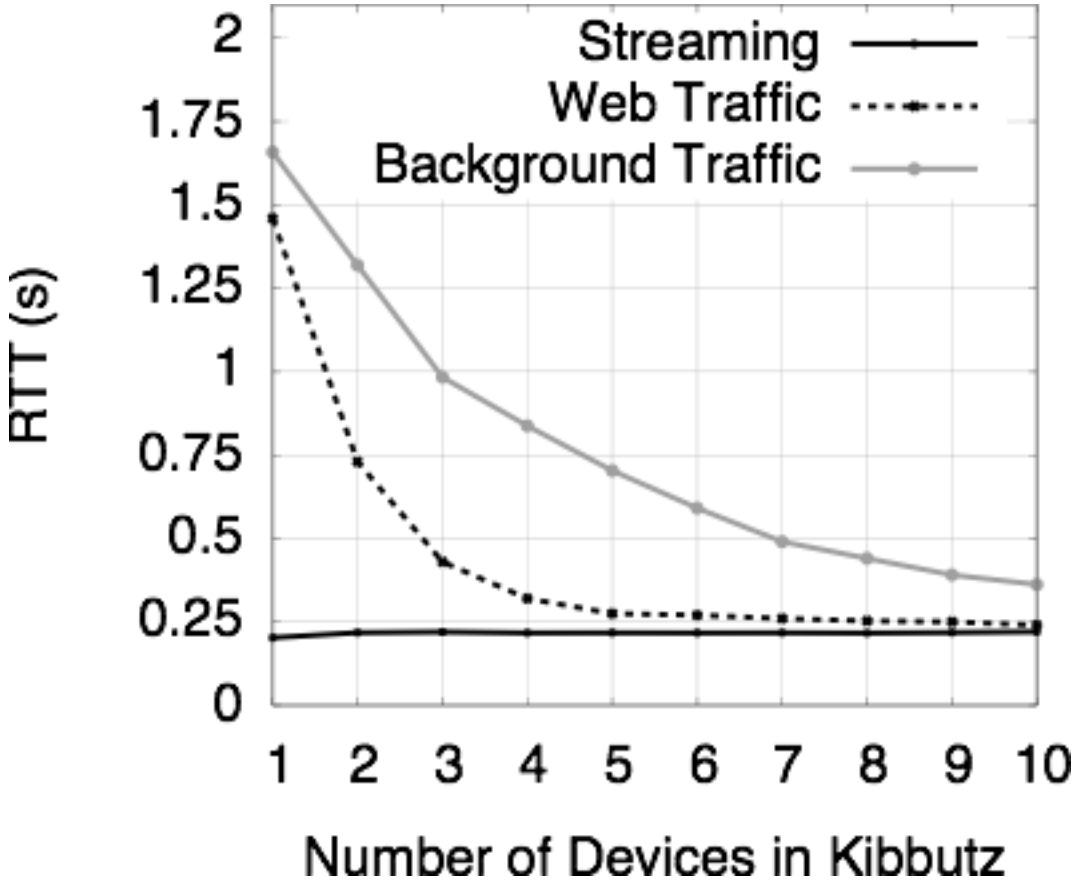


Simulations



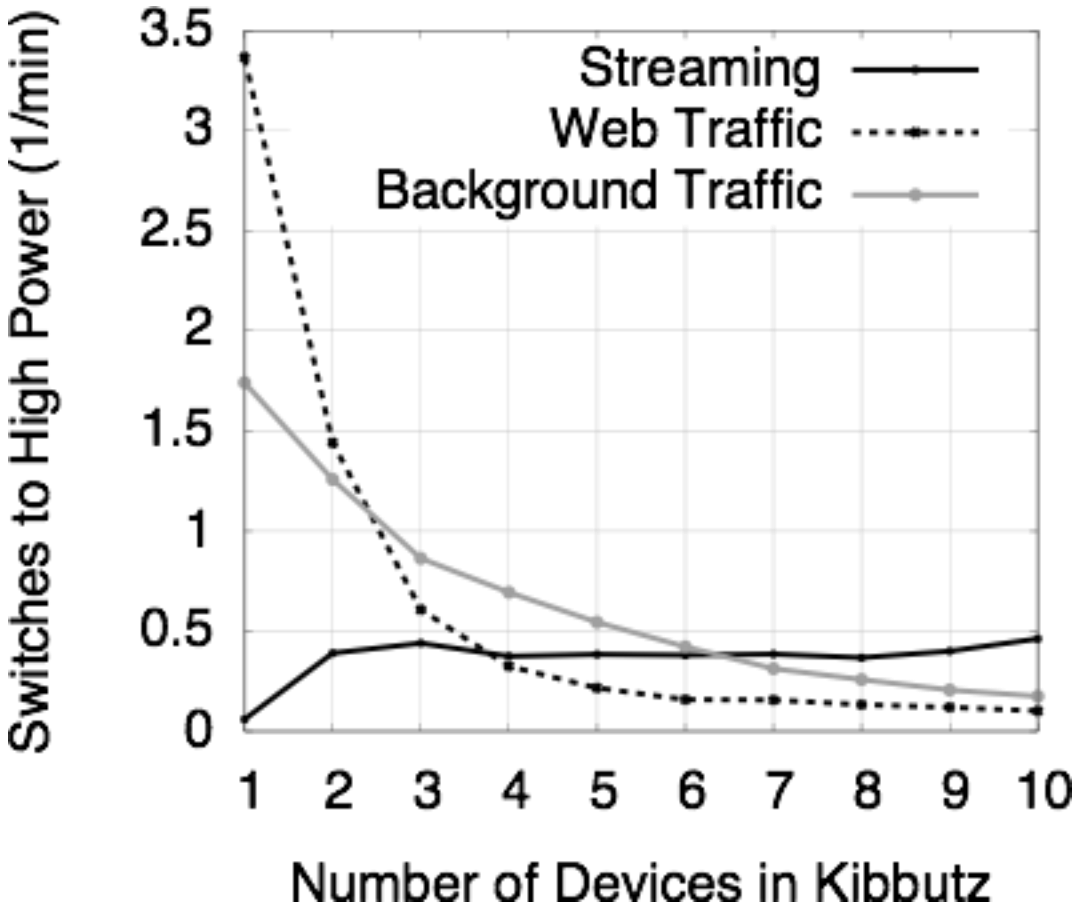
3G gets used less when in a kibbutz

Simulations



RTT decreases with more users

Simulations



Operators want lower signaling

Related work

- **The idea of tethering is not new**
  - Prism, Combine, CoolTether, CoolSpots, Shair, Erdos, 3GOL
  - Kibbutz uses it to save energy

- **Reducing mobile energy consumption**
  - For background traffic: TailEnder, Stratus, Catnap, MakeIdle, BarTendr
  - Main ideas are batching & fast dormancy
    - both hurt interactive apps like web browsing.

Summary

- **key observation**
  - cellular links are only efficient when fully used
- **mobiles cooperate => reduce energy AND delay**
  - By pushing cellular links into more efficient operating points
  - Local connectivity is power proportional, << cellular
- **kibbutz is deployable**
  - Reuses accounting mechs to guard against malicious users
  - Uses tit-for-tat to ensure short-term energy fairness.
  - No app knowledge, no OS instrumentation, no batching