PARCEL: Proxy Assisted BRowsing in Cellular networks for Energy and Latency reduction

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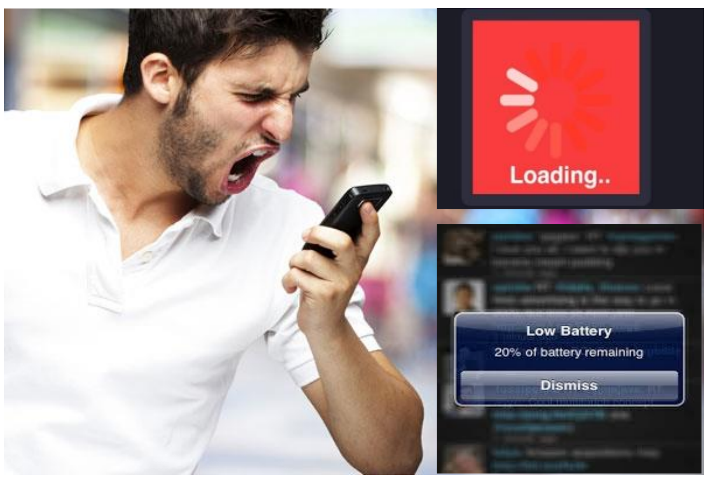
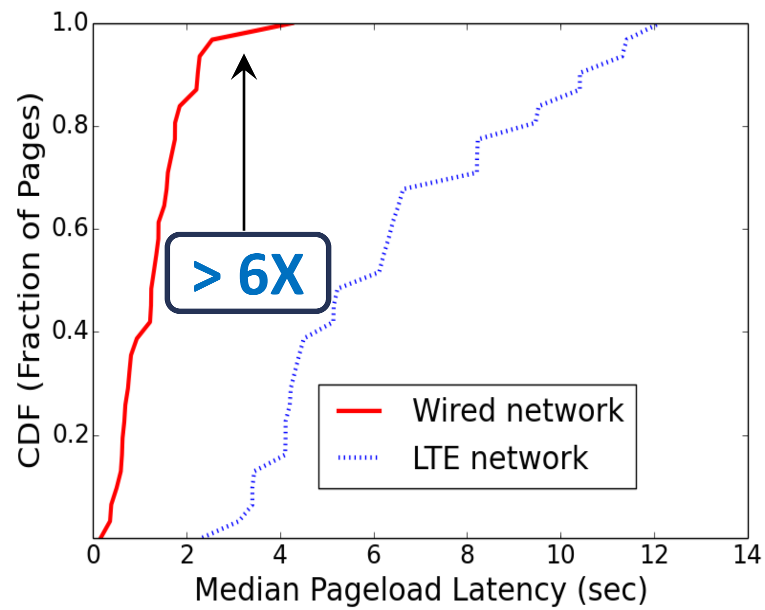
Mobile Web Browsing in Cellular Networks

Mobile web browsing technology :
slow and power-hungry



- E.g. Our measurements on a subset of Alexa top 500 pages – 6X longer



What are the drivers of poor performance?

Characteristics of Modern Webpages

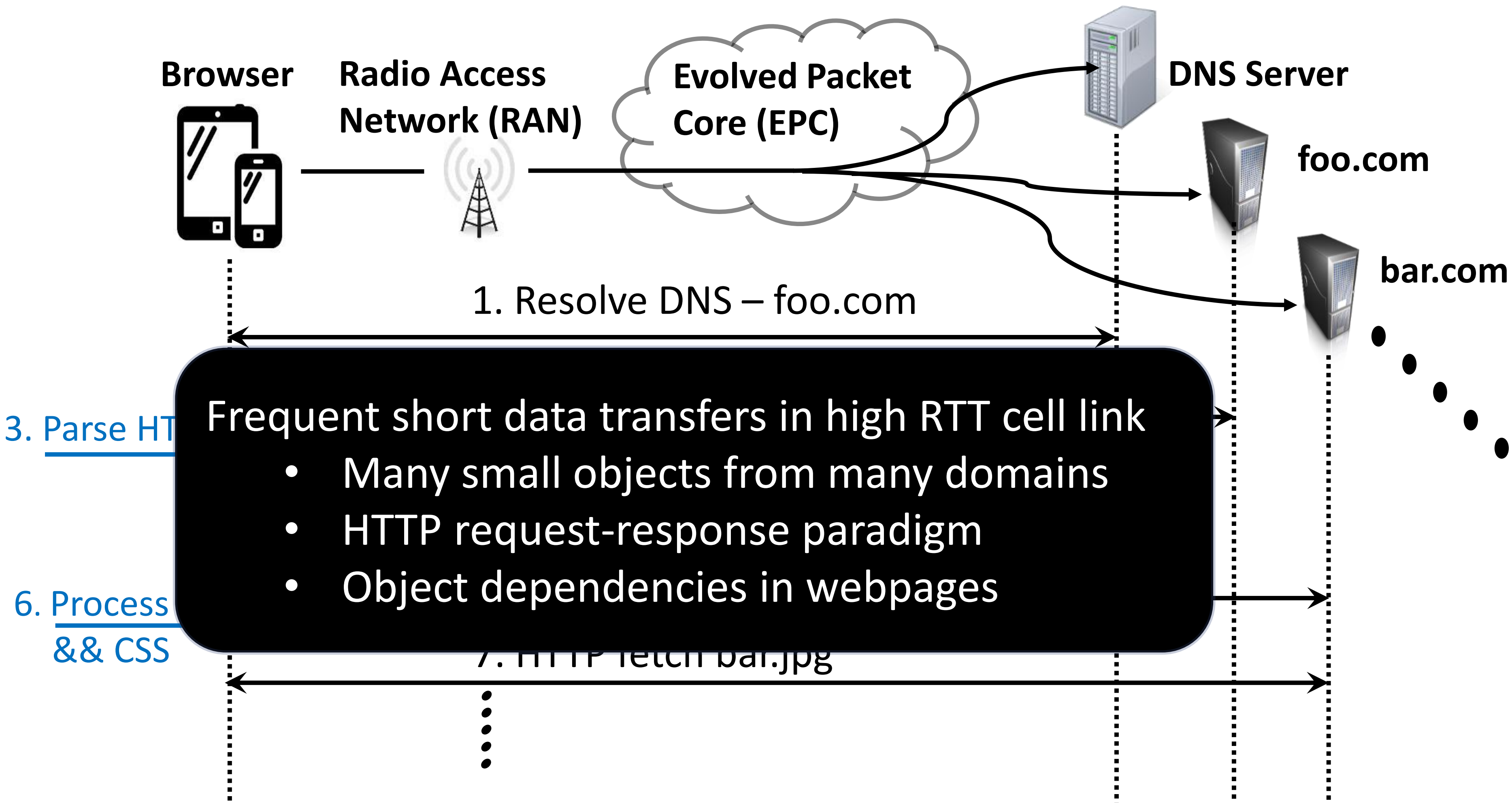
- 100’s of objects from many domains

40% of Alexa top 500 pages : >= 100 objects

95% of obj. in Alexa top 500 pages : < 386 KB

- Dynamic objects (e.g. JavaScript-generated) supporting rich interactivity

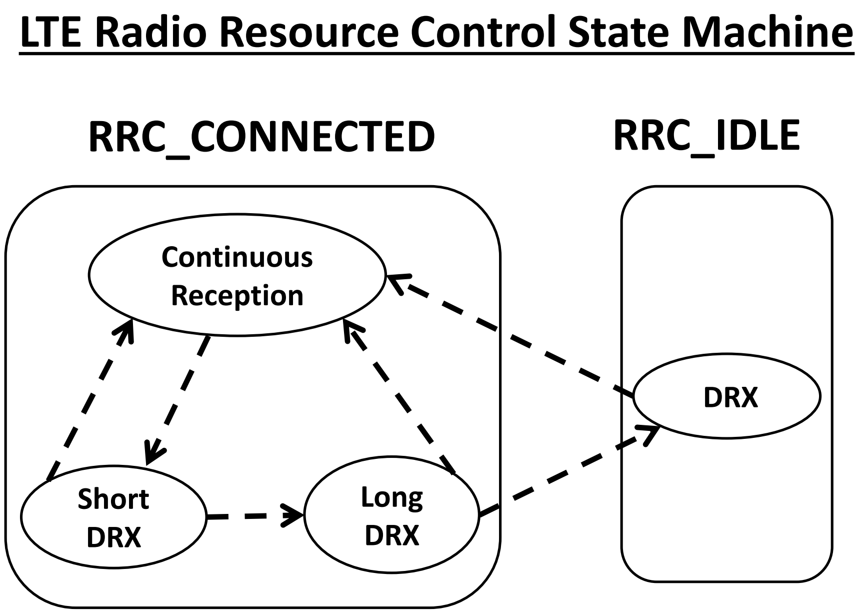
Why Web Downloads Are Slow in Cell Networks?



Frequent short data transfers in high RTT cell link

- Many small objects from many domains
- HTTP request-response paradigm
- Object dependencies in webpages

Why Web Downloads Have High Radio Energy Usage ?



- Cellular radio interface -> a growing component of the total device power
- Complex state machine for energy efficiency
- Different states with different power consuming modes
- Transition to IDLE -> typically >10sec inactivity (hard in web downloads)

- High radio energy usage caused by
  - ✓ Long page load times
  - ✓ Frequent transitions inside high power RRC_CONNECTED

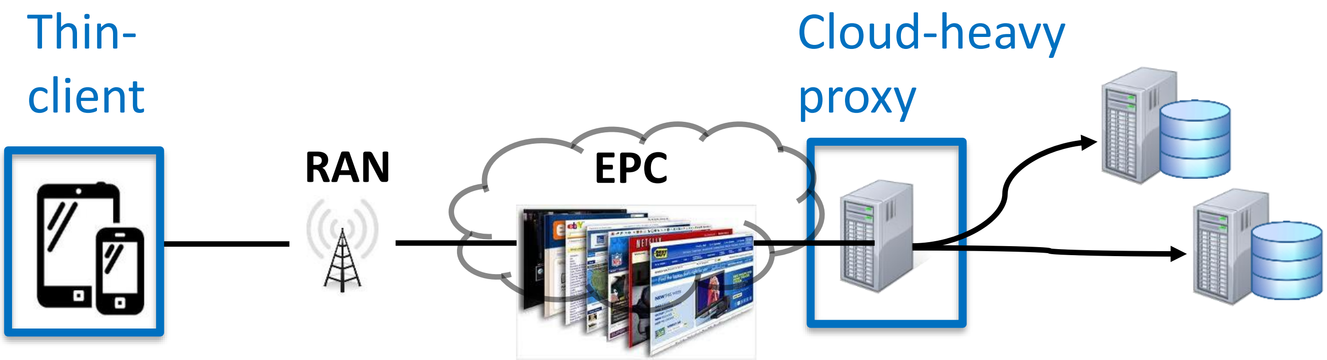
Contributions

- **PARCEL** – a proxy-assisted mobile web browsing architecture
- Key distinction from existing approaches – Judicious refactoring of web browsing functionality
- Benefits over traditional browsers
  - ✓ Significantly lower ‘Onload’ latencies
    - Onload : Browser triggers this event after receiving all objects to render an initial version of the page
  - ✓ Significantly lower radio energy usage

Outline

- **Existing Solutions**
- PARCEL Design
- Evaluation Methodology
- Results and Conclusion

Existing Cloud-heavy Thin-client Approaches



- All browsing functionality in the proxy [SkyFire, Opera Mini, Zhao et al ICDCS'11]
- All user interactions (e.g. mouse clicks) communicated to the proxy
  - JavaScript to handle the click executed only in the proxy
- User-interactions incur higher latency and radio energy consumption [Sivakumar et al HotMobile'14]

Other Related Approaches

- New application protocols (e.g. SPDY)
  - All browsing functionality in the client
  - Multiplexes multiple requests and responses unlike HTTP
  - Dependencies in web pages => SPDY poor performance in real world [Erman et al CoNEXT'13, Wang et al NSDI'14]
- Page transformation and compression (e.g. Pagespeed)
  - Compression by itself does not always result in latency and radio energy savings [Sivakumar et al HotMobile'14]
- Split-browsing architecture (e.g. Amazon Silk)
  - Black-box, proprietary

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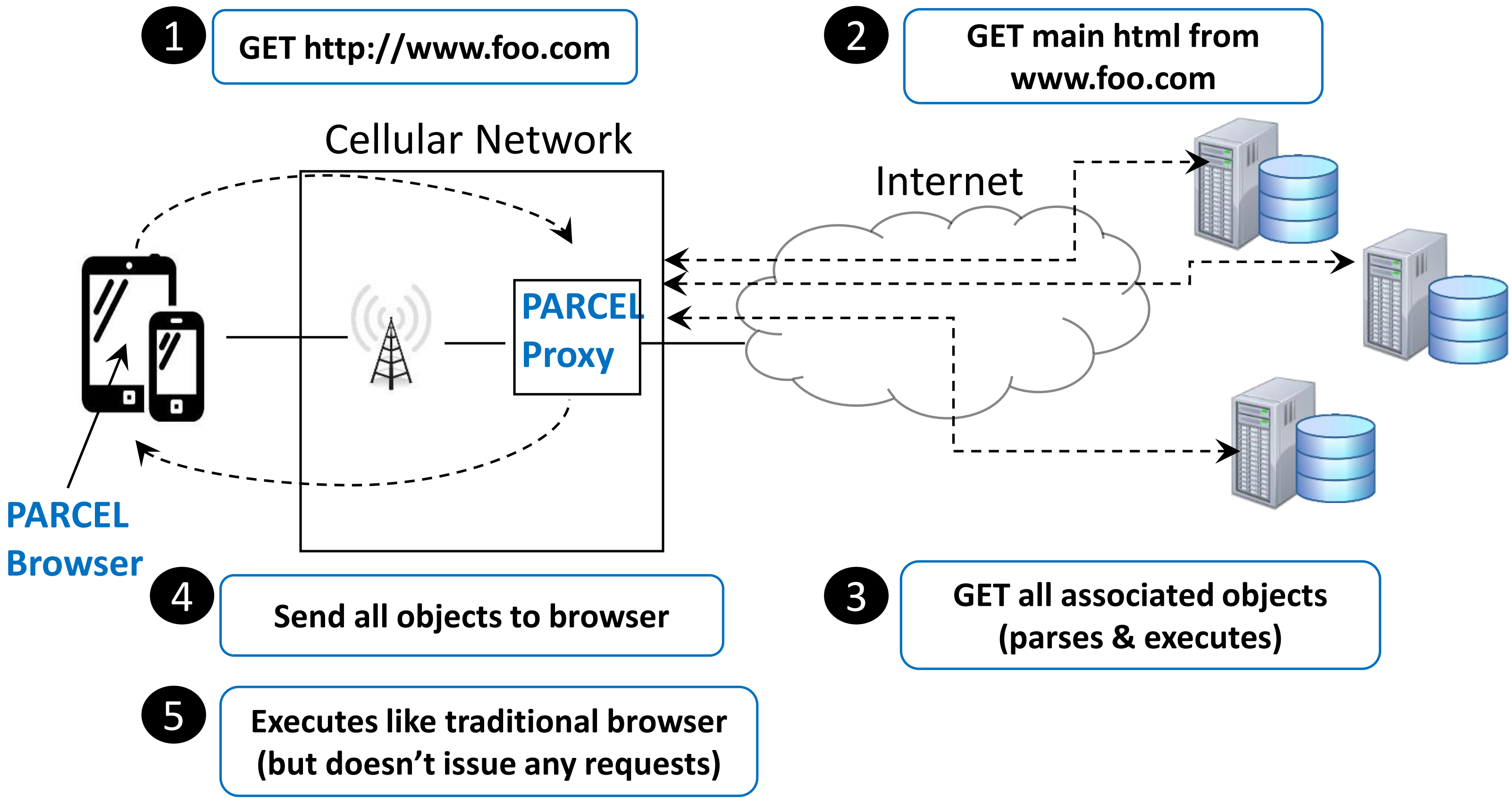
Key Design Considerations of PARCEL

- PARCEL Design Considerations:
  - ✓Minimize per-object HTTP request-response
  - ✓Responsive and energy-efficient client interaction
  - ✓Cellular-friendly and latency-sensitive data transfer

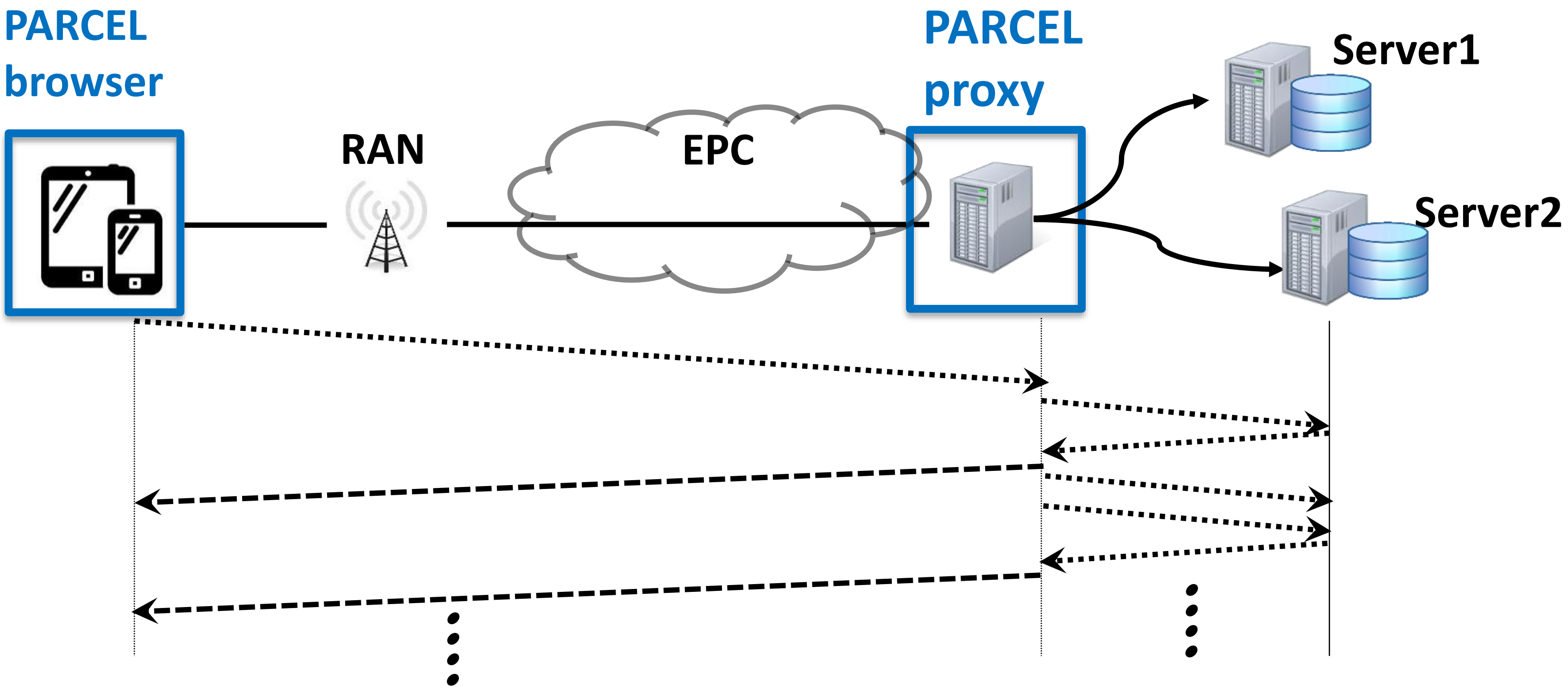
PARCEL Design and Benefits



Client execution – to handle user-interaction

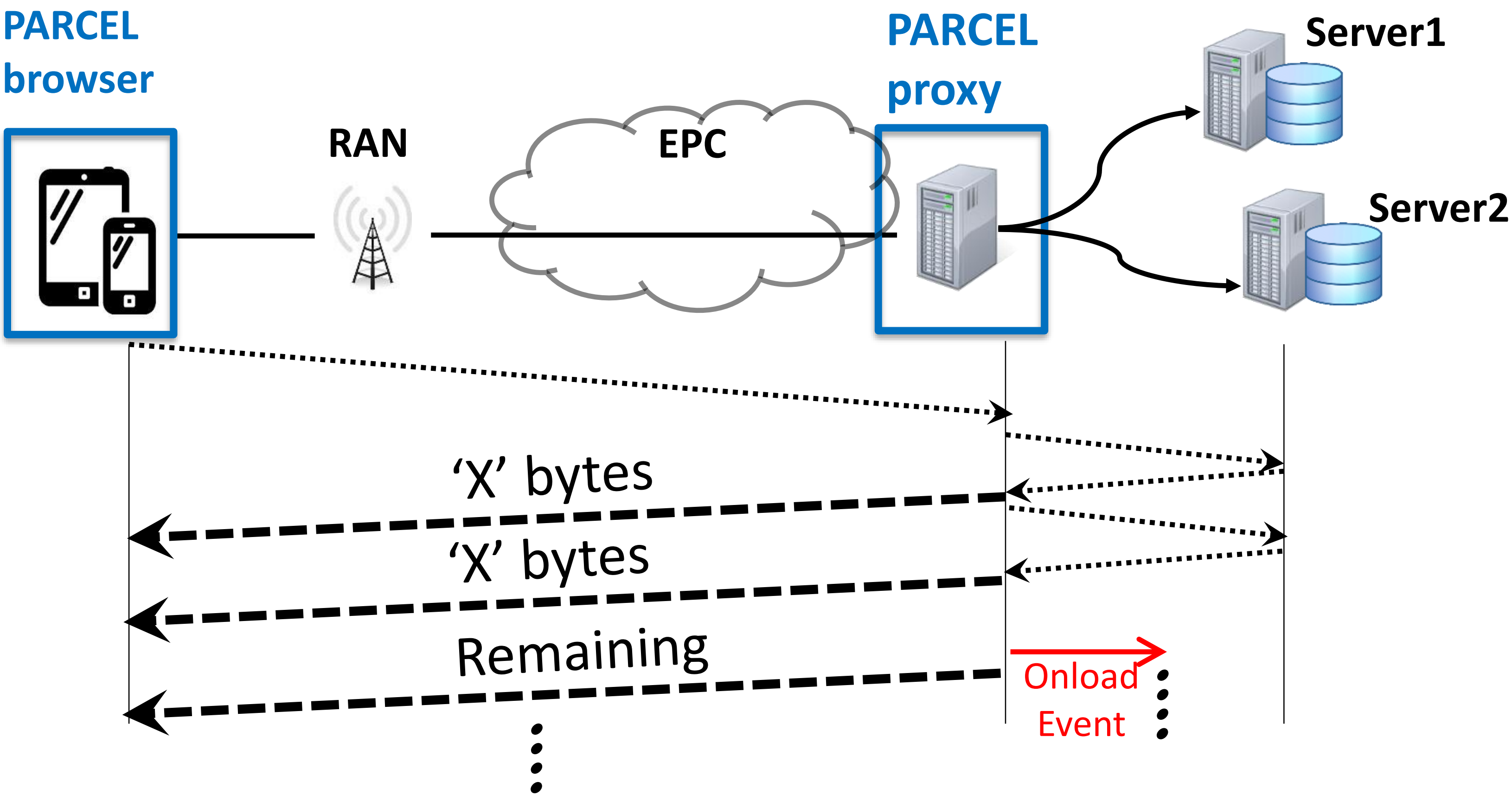
Proxy execution - Only to identify objects to fetch

Latency-efficient Data Transfer Strategy (IND)



Transfer individual objects as they arrive from the server

Energy-efficient Bundled Data Transfer Strategy (X)



Multiple bundles of 'X' bytes each

What is the Right Bundle Size?

- Smaller bundle sizes -> latency-efficient
- Larger bundle sizes -> radio energy savings
- More generally depends on
  - Web page size (s)
  - Network bandwidth (B)
  - LTE radio power model parameter (α)
- Our analysis shows, optimal bundle size, $b^* = \alpha\sqrt{sB}$ (Measured α = 0.74)
  - E.g. For a 2MB webpage, with LTE speed of 6Mbps – optimal bundle size is 0.9 MB

Practical Issues and Solutions

- How to make the proxy aware of client cache content and cookies?
  - Proxy maintains per-client state
  - Tracks object versions to avoid redundant object transfer
- How to make the proxy respect client-specific customization to pages?
  - Browser sends attributes like UA, screen resolution and the proxy mimics the client
- How to handle HTTPS traffic at the proxy?
  - Personalized trusted proxy setting up independent secure connections

Prototype Implementation Details

- Developed the proxy as a Firefox add-on (uses the parser and JavaScript engine of Firefox)
  - 1.5K lines of JavaScript code

- Developed a custom parcel client application using android webview to render
  - 2K lines of Java code

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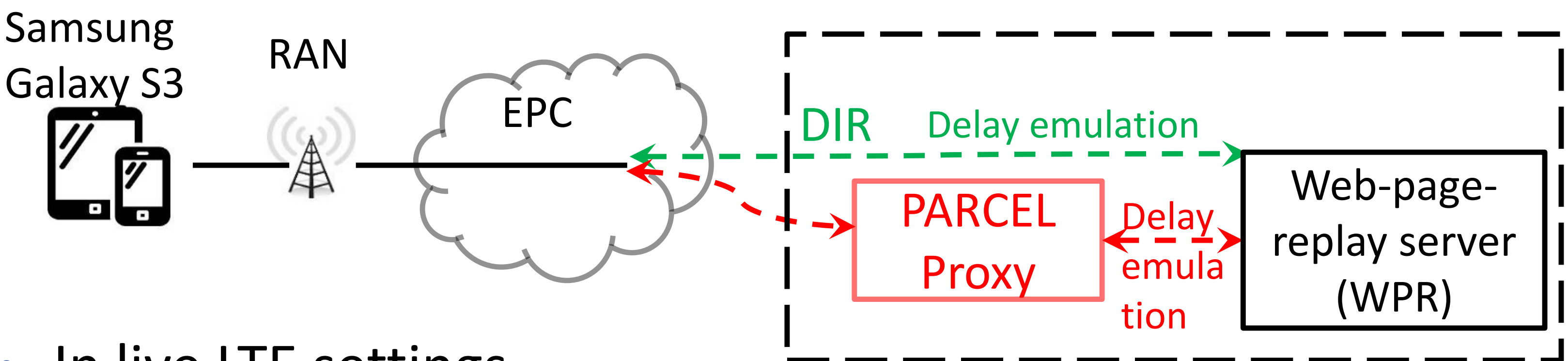
Evaluation Setup and Methodology



- In live LTE settings
- Workload : Subset of Alexa top 500 pages
- To minimize page variability
  - Replay recorded pages with WPR
- To minimize radio network variability
  - Multiple back-to-back runs (DIR and PARCEL) in the night
  - Discard runs with poor signal strength
  - Only consider runs with all LTE (discard 3G/LTE hand-off)
- Also evaluated with real web servers – for realism

Metrics Compared

- Onload Time (OLT)
  - Time to download all objects until Onload event measured from packet trace collected at the mobile client
- Total Download Time (TLT)
  - Time to download all objects beyond onload measured for the experiment duration
- Total Radio Energy Usage
  - Compute LTE radio power consumption using open source ARO tool [Qian et al MobiSys’11]

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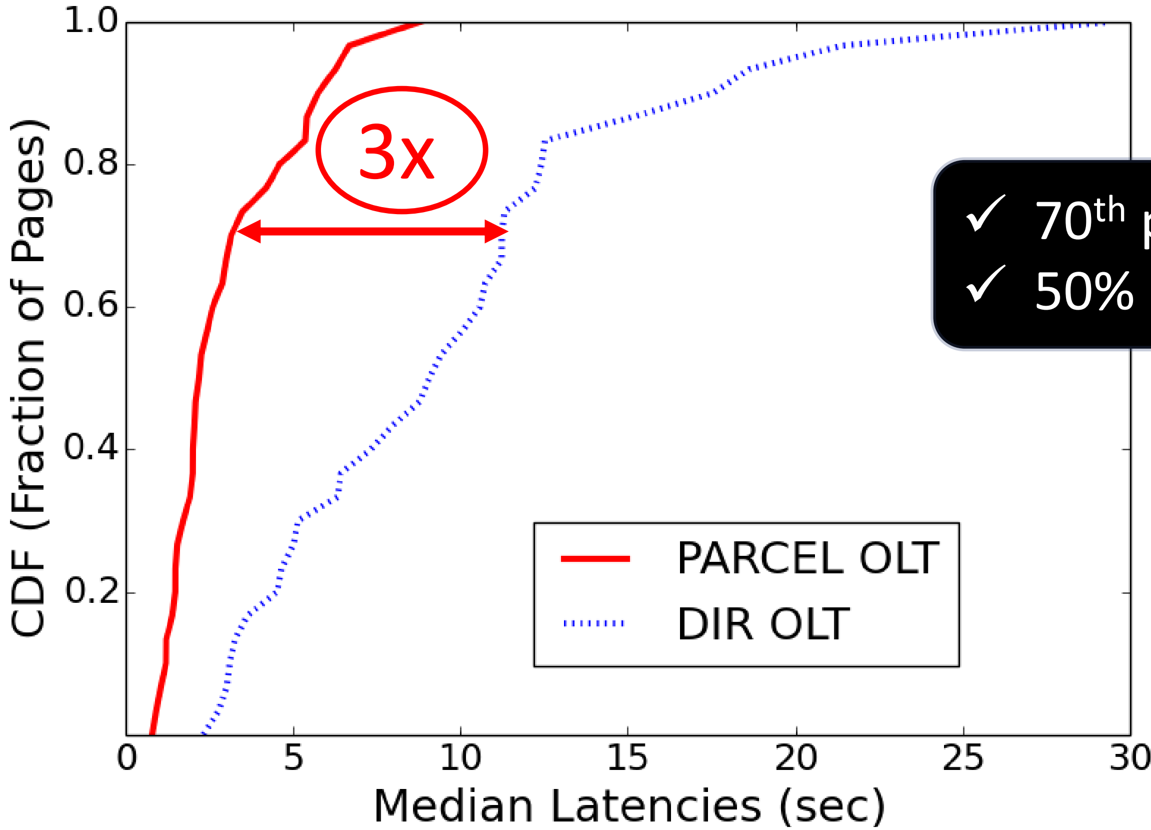
Latency Benefits With PARCEL

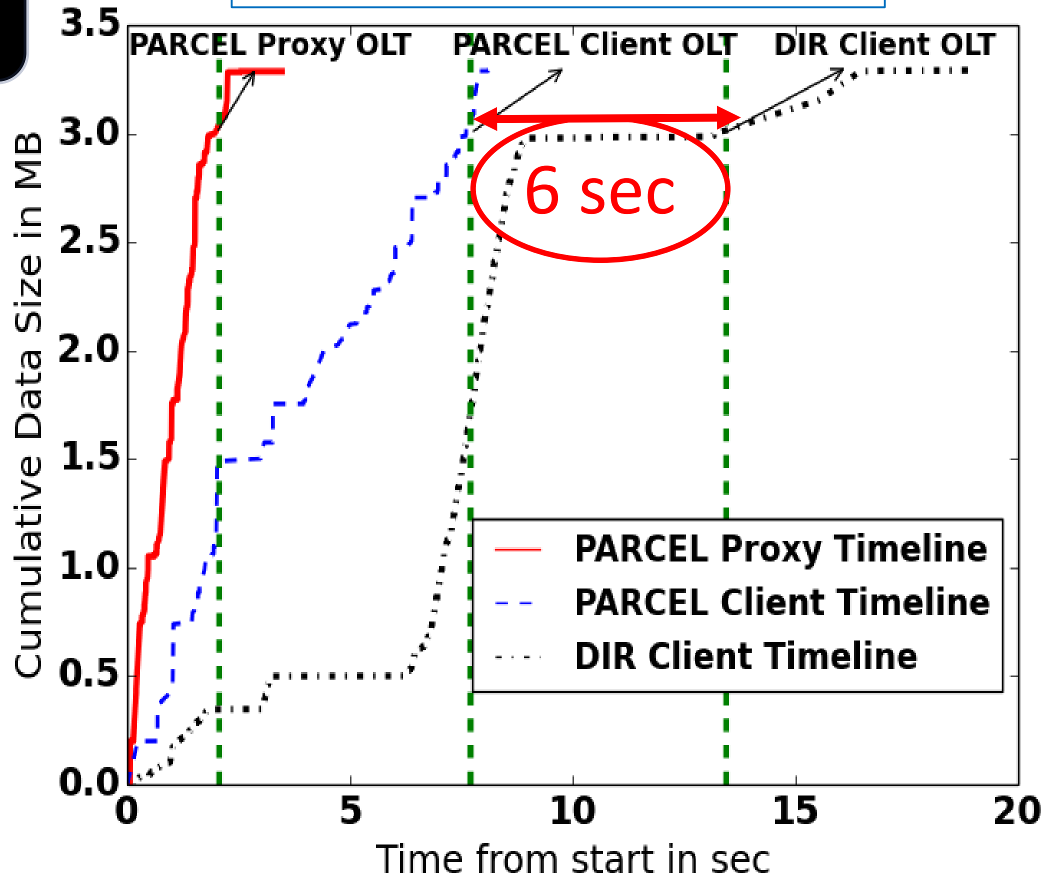


- ✓ 70th percentile – 3X
- ✓ 50% average reduction

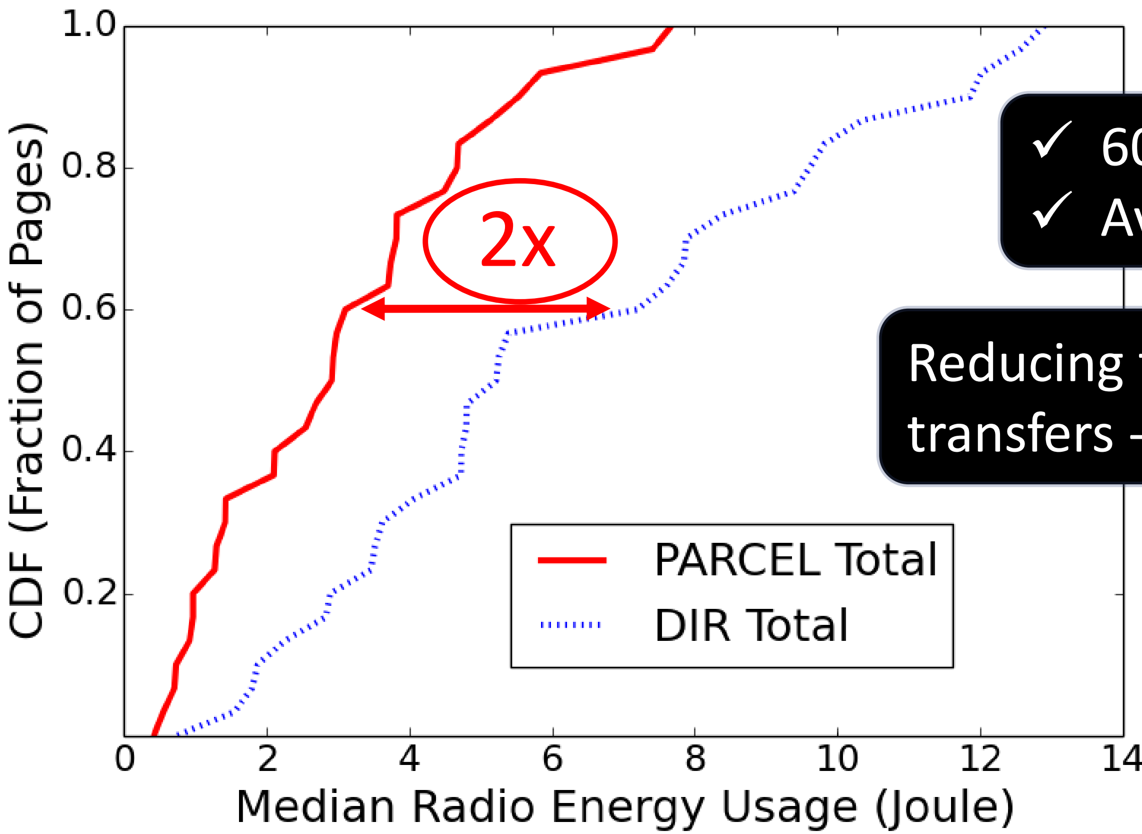
Understanding Latency Benefits

- ✓ Minimizing round trips -> reduced client latency
- ✓ Faster object identification and fetch

Sample Page Download



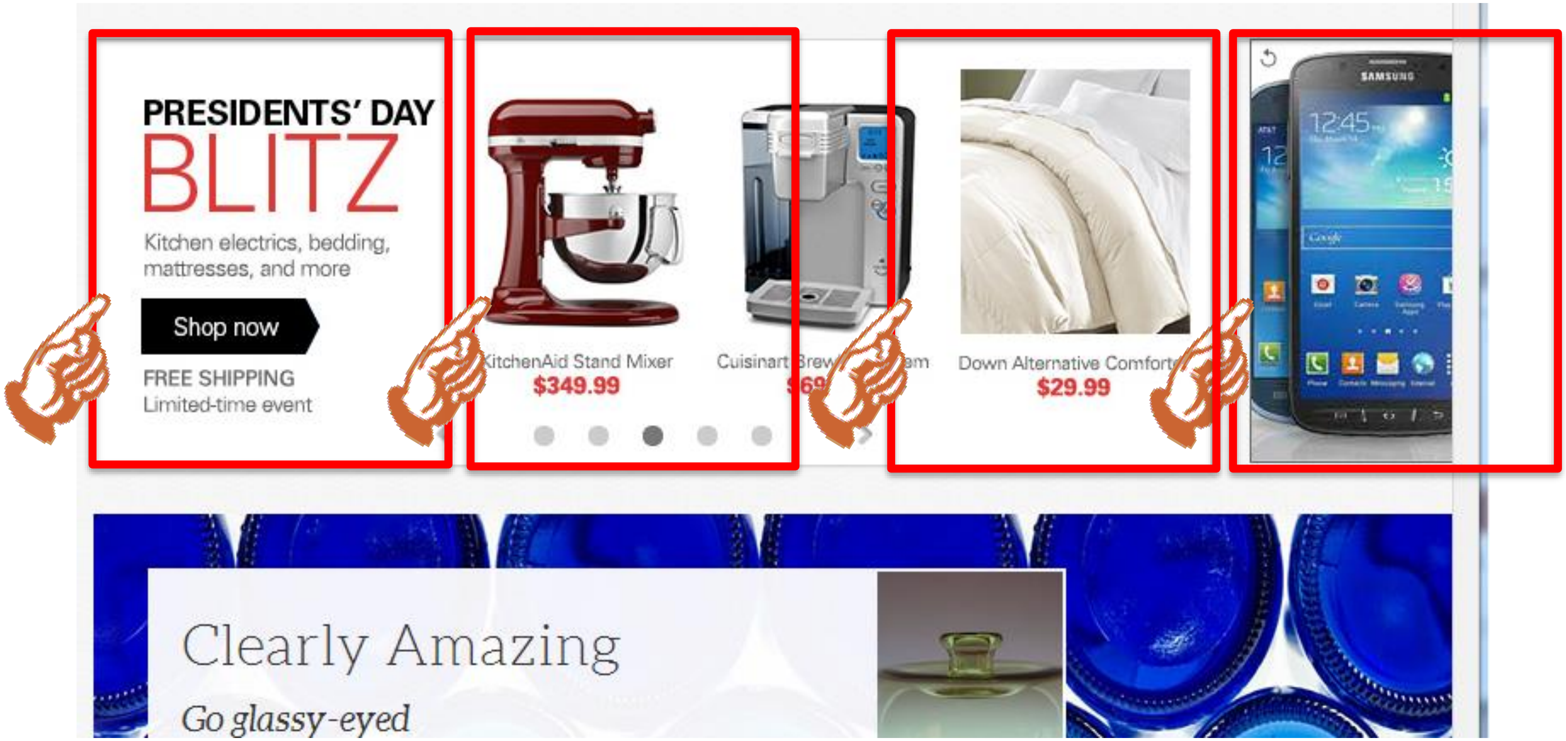
Radio Energy Usage With PARCEL



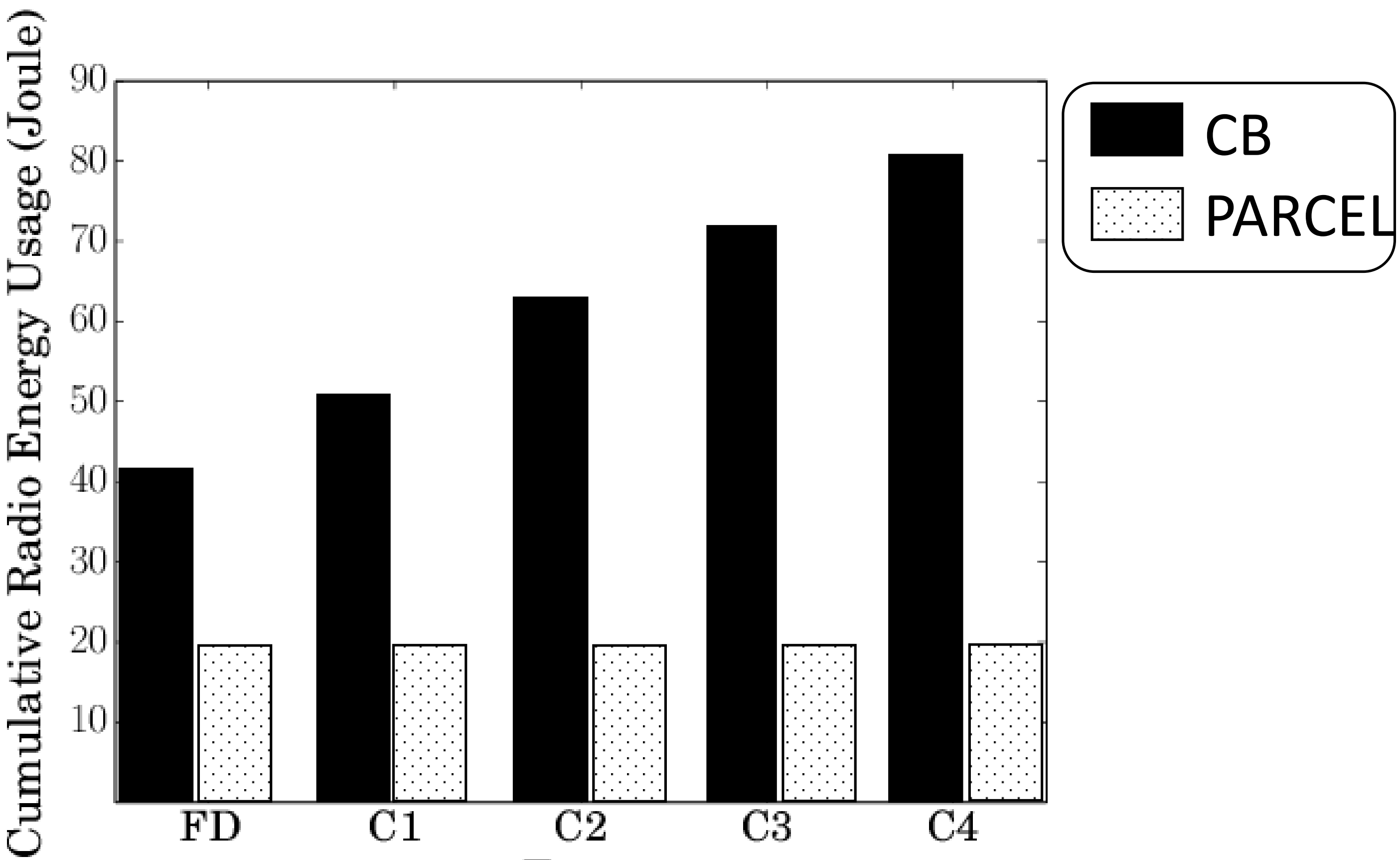
- ✓ 60th percentile = 2X
- ✓ Average 65% reduction

Reducing the gap between object transfers -> radio energy savings

Comparing With Cloud-heavy Approaches



PARCEL Performs Well Under User Interaction



Local JS execution avoids unnecessary network communication

Summary of Other Evaluation Results

- Bundling benefits
  - All bundling strategies and baseline (IND) benefit over DIR
  - For large pages (>1MB) – bundling provides additional benefits and smaller bundle size (512 KB) better
    - E.g. With < 3% increase in OLT and > 20% radio energy savings
  - For small pages – all bundling strategies perform similar to baseline PARCEL (IND)
- Real web servers
  - Median onload time reduction of 3X

Conclusions

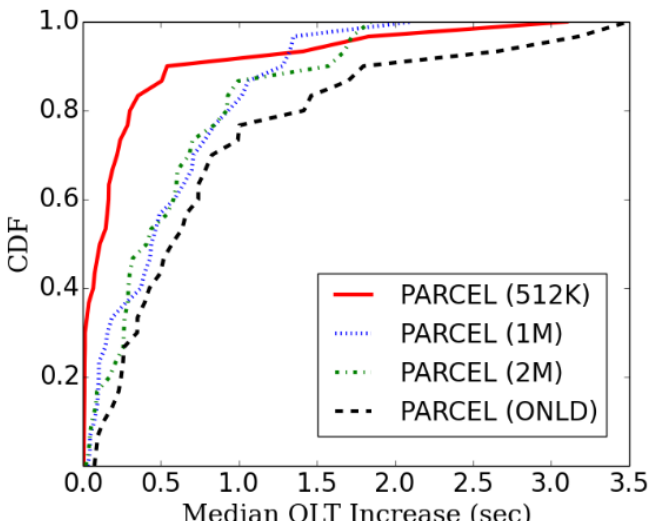
- PARCEL – optimizes mobile web download process using proxy
- Judicious browsing functionality refactoring
  - Object identification and fetch at the proxy
  - Client executes JS locally to support interaction
- Latency-efficient cellular-friendly data transfer schemes for radio energy savings
- Significant latency and energy reduction in live LTE settings

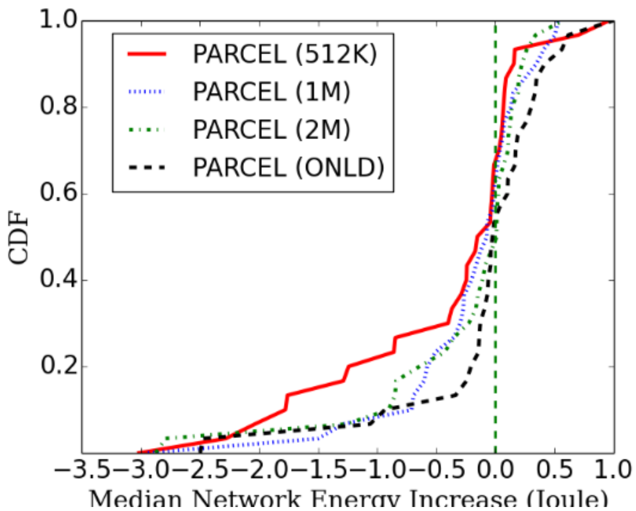
Backup

Table Comparing PARCEL to Existing Proxy-Based Approaches

	HTTP proxies	SPDY proxies	Cloud browsers	PARCEL
# of HTTP requests	**Per object**	**Per object**	**Single**	**Single**
Object identification and Fetch	**Client**	**Client**	**Proxy**	**Proxy**
Interactive JS	**Client**	**Client**	**Proxy**	**Client**
Cellular-friendly transfer	**No**	**No**	**No**	**Yes**

Bundling Benefits Beyond Baseline PARCEL





Smaller bundle sizes better (lower OLT increase and provide radio energy savings)