Cellular Handsets

Performance & end-user experiences

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Introduction

- Smartphones **global 2016 shipments** reached a record high 1.5 billion units
  - 3 percent year-over-year increase
- Need for increase of Quality of Experience (QoE)
  - The degree of delight or annoyance of the user of an application or service (web browsing, phone call, TV broadcast, call to a Call Center).

Statistics on User Experiences

- 2/3 of cellular handsets users encounter slow websites weekly(1)
- 49% of these users abandon the website
- Users' attention span range is 2-5 seconds
- 1 second delay in page load times = $2.5M loss in sales for an e-commerce website
- Cellular handset users' behaviors differ by one or more orders of magnitude
  - E.g. amount of data received per day varies from 1 to 1000 MB(2)
  - How can we satisfy everyone? Adapt to user behavior

(1) Singh, Shailendra, Harsha V. Madhyastha, Srikanth V. Krishnamurthy, and Ramesh Govindan. "Network-Aware Compaction for Accelerating Mobile Web Transfers." *FlexiWeb*. ACM, n.d. Web.
(2) Falaki, Hossein, Ratul Mahajan, Srikanth Kandula, Dimitrios Lymberopoulos, and Ramesh Govindan. "Diversity in Smartphone Usage." ACM Digital Library. ACM, 18 June 2010. Web.

Outline

- **Current issues for cellular handsets**
  - I. Bandwidth
  - II. Battery
  - III. Load times
- **Challenges**
- **Current solutions**
  - I. Integrated LTE-WiFi Networks
  - II. RRC States
  - III. Page Content Compressions
- **Drawbacks of current implementations**
- **Examples of design improvements**
  - I. ATOM
  - II. FlexiWeb
  - III. RRC Dynamics Considerations

Current Issues for Cellular Handsets

1. **Bandwidth-intensive mobile services.**
   - **Network capacity < bandwidth demand**
2. **Limited battery life**
3. **Network conditions and degradation in page load times**

Current Solutions and Drawbacks

I: Integrated LTE-WiFi Networks

1. **Bandwidth intensive mobile services:**
   - Operators globally deploying WLANs for additional capacity.
   - Upgrading to LTE for superior rates.
   - Deploying WiFi APs in areas of high network access to relieve pressure.
2. **Naive static policies[(1)]:**
   - Select WiFi as the default when available
   - Select WiFi as the default if signal strength is above some threshold
3. **Drawbacks:**
   - No seamless flow during switching
   - Does not account for current load on AP – suffer during congestion
   - Select at initiation -- Wireless conditions change between departure & arrival

(1) Mahindra, Rajesh, Hari Viswanathan, Karthik Sundaresan, and Mustafa Y. Arslan. "A Practical Traffic Management System for Integrated LTE-WiFi Networks." *ACM Digital Library*. ACM, n.d. Web.

II: RRC States

RRC: Radio Resource Control

- States that cellular networks transition between due to different traffic patterns(1)
- Have different performance & energy consumption characteristics
- Experience good performance on resource-constrained devices
- Affect application power consumption

Drawbacks in current measurement studies:

- Non-ideal RRC State behavior
- Performance vs. power consumption
- Transition delays
- Demotion delays ignored

(1) Rosen, Sanae, Haokun Luo, Qi Alfred Chen, Z. Morley Mao, Jie Hui, and Aaron Drake. "Discovering Fine-grained RRC State Dynamics and Performance Impacts in Cellular Networks." *ACM Digital Library*. ACM, 7 Sept. 2011. Web.

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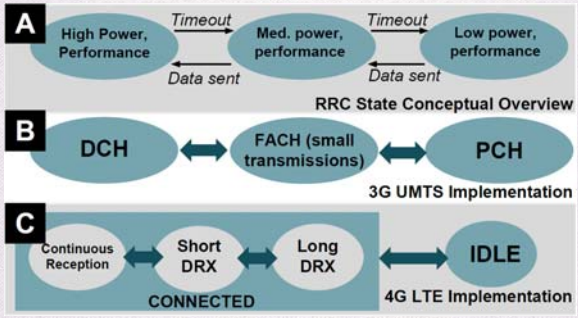
II: RRC States



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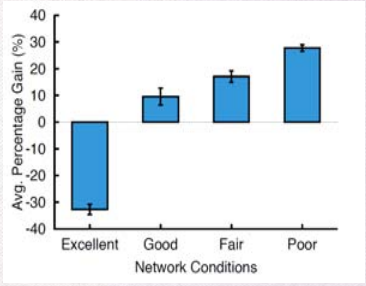
III: Page Content Compressions

- **Proxy-based solution**
  - Use of cloud-based middleboxes
  - Compression
  - Up to 32% degradation in page load times in excellent wireless conditions
  - Minify and zip text-based content
  - Fixed image format with fixed image ratio
- **Client-based solution**
  - Mobile-friendly websites
  - Parallelization – decomposing into mini pages
- **Drawbacks**
  - Negative gain in excellent conditions
  - Wasted compression on small files/images



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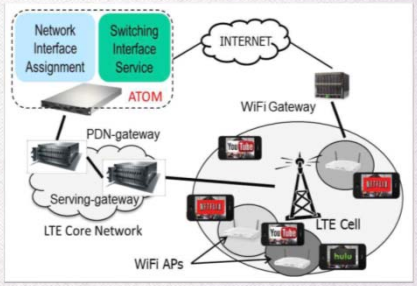
Design Improvements

Strategies & Examples

ATOM: end-to-end system for traffic adaptive offloading

- Network centric
- Network interference assignment
- Interface Switching Service (ISS)
  - seamless
  - manages flows belonging to several LTE cells and WiFi APs.
- Computes the specific WiFi AP or LTE base station that is used by each user flow.



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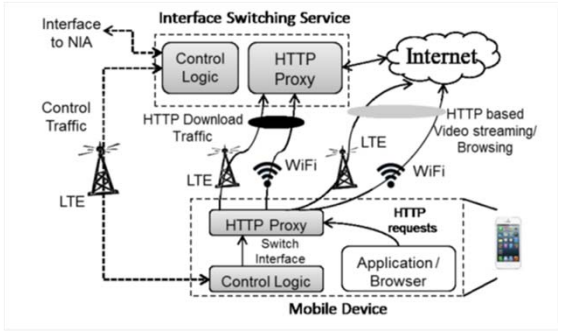

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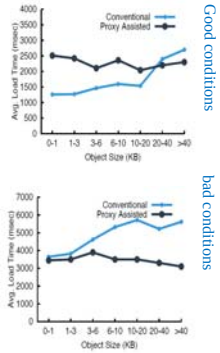
FlexiWeb: Network Aware Compactions

- Assessing Network Conditions
- Splitting requests
  - Predicting object sizes
- Network-Aware
  - Compressing based on network conditions
  - Deliver page within user's attention span
- QoE vs. page load latency

Network Condition	0–1 KB	1–3 KB	3–6 KB	6–10 KB	10–20 KB	20–40 KB	> 40 KB
Excellent	Direct	Direct	Direct	Direct	Direct	Proxy	Proxy
Good	Direct	Direct	Direct	Direct	Proxy	Proxy	Proxy
Fair	Direct	Direct	Proxy	Proxy	Proxy	Proxy	Proxy
Poor	Proxy	Proxy	Proxy	Proxy	Proxy	Proxy	Proxy

Mapping that dictates when to fetch an object directly from the source server and when to fetch it via the proxy



Good conditions

bad conditions

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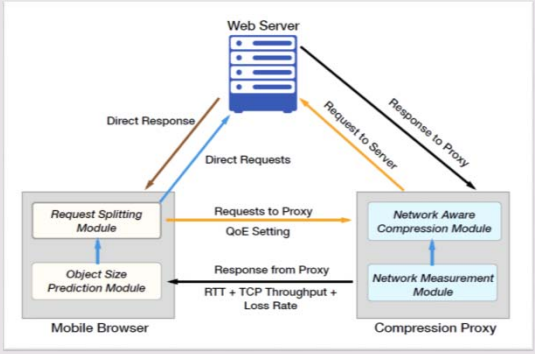
FlexiWeb: Network Aware Compactions



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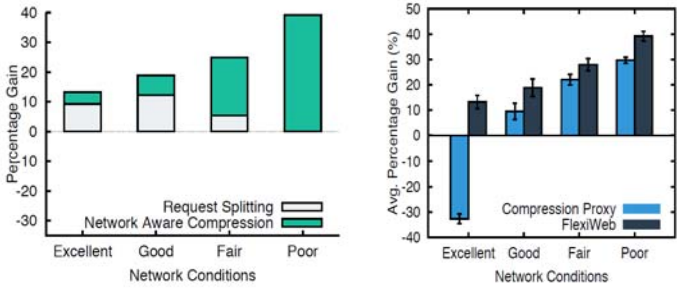
Evaluation of **FlexiWeb**



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Considerations of RRC State Dynamics

- **Delay causes:**
  - DRX in poor network conditions
  - Messages to measure channel conditions
  - Configuration messages
  - Demotion process in 3G
  - Demotions to FACH impacted by long delays
- **Recommendations:**
  - Impact is complex, unpredictable, and highly dependent on implementation details
  - Longer timers to decrease demotion delays
  - QxDM (debugging tool)
    - Configuration or implementation bug
  - Elimination of FACH
  - Global monitoring of cellular network configurations

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