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

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

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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

II: RRC States

RRC: Radio Resource Control

- States that cellular networks transition between due to different traffic patterns
- 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

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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

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.

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

<table>
<thead>
<tr>
<th>Network Conditions</th>
<th>Good Conditions</th>
<th>Bad Conditions</th>
</tr>
</thead>
<tbody>
<tr>
<td>6-9 kB</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>10-19 kB</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>20-50 kB</td>
<td>Medium</td>
<td>High</td>
</tr>
<tr>
<td>60-120 kB</td>
<td>Medium</td>
<td>High</td>
</tr>
</tbody>
</table>

FlexiWeb: Network Aware Compactions
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