Over-The-Top (OTT) Aggregation Solutions

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Agenda

• Introduction
• Why aggregation is important?
• Traditional Aggregation Solutions
• Over-The-Top (OTT) Aggregation Solutions
• Analysis of OTT aggregation solution benefits to MSOs
• OTT Aggregation Testing at CableLabs
• OTT Aggregation demo
• Q & A
Introduction

• Common goal of wireless operators
  o Provide enhanced network performance with improved coverage and increased capacity
  o Enhance quality of service with increased data rates and better user experience

• Aggregation combines small blocks of spectrum to increase the overall transmission bandwidth

• Aggregation technologies implemented by operators include:
  o Traditional carrier aggregation or channel bonding
  o LTE-Unlicensed (LTE-U) and License Assisted Access (LAA)
  o LTE WLAN Aggregation (LWA) and LTE WLAN Aggregation using IPSec Tunnel (LWIP)
  o Multipath Transmission Control Protocol (MPTCP)

• Each technology has unique network requirements and associated costs

• OTT aggregation introduces an economical way for operators to increase data rates using existing LTE and Wi-Fi infrastructures without the need to own or have access to LTE network
Why is aggregation important?

• Need for aggregation:
  o Satisfies increasing user demand with regards to high data rates for HD videos, videoconferencing, interactive gaming, etc.
  o Provide connectivity to increasing number of wireless users and IoT devices

• Benefits of Aggregation:
  o Adds capacity and provide coverage benefits by increasing the overall bandwidth
  o Enhances network performance and ensures a high-quality user experience by enabling operators to provide higher uplink and downlink data rates

• Current aggregation methods employed by wireless operators include:
  o Carrier Aggregation (CA) in LTE used by MNOs
  o Channel bonding in Wi-Fi used by MSOs

• To further increase data rates, wireless operators are exploring new ways to implement aggregation
# Standard Aggregation Solutions

<table>
<thead>
<tr>
<th>Aggregation using LTE only</th>
<th>Aggregation using both LTE and Wi-Fi</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Aggregating LTE carriers across licensed and unlicensed spectrum</td>
<td>• Aggregating carriers by using LTE in licensed spectrum and Wi-Fi in unlicensed spectrum</td>
</tr>
<tr>
<td>o LTE-U standardized by LTE-U Forum</td>
<td>o LWA standardized by 3GPP</td>
</tr>
<tr>
<td>o LAA standardized by 3GPP</td>
<td>o LWIP standardized by 3GPP</td>
</tr>
<tr>
<td>• LTE-U and LAA uses primary LTE carrier acting as an anchor in licensed spectrum and secondary LTE carrier in unlicensed 5GHz spectrum</td>
<td>• LTE and Wi-Fi integration occurs at Packet Data Convergence Protocol (PDCP) layer with LWA and at the Internet Protocol (IP) layer with LWIP</td>
</tr>
<tr>
<td>• LTE-U does not use listen-before-talk (LBT) protocol in unlicensed spectrum similar to LAA</td>
<td>• LWA requires upgrade of Wi-Fi infrastructure while LWIP is a solution that is agnostic to the Wi-Fi infrastructure</td>
</tr>
<tr>
<td>• LTE-U and LAA require new access equipment, hardware changes on end user device</td>
<td>• LWA and LWIP require software upgrades on existing access equipment and on end user devices</td>
</tr>
<tr>
<td>• Does not utilize existing Wi-Fi infrastructure making deployments by traditional Wi-Fi operators difficult</td>
<td>• Leverages both LTE and Wi-Fi infrastructures, resolving coexistence problems with LTE-U and LAA</td>
</tr>
</tbody>
</table>
OTT Aggregation Solution

- Leverages inherent and independent LTE and Wi-Fi interfaces on mobile devices

- OTT aggregation solutions consist of two major components:
  - Aggregation Server, cloud hosted or VM-based solution
  - Client application embedded on the end user device (UE)

- Enables simultaneous use of both interfaces for data sessions by creating an IPSec tunnel between the OTT aggregation embedded app on the mobile device and the OTT aggregation server hosted in the cloud

<table>
<thead>
<tr>
<th>Aggregation Server</th>
<th>Client Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Enables customized policies for optimal user experience and maximum offload to reduce costs</td>
<td>• Virtualizes hardware and software components and exposes a multi-path data plane in the form of a tunnel</td>
</tr>
<tr>
<td>• Measures parameters such as sub-flow throughputs, estimated bandwidths, packet loss, and latency</td>
<td>• In active state, securely establishes multi-path connections over all available network interfaces</td>
</tr>
</tbody>
</table>
OTT Aggregation Solution Operation

### Operation in Downlink (DL)
- Aggregation server segregates traffic on both LTE and Wi-Fi links in DL based on policies set on the aggregation server.
- User Equipment (UE) receives requested downlink data utilizing both LTE and Wi-Fi networks simultaneously improving the user experience and increasing the data throughput.
- Client application on UE combines data which was segregated by the aggregation server.

### Operation in Downlink (UL)
- Client application on the UE will segregate the data onto both LTE and Wi-Fi links.
- UE sends uplink data utilizing both LTE and Wi-Fi networks simultaneously improving the user experience and increasing the data throughput.
- Aggregation server combines data which was segregated by the client application on UE.
OTT Aggregation Solution Benefits

**Key Benefits:**
- Faster deployment
- Seamless integration
- Increased data rates
- Seamless transition with packet duplication
- Reduced operating costs

**Other benefits:**
- Minimal tunneling overhead
- Ability to perform content-based aggregation, location and SSID based aggregation, etc.
- Ability to switch real-time between available networks
- Ability to perform packet-based and flow-based aggregation

**Unique Benefits for MSOs**
- Offload traffic to less expensive connections
- Aggregate traffic on MSO owned CBRS and Wi-Fi network
# Comparison of Aggregation Solutions

<table>
<thead>
<tr>
<th>Parameters</th>
<th>OTT Aggregation</th>
<th>LTE-Unlicensed/Licensed Assisted Access</th>
<th>LTE WLAN Aggregation/LTE WLAN Aggregation with IPsec Tunnel</th>
<th>MPTCP</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Infrastructure Requirements</strong></td>
<td>Can be deployed by any operators irrespective of what network infrastructure they own</td>
<td>Operators are required to own licensed spectrum and cellular network</td>
<td>Operators are required to own licensed spectrum and infrastructure or have an MVNO agreement</td>
<td>Can be deployed by any operators irrespective of what network infrastructure they own</td>
</tr>
<tr>
<td><strong>Co-existence Issues</strong></td>
<td>No co-existence issues</td>
<td>Co-existence issues with LTE and Wi-Fi operating in same unlicensed spectrum</td>
<td>No coexistence issues</td>
<td>No coexistence issues</td>
</tr>
<tr>
<td><strong>New network elements, interfaces or protocols</strong></td>
<td>Aggregation server and client agnostic to the existing LTE and Wi-Fi infrastructure</td>
<td>New radio access equipment</td>
<td>New protocols, interfaces and network elements</td>
<td>New network elements</td>
</tr>
<tr>
<td><strong>End Device Support</strong></td>
<td>End Device agnostic</td>
<td>Needs change in end device</td>
<td>Needs change in end device</td>
<td>Needs change in end device</td>
</tr>
<tr>
<td><strong>Cost Effective</strong></td>
<td>Economical</td>
<td>High CAPEX and OPEX</td>
<td>High CAPEX and OPEX</td>
<td>Economical</td>
</tr>
</tbody>
</table>
OTT Aggregation Solution Operating Modes

• Maximum throughput mode
  o Allow users to get aggregated maximum throughput using both LTE and Wi-Fi links
  o Used when user has access to multiple networks and is using high throughput applications

• Target Throughput mode
  o Uses Wi-Fi link for all data traffic and utilizes LTE link only for the “spill over” throughput
  o Used when Wi-Fi network health is good and can handle most of the user requested throughput

• Gapless Handover mode
  o Provides a smooth transition while moving between LTE and Wi-Fi networks with packet replication
  o Used when user is transitioning between networks

• Redundancy mode
  o Provides a robust network, in case of high latency or packet loss environment, by transmitting same packets over both LTE and Wi-Fi networks
  o Useful when the network health on either or both networks is poor
OTT Aggregation Test Equipment and Setup

Network components
• LTE Evolved Packet Core (EPC)
• LTE eNodeB (ENB)
• Wi-Fi Access Point (AP)
• End User Device

OTT Aggregation Solution components
• Aggregation Server
• Client application

Test Equipment
• Network Emulator to replicate real world network issue such as latency, bandwidth control and frame drops
• Traffic Generator to simulate application traffic across multiple clients, generate TCP flows and record application layer throughput
## OTT Aggregation Solution Test Cases

<table>
<thead>
<tr>
<th>Test Case</th>
<th>Operating Mode</th>
<th>Description</th>
<th>OTT Solution Expected Performance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standalone Baseline Throughput Characterization</td>
<td>None</td>
<td>Evaluate baseline performance of standalone LTE and Wi-Fi networks with and without aggregation enabled</td>
<td>Minimal tunneling overhead with OTT aggregation solution</td>
</tr>
<tr>
<td>Aggregation Throughput Characterization</td>
<td>Maximum Throughput</td>
<td>Evaluate the LTE and Wi-Fi aggregation performance with aggregation enabled</td>
<td>Increased aggregated throughput</td>
</tr>
<tr>
<td>Maintaining quality of service (QoS)</td>
<td>Target Throughput</td>
<td>Evaluate the performance using Wi-Fi network for achieving target throughput and using LTE network for the “spill over” throughput</td>
<td>Efficient use of cellular network when Wi-Fi is regulated to achieve the target throughput</td>
</tr>
<tr>
<td>Mobility with LTE-Wi-Fi Aggregation</td>
<td>Gapless Handover</td>
<td>Evaluate performance when the device moves between LTE and Wi-Fi networks</td>
<td>Gapless Handover by duplicating traffic while transitioning between LTE and Wi-Fi networks</td>
</tr>
<tr>
<td>Adjacent Channel Interference Performance</td>
<td>Target Throughput/Redundancy</td>
<td>Evaluate user experience when Wi-Fi networks experience degradation from adjacent channel interference</td>
<td>Efficient use of cellular network to achieve target throughput and duplication of traffic increasing probability of traffic delivery</td>
</tr>
<tr>
<td>Congestion with multiple client</td>
<td>Target Throughput/Redundancy</td>
<td>Evaluate performance with multiple clients at cell edge connected to both LTE and Wi-Fi networks creating congestion conditions</td>
<td>Efficient use of cellular network to achieve target throughput and duplication of traffic increasing probability of traffic delivery</td>
</tr>
</tbody>
</table>
Maximum and Target Throughput Mode Testing

- Both LTE eNodeB and Wi-Fi AP are collocated
- Device placed at cell center of both LTE eNodeB and Wi-Fi AP
- Device has aggregation enabled operating in either maximum or target throughput mode
- In maximum throughput mode, the device utilizes both LTE and Wi-Fi interfaces to get maximum achievable throughput
- In target throughput mode, the device utilizes only Wi-Fi interface, if the target throughput is achieved and utilizes LTE interface only for the "spill over" throughput; when the target throughput is not achieved by the Wi-Fi interface
- User benefits from high data rates with maximum throughput mode and consistent throughput with target throughput mode
Gapless Handover Mobility Testing

- Gapless Handover mode tested in both collocated and non-collocated scenario with overlapping coverage areas

- In the non-collocated scenario, the device is connected to LTE network at cell center and is then moved towards the cell center of Wi-Fi network and vice versa

- In the collocated scenario, the device is connected to both LTE and Wi-Fi network at cell center and is then moved away towards the cell edge

- The device can operate in maximum throughput mode or target throughput mode when in coverage area of both LTE and Wi-Fi networks while operating in redundancy mode while transitioning between networks

- User benefits from high data rates and enhanced user experience
Interference and Congestion Testing

- Both LTE eNodeB and Wi-Fi AP are collocated.
- In interference testing, multiple Wi-Fi APs operating in an adjacent channel are placed in close proximity to the Wi-Fi AP used for aggregation.
- In multiple client testing, multiple end devices located at cell center, cell middle and cell edge are connected to the LTE eNodeB and Wi-Fi AP involved in aggregation to create congestion and loading effect.
- In both scenarios, the end devices under test can utilize the target throughput and redundancy mode to enhance the user experience in challenging conditions.
- User benefits with achieving target throughput with efficient use of cellular link and with improved user experience with simultaneous redundant packet transmission on both LTE and Wi-Fi interfaces.
OTT Aggregation Demo

- With introduction of spectrum sharing in LTE using Citizen’s Broadband Radio Service (CBRS), cable operators can increase data rates, by aggregating CBRS and Wi-Fi

- Demo showcases OTT aggregation with:
  - Citizen’s Broadband Radio Service Device (CBSD) operating with bandwidth of 20MHz in Band 43 with a downlink/uplink ratio of 80/20
  - Wi-Fi AP operating in 5GHz in Channel 36 with bandwidth of 20MHz

- The CBSD is backhauled using DOCSIS with a cable modem (CM) and cable modem termination system (CMTS) between the CBSD and the LTE virtualized evolved packet core (vEPC)