The Value of Cross-Layer Optimization for 3G Networks

CDG Tech Forum
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### Product and User Segments

#### Basic Data Services
- Instant Messenger
- Email
- Transactional – Digital Music, Ringtones
- Rich Media Store and Forward (MMS)

#### Mobile Workforce
- Mobile Data Connectivity
- Always-on Email
- VPN Access

#### Wireline Broadband Alternative
- 3G, 802.16x Broadband Services
- 3G to Wi-Fi gateway
- Narrowband made “Broadband”
- Rural or emerging markets with low Internet penetration

#### Infotainment Services
- VoD and Video Streaming
- High Quality Audio Streaming
- Networked Gaming
- Entertainment
- Location Based Services
3G Mobile Data Adoption

- **High Expectations from Users**
  - Shaped by previous experiences with Wi-Fi, DSL, Cable
  - Cost of not meeting expectations: low adoption, high churn, high customer care costs

- **Mobile E-Commerce Requires Consistency**
  - Session connectivity critical for mobile e-commerce
  - Higher level of user frustration/time lost vs. voice calls

- **New 3G Services Assumes Consistency**
  - Consumers assume video/audio content to behave like TV/radio
  - Long buffering and interruptions kill the user experience
Effective Spectrum Efficiency – Important in a Growing User Base

More Traffic

- Maximize subs/Hz
- Lower CAPEX per sub – infrastructure costs
- Lower OPEX per sub – customer care and backhaul

More Users

Efficient Utilization of Assets Become More Critical
Combining IP and Radio Network Stacks - Challenges

**Goals**
- Robust point to point data delivery
- Congestion control

**Technology Evolution**
- UDP for streaming
- TCP for transaction-based applications

**Goals**
- Spectrum efficiency
- Optimized for voice traffic

**Technology Evolution**
- Scheduling algorithms
- Link adaptation techniques
- Hybrid ARQ techniques
- Frequency hopping
- Diversity antenna

Tradeoffs between application robustness and spectrum efficiency
Radio Link Variances Impact Overall Network Performance

RF Quality Metrics Affected: RSSI, SINR, BER/FER

Signal Strength  Interference  Fading  Network Load

Loss (p)

Proportion of successful packets
Leading to Inconsistent Throughput

Throughput Can Degrade 80% in Poor RF Areas

- Good RF conditions
- Average RF conditions
- Poor RF conditions

- Degraded Signal
- Interference
- Fading
- High Load

Average Median Time to Download (secs)

Service Unusable
And Unpredictable Availability

Frequent Timeouts under Poor RF

Request Timed Out

Your request could not be completed within the time allowed by the application server.
TCP Does Not Efficiently Utilize the Wireless Network Efficiently

- Bandwidth efficiency swings due to radio link variances
- Retransmission and prolonged wait for ACKs force application protocols to timeout
Impact on Subscriber Adoption and Loyalty

Examples

Why does it take so long to download this email?

Why can’t this submit request go through?

Why is this media freezing so often?

Was I supposed to make the right turn at the last signal?

RESULT

- Lower service uptake
- Higher customer support costs
- Higher cancellation rate
- Brand is impacted
Cross Layer Optimization

- Optimization of the application layer (IP network) and the radio link layer
- Inter-layer exchange across the protocol stack

Cross Layer Optimization addresses the challenges of IP over the wireless environment
Layered Optimization Elements

Exhibit 1. Cross Layer Optimization involves entire protocol stack
Source: Venturi Wireless, 2005

<table>
<thead>
<tr>
<th>Protocol Stack</th>
<th>Optimization Methods</th>
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<tbody>
<tr>
<td>Application (e.g. HTTP)</td>
<td>Payload compression, content caching</td>
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<tr>
<td>Session</td>
<td>Connection persistence, pipelining, multiplexing</td>
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<tr>
<td>Transport (e.g. TCP)</td>
<td>Retransmission reduction, adaptive flow control, efficient congestion control</td>
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<tr>
<td>Network (e.g. IP)</td>
<td>IP header compression</td>
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<tr>
<td>Link</td>
<td>Link BER reduction through hybrid ACK mechanism</td>
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<tr>
<td>PHY</td>
<td>Power level control to achieve best throughput and minimum interference</td>
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Venturi Applies the Cross Layer Concept, Optimizing Transport and Application Layers

Venturi Wireless Transport Architecture

VTP provides an application-transparent method of flow control on the RAN segment.

TCP’s congestion control continues to function along the internet segments.

Web server can maintain generic TCP configuration for wireless client.
Cross Layer Optimization Even More Relevant for Handset

- QoS scheduling is most efficient at the chip level
- Phoneware driver can feed radio parameters back into transport layer
- Better traffic throttling control through control plane interaction
Adaptive Airlink Optimization™  
Patented Venturi Transport Protocol (VTP)

TCP Inefficiencies over Wireless Networks
- High latency
- Inefficient bandwidth utilization – slow starts
- Extraneous retransmissions

VTP Overcomes TCP Limitations
- Adaptive, rate-based flow control
- Quicker transaction completions - more capacity
- Fewer and more efficient retransmissions
- More efficient bandwidth utilization
## The Venturi Impact

<table>
<thead>
<tr>
<th>Improved Data Throughput</th>
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<tbody>
<tr>
<td><strong>Accelerated Data Speeds</strong></td>
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<tr>
<td>- 2-9X faster data throughput</td>
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<tr>
<td>- 2-3X faster video/audio downloads</td>
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<td>- Shorter buffering time and improved image quality for streaming media</td>
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<th>Service Consistency</th>
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<tr>
<td><strong>Greater Reliability</strong></td>
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<tr>
<td>- Reduced drops and connection time-outs</td>
</tr>
<tr>
<td>- Fewer interruptions during streaming</td>
</tr>
<tr>
<td><strong>Enhanced Coverage</strong></td>
</tr>
<tr>
<td>Consistent data speeds throughout the cell</td>
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<th>Increased Network Efficiency</th>
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<tr>
<td><strong>Lowered Cost per Sub</strong></td>
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<tr>
<td>Up to 50% reduction in network CAPEX together with lower OPEX</td>
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<tr>
<td><strong>Improved Capacity Utilization</strong></td>
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<tr>
<td>More subscribers on existing infrastructure and spectrum</td>
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</tbody>
</table>
Content Delivery Time is Improved 40-60%

- E-Mail: 50% Reduction
- Games/Ringtones: 39% Reduction
- Web/Info: 62% Reduction
- Audio/Video Streaming, Program Streaming & Downloads: 55% Reduction

Without Venturi  With Venturi
More Available Capacity

Traffic Flow Diagram

Forward Traffic Channel
Physical Layer Packet
Transmissions with 2.4 Mbps (normal termination - 4 Transmit Slots)

Traffic Channel
Transmit Slot 1
Transmit Slot 2
Transmit Slot 3
Transmit Slot 1

DRC Channel
Transmission Request
DRC

ACK Channel
Half-Slot Transmissions
One Slot
NAK
NAK
ACK

First Slot for the Next Physical Layer Packet Transmission

1xEV-DO-CDMA2000* evolution - data only
ACK - Acknowledgment
ARQ - Automatic request control
DRC - Date rate control
NAK - Negative acknowledgment

Faster Transaction Delivery Time with Venturi
= More Available Capacity
Reliable Access and Stable Connections

Download Success Rate (Poor RF)

without Venturi

53%

with Venturi

93%

Notes: RSSI= -106 dB; Tests performed on EV-DO network in Las Vegas, NV (12/16/04)
The User Experience is Consistent Across the Network

- Download Time with TCP: Performance Degrades 5X
- Download Time with Venturi: Performance Stays Consistent

- Poor RF: 87 secs, 19 secs, 17 secs
- Good RF: 7 secs, 8 secs, 12 secs
**Venturi Enhances Multimedia Performance**

**Typical performance w/o Venturi**
- Buffering time: 30 sec
- Frame rate: 15 frames per second
- 25% of frames dropped
- Player auto-adjusts to 100 kbps

**Typical performance with Venturi**
- Buffering time: 10 sec
- Frame rate: 30 frames per second
- Zero dropped frames
- Player auto-adjusts to 450 kbps
Conclusions

- Consistent user experience necessary to drive adoption
  - User expectations must be met
- Subscriber efficiency becomes critical as the market for 3G services grows
- Cross layer optimization addresses radio link challenges, improving the user experience and subscriber efficiency
- Venturi optimization delivers
  - Better capacity utilization
  - 2X – 7X improved throughput
  - Overall increased reliability and coverage