Wireless Backhaul Trends: The Future Role of Wireless, Fiber Optics, and Copper Wire

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Agenda

- An overview of mobile backhaul
- Disruptive forces
- Industry trends
- Backhaul technologies
- Conclusions
Mobile Backhaul Overview
Huge Cellular Phone Advances
Cellular Evolution

Dr. Martin Cooper of Motorola - “father” of the modern mobile phone - has observed:

*The number of simultaneous voice and data connections has doubled every 2.5 years since wireless began (1900)*

Cooper’s Law
What is Mobile Backhaul?

“Access”

“Transport”

“Transmission”
Typical Mobile Backhaul Network

BST: Base Station,  RPTR: Repeater Site,  HUB: Hub Site,  MSC: Mobile Switching Center
Some Facts

- **Globally**
  - Over 2.5M cell sites
  - 2007 backhaul spending: $20B services, $4B equipment
  - Wireless backhaul dominates

- **USA**
  - About 200,000 cell sites
  - Cell site growth >10% pa for last 5 years
  - 80-90% copper T1s, ~15% fiber

Source: Heavy Reading, Nov 2007
Disruptive Forces
Mobile Subs Increasing ...

- Over 1 B new phones sold annually
- Even market for used phones

Worldwide Mobile Subscribers

Source: Infonetics Research, March 2009
... Mostly In Developing Countries
Carriers Actively Courting Low ARPU Users

Today’s challenge: connecting the next billion

4 billion mobile subscriptions 2009
3 billion mobile subscriptions 2007

World population split according to income segment (USD per capita per day)
Number of Cell Sites Growing

Source: Infonetics Research
Consumer Patterns Changing

- Emerging traffic drivers
  - More content generated outside traditional carrier network
  - Open devices drive significantly more traffic
    - iPhone model fundamentally changing carriers business
  - “All you can eat” pricing encourages high traffic usage
Examples

- iPhone
  - Data contract required
  - Stunning traffic growth, despite small market share
  - Christmas 2007: Google traffic from iPhones exceeded traffic from all other mobile devices combined

- Blackberry
  - Significant growth in network traffic since 2007 Facebook application launch
New Technologies Drive Higher Data Rates …

Source: Alcatel-Lucent, 2008
### And Bigger Channels Sizes

<table>
<thead>
<tr>
<th>System</th>
<th>Peak data rate</th>
<th>Channel Width</th>
<th>Frequency reuse</th>
<th>Peak Spectral efficiency</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMPS</td>
<td>9.6 kbps</td>
<td>30 kHz</td>
<td>7 / 21</td>
<td>0.015</td>
</tr>
<tr>
<td>GSM</td>
<td>9.6 – 14.4 kbps</td>
<td>200 kHz</td>
<td>4 / 12</td>
<td>0.032 - 0.048</td>
</tr>
<tr>
<td>GPRS</td>
<td>171 kbps</td>
<td>200 kHz</td>
<td>4 / 12</td>
<td>0.07</td>
</tr>
<tr>
<td>EDGE</td>
<td>474 kbps</td>
<td>200 kHz</td>
<td>4 / 12</td>
<td>0.2</td>
</tr>
<tr>
<td>W-CDMA</td>
<td>2 Mbps</td>
<td>5 MHz</td>
<td>1</td>
<td>0.4</td>
</tr>
<tr>
<td>HSDPA</td>
<td>14 Mbps</td>
<td>5 MHz</td>
<td>1</td>
<td>2.8</td>
</tr>
<tr>
<td>LTE</td>
<td>100 Mbps</td>
<td>20 MHz</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>HSDPA+ 64QAM &amp; 2x2 MIMO</td>
<td>42 Mbps</td>
<td>5 MHz</td>
<td>1</td>
<td>8.4</td>
</tr>
<tr>
<td>LTE 2x2 MIMO</td>
<td>172.8 Mbps</td>
<td>20 MHz</td>
<td>1</td>
<td>8.6</td>
</tr>
<tr>
<td>LTE 4x4 MIMO</td>
<td>326.4 Mbps</td>
<td>20 MHz</td>
<td>1</td>
<td>16.3</td>
</tr>
</tbody>
</table>
Increased Cell Site Backhaul

Backhaul Capacity Required per Cell Site

Source: Heavy Reading, 2008
Increased Backhaul CAPEX

Worldwide Mobile Backhaul Equipment* Revenue

Calendar Year

Revenue (US$Billions)

CY07 CY08 CY09 CY10 CY11

$0B $4B $8B $12B

*Equipment includes Ethernet copper/fiber, Ethernet microwave, PDH/SDH microwave, PDH MIU, SONET/SDH, and other

Revenue & Traffic Decoupled

- Voice generates 80% revenue
- Data traffic >> voice traffic

Costs follow traffic line!
Summary of Fundamental Shifts

- Mobile subscribers and their bandwidth requirements are growing strongly
  - Mobile users going broadband; broadband users going mobile
- Data traffic grows and video coming
- 2G and 3G collocation at same cell site
- Multiple operators at same cell site
- WiMAX and LTE coming

Current backhaul networks are a major bottleneck
Industry Trends
Shift Towards Ethernet

- Scalable Costs
- T1 costs linear
  - $300 pm per T1
- Ethernet non-linear
  - $75/Mbps pm for 10 M
  - $20/Mbps pm for 100 M
  - $3/Mbps pm for 1 G

Source: Axerra Networks, 2008
Ethernet Backhaul Challenges

- “Five Nines”
- Synch/timing
- Legacy integration

- Bandwidth
- Lower cost
- Flexibility

- Hard & soft handover
- Sectorization
- Spectrum efficiency
- Radio resource management

Optimized Ethernet Backhaul
Metro Ethernet Forum (MEF)

The 5 Attributes of Carrier Ethernet

Carrier Ethernet is a ubiquitous, standardized, carrier-class SERVICE defined by five attributes that distinguish Carrier Ethernet from familiar LAN based Ethernet.

Carrier Ethernet Attributes:
- Standardized Services
- Scalability
- Service Management
- Reliability
- Quality of Service

Source: Metro Ethernet Forum
Expect Rapid Ethernet Growth

- Microwave is king
- Ethernet fastest growing
- Equipment revenue
  - 2006 = $3.9B
  - 2010 = $6.0B

Source: Infonetics Research Mobile Backhaul Equipment, Installed Base & Services, March 2007
Collocation of 2G and 3G Sites

- ~80% of 3G cell sites are collocated with 2G cell sites
- 2G could be here for another 10 years!

Source: Alcatel-Lucent 2006
Mixed Mode (Hybrid) Networks

- **2G network**

- **2G + 3G network**
A Few T1s are OK, For Now

- Most cell sites today are serviced by 1 to 4 T1s (1.5 Mbps to 6 Mbps)
- The amount of backhaul required is function of 2 parameters
  - Amount of wireless spectrum available
  - Spectral efficiency of the wireless interface.
- Examples: 3-sector cell sites

<table>
<thead>
<tr>
<th>Technology</th>
<th>Spectrum</th>
<th>Backhaul</th>
</tr>
</thead>
<tbody>
<tr>
<td>2G GSM</td>
<td>1.25 MHz</td>
<td>&lt; 1 T1</td>
</tr>
<tr>
<td>2.5G EDGE</td>
<td>3.5 MHz</td>
<td>4 T1</td>
</tr>
<tr>
<td>3G HSDPA</td>
<td>5 MHz</td>
<td>13 T1</td>
</tr>
</tbody>
</table>
But LTE and WiMAX Coming

- LTE and WiMAX → 100+ Mbps
- Different service offerings require more dedicated bandwidth

<table>
<thead>
<tr>
<th>Service Type</th>
<th>Bandwidth Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internet connection</td>
<td>10:1 to 25:1</td>
</tr>
<tr>
<td>Voice service</td>
<td>5:1 to 10:1</td>
</tr>
<tr>
<td>Online gaming</td>
<td>5:1 to 10:1</td>
</tr>
<tr>
<td>Video conference</td>
<td>1:1 to 2:1</td>
</tr>
<tr>
<td>Video broadcast</td>
<td>1:1 (no contention)</td>
</tr>
<tr>
<td>Audio broadcast</td>
<td>1:1 (no contention)</td>
</tr>
<tr>
<td>Video on demand</td>
<td>1:1 (no contention)</td>
</tr>
</tbody>
</table>
Cell Size Reductions

- 1980s: Macro cells – 35 km radius
- 1990s: Micro cells – 5 km radius
- Currently: Average distance between US cell sites
  - Urban: 1.7 km
  - Suburban: 3.8 km
  - Rural: 12.5 km
- Current vogue is to talk about femtocells – 10m radius
  - Femtocells = Home Base Stations
  - End-user deployed, but subject to operator control
  - Very controversial
    - Break long-standing regulatory assumptions
    - Seriously challenge current business models
    - Considerable challenges in managing interference due to uncoordinated end-user deployment
Technology Solutions
Pseudowires

- Pseudowire (PW) emulates the operation of a “transparent wire”, carrying a native service over a Packet Switched Network (PSN)
Pseudowire - Pros

- Lower network costs – fewer boxes
- Simpler network – “flat”
Pseudowire - Cons

- Latency and overhead penalties
- Network synchronization

- Timing over packet (IEEE 1588)
- Differential timing (e.g. GPS)
Copper Wires
Ethernet over Copper (EoCu)

- IEEE 802.3ah – Ethernet over copper wiring in the local loop
  - 10PASS-TS: 10 Mbps to 2,500 ft
  - 2BASE-TL: 5.7 Mbps to 18,000 ft
- Bonding
  - 1 to 8 pairs combined as a unified physical layer, yielding virtual pipe up to 45 Mbps symmetrical
- Grooming
  - Compensating for deteriorating effects of often ancient and poorly maintained copper plant
Ethernet over Copper (EoCu)

**Pros:**
- Reuses existing local loop copper wiring
- Practical as wide use of Cu to cell sites
- Cost effective

**Cons:**
- Imperfect copper transmission medium
- Speed and distance limitations

**Conclusion:** Good “Mid-band Ethernet” solution for 2 to 20 Mbps in US
Fiber

- PON – Passive optical networks
  - GPON – Gigabit PON
- PTP – Direct fiber solution
GPON

- Popular for residential triple play

- Applications for cellular backhaul

  - **Pros**
    - Splits network costs across many cell sites
    - Improved CO floor space - less patch panels
    - TDM clocking support

  - **Cons**
    - Substantial fiber install costs
    - Complex trouble shooting – no visibility beyond splitter
    - Difficulty delivering high data rates to end users
Point to Point Fiber

- Connect point A with point B
- Very expensive to implement
  - Fiber trenching $100/ft

Conclusion: If available, fiber is often the best option, if it can be cost-effectively leased. If not, expensive and limited to highest ROI part of network
Wireless
Microwave Backhaul

- Point to point microwave market worth ~$4B annually
  - Strong growth in last 4 years
  - ~1 million units shipped in 2007
- >70% shipments for mobile backhaul
- ~50% cell sites worldwide connected by microwave wireless
- Ethernet microwave is fast growing segment
Decouples Cost and Capacity

- Rough pricing guide

<table>
<thead>
<tr>
<th></th>
<th>Leased line cost</th>
<th>PTP wireless link</th>
</tr>
</thead>
<tbody>
<tr>
<td>4 x T1 (6 Mbps)</td>
<td>$1,200 per month</td>
<td>$10K</td>
</tr>
<tr>
<td>16 x T1 (4 X)</td>
<td>$3,000 pm (3.5 X)</td>
<td>$15K (1.5 X)</td>
</tr>
<tr>
<td>OC-3 / Fast Eth (100-155 Mbps) (25 X)</td>
<td>$6,000 pm (5 X)</td>
<td>$25K (2.5 X)</td>
</tr>
<tr>
<td>GigE (1,000 Mbps) (100+ X)</td>
<td>$10,000 pm (8 X)</td>
<td>$35K (3.5 X)</td>
</tr>
</tbody>
</table>
Total Cost of Ownership (TCO)

- Lease costs dominate TCO
- CAPEX is a small part of TCO

Source: DragonWave 2008
Mixed Mode and IP Support

- Mixed mode transport in the Low-RAN access
- IP/MPLS transport from aggregation hub site
- High-capacity Ethernet links in High-RAN

Source: Harris Stratex, 2008
Multi-Protocol Support

Access Low-RAN
- 10-15 sites per cluster
- Native Mixed Mode
- Adaptive Modulation

Access High-RAN
- All-IP Transport (IP/MPLS)

Metro + Core
- PWE3
- BSC (2G)
- RNC (3G)
- MME (LTE)
- S-GW (LTE)

Source: Harris Stratex, 2008
Limitations - Rain Fade

Propagation

Typical Microwave Availability

Average Guaranteed Wireline Availability

CIRCUIT LENGTH (MILES)

6 GHz 11 GHz 18 GHz 23 GHz

1-Way Outage, Min/Year

526 (8.7 Hours)
HISTORY'S FIRST WIRELESS SIGNAL INTERFERENCE
Significant Product Innovation

- Adaptive modulation
- All outdoor, small form factor devices
- Opening of new bands for ultra-high capacity systems
Wireless Freq Allocations

- Microwave bands have channel sizes up to 50 MHz
  - Limits practical data rates to 200 Mbps
- Millimeter-wave bands have 100x greater channel sizes to 5 GHz
  - Gbps and beyond data rates possible
  - Shorter distance transmission
Other Applications
Conclusions
Dynamic Marketplace

- Cellular Trends
  - Mobile ↔ Broadband
  - Data rates increasing
    - Consumer wants / needs
    - Technology advances
  - Subscribers increasing
    - Role of developing countries
  - CAPEX and OPEX costs rising

- Backhaul Challenges
  - Bring Ethernet to all cell sites
  - Convergence – support 2G, 3G and 4G at same site
  - Minimize capital and $/bit expenses
  - Maintain high QoS, latency, jitter, sync, etc
  - Migrate legacy services to packet
Potential Solutions

- Pseudowires
  - Convergence of multiple protocols over Ethernet transport
  - Latency and clocking issues

- Ethernet over copper
  - Reuse of existing infrastructure
  - Bandwidth and resiliency issues

- Ethernet over fiber
  - Increased bandwidth and scalability, supports exponential demand
  - Expensive and not widely available

- Ethernet over wireless
  - Multiple flexible and scalable approaches, bypassing wireline providers
  - Distance limitations
One Possible Progression?

- **Near term:**
  - Reuse as much of existing infrastructure as possible
  - Migrate to Ethernet where possible in high ROI spots
  - Install owned or leased Ethernet at green field sites
  - Significantly lower leasing costs as demand rises

- **Long term:**
  - Owned fiber & wireless Ethernet backhaul
  - Best economics, with scalability and future proofing
Thank You For Listening!

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