AJIS LLC

Wireless Technology Consulting

The Future of Cellular Infrastructure

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Jonathan Wells Introduction

- 15+ years in wireless industry
  - Last 4 years as freelance consultant
- Work history
  - California Microwave, Adaptive Broadband, Microwave Data Systems, Digital Microwave, Stratex Networks, GigaBeam
  - Currently President of AJIS LLC, 2 person consultancy
- Qualifications
  - PhD Physics, MBA, Senior Member IEEE, CNSV Member
  - 30+ publications, conference presentations
- Worked in US, UK and New Zealand

Agenda

- An overview of cellular infrastructure
- Disruptive forces
- Industry trends
- Backhaul technologies
- Conclusions

Cellular Infrastructure Overview

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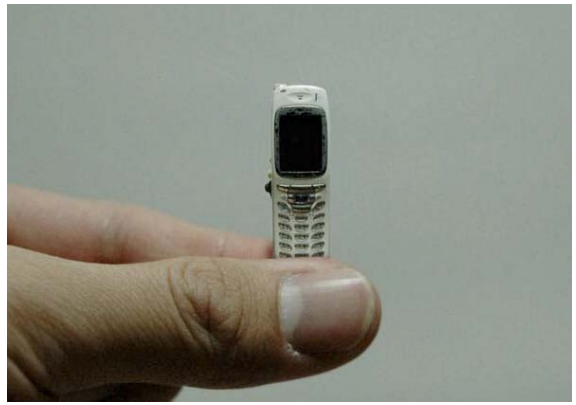
Huge Cellular Phone Advances



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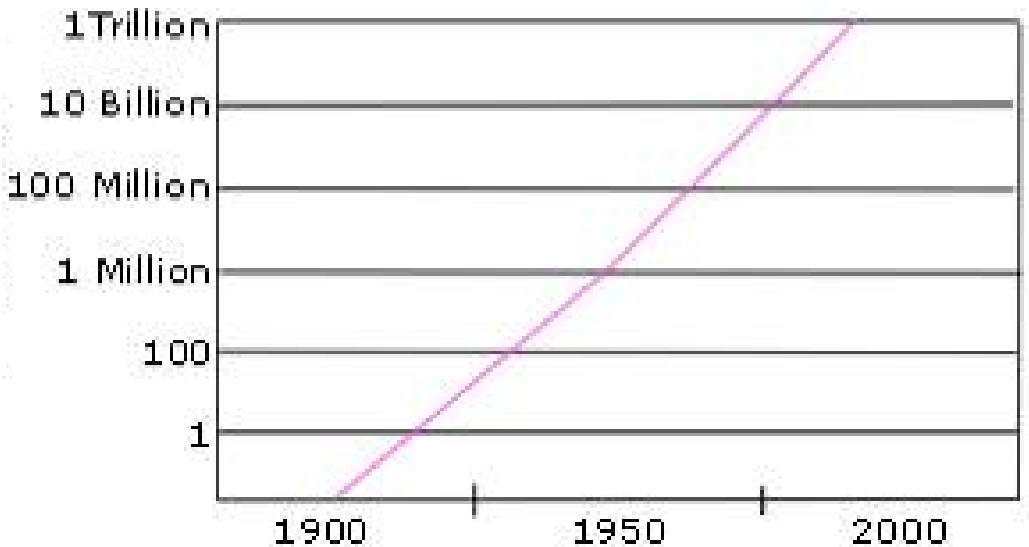
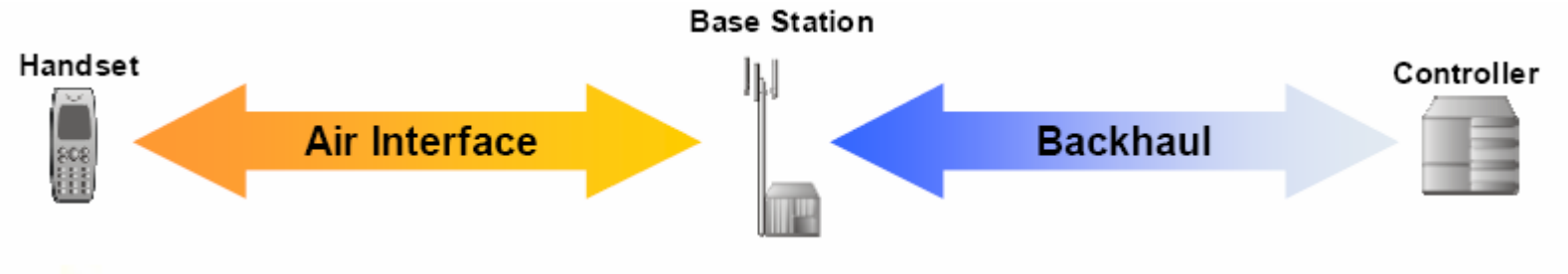
Cellular Evolution

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)



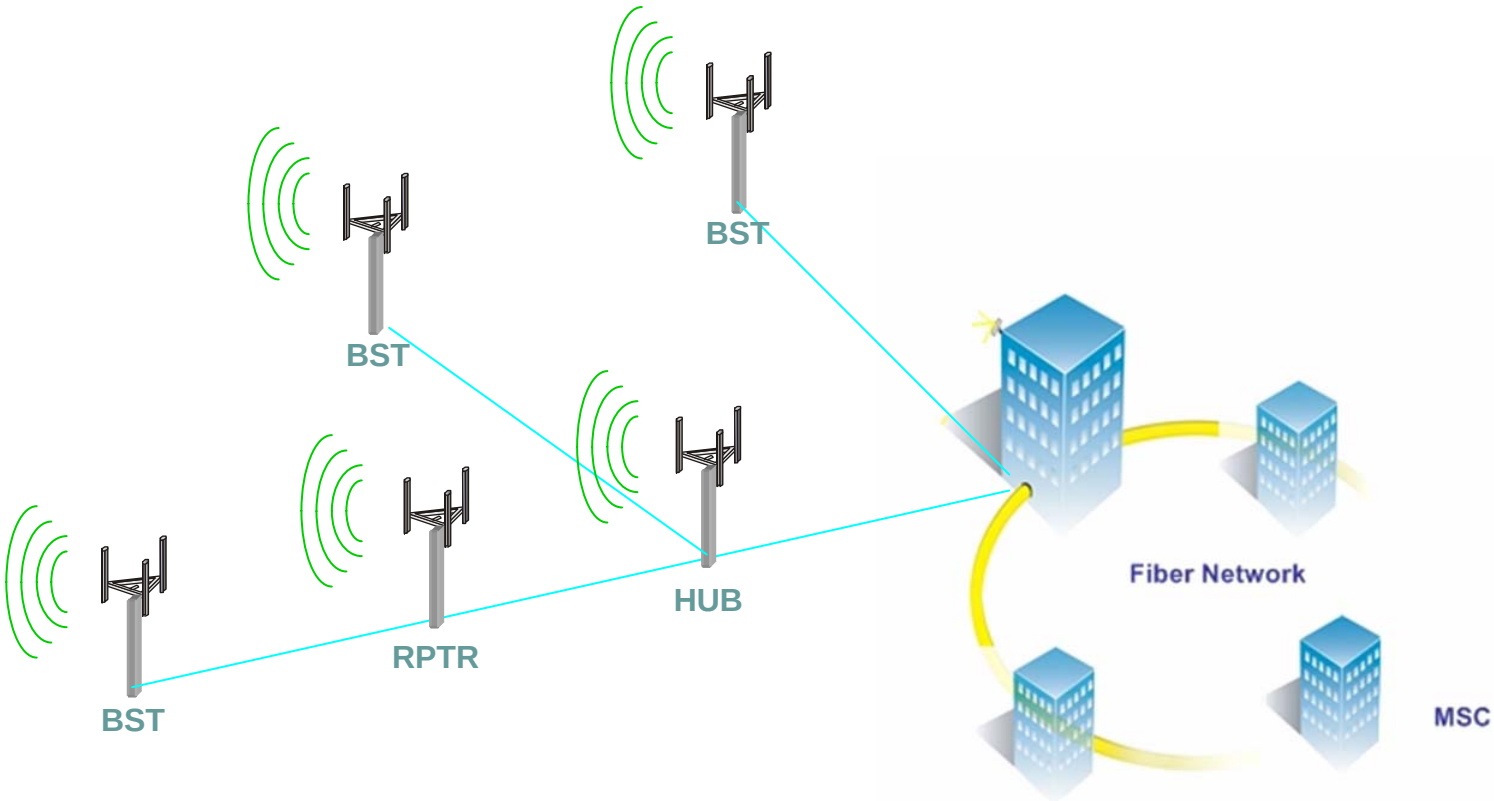
Definitions



"Access"

"Transport"
"Transmission"

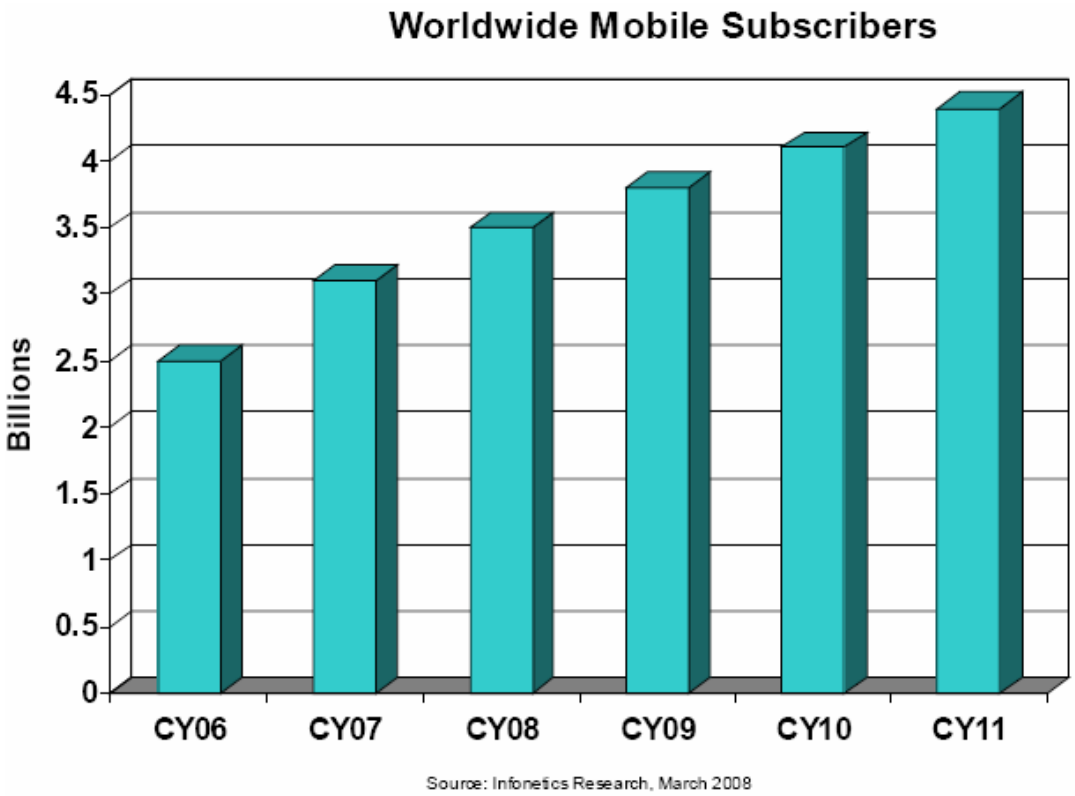
Typical Mobile Network



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

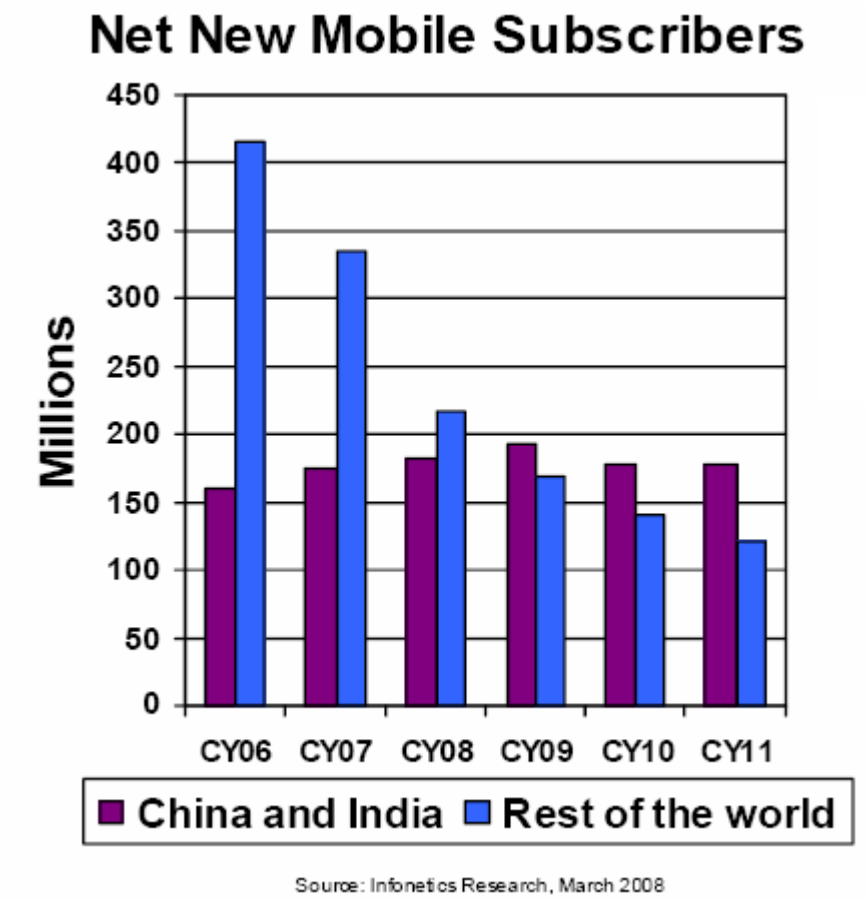
Disruptive Forces

Mobile Subs Increasing ...



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

… Mostly In Developing Countries



Carriers Actively Courting Low ARPU Users

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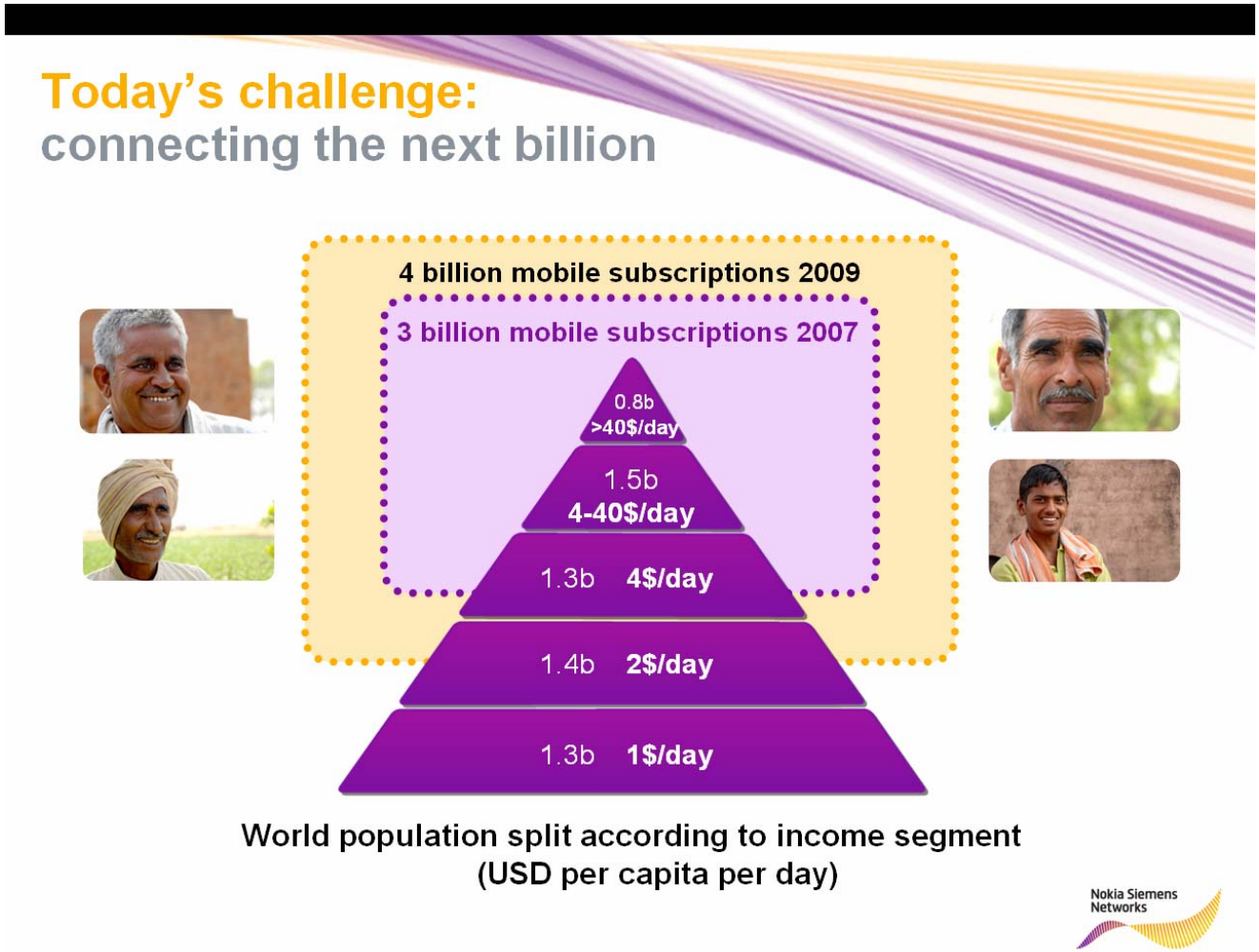
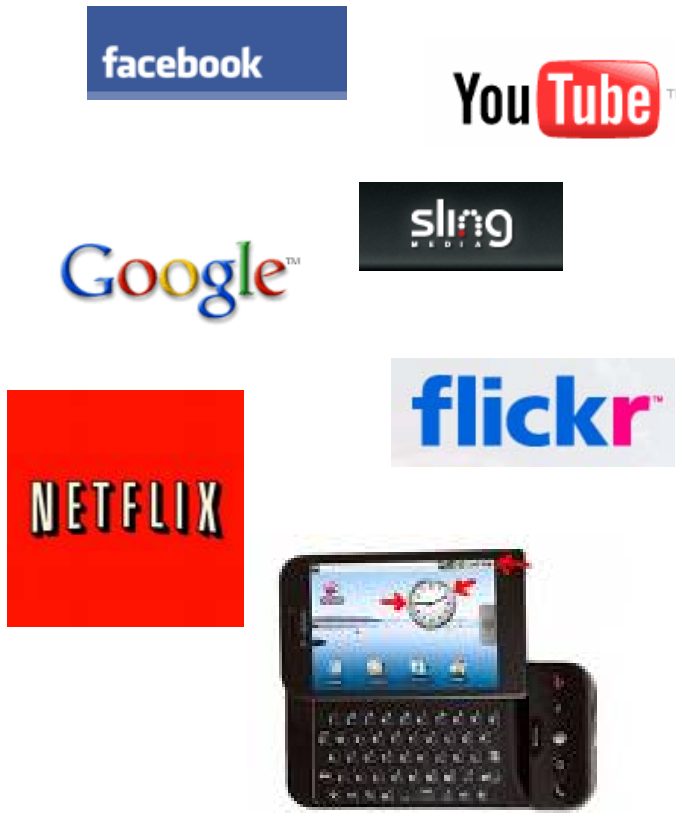
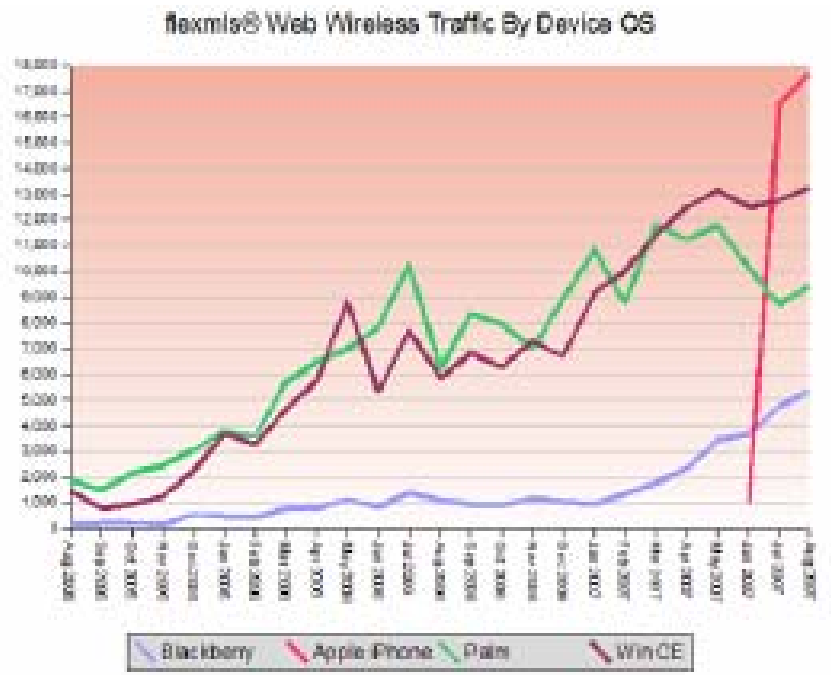


Consumer Patterns Changing

- 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

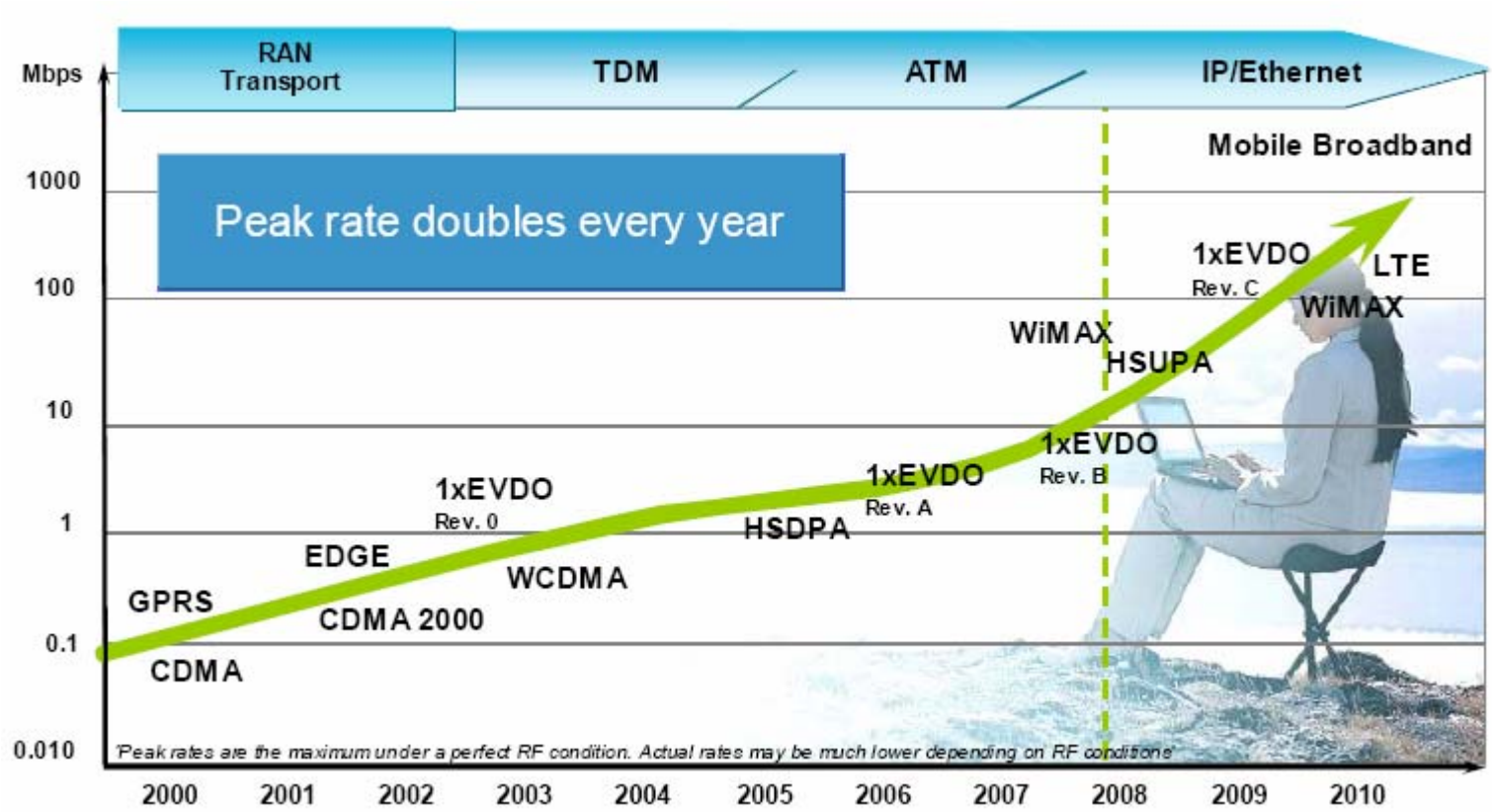


Examples



- 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 …



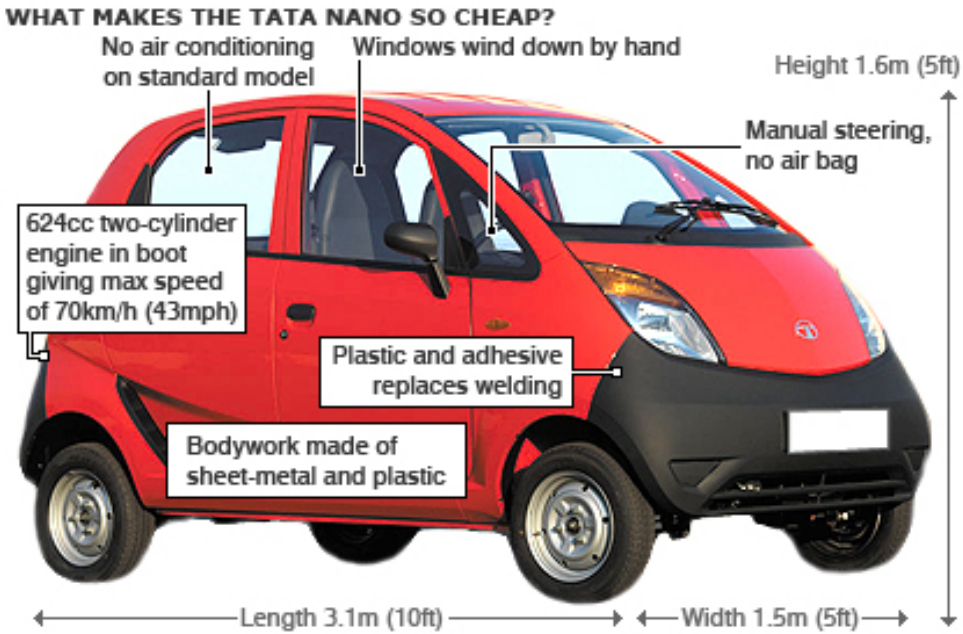
Source: Alcatel-Lucent, 2008

….And Bigger Channels Sizes

System	Peak data rate	Channel Width	Frequency reuse	Peak Spectral efficiency
AMPS	9.6 kbps	30 kHz	7 / 21	0.015
GSM	9.6 – 14.4 kbps	200 kHz	4 / 12	0.032 - 0.048
GPRS	171 kbps	200 kHz	4 / 12	.07
EDGE	474 kbps	200 kHz	4 / 12	0.2
W-CDMA	2 Mbps	5 MHz	1	0.4
HSDPA	14 Mbps	5 MHz	1	2.8
LTE	100 Mbps	20 MHz	1	5
HSDPA+ 64QAM & 2x2 MIMO	42 Mbps	5 MHz	1	8.4
LTE 2x2 MIMO	172.8 Mbps	20 MHz	1	8.6
LTE 4x4 MIMO	326.4 Mbps	20 MHz	1	16.3

A Tale of Two Cars

Tata Nano $2,500



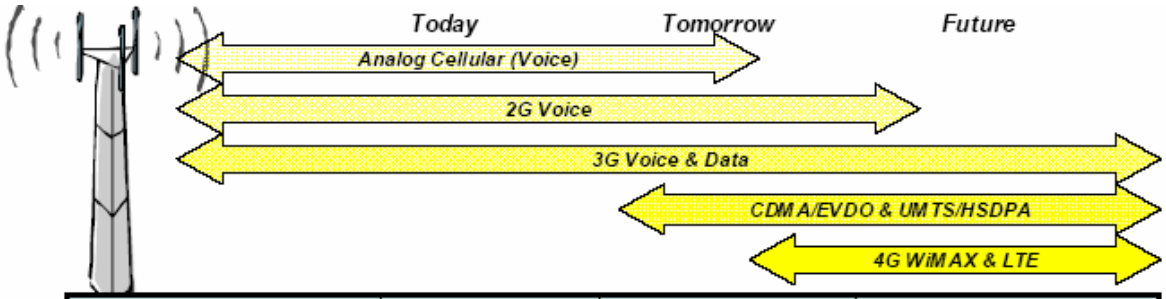
(Single band GSM)

Bugatti Veyron $1,500,000

(326.4 Mbps 4x4 MIMO hex-band LTE)

And the winner is…?

Collocation of 2G and 3G Sites

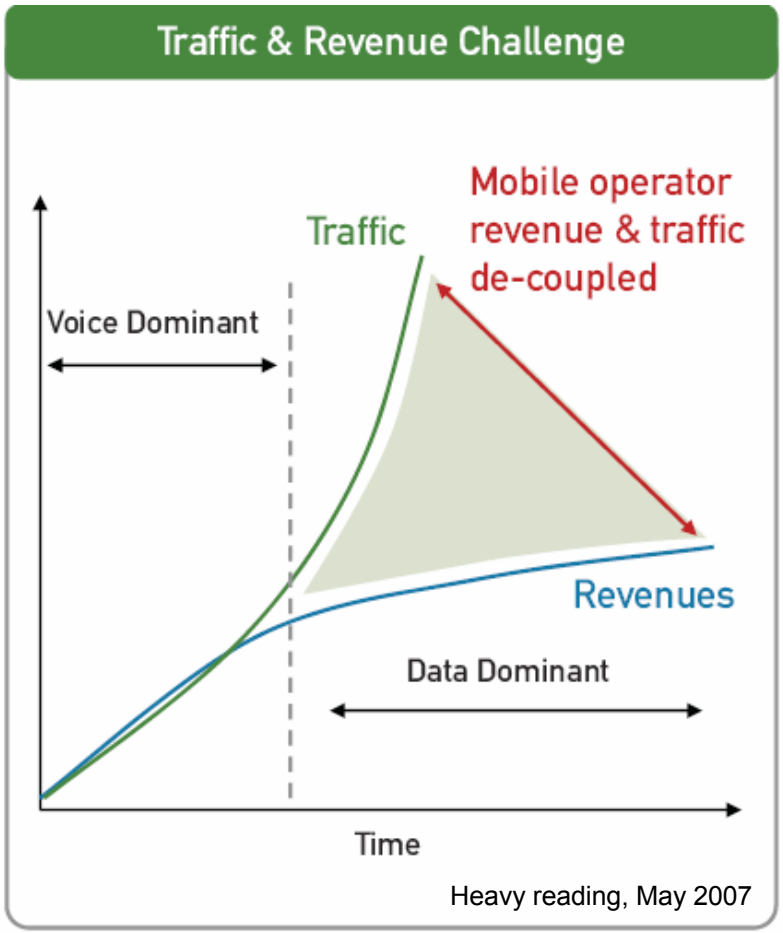


	2006	2008	2010
Analog Cellular	1-2 T1	1 T1	-
2G TDMA digital cellular	2-4 T1	1-2 T1	-
3G Voice & Data	2-8 T1	4-12 T1	2-8 T1
3G w/ EVDO or HSDPA	1-2 T1	2-4 T1 / 6 Mb Eth	10 Mb Eth
4G WiMAX & LTE (IP-based)	-	4 Mb Eth	10-20 Mb Eth
Total	6-16 T1 6-25 Mb/s	8-19 T1 / 10 Mb Eth 20-40 Mb/s	2-8 T1 / 20-30 Mb Eth 25-50 Mb/s

Source: Alcatel-Lucent 2006

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

Revenue & Traffic Decoupled



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

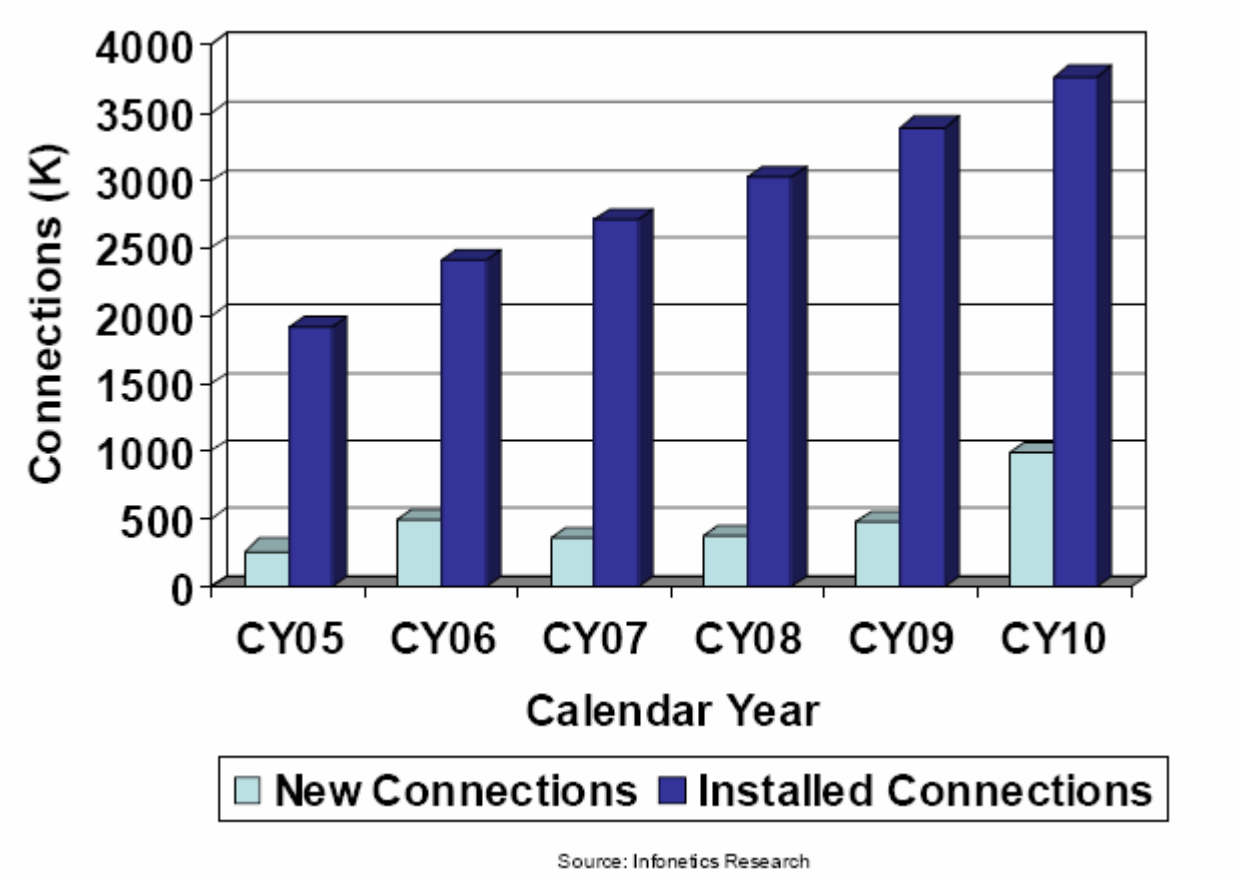
Costs follow traffic line!

Summary of Fundamental Shifts

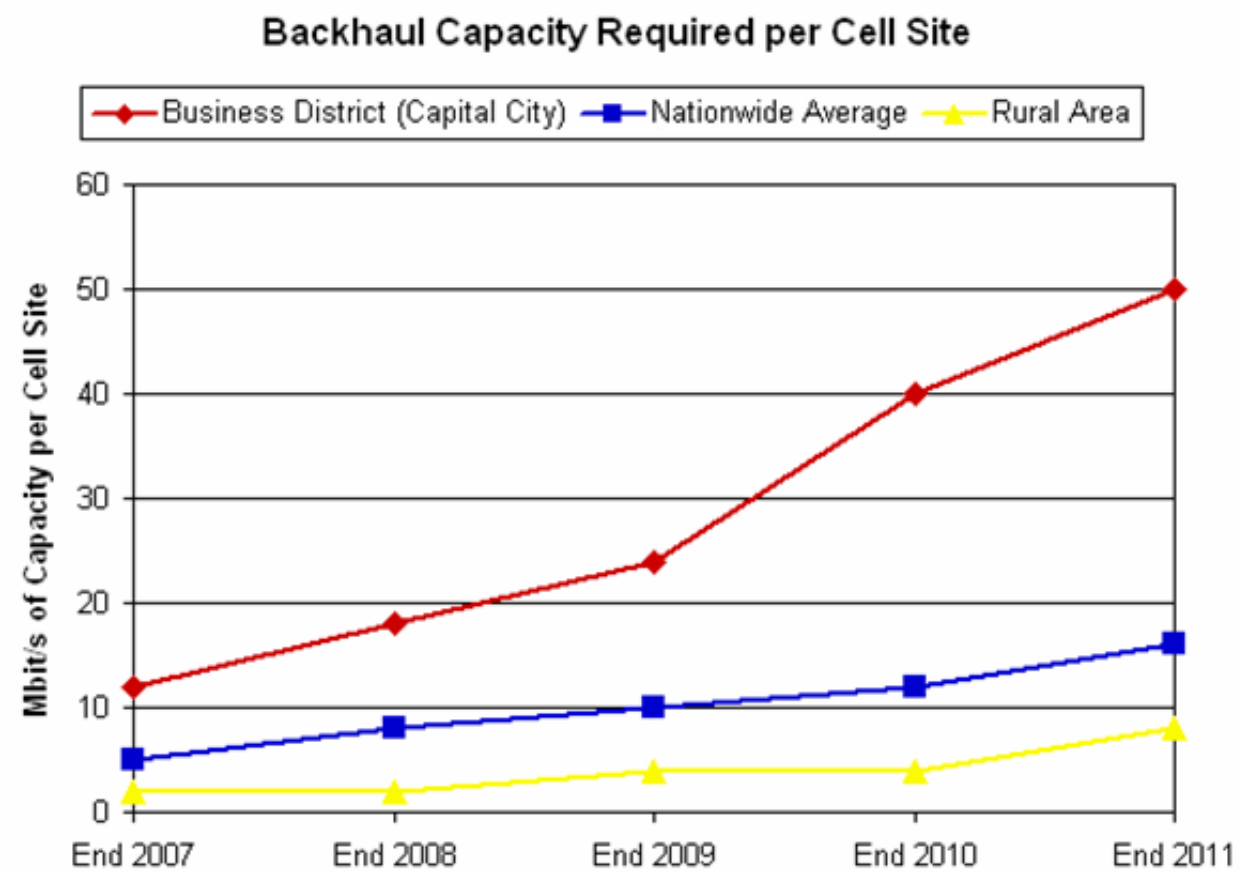
- Mobile subscribers and their bandwidth requirements are growing strongly
  - Mobile users going broadband; broadband users going mobile
- Data traffic grows and video coming
- 2G and 3G collocation at same cell site
- Multiple operators at same cell site
- WiMAX and LTE coming

Industry Trends

Number of Cell Sites Growing



Increased Cell Site Backhaul

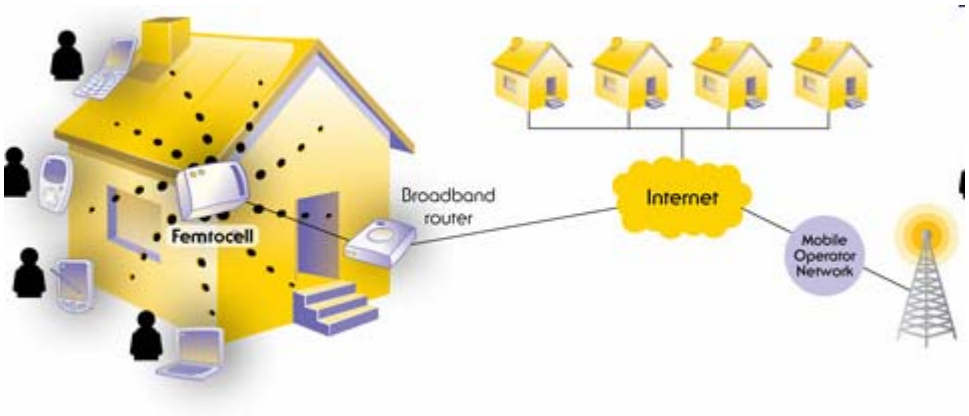


Source: Heavy Reading, 2008

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

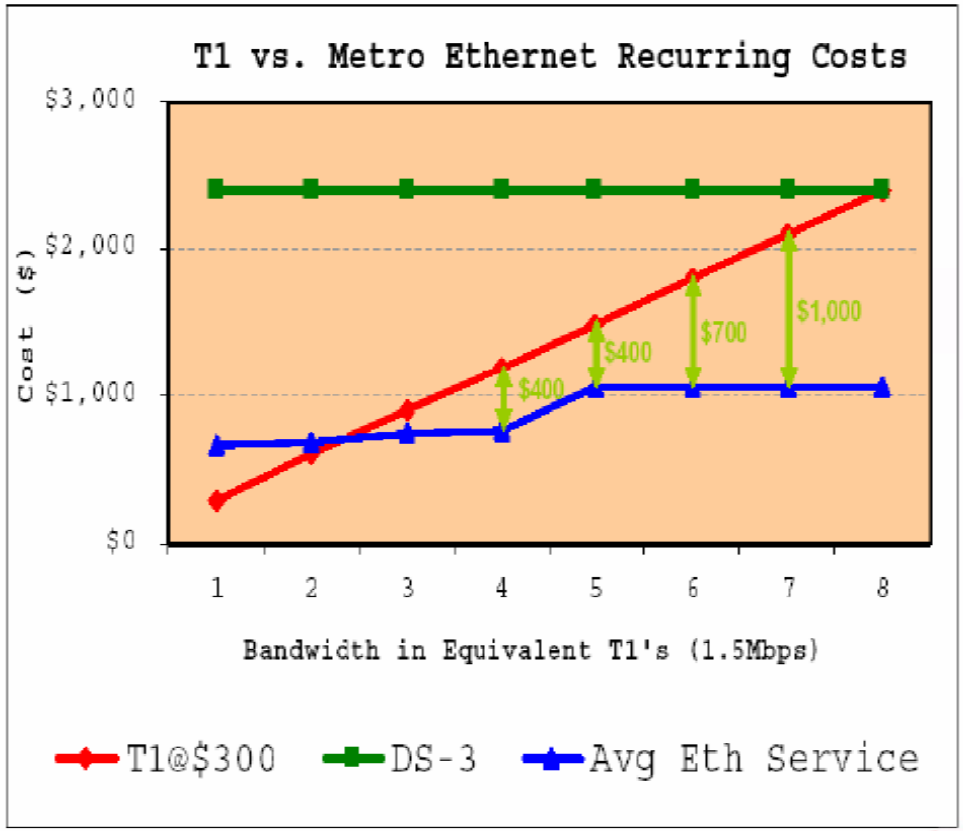
Femtocells



- Home Base Stations with 10m radius
  - 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

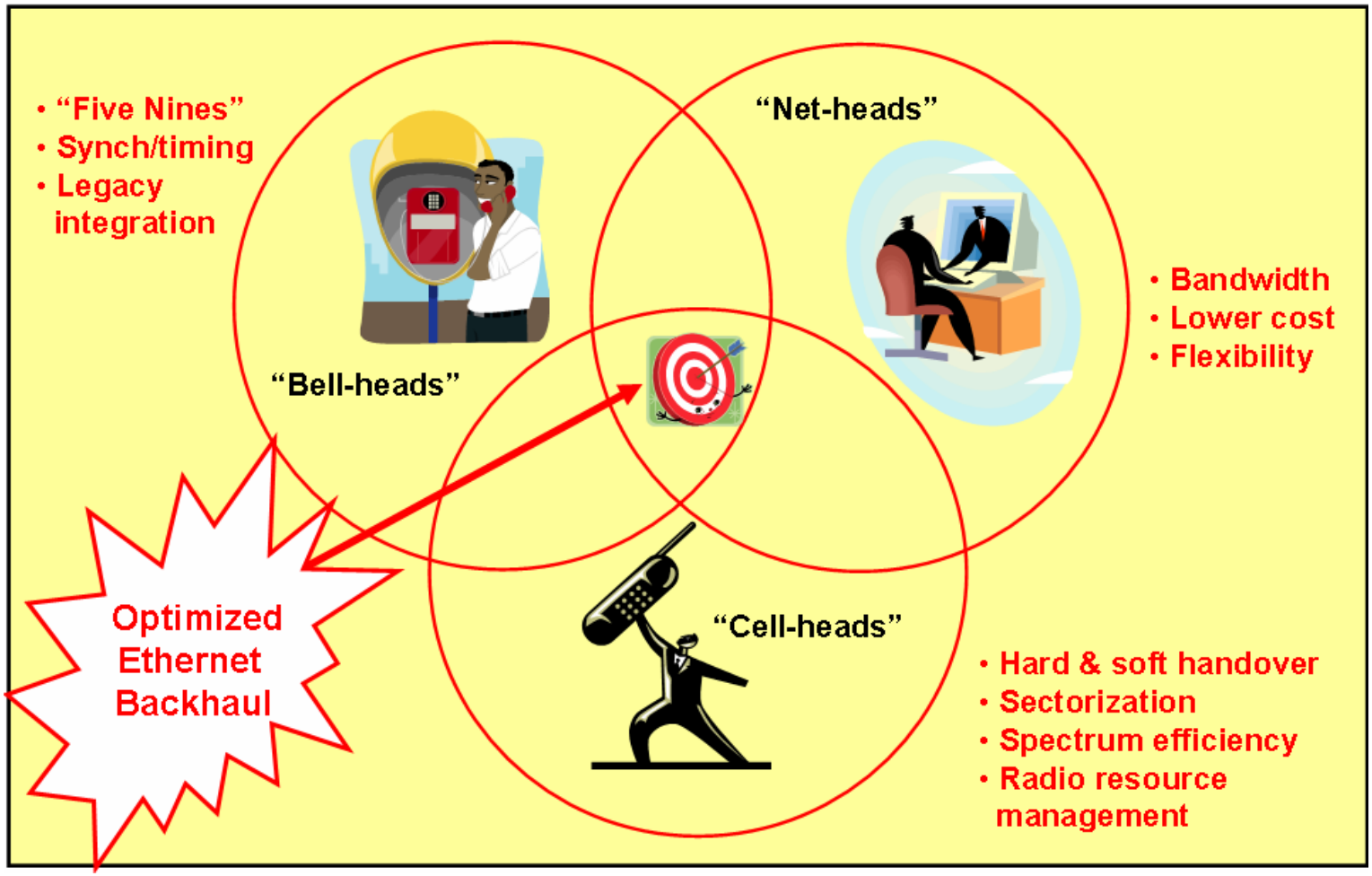
Shift Towards Ethernet

- 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



Metro Ethernet Forum (MEF)

The 5 Attributes of Carrier Ethernet

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

LTE and WiMAX Are Coming

LTE – Long Term Evolution

- IP-based 4G network
- Meets key requirements of ITU 4G Next Generation Networks
  - Downlink peak rates of > 100 Mbps, 50 Mbps uplink
  - Latency < 10 ms
- Seamless connection to existing GSM, CDMA, HSPA, WCDMA networks
- Support from all major global carriers
  - Verizon to offer LTE services in 25-30 markets by 2010

WiMAX

- IEEE standard
  - 802.16-2004 (“802.16d” or “fixed WiMAX”)
  - 802.16e-2005 (“802.16e” or “mobile WiMAX”)
- WiMAX Forum founded in 2001 to certify and promote interoperability
- Technology characterized by massive hype
  - “70 Mbps over 30 miles” - Intel
  - “400 commercial networks in over 130 countries” – WiMAX Forum
  - “Over 100M subs expected by 2012” – Analysts
  - “WiMAX is a 4G technology” – Everyone!

WiMAX Realities

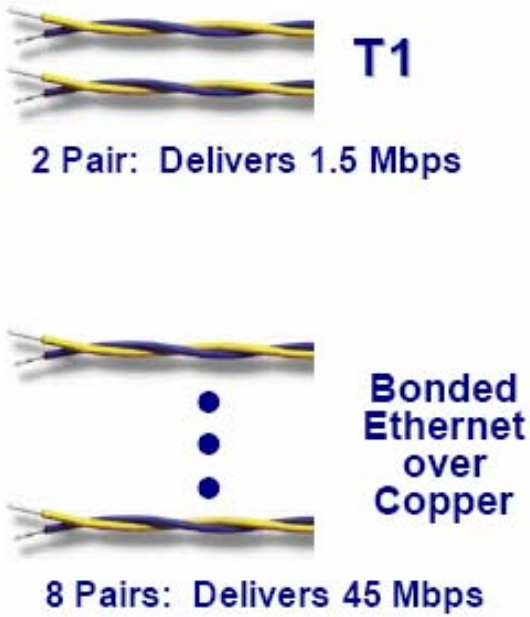
- Support of just one major carrier
  - Clear - $2 B joint venture between Sprint, Clearwire, Google, Intel, Comcast, Time Warner
  - Only 2 US markets served
    - Baltimore – 2-4 Mbps service, 20 Mbps backhaul, 80% reuse of Sprint cell sites, ¼ mile cell site spacing, uncongested spectrum
- Nevertheless, if every laptop comes with a “free” embedded WiMAX chipset …?
- WiMAX has applications for mobile broadband, rural applications, developing countries

Technology Solutions

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



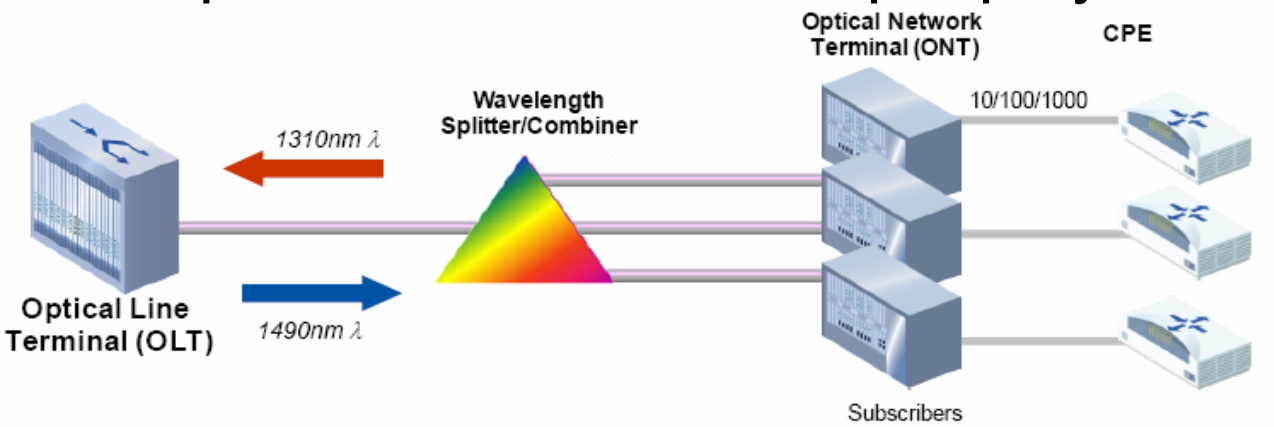
Ethernet over Copper (EoCu)

- 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

- 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

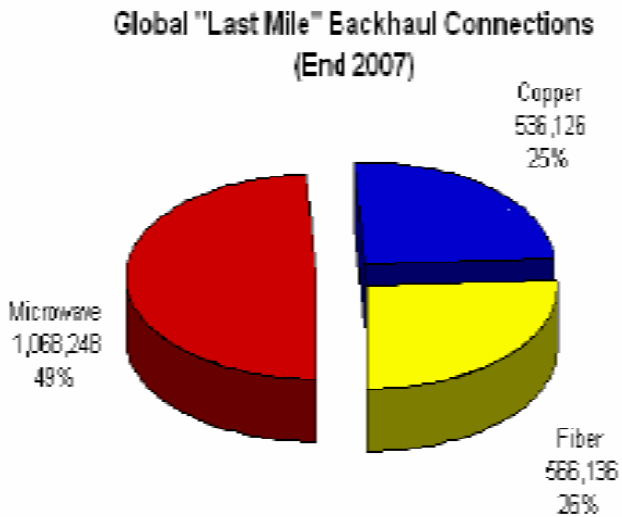
- Connect point A with point B
- Very expensive to implement
  - Fiber trenching $100/ft

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
  - 1.1 million units shipped in 2007
- 80% shipments for mobile backhaul
- 50% cell sites worldwide connected by microwave wireless
- Ethernet microwave is fast growing segment

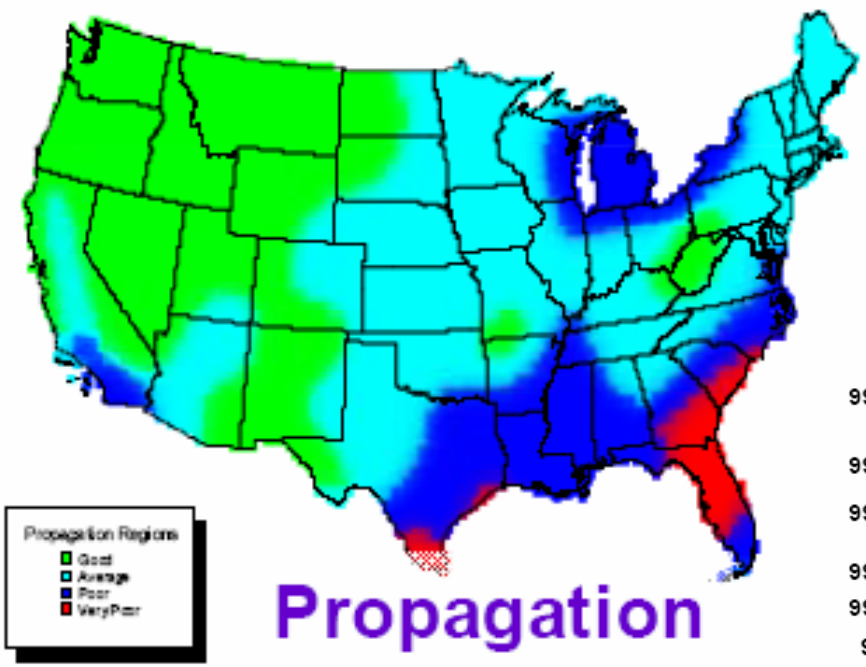


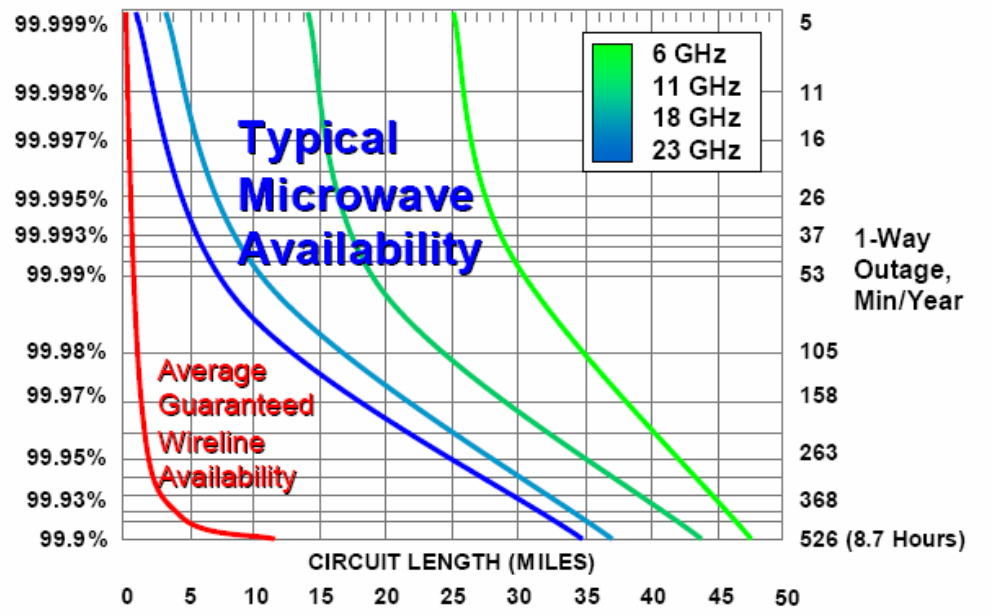
Decouples Cost and Capacity

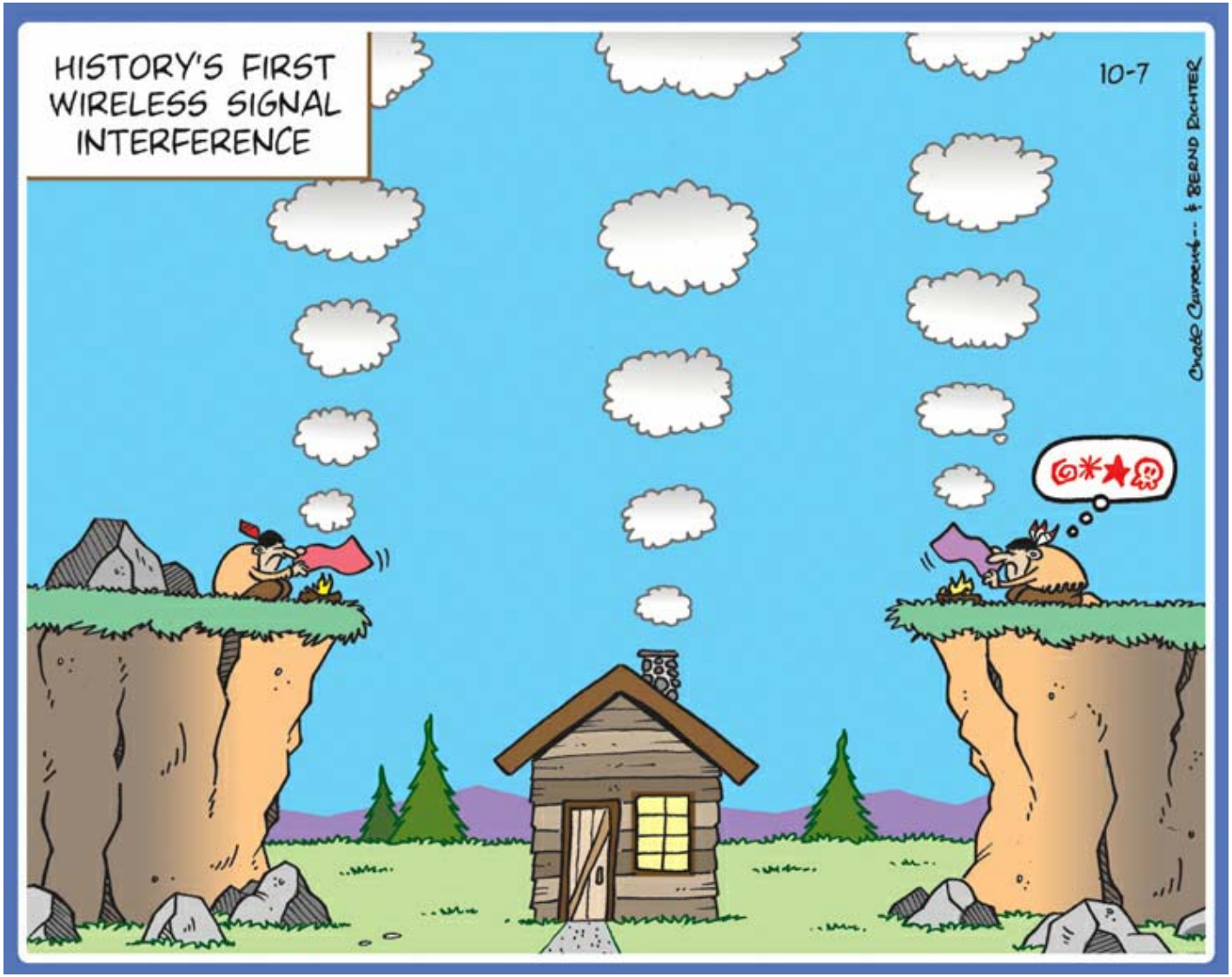
- Rough pricing guide

	Leased line cost	PTP wireless link
4 x T1 (6 Mbps)	$1,200 per month	$10K
16 x T1 (4 X)	$3,000 pm (3.5 X)	$15K (1.5 X)
OC-3 / Fast Eth (100-155 Mbps) (25 X)	$6,000 pm (5 X)	$25K (2.5 X)
GigE (1,000 Mbps) (100+ X)	$10,000 pm (8 X)	$35K (3.5 X)

Limitations - Rain Fade



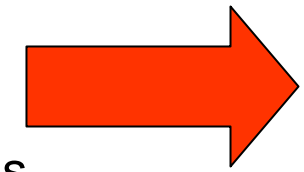



HISTORY'S FIRST WIRELESS SIGNAL INTERFERENCE
10-7
BERND RICHTER

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



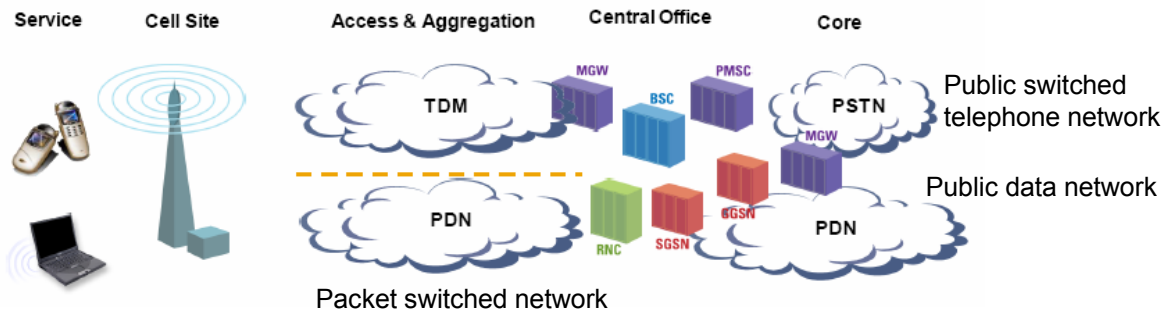
- Infrastructure Challenges
  - Bring Ethernet to all cell sites
  - Convergence – support 2G, 3G and 4G at same site
  - Minimize capital and $/bit expenses
  - Maintain high QoS, latency, jitter, sync,etc
  - Migrate legacy services to packet

Potential Solutions

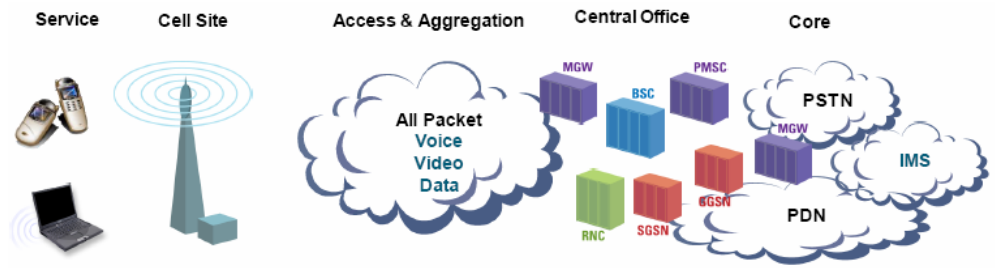
- Ethernet over copper
  - Reuse of existing infrastructure
  - Bandwidth and resiliency issues
- Ethernet over fiber
  - Increased bandwidth and scalability, supports exponential demand
  - Expensive and not widely available
- Ethernet over wireless
  - Multiple flexible and scalable approaches, bypassing wireline providers
  - Distance limitations

Possible Progressions?

- Near term:
  - Reuse as much of existing Cu infrastructure as possible
    - Migrate to Ethernet where possible in high ROI spots
  - Install owned or leased wireless 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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