Broadband Access Platforms

FCC Tutorial
Communications Networks and Services

Stagg Newman
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McKinsey and Company

TECHNOLOGIES PROFILED

Wireline

Twisted Copper Pair

- **xDSL**
- Voice-over-DSL
- VDSL

Hybrid Fiber Coax

- Cable Modem/VoIP

Optical Fiber

- Gigabit Ethernet
- Passive Optical Networks

Powerline

- Powerline Telecommunications

Wireless

Fixed

- MMDS
- LMDS
- Free-space optics
- Unlicensed fixed wireless
- Wireless Mesh
- Satellite

Nomadic/mobile

- WLAN
- Next-Generation Mobile

xDSL – TALKING POINTS

Basics

- Copper-based broadband technology for the local loop
- Targets residential and SME market
- Leverages ubiquitous telephone network infrastructure to offer high-speed data

Issues

- Profitability has been a challenge both for CLECs and ILECs
- Provisioning rate constrained by back-office bottlenecks
- Improvements in OSS required to handle provisioning, billing/customer care and support for advanced services

DIGITAL SUBSCRIBER LINE (xDSL) – OVERVIEW

Platform basics | **Advantages** / **Challenges** | **Equipment vendors** / **Service providers** | **Customers**

- Data rates vary with version of DSL and loop length
  - For the most popular version, ADSL, the international standard from ITU-T specifies a maximum speed of 6.1 Mbps downstream and 640 Kbps upstream*
  - In practice, the top speed of 6.1 Mbps is only possible for loops up to 9kft, going down to 1.5 Mbps for loops up to 15kft
  - Typical speeds available from 640 Kbps to 1.5 Mbps
  - The fastest version, VDSL**, supports 55 Mbps downstream for 1kft loops and 13 Mbps for 4.5kft loops, with upstream speeds of 1.6-2.3 Mbps
- Each user has a dedicated line from premise to the DSLAM located at central office or remote terminal
- Supported services
  - Data and VoDSL (with voice gateway)
  - ADSL shares the same copper line with analog telephony
  - VDSL can support switched video
- Addressability
  - Requires “clean” end-to-end copper line without loading coils or bridge taps
  - Maximum copper distance of 15kft
  - No DLC system in loop, unless DSLAM is installed in remote terminal
- CPE consists of ADSL modem
  - Voice gateway required for VoDSL

Advantages:
- Proven technology with more than 3 million lines in service
- Industry standards from ITU-T and ANSI
- Uses the ubiquitous telephone network already connected to every SME and household in the country
- Under favorable conditions, it can be deployed as an easy highly variable capital overlay to telco networks

Challenges:
- Provisioning
- OSS
  - Provisioning
  - Customer care/billing
  - Support for value-added services
- Addressability limited by
  - Copper distance
  - DLCs in the loop
- Profitability
  - Reasonable returns to ILECs when viewed broadly
  - Very challenging for CLECs

Equipment vendors:
- Modems
  - Thomson Multimedia
  - Westell
  - Efficient Networks
  - Orckit
  - Intel
- DSLAM
  - Alcatel
  - Lucent Technologies
  - Siemens
  - Cisco
  - Copper Mountain
  - Nokia
- Other
  - Redback (subscriber management system)
  - Spirent (testing equipment)
  - Teradyne (testing equipment)

Service providers (1Q01, thousand lines)
- ILECs
  - SBC (954)
  - Verizon (720)
  - Qwest (306)
  - Bell South (303)
- CLECs
  - Covad (319)
  - Rhythms (67)
  - DSL.net (16)

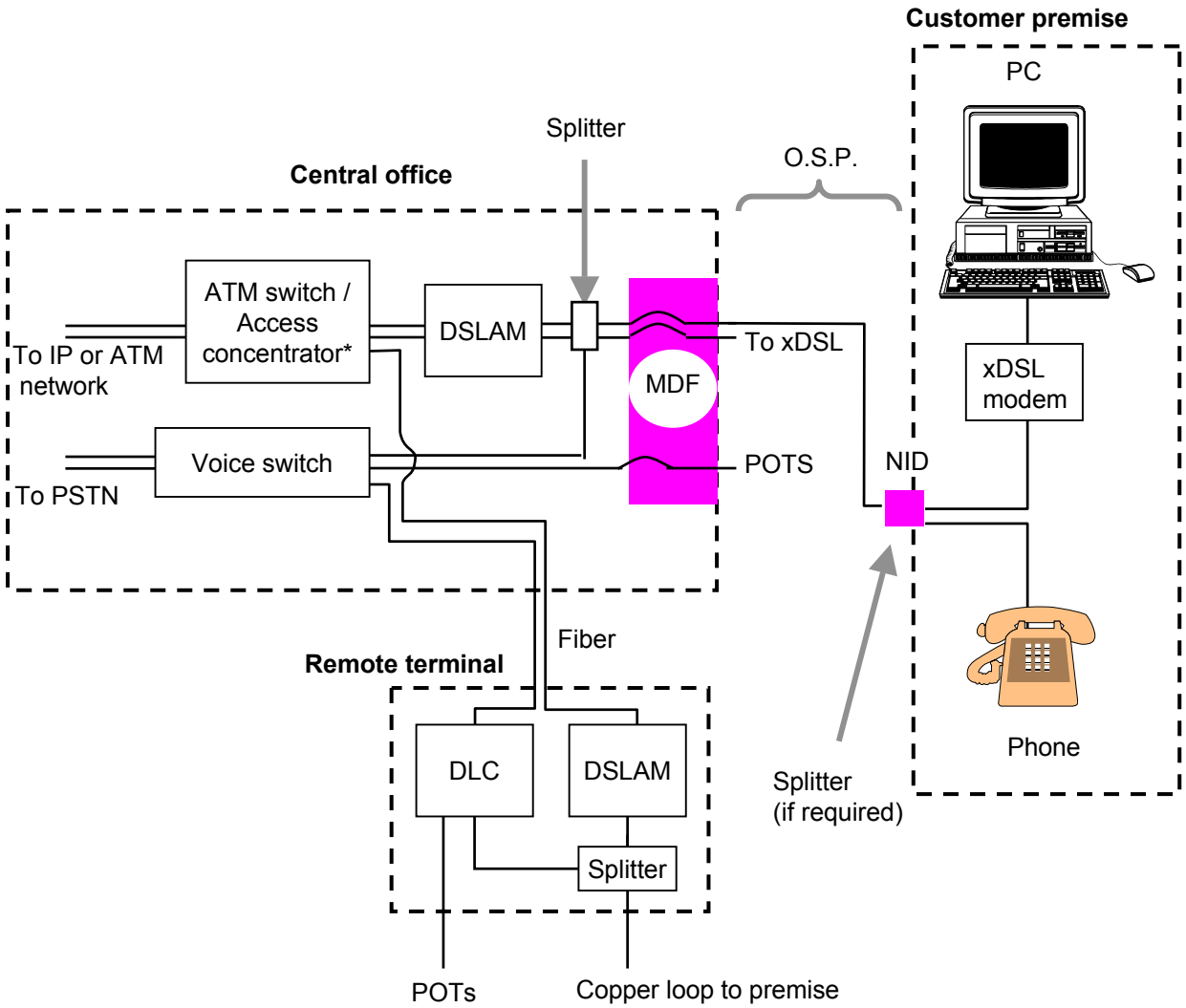
Target customer segments:
- Consumer
- SME

Market size:
- 2.1 million lines at end of 2000
  - 1.6 million residential lines
  - 0.5 million business lines
- Estimated 18.5 million lines at end of 2005
  - 14.8 million residential lines
  - 3.7 million business lines

* Higher speeds are supported by most equipment manufacturers

** Very limited deployment due to unfavorable economics

xDSL – NETWORK ARCHITECTURE



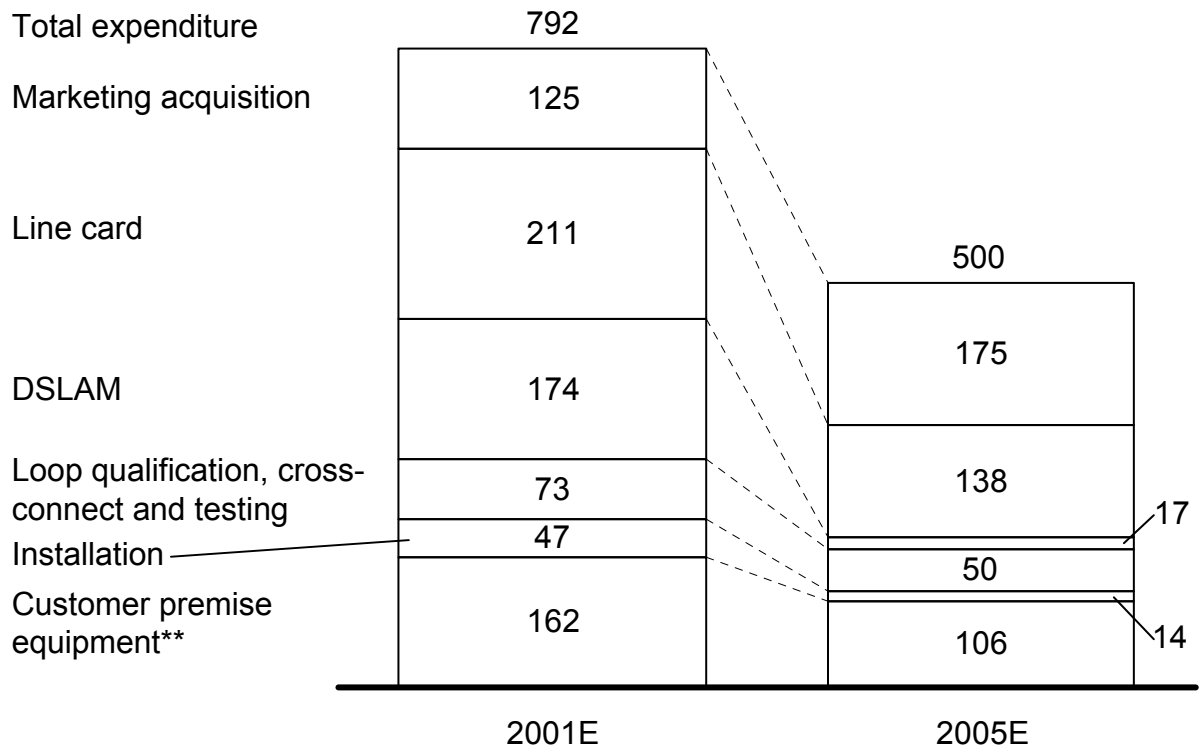
* Manages data channel between customer and ISP

xDSL – FACTORS DETERMINING ADDRESSABLE MARKET SIZE

Factor	Description
Loop length	• In order to support DSL service, copper part of loop has to be shorter than 15kft • Higher speed versions require shorter loops (e.g., 6 Kbps requires 3kft and 13 Mbps requires 4.5kft)
Loops served by DLCs	• The DSLAM must attach directly to the copper loop • In areas served by fiber-based DLC systems, the copper terminates at a remote terminal in the neighborhood and therefore it cannot be connected to a DSLAM at the central office
Service not adequate for large business	• Data rates offered over xDSL are not adequate for large and medium enterprise customers

xDSL RETAIL CUSTOMERS EXPENDITURES (OPEX+CAPEX), 2001E-2005E

$ per subscriber add*



* Acquisition, loop qualification, installation and CPE costs are incurred for each gross add. Because DSLAM and line cards can be reused their costs are only incurred for net adds

** CPE includes modem, microfilters, and installation software CD

Source: Company interview; McKinsey and JPMS analysis and estimates

CLECs FACE SIGNIFICANT CHALLENGES TO OFFER xDSL SERVICE

Provisioning and operations

- Delays in loop conditioning
- Difficult to manage CLEC-ILEC work flow
- High loop-conditioning fees charged by ILECs
- Ability to obtain operations support
  - Information required for deployment of CLEC's technology not always available
  - Accuracy of outside plant records questionable
  - May involve paper-intensive manual process

Collocations at CO

- Access to copper loop requires collocation at ILEC's CO
  - Space limitations and high collocation fees
  - Slow and complex authorization process
  - Difficult to reach scale in transport from CO to CLEC point of concentration
  - ILECs limit ability of CLECs to deploy technology of choice by claiming treats to network integrity

Regulatory challenges

- Delays caused by ILEC's systematic challenge of FCC orders
- Delays in reaching contracts with ILECs on pricing of UNE, space, network engineering, etc.
- New regulatory environment is likely to be more ILEC friendly

DLC-based loops

- Collocation at DLC remote terminal is a much bigger challenge than at CO
- Technical feasibility of collocation at RT is point of contention
- Lack of space and transport from RT to CO
- Very difficult to achieve scale with small number of customers per RT
- Additional costs
  - Upgrades to space and power
  - Additional truck roll to cross connect loop to CLEC equipment

DSL only model has proven untenable

- NorthPoint
  - Discontinued service
  - Bought by AT&T in bankruptcy court
- Covad
  - Posted $1.35 billion loss from operations in 2000
  - Market value down 97% from 1 year ago*
- Rhythms
  - Discontinued service
  - Key assests bought by Worldcom in bankruptcy court

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VoDSL – TALKING POINTS

Basics

- VoDSL leverages a single local loop to carry multiple voice lines by exploiting the increased capacity of its DSL band
  - Circuit-switched VoDSL, the dominant solution, connects calls through a legacy class 5-switch
  - Soft-switched VoDSL, employed by Sprint ION, runs over an end-to-end packetized network
- VoDSL is targeted at DSL addressable SMEs and multi-line households
- VoDSL deployments have been limited to trials of less than 2,500 customers

Issues

- VoDSL has not proven its ability to scale. Technological and operational issues may emerge with large-scale deployment.
- Sprint ION's soft-switched VoDSL is being scaled back due to problems with service quality

VoDSL – OVERVIEW

Platform basics | **Advantages** / **Challenges** | **Equipment vendors** / **Service providers** | **Customers**

- Supports multiple voice lines over a single copper loop by leveraging increased capacity of DSL band
- Standard circuit-switched VoDSL is not an end-to-end packet solution
  - Connects calls through a legacy Class 5 switch and supports all CLASS services (call-waiting, caller ID, etc.)
- Existing VoDSL systems support up to 16 toll-quality voice lines
- Dynamically allocates bandwidth across voice and data
- May have most potential in Europe where shorter loop lengths and under-developed cable modem market may give DSL dominate share of access space
- Substitutes: POTS/DSL, cable telephony, VoIP, PBX/T1, Centrex

Advantages:
- Reduces copper related costs. Lowering number of leased lines for attackers and relieving copper-exhaust for incumbents
- CPE is a router that can integrate devices other than telephones and PCs, creating a potential platform for home networking

Challenges:
- Technology still unproven on large scale (1Q01)
- Potential problems with service quality
- Installation can be complicated – especially for residential customers. Sprint ION* requires 5 hour installation by a technician
- DSL-band voice lines do not work in a power outage

Equipment vendors:
- Jetstream
- CopperCom
- TollBridge
- General Bandwidth
- Accelerated Networks
- Nortel
- Lucent

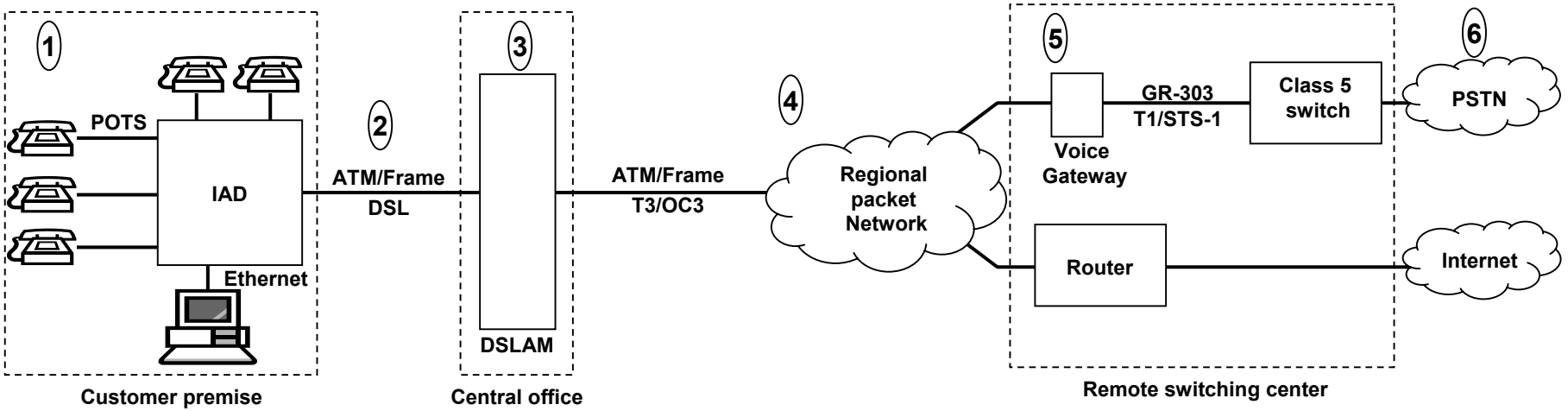
Service providers:
- No existing large-scale deployment
  - Circuit-switched deployments limited to test markets of no more than a few hundred
  - Largest soft-switched deployment by Sprint ION* (2,500 customers) being scaled back due to voice-quality issues

Promising customer segments:
- DSL-addressable SMEs with 2-16 phone lines
- DSL-addressable multi-line residential households

Addressable market:
- Attackers could reach up to approximately 4 million small businesses and roughly 9 million households

* Sprint ION's integrated voice and data solution runs over an end-to-end ATM network. While Sprint ION carries voice and data over DSL, its soft-switched solution does not employ the same equipment as circuit-switched solutions offered by most VoDSL vendors

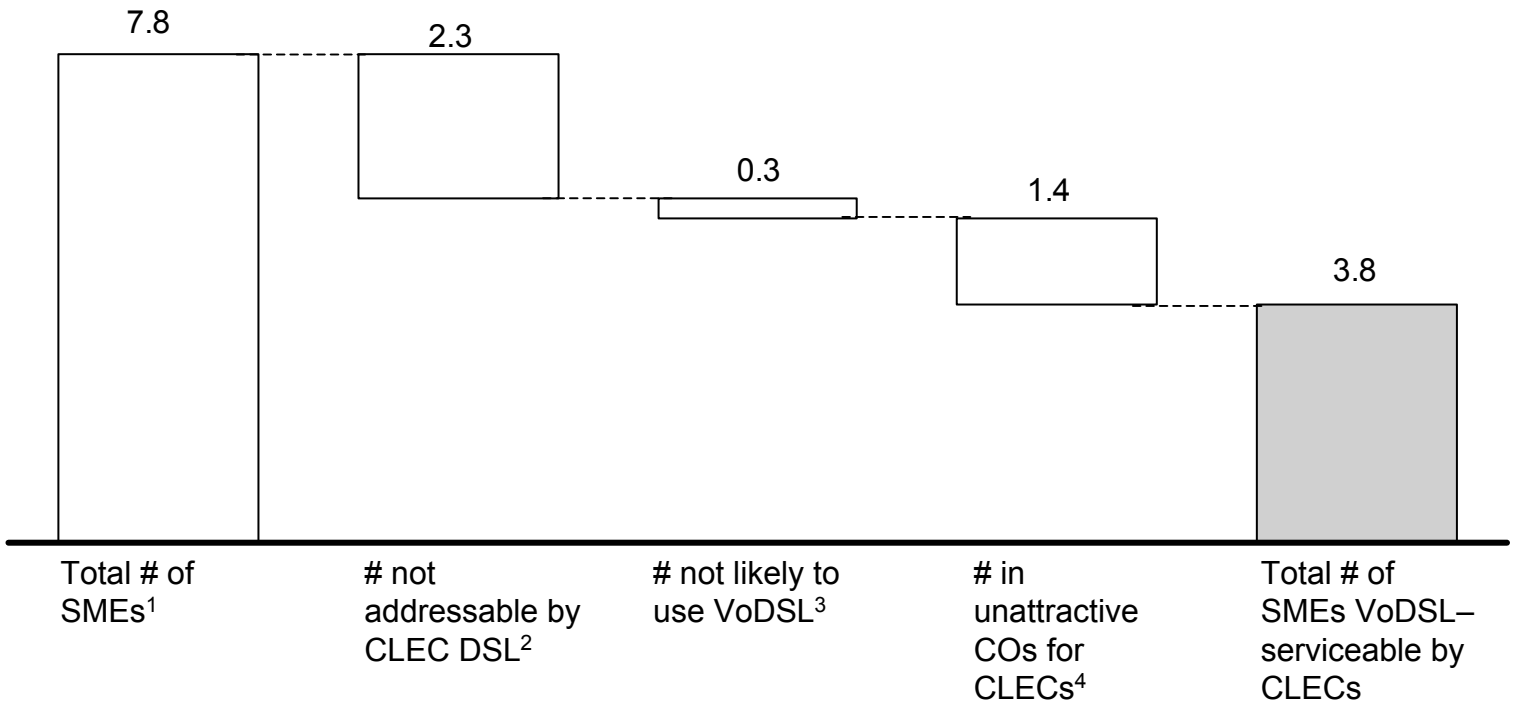
VoDSL – ARCHITECTURE OF CIRCUIT-SWITCHED ATTACKER'S NETWORK



1. Integrated Access Device (IAD) at customer premise compresses and packetizes voice lines and gives voice packets priority over data packets
2. Voice and data transmitted over Digital Subscriber Line (DSL) as ATM/Frame packets
3. DSLAM combines voice and data packets from multiple customers onto a high-bandwidth connection (T3/OC3) for transmission to remote switching center
4. Regional packet network delivers voice packets to the voice gateway and data packets to the router in the remote switching center
5. Voice gateway decompresses voice data and transmits it to the class 5 switch using the GR-303 protocol on a T-1/STS-1
6. The call is completed on the Public Switched Telephone Network (PSTN)

SMALL AND MEDIUM ENTERPRISES THAT ARE POTENTIAL CLEC VoDSL ADOPTORS

Millions of enterprises

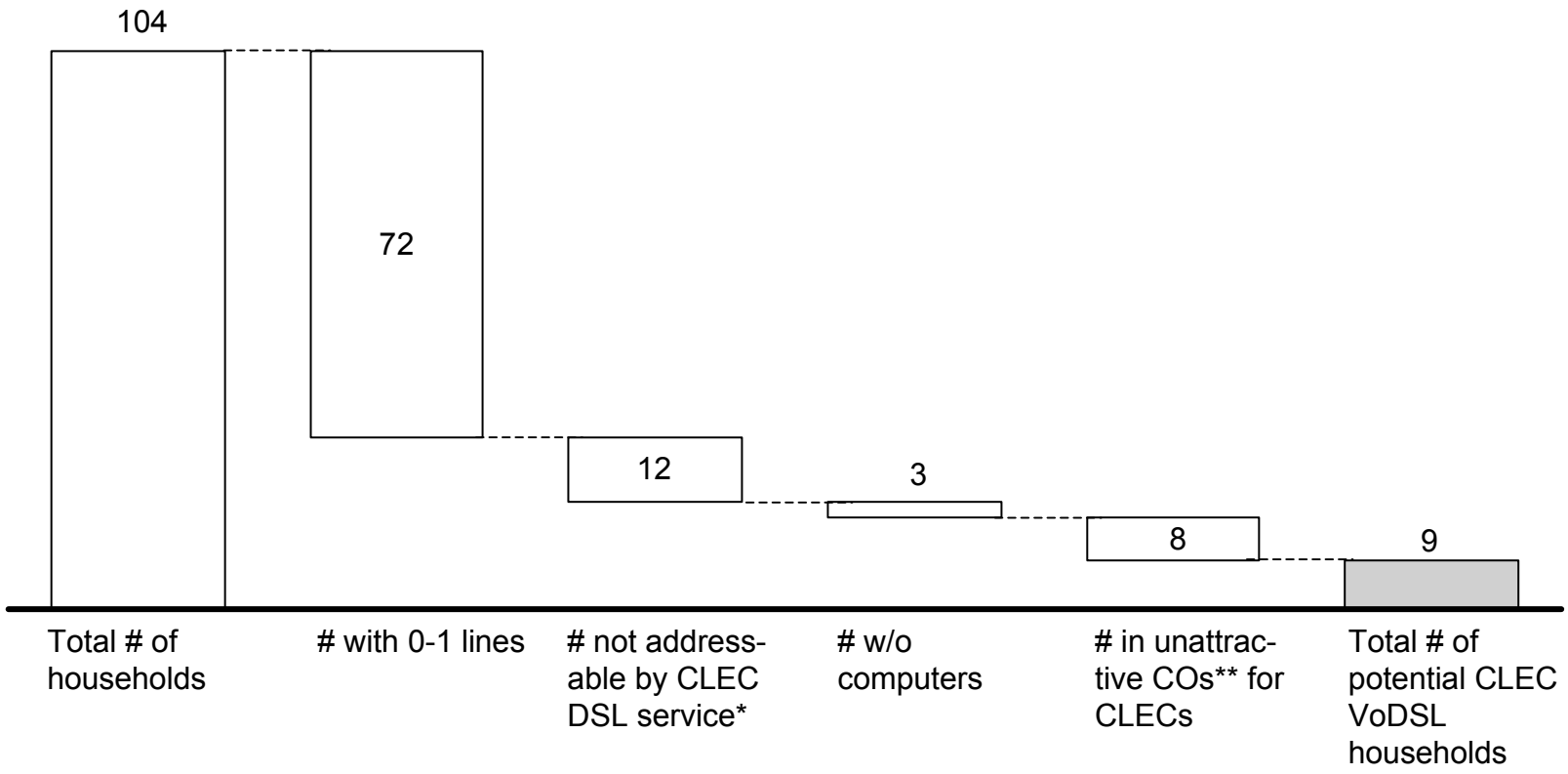


1 Refers to businesses with 1-500 employees
2 SMEs more than 15,000 feet from central office or served by remote terminal
3 SME locations with only 1 or greater than 16 phone lines and/or PBX
4 SMEs served by central offices with less than 1,000 business lines or outside of MSA Tiers 1-4

Source: McKinsey and JPMS analysis

POTENTIAL RESIDENTIAL CLEC VoDSL CUSTOMERS

Millions of households



* Households more than 15,000 feet from central office or served by remote terminal

** Households served by central offices with less than 1,000 business lines or outside of MSA Tiers 1-4

Source: McKinsey and JPMS analysis

BARRIERS FACED BY CLECS IN OFFERING VoDSL

BACK-UP

Sales and marketing challenges

- Consumers skeptical of buying voice services from unknown CLECs, who have yet to establish a reputation for reliability
- 75% of SMEs are satisfied with their local calling service

Operational challenges

- OSS: must be upgraded to handle integrated voice and data. New inventory, monitoring, management, and maintenance systems required
- Provisioning: VoDSL requires a truck roll and may require major rewiring of customer premise. Sprint ION residential service requires a 5-hour installation
- Network management: bandwidth capacity of connection must be maintained so voice lines are not dropped, and voice-quality is maintained

Pressures on CLEC industry

- Regulatory uncertainty with respect to access to DSL services delivered through a DLC
- Downturn of capital markets is making it difficult to raise cash
- Threat of legal battles from ILECs to stall deployment

Source: JP Morgan; McKinsey analysis

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HFC – TALKING POINTS

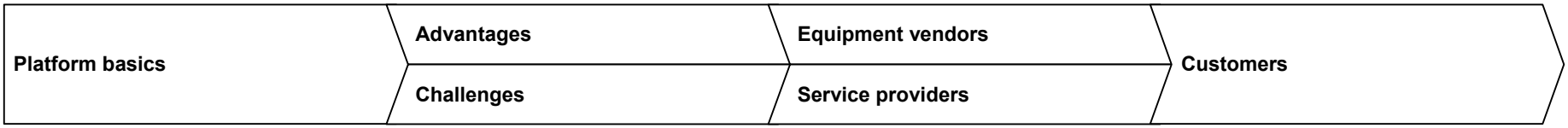
Basics

- The cable industry in now completing a multi-billion-dollar rebuild of one-way 350-450 MHz cable plant into two-way 750-plus MHz networks capable of offering broadband access over a cable modem platform
- HFC is expected to grow from 3.7 million broadband access subscribers at YE2000 to 20.4 million at YE2005

Issues

- Provisioning constrained by low rate of self-installation and back-office bottlenecks
- Lack of voice offer
- Overbuilder profitability

HYBRID FIBER COAXIAL (HFC) – OVERVIEW



- DOCSIS 1.1 supports 40 Mbps (down) 10Mbps(up) shared data channels
- Typical speed available, limited by RF noise and sharing of data channels, is 0.5-1Mbps down and 256-500kbps up
- DOCSIS 1.1 provides support for QoS
- Supported services
  - Cable modem supports data and voice over IP (with VoIP adapter)
  - Besides cable modems, the same HFC platform supports:
    - Video (analog and digital)
    - Voice (cable telephony)*
- Addressability
  - Requires two-way upgraded cable system with small node size (125-500hh passed)
  - MSOs do not cover commercial areas or low-density areas (linear density <20hh/mile)
  - Overbuilders typically target areas with linear density >75hh/mile
- CPE consists of
  - Cable modem for data (integrated VoIP adapter required for VoIP)
  - Other services sharing HFC platform require set top box for video and network interface unit (NIU) for cable telephony

Advantages:

- Proven technology with more than 4 million CM in the U.S.
- Industry standards from CableLabs
  - DOCSIS for data
  - PacketCable for voice over IP (unproven)
- Large addressable residential market
- Good economics
  - Upgrades paid by digital video service

Challenges:

- Provisioning
  - Provisioning constrains supply
  - Low-rate of self-provisioning
  - Inside wiring
- VoIP offer not ready
- Shared medium
  - Users experience lower data rates when many users access the network
- Overbuilder profitability
- Business market
  - Low addressability in commercial areas
  - Reputation with business customers

Equipment vendors:

- Cable modems
  - Motorola
  - 3Com
  - Toshiba
  - Thomson
  - Samsung
- Data equipment for head end
  - Cisco
  - Harris Interactive
  - Motorola
  - ADC
  - RiverDelta

Service providers:

- MSOs
  - AT&T
  - Time Warner
  - Comcast
  - Cox
- Over-builders
  - RCN
  - Knology
  - WOW
  - Utilicom

Target customer segments:

- Residential market
- Limited SME offer

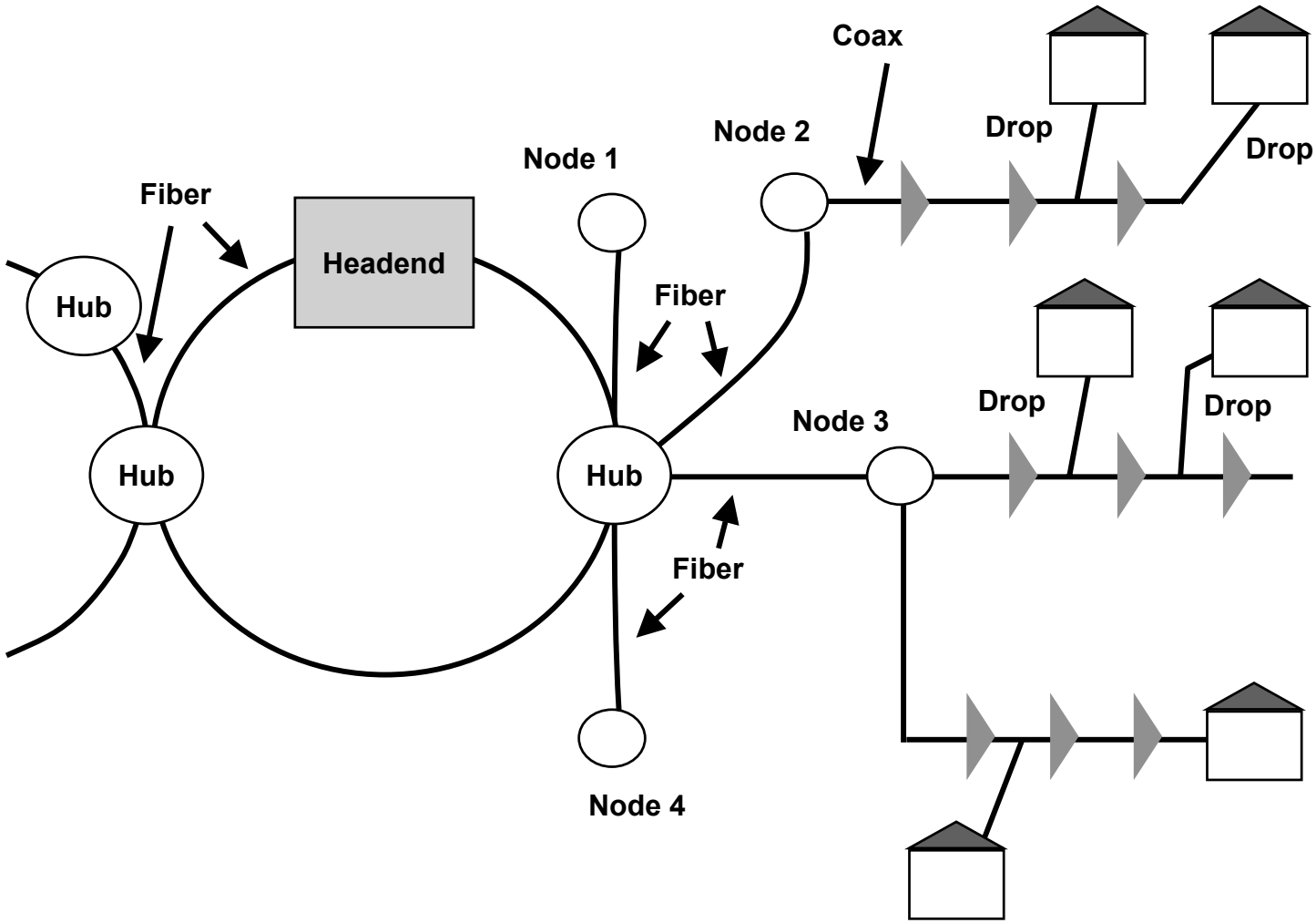
Market size:

- 3.7 million residential subs end of year 2000 and estimated 20.2 million subs end of year 2005
- Two-way enabled homes passed estimated 73 million YE2000 and 94 million YE2004

* Deployment limited to AT&T and Cox with a total of 788,000 customers in 2000

Source: JP Morgan; McKinsey research

HFC – NETWORK ARCHITECTURE



HFC – FACTORS DETERMINING ADDRESSABLE MARKET SIZE

Factor	Description
Coverage of MSO two-way cable systems	• Almost no coverage of commercial areas seriously reduces HFC opportunity in SME market • Cable modems require a two-way enabled cable system. • Two-way enabled homes at 74% of homes passed in 2000 growing to 92% in 2004 • Cable systems do not cover low-density rural areas, accounting for 7% of households
Coverage of overbuilders	• Attractive areas for overbuilders have – High linear density (more than 75 households per mile) – Low construction cost (high proportion of aerial plant) – High telecom spending
Service not adequate for large businesses	• Data rates offered over HFC are not adequate for large and medium enterprise customers

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GIGABIT ETHERNET (GIGE) – TALKING POINTS

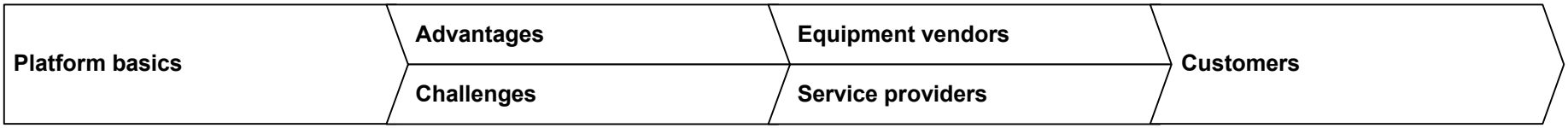
Basics

- GigE is an optical networking platform with low-cost equipment that is easily interfaced with corporate LANs and the IP world
- GigE access provides Internet access and transparent LAN services to:
  - Large enterprises
  - SMEs in MTUs

Issues

- While GigE offers some cost-advantages over SONET, it still faces serious issues common to all fiber platforms
  - Expense to lay fiber infrastructure (at least $10,000 per mile)
  - Cost of CPE (at least $10,000)
- GigE's lack of QoS controls limits its ability to offer voice and legacy data services

GIGABIT ETHERNET – OVERVIEW



- Data rates from 1 Mbps to 1 Gbps, but cannot guarantee a committed bit rate
- Supports most data applications (Internet access, transparent LAN services, IP-VPN), but real-time media applications (voice, teleconferencing) require stricter QoS controls
- Requires fiber to the building and GigE switch or router in building. Customer can interface their LAN with switch/router using standard inexpensive Ethernet equipment (CAT5 cable, Ethernet NIC)
- Substitutes: Traditional Private Lines, PONs, LMDS, Free-Space Optics

Advantages:
- Natural interface between Ethernet LANs and the Internet
- Fewer and simpler network elements than SONET
- 8:1 cost savings on opto-electronics over SONET on a per Mbps basis
- Adoption of IEEE 802.3ae ensures interoperability and competition across equipment vendors
- Existing GigE network management systems allow rapid provisioning of additional bandwidth

Challenges:
- Fiber access network infrastructure is underdeveloped
- CPE is too expensive to support deployment to small buildings
- Voice applications are not fully supported
- Does not support legacy data
- QoS cannot match ATM/SONET
- Limited ability to monitor and manage network, detect faults
- Unkproven ability to scale to large/complex networks

Equipment vendors:
- Cisco
- Extreme
- Foundry
- Riverstone

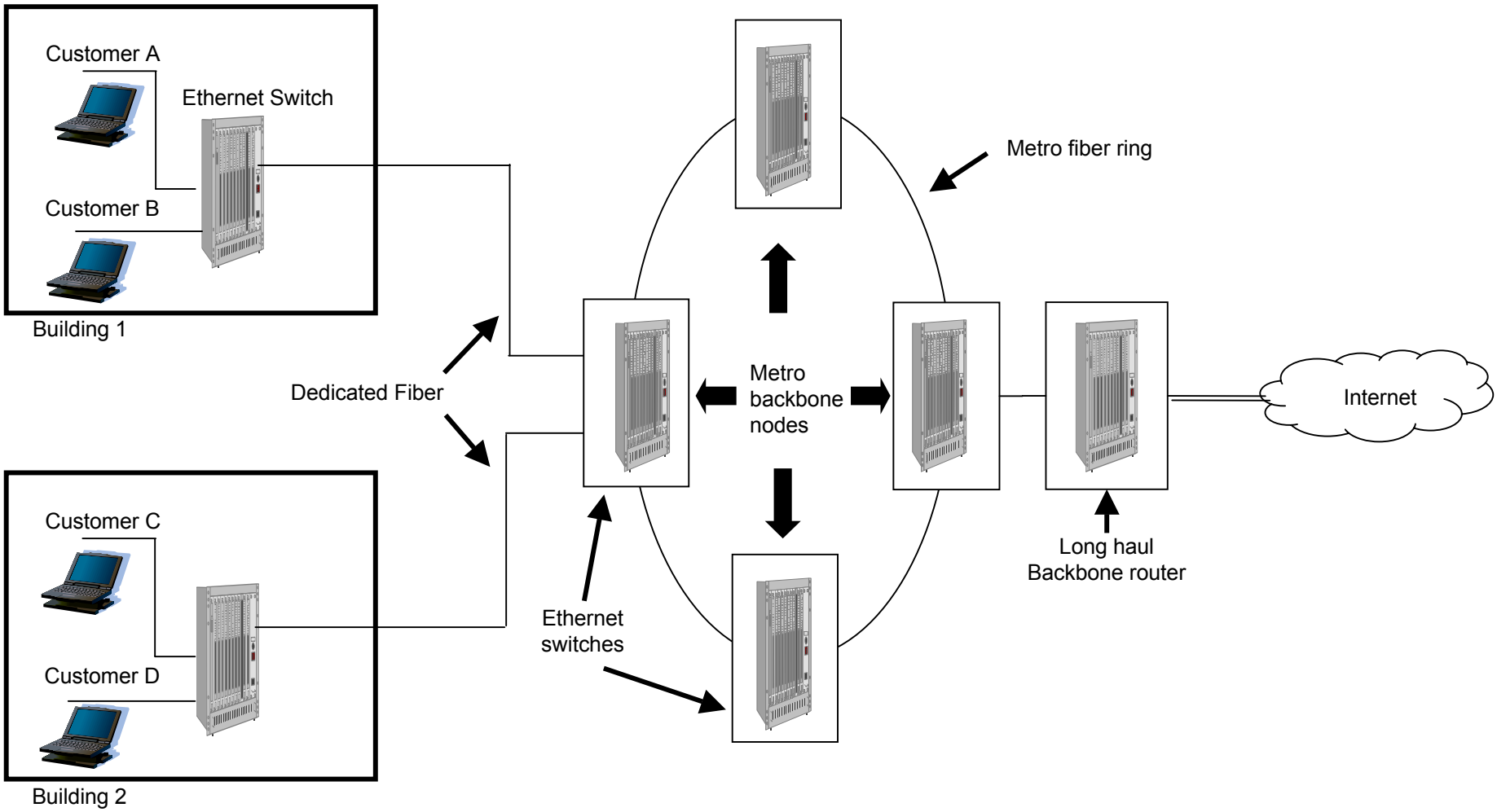
Service providers:
- Cogent
- Yipes
- Intellispace
- XO
- BellSouth
- SBC

Others:
- Network management system providers
- Construction technology

Promising customer segments:
- Internet access to
  - Large and medium enterprises in close proximity to fiber
  - SMEs in large MTUs in close proximity to fiber
  - Consumers in large MDUs or hotels in close proximity to fiber
- Transparent LAN services to
  - Large and medium enterprises with multiple locations near fiber within a metro area

Addressability:
- GigE addresses roughly only 5% of large U.S. buildings and only 8% of U.S. telecom spend

GIGABIT ETHERNET – EXAMPLE HUB AND SPOKE ARCHITECTURE



GIGABIT ETHERNET – FACTORS DETERMINING ADDRESSABLE MARKET SIZE

Factor	Description
Proximity to fiber	• High cost to lay fiber limits reach of GigE. There are roughly 60,000 buildings in the U.S. on or near fiber.
Telecom spend	• High cost of building-level CPE limits market for GigE access to firms in buildings with high levels of wireless telecom spend. Depending on distance from fiber, monthly spend could be as low as $3,000/month, but most candidate buildings spend upwards of $10,000/month*
Data spend	• Since GigE services do not offer carrier-class voice, only data revenues are addressable
IP data spend	• Since GigE cannot support legacy data services (e.g. ATM, Frame Relay, Private Line) only IP data spend is addressable

GIGABIT ETHERNET HAS A BROAD RANGE OF APPLICATIONS

BACK-UP

Access applications

Gigabit Ethernet is a high-speed implementation of Ethernet
- Supports speeds up to 1,000 Mbps
- Is easily interfaced with Ethernet LANs
- Offers up to a 8:1 cost savings on optoelectronics on a per Mbps basis compared to SONET
- Enables flexible provisioning of bandwidth; users can alter their service level on demand and in small increments

Landscape of Gigabit Ethernet Applications

Application	Description	Service Providers	Competing Platforms	Potential Adopters
LAN	• Connect computers and peripherals in a local area network	• In-house IT departments, SIs	• Fast Ethernet, Token Ring, LocalTalk	• Large enterprises and dot-coms needing a high-speed LAN backbone
Internet access	• Provide Internet connectivity at speeds up to 1,000 Mbps	• Yipes • Cogent	• Private line • DSL, MMDS, LMDS, cable, satellite	• Large enterprises, dot-coms and data-centers needing high-speed Internet access • SMEs in MTUs
Transparent LAN services	• Connect multi-site LANs within a metro or across a wide area	• Yipes • XO	• Frame Relay, Private line	• Large and medium enterprises needing to connect LANs across multiple locations
MAN	• Provide metro area network backbone	• Sigma Networks • Telseon	• SONET	• Telecom and hosting service providers with large amounts of traffic within a metro area

Source: Company interviews; McKinsey and JPMS analysis

POLICY-BASED BANDWIDTH MANAGEMENT CAN APPROXIMATE BUT NOT GUARANTEE QOS OVER A GIGE NETWORK

BACK-UP

Policy-based bandwidth management:

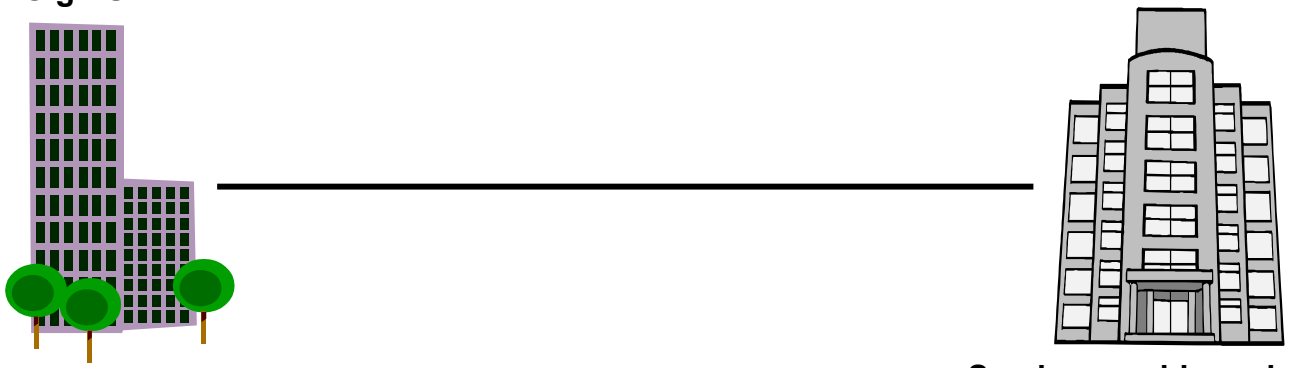
- Tags IP packets with class of service information
- Implement classes of services at IP level with various queuing techniques
- Addresses all four dimensions of QoS
- Cannot guarantee QoS when network operates at or near capacity

QoS Metrics	Description	Solution based on Policy Management
• Bandwidth requirement	• Defines the peak traffic rate as well as traffic pattern (sustained, bursty or interactive)	• Adding bigger pipes according to network scale – Aggregate traffic must be supported by raw bandwidth provided. Ethernet can support speeds from 10/1000 Mbps to 2.5 Gbps
• Latency	• Delay in transmission of data across a network	• Addresses all three of these dimensions by – Defining traffic groups, a high level rule defining overall resource allocation – Defining QoS profiles including : • Relative priority • Minimum bandwidth guaranteed • Maximum bandwidth allowed – Supporting conflict resolution tools that resolve policy precedence issues
• Jitter	• Variation of delays experienced by data packets	
• Packet loss rate	• Percentage of packet lost due to network congestion	

Source: Cisco; Extreme; McKinsey analysis

INCREMENTAL CAPITAL EXPENDITURES TO PROVISION ONE BUILDING FOR BASIC GigE SERVICE

BACK-UP



Customer premise	Fiber	Service provider point of presence
Install switch or router in building:	Connect building to point of presence:	Install GigE port in switch/router[4]:
• $10,000-$20,000	• Leased fiber[2] $750-$1,000/mile/year • New-build fiber[3] $430,000-$540,000/mile	• $5,000-$6,000

1 Various GigE service models exist; the capex noted here describes a basic model where the service provider installs a switch or router in the basement to which the customer(s) are responsible for connecting their LAN(s); various tiers of service may require more expensive CPE (CoS, security, protection switching)
2 Cost to lease a single strand
3 Cost to lay new fiber and conduit underground in central business districts of Tier 1 and 2 markets; cost can be as low as $10,000/mile in less dense areas
4 Does not include allocated cost of switch/router

Source: Company interviews; McKinsey and JPMS analysis

COST TO LAY FIBER – A CLOSER LOOK

BACK-UP

Cost of fiber – roughly the same from installation to installation

Type of cable	Cost per mile
• 12 strands of single-mode fiber – Typically used for laterals	• $2,000
• 96 strands of single-mode fiber – Typically used for metro rings	• $14,000

Cost of construction and ROW* – varies dramatically from installation to installation and from market to market

Construction technique	Cost per mile
• "Aerial" – string along utility poles, mostly rural areas	• $5,000-$10,000
• "Bury" – lay fiber in shallow earth trench, mostly suburban areas	• $20,000-$60,000
• "Directional Bore" – sideways drilling, outlawed in some markets due to collisions with water and gas mains	• $100,000-$120,000
• "Trench" – dig up earth and lay new conduit and fiber, used in urban areas	• $150,000-$550,000
• "Pull-through" – run through existing underground conduit	• $12,000-$25,000

- Several fiber-based service providers quote an average total cost of $100 per foot to lay laterals in central business districts of Tier 1 and 2 markets
- Typical breakdown of costs for typical trenching
  - Labor, 80%-85%
  - Equipment, 5%-10%
  - ROW, 5%-10%
- Performing sensitivity analysis to determine impact of cost-to-lay fiber on size of addressable market

* Costs can vary dramatically from market-to-market, and even block-to-block

Source: Company interviews and websites; McKinsey analysis

GIG-E AS STAND-ALONE BUSINESS MODEL HAS CHALLENGING ECONOMICS

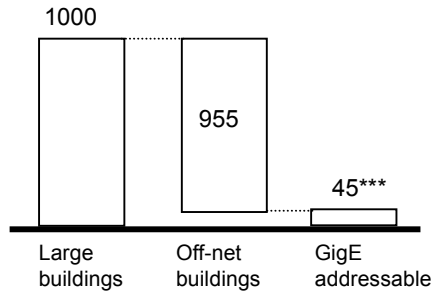
GigE economics highly dependent upon fiber location…

Estimated GigE break-even revenue* per building required to support fiber build
$ Thousands/year

Incremental EBITDA margin	Miles from fiber 0	1/8	¼	½
60%	**12**	**76**	**141**	**270**
70%	**10**	**65**	**121**	**232**
80%	**9**	**57**	**106**	**203**

… currently can address only a small portion of telecom spend

GigE limited without fiber build
On-net buildings, thousands



- Reaches <5% of buildings
- Addressable spend ≈ $25B**
- Total market = <8% of telecom spend

…and adoption faces many additional constraints

- Current lack of voice capability
- Reliability not yet at carrier-class standards
- <10% of SMEs addressable by GigE
- Investors hesitant to fund yet another “commodity” service build out

* Revenue required to break-even on a PV basis within five years, reflecting cost to provision a single building in a dense metro area; breakeven revenue can be lower when construction costs are allocated across multiple buildings or when less expensive construction techniques and ROWs are available; CAPEX includes costs of optoelectronics at $12,000 and cost to lay new fiber and conduit underground at $540,000/mile; provider pays 10% of gross revenues for access to building; WACC=16%; tax rate=41%; FCF=EBITDA x (1-tax rate)

** 31% of total datacomm spend

*** Performing sensitivity analysis to determine impact of alternative construction techniques on reach of fiber

Source: JPMS; McKinsey; FCC; IDC; Company reports

TECHNOLOGIES PROFILED

Wireline

Twisted Copper Pair
- xDSL
- Voice-over-DSL

Hybrid Fiber Coax
- Cable Modem/VoIP

Optical Fiber
- Gigabit Ethernet
- **Passive Optical Networks**

Powerline
- Powerline Telecommunications

Wireless

Fixed
- MMDS
- LMDS
- Free-space optics
- Unlicensed fixed wireless
- Wireless Mesh
- Satellite

Nomadic/mobile
- WLAN
- Next-Generation Mobile

PASSIVE OPTICAL NETWORKS (PONs) – TALKING POINTS

Basics

- Passive optical networks are a relatively inexpensive platform for extending and operating fiber deeper into access networks
- PONs are likely to be deployed first in new neighborhoods providing
  - Fiber to the home or small-business in rural areas
  - Fiber to the curb in denser areas
- PON hardware market was $35 million in 2000

Issues

- While PON is a relatively inexpensive platform for deep fiber, it still faces serious issues common to all fiber platforms:
  - Expense to lay fiber infrastructure (at least $10,000 per mile)
  - Cost of CPE (currently at $4,000)

PASSIVE OPTICAL NETWORKS (PONs) – OVERVIEW

Platform basics

- A single fiber connection, carrying up to 1.25 Gbps is shared among up to 64 users
- Three major “layer two” protocols for PON, in order of increasing cost
  - BPON: Broadband PON
  - EPON: Ethernet PON
  - APON: ATM PON
- APON can guarantee QoS
- PONs support all IP applications. APON supports voice and other real-time applications, as well as TDM, ATM, and frame. BPONs can efficiently support broadcast video
- Requires fiber to the customer premise, and Optical Network Unit (ONU) as CPE
- Substitutes: cable modem, xDSL, dedicated fiber

Advantages / Challenges

Advantages:
- Shared architecture uses outside plant efficiently, reducing cost per customer to deploy network
- Passive nature of outside plant reduces operational expenses (power and maintenance)
- FSAN G.983 standard for APON ensures competition and interoperability between equipment vendors
- Existing CPE can support either Ethernet, ATM or TDM at customer site
- In the long run, FSAN DWDM standards may provide an efficient means for scaling PON capacity

Challenges:
- Fiber access infrastructure to households and SMEs is not in place
- CPE is currently too expensive ($4,000) for most households and SMEs
- PON’s shared medium requires additional overhead to ensure
  - Security
  - QoS

Equipment vendors / Service providers

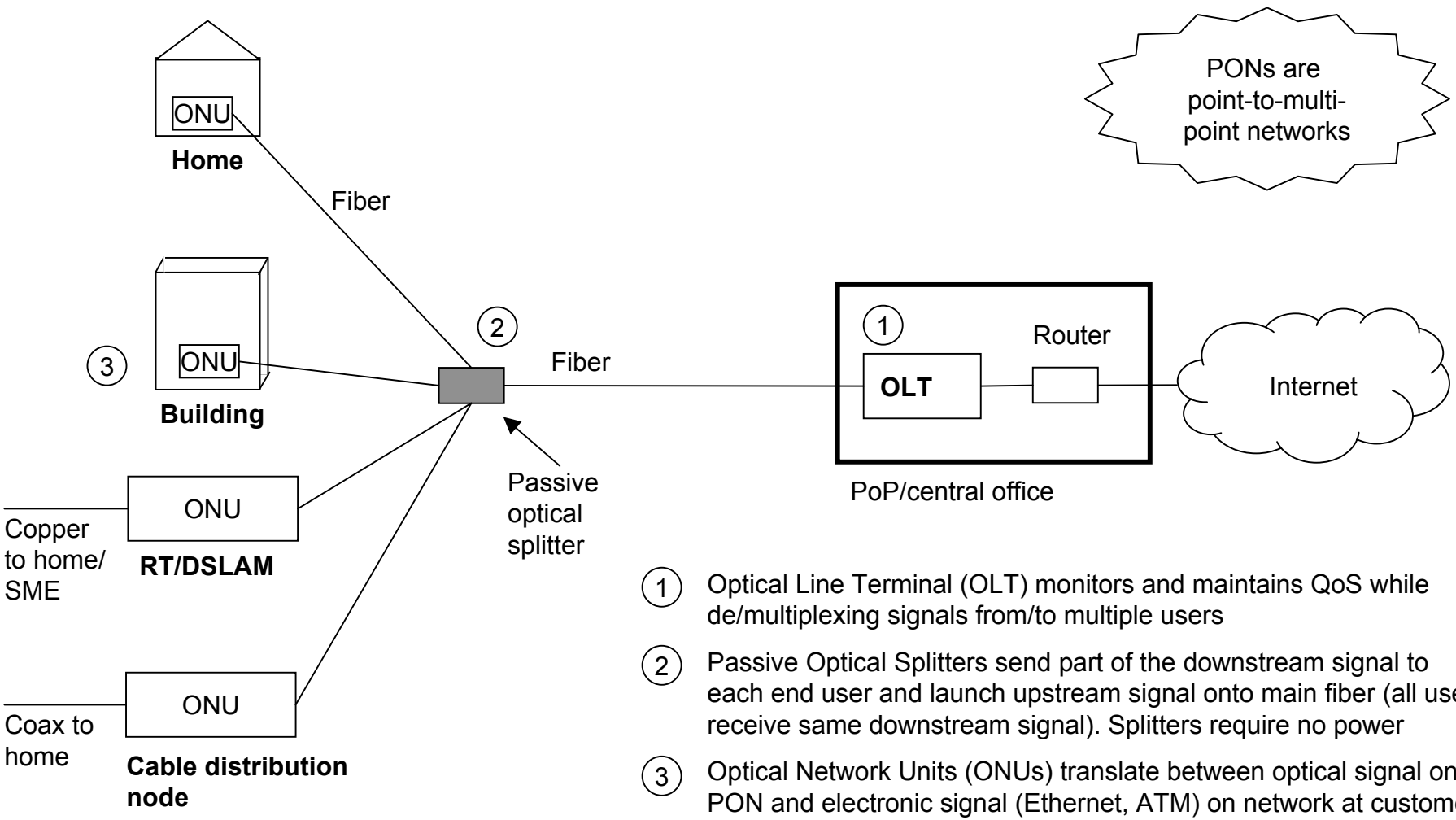
Equipment vendors:
- APON
  - Alcatel
  - Lucent
  - NEC
  - Quantum Bridge
  - Terawave
- EPON
  - Cisco
  - Nortel
  - Worldwide Packets
  - OnePath
  - AllOptic
- BPON
  - Lucent
  - Marconi
  - Paceon
  - Optical solutions

Service providers
- SBC plans to roll out Paceon’s WDM/BPON to 9,000 SMEs and 6,000 households by EOY 2002 (Supercomm 2001 announcement)
- Bell South has done trials with APON
- A number of small incumbent telcos in rural areas

Customers

Promising customer segments:
- Fiber to the home, especially in low density areas with no existing DSL or HFC plant, providing Internet access or bundled voice, data and video to households and SMEs
- Fiber to the curb, especially in relatively dense new neighborhoods in urban/sub-urban areas, increasing available data rates for:
  - xDSL, by reducing loop length
  - HFC, by reducing the number of customers per node

PON – SCHEMATIC TECHNOLOGY OVERVIEW*



1. Optical Line Terminal (OLT) monitors and maintains QoS while de/multiplexing signals from/to multiple users
2. Passive Optical Splitters send part of the downstream signal to each end user and launch upstream signal onto main fiber (all users receive same downstream signal). Splitters require no power
3. Optical Network Units (ONUs) translate between optical signal on PON and electronic signal (Ethernet, ATM) on network at customer premise

* For data service only. Voice and video may require additional equipment at PoP/CO

PON – FACTORS DETERMINING ADDRESSABLE MARKET SIZE

Factor	Description
Cost to lay fiber	• High cost to lay fiber limits reach of PON. There are currently about 60,000 fiber-addressable buildings in the U.S.
Telecom spend	• Expensive CPE (>$500) and high cost to provision limits market for PON to households/SMEs who spend a large amount on data, voice, and video
Video spend	

PON EQUIPMENT COSTS

ONU

- ONU (CPE) about $4,000 today, could drop to $500 as manufacturers achieve scale and less expensive components become available

Splitters

- About $50 per customer (more for DWDM)

OLT

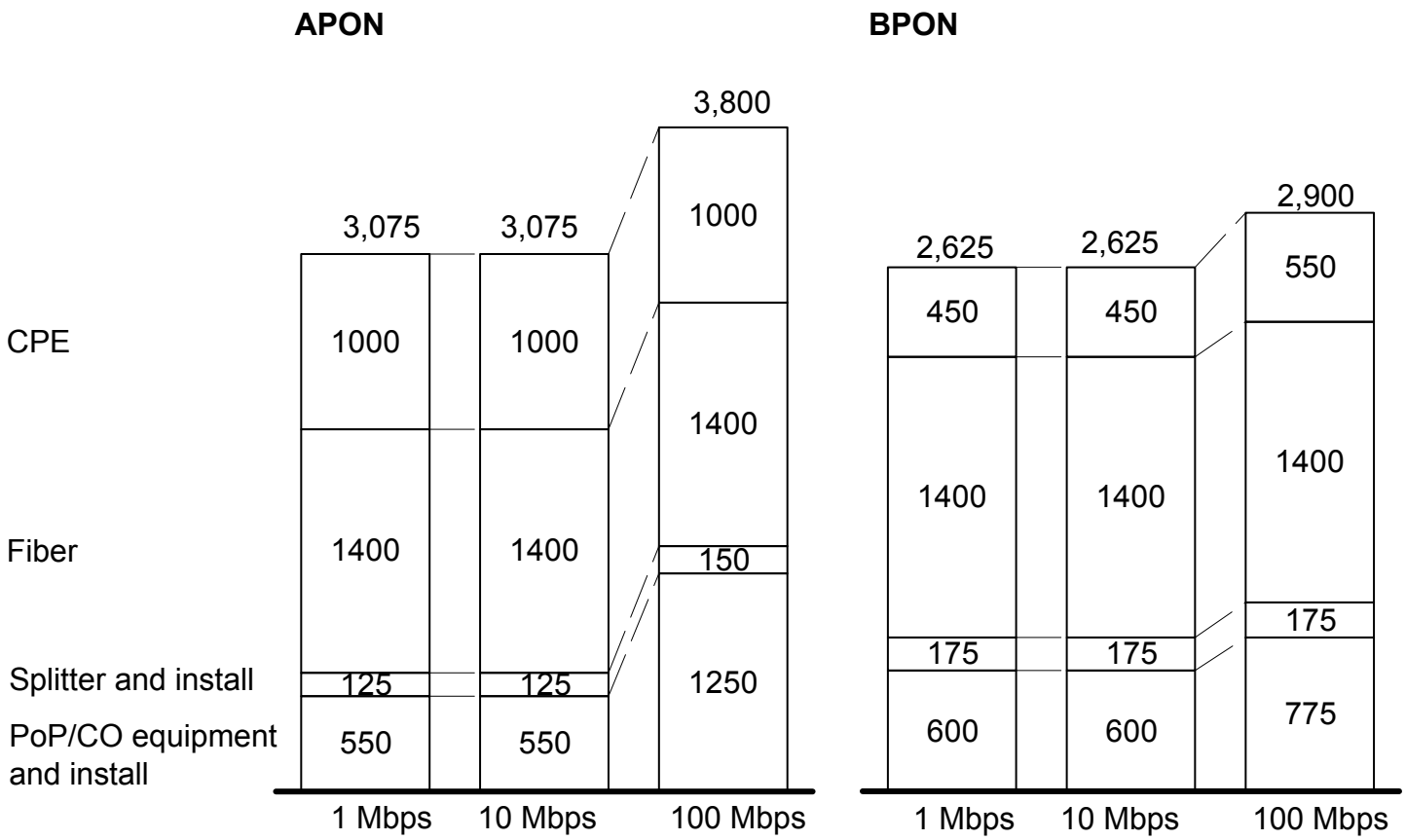
- OLT (at PoP/CO) supporting 16 nodes currently costs $6,000, could drop to $3,000 as manufacturers reach scale

Source: Merrill Lynch 2Q01; McKinsey estimates 2000

BREAKDOWN OF PON FTTH CAPEX

ROUGH ESTIMATE

Capital expenditures – voice, data and video
$ per sub



Assumptions

- 1,000 homes/sq mi.
- PON at 35% capacity (35 subs/100 homes passed)
- Greenfield deployment
- Forward-looking ONU/OLT pricing based on vendors attaining scale

Source: McKinsey analysis and estimates (2000)

TECHNOLOGIES PROFILED

Wireline

Twisted Copper Pair
- xDSL
- Voice-over-DSL

Hybrid Fiber Coax
- Cable Modem/VoIP

Optical Fiber
- Gigabit Ethernet
- Passive Optical Networks

Powerline
- **Powerline Telecommunications**

Wireless

Fixed
- MMDS
- LMDS
- Free-space optics
- Unlicensed fixed wireless
- Wireless Mesh
- Satellite

Nomadic/mobile
- WLAN
- Next-Generation Mobile

POWERLINE TELECOMMUNICATIONS – TALKING POINTS

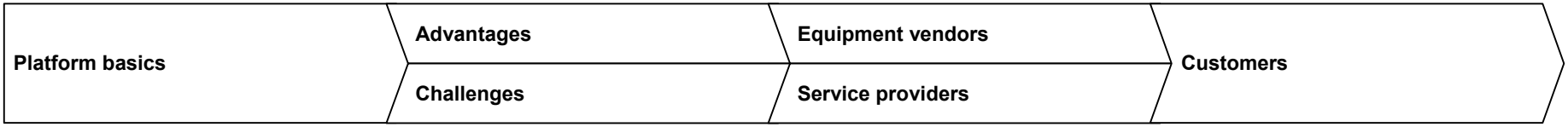
Basics

- Provides high speed Internet access via electrical grid
- PLT is a potentially disruptive technology
  - Exploits the ubiquitous electric utility grid to provide high speed Internet access
  - Based on technology developed for home powerline networks
  - Leverages RF signal processing techniques used in HFC, DSL, and wireless
- Significant development and experimentation in Europe (>10 trials, first commercial roll-out announced)

Issues

- Significant technical hurdles
  - Harsh RF environment created by electrical grid
  - Shared media network was not designed with a communications network topology
  - Cost of getting signal onto low voltage net, particularly in U.S.
- Lack of industry base
  - No suppliers with volume production, sales and service support
  - No commitment by electrical utilities, high cost of their work force
- Regulatory issues including RF emission, cost allocation, jurisdiction

POWERLINE TELECOMMUNICATIONS – OVERVIEW



- Transmits data over electrical power grid
- Provides high-speed Internet access at speeds up to several Mbps per user
- Backhaul connection by fiber. Some architectures use power grid or wireless for backhaul
- Shared media architecture similar to cable modem system
- CPE consists of Universal Information Box that takes signal from power grid and connects to LAN or PC in home or business either directly or through home powerline network

Advantages:
- Exploits powerline infrastructure
  - Does not new digging and/or stringing poles
  - No need for antennae siting and spectrum purchases
- Network costs can be shared with new power management applications
  - Time of day billing
  - Load shedding
  - Meter reading
- Synergy with home powerline networking

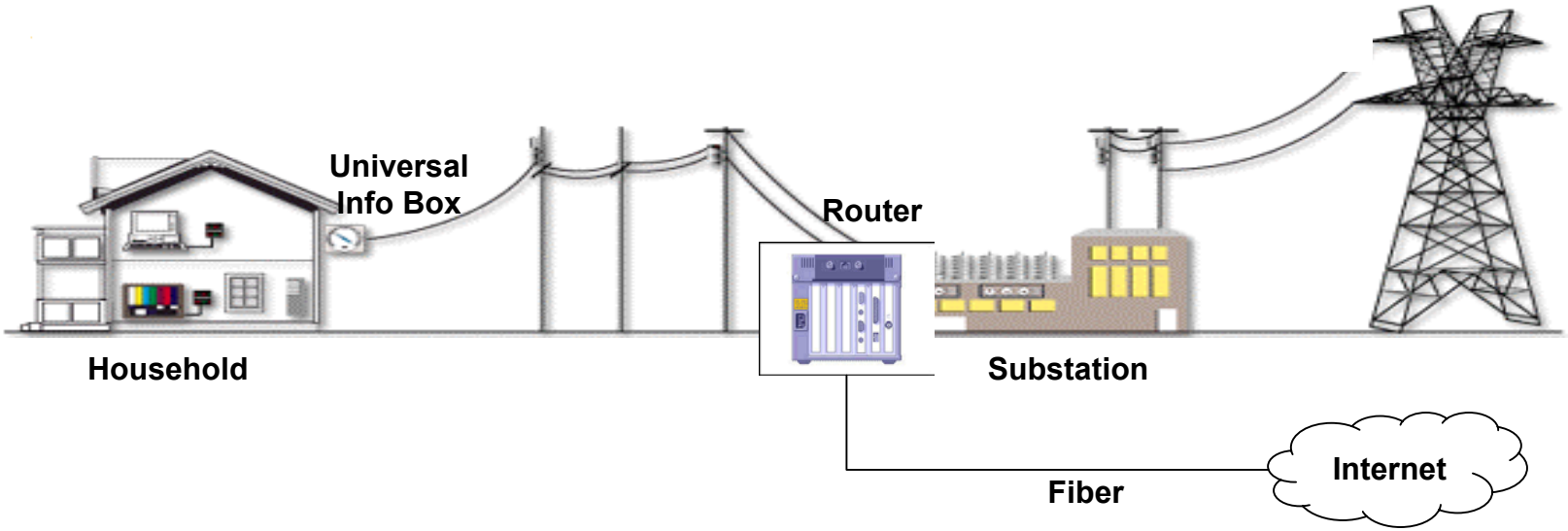
Challenges:
- Unproven technology
  - Harsh RF environment within powerlines
  - Network management and security in shared media network
- Professional installation by expensive highly trained labor in network & CPE
- Regulatory Issues
  - Powerline RF emissions limits
  - Utility regulations: prices, equality obligations, cost allocation
  - Jurisdiction
- Lack of manufacturing infrastructure
  - No volume production
  - No sales channel, servicing
- Capacity/scalability, particularly in countries with low subs beyond last transformer

Equipment vendors:
- Keyin
- Ascom
- ABB
- Alcatel
- Siemens
- ONELINE
- Enikia
- Norweb (Nortel subsidiary – exited market in ’99 due to cost of going to scale)

Service providers in test
- VEBA AG
- RWE
- MVV AG
- Tenaga
- EnBW
- Endesa
- EDP
- Two U.S. trials in ’99 discontinued when Norweb exited business
- New U.S. trials underway

Promising customer segments:
- Areas with low DSL addressability and/or lack of cost effective cable modem access
- Areas with favorable cost of deployment (e.g.customers per substation) and low customer opinion of current service providers

POWERLINE TELECOMMUNICATIONS ARCHITECTURE – ONE EXAMPLE



Needed add-ons	Short explanation
Router	• Interface between the server and households served by the router (communicates with all houses connected to the substation)
Universal information box	• The device connects the house to the PLT network and communicates with the previous and next device in the network. Therefore per location its function differs between a modem, a repeater and a network interface. Current device estimated to cost $800 for simple version

Many variations of this architecture exist, including wireless bypass of low voltage net and U.S. specific architectures

Source: Deutsche Bank; Yankee Group; internet sites of utilities and manufacturers (see appendix)

MAIN IDENTIFIED PLAYERS IN TESTING PLT

Worldwide

Utility	Manufacturing partner	Country	Bandwidth	Status
VEBA AG	• ONELINE	• Germany	• 2 Mbps	• Successful test over 8 households; expanding to >200 households by end of 2000
RWE	• Keyin • Ascom	• Germany	• Testing at 1.5 - 2 Mbps • 1st generation will be 3 Mbps	• Testing with Ascom in Leichlingen • On market in beginning 2001
MVV AG	• ABB • Alcatel	• Germany		• Fuchs Petrolub first commercial customer in may 2000
Tenaga	• Keyin • Ascom	• Malaysia		• Testing
EnBW Endesa	• Siemens	• Germany • Spain	• > 1 Mbps	• To market in 2001 • Testing
Enel	• Ascom	• Italy		• Testing
Iberdrola	• Ascom	• Spain		• Testing
EDP	• Ascom	• Portugal		• Testing
United Utilities	• Nortel	• United Kingdom		• Technology dropped in 1999

Note: Statement from CEO of RWE Energie (Manfred Remmel)
Source: Deutsche Bank; Internet

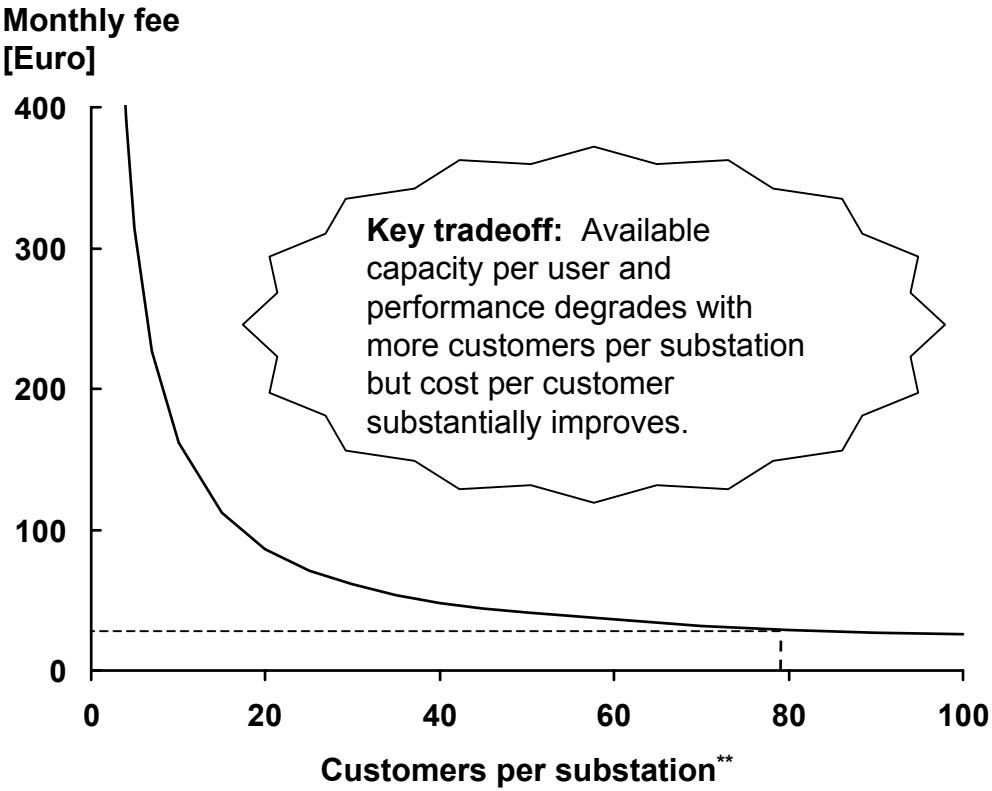
MAIN IDENTIFIED MANUFACTURES DEVELOPING PLT TECHNOLOGY

Worldwide

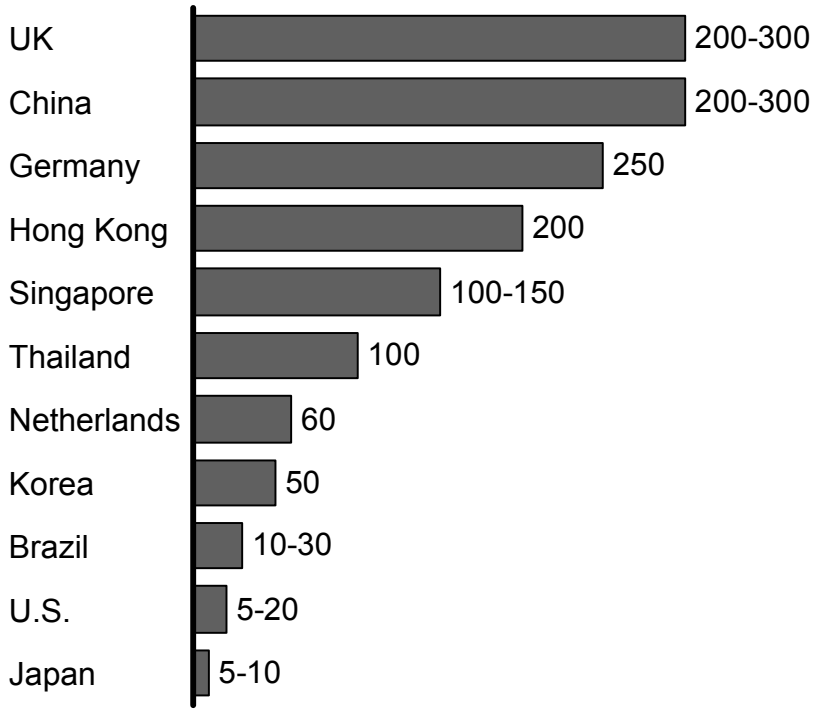
Manufacturers	Location	URL	Status
Alcatel	• Hannover, Germany	• www.ke-online.de	• Field trial with RWE in Essen • Running at 2.3Mbps over 400-2000m (including repeater) over middle voltage net
Ascom	• Magenwil, Switzerland	• www.ascom.ch/plc	• Field trial running at 1.3Mbps with RWE in Leichlingen (objective 2Mbps) • 1st generation running at 3Mbps • 350m;12MHz;250 houses
Keyin	• Seoul, Korea	• www.keyin.co.kr	• Low voltage net: 4Mbps • Expectations middle voltage net: – 3Mbps per channel in 2000 – 10Mbps per channel in Q3 2001
ONELINE *Siemens*	• Barleben, Germany • Nurnberg, Germany	• www.oneline-ag.de • www.siemens.de/plc	• Claim bandwidth of 8Mbps in access area • Field test in Salzburg running • Bandwidth of 2.3Mbps over 300m; 6MHz; 200 houses • Q1 2001 to market

ECONOMICS ARE HIGHLY DEPENDENT ON TOPOLOGY AND OTHER NATIONAL NETWORKS FACTORS
EXAMPLE: SUBSCRIBERS PER SUBSTATION – EUROPEAN EXAMPLE

Monthly fees required to achieve 10% return*



Number of households per substation in different parts of the world



* Calculations for the Keyin system based upon a WACC of 10% and a forecast period of 10 years.

** Number of customers is determined by:
- Customers reached (= number of households per substation)
- Penetration

Source: Deutsche Bank, McKinsey Analysis

TECHNOLOGIES PROFILED

Wireline

Twisted Copper Pair
- xDSL
- Voice-over-DSL

Hybrid Fiber Coax
- Cable Modem/VoIP

Optical Fiber
- Gigabit Ethernet
- Passive Optical Networks

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Wireless

Fixed
- **MMDS**
- LMDS
- Free-space optics
- Unlicensed fixed wireless
- Wireless Mesh
- Satellite

Nomadic/mobile
- WLAN
- Next-Generation Mobile

MULTIPOINT MULTI-CHANNEL DISTRIBUTION SERVICE (MMDS) – TALKING POINTS

Basics

- MMDS is a multi-service platform originally created to deliver video that is now also being used to offer Internet access to residential and small business customers
  - Current: data-only service requiring rooftop installation and line-of-sight. Data-service based on cable modem (DOCSIS 1.0)
  - Emerging: integrated desktop CPE offering voice and data, higher data rates, lower price points (expected mid-2002)
- Sprint and WorldCom have licensed most of the spectrum, with 30M and 45M licensed household, respectively
- MMDS service revenues totaled $28 million in 2000 over a base of 39 thousand subscribers in about 70 markets

Issues

- Sprint and WorldCom have dramatically scaled-back MMDS deployment plans (Sprint has deployed in 20 out of 80 licensed markets, WorldCom in 5 out of 160)
- Line-of-sight limitations, high cost of CPE ($500-$700), and difficult installation reduce addressable market size and have slowed deployment
- Spectrum is difficult to consolidate into substantial contiguous geographic and spectral pieces. Spectrum may be reallocated for mobile applications (3G)

MMDS – OVERVIEW

Platform basics | **Advantages** / **Challenges** | **Equipment vendors** / **Service providers** | **Customers**

- MMDS broadband access is delivered over multiple spectral bands, allocated in 6 MHz channels:
  - MDS, near 2.2GHz, 2 channels
  - ITFS, 2.5-2.7GHz, 20 channels
  - MMDS, 2.6-2.7GHz, 11 channels
- CPE consists of antenna, radio, and modem
- Current CPE supports data rates up to 5Mbps, (typical: 1-2Mbps down, 128-256Kbps up) actual data rates depend on number of simultaneous users and distance from base station
- 6MHz channels each support 10-27Mbps, depending on modulation scheme and distance from base station
- Requires near line-of-sight between CPE and base station
- Current equipment supports data only. Next generation systems are being developed to offer voice
- Substitutes: xDSL, cable, other fixed wireless, satellite

Advantages:
- Cell radii up to 30 miles
- Scalability by cell splitting
- Offers CLECs and IXCs a facilities-based DSL-quality solution independent of ILECs

Challenges:
- Line-of-sight reduces addressable market size
- High cost of CPE makes MMDS unattractive to residential customers
- Installation: requires expensive truck-roll ($200-$300)
- Regulation making spectrum difficult to acquire and operate
- Risk of reallocation to mobile applications
- Does not support voice service

Equipment vendors:
- Incumbent (based on cable modem)
  - Hybrid networks
  - Vyyo (ADC, Nortel resells)
  - Breezcom (outside U.S., Alcatel resells)
- Next-generation (mid-2002)
  - Cisco
  - NextNet
  - Iospan
  - Malibu Networks
  - Aperto

Service providers
- National/regional operators
  - Sprint
  - WorldCom
  - Nucentrix
  - (Bell South – video only)
- Local operators
  - More than 250 operators provide “wireless cable” over MDS, ITFS, and MMDS bands
  - About 25 of them are offering data services

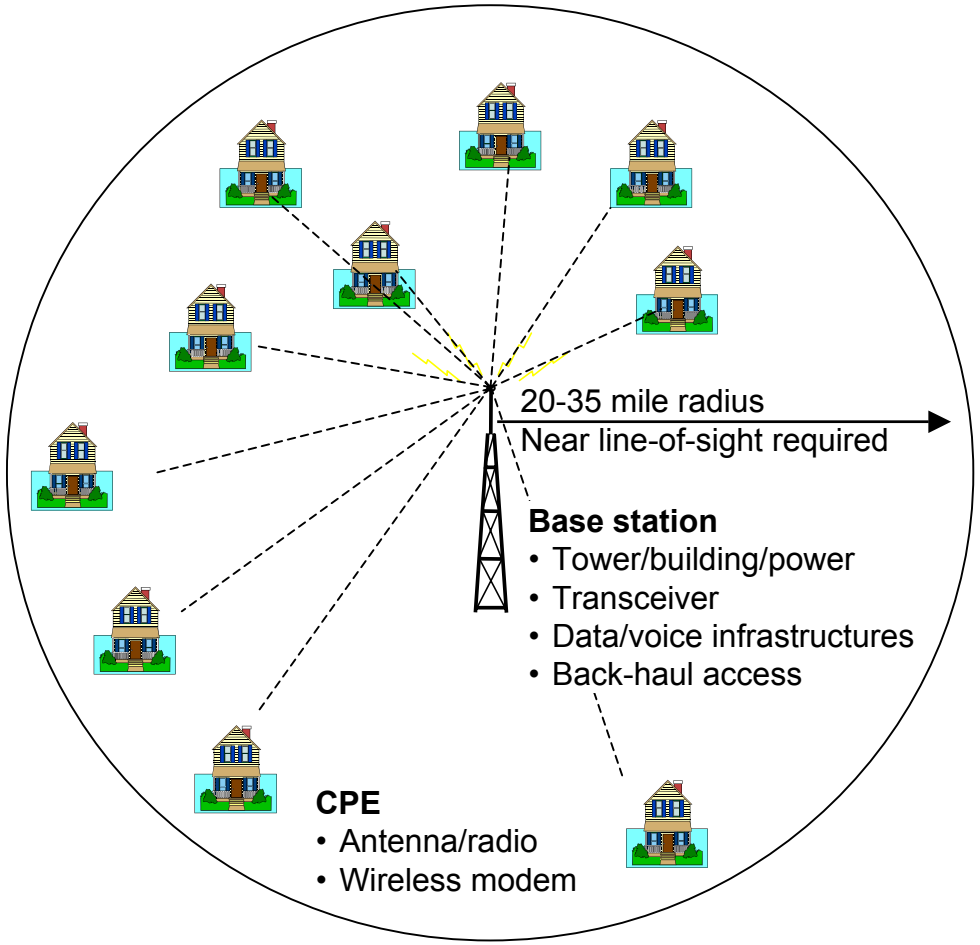
Promising customer segments:
- Residential, SOHO, SME in suburban and rural areas not covered by HFC or xDSL

Market size:
- About 39,000 subscribers in the U.S. in 2000

MMDS – NETWORK ARCHITECTURE

Cell capacity

- 10-27Mbps of shared capacity per 6MHz channel
- Using existing duplexing technology,* upstream and downstream channels must be separated by 4 channels*
- An operator owning all 11 MMDS channels can support a total downstream capacity (5 channels) up to 135Mbps and upstream capacity up to 54Mbps in a single unsplit cell
- Splitting cell into sectors or smaller cells increases capacity through spectrum reuse



* Frequency Division Duplexing (FDD) puts upstream and downstream data on separate channels, which must be separated by roughly 4 channels to minimize interference. Time Division Duplexing (TDD) an emerging technology, allows upstream and downstream data to travel over same channel, with more efficiency use of spectrum

Source: Company interviews; McKinsey analysis

MMDS – FACTORS DETERMINING ADDRESSABLE MARKET SIZE

Factor	Description
Terrain	• Topography, trees, and building can disrupt line-of-sight
Rooftop access	• Customers in MTUs/MDUs may not have access to rooftops
Data spend	• Currently deployed MMDS systems only support data service
Availability of wireline access	• Hassles of rooftop installation and lack of support for voice may lead customers to choose wireline technologies (xDSL, HFC) over MMDS

TECHNOLOGIES PROFILED

Wireline

Twisted Copper Pair
- xDSL
- Voice-over-DSL

Hybrid Fiber Coax
- Cable Modem/VoIP

Optical Fiber
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LOCAL MULTIPOINT DISTRIBUTION SYSTEM (LMDS) – TALKING POINTS

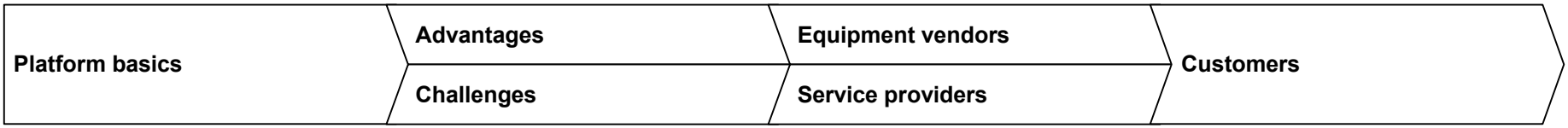
Basics

- LMDS provides high-capacity point-to-point and point-to-multipoint fixed wireless connections delivering voice and data services
- LMDS is targeted at large enterprises and MTUs as a substitute for fiber
- U.S. LMDS equipment revenues were roughly $100 million in 2000

Issues

- LMDS-pure-plays have collapsed under large customer and site acquisition costs, substantial customer installation and base station costs, and concerns about reliability
- Strict line-of-sight and range limitations limit addressable market size
- Expensive CPE (at least $5,500) and difficult installation limits applicability to large enterprise and MTU markets

LOCAL MULTIPOINT DISTRIBUTION SYSTEM (LMDS) – OVERVIEW



- LMDS access systems operate in spectral bands above 10GHz*
- LMDS is deployed in two architectures, point-to-point and point-to-multipoint
- Supports data rates up to 155 Mbps
- Basic CPE consists of rooftop antenna, radio, and modem. MTU service requires additional switch/router and risers
- Customer must be within 2 mi and have a direct line-of-sight to the base station
- Supports all data applications in addition to voice and broadcast video
- Substitutes: fiber, xDSL, and T1/T3 over copper

Advantages:
- Service features rivaling fiber without the need to lay fiber, and relatively low up-front capital required
  - – Relatively rapid deployment
  - – Relatively low maintenance and operating costs
- LMDS bands have a lot of capacity, with 1.15GHz in the proper LMDS band alone

Challenges:
- Line-of-sight restrictions limit addressable market size
- Range limitations require dense base station coverage
- Equipment is expensive
- Installation is expensive

Equipment vendors:
- Alcatel
- Floware (retail through Siemens, NEC)
- Triton Network Systems
- Netro (sold to Lucent, which exited)
- Nortel (exited)

Service providers
- XO holds licenses covering 95% of population in top 30 markets. Number of customers un-disclosed
- Winstar – bankrupt April 2001
- Teligent – bankrupt May 2001

Promising customer segments:
- Large and medium enterprises and MTUs just outside the reach of fiber networks
- Potential opportunity in parts of Latin America and of Asia where availability of fiber is limited and incumbents are slow-moving
- Roughly 3% of buildings in the U.S. are within LMDS's sweet-spot (near, but not on fiber). Within these buildings lie 2% of SMEs, spending $2 billion on telecom per year

* Strictly speaking, the LMDS band resides between 28 and 31GHz, but with Teligent and Winstar deployments at 24 and 38GHz, the term has been applied more broadly

LMDS – NETWORK ARCHITECTURE

Central office

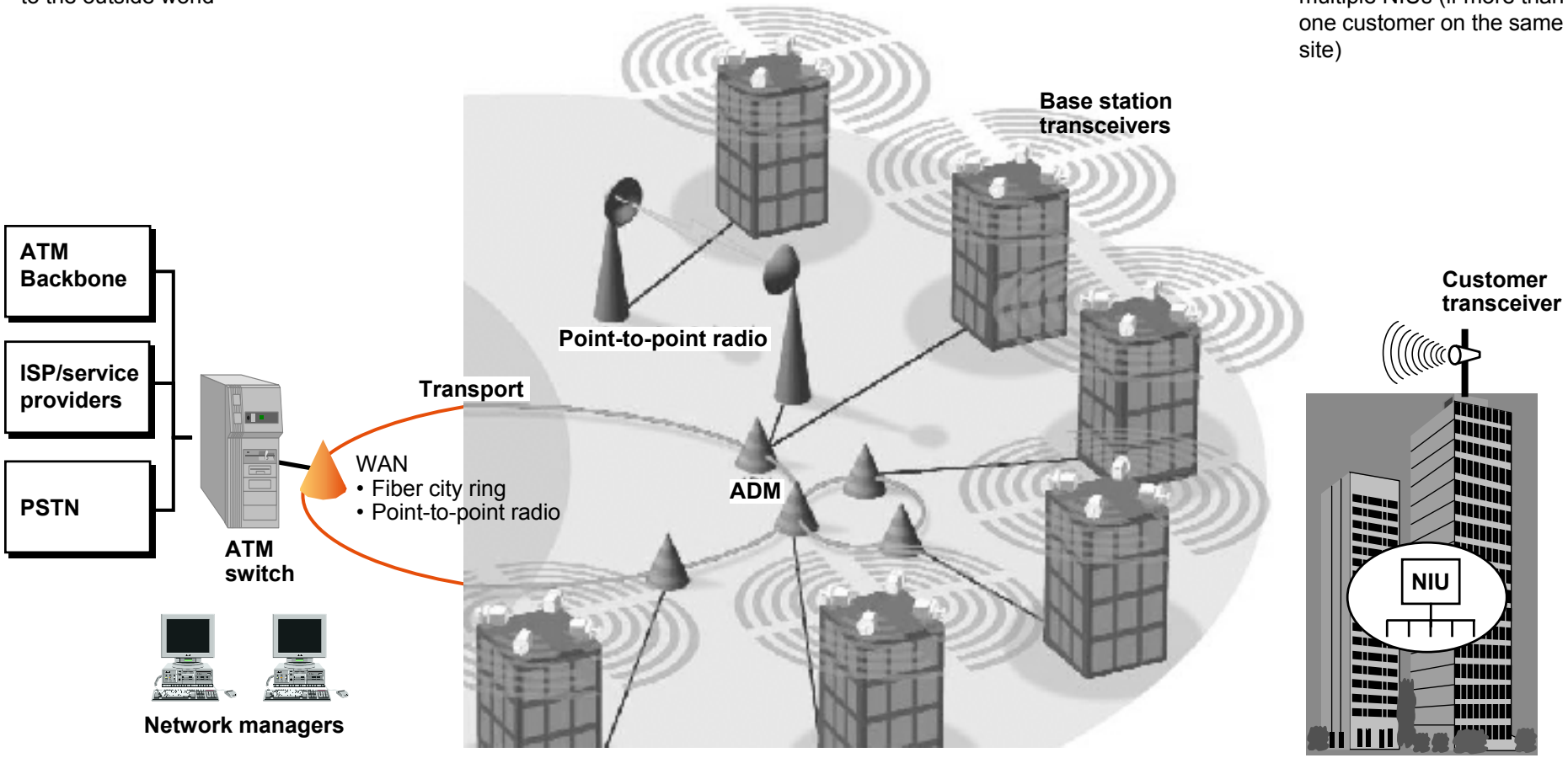
The network is centrally managed from the central office with wireline connections to the outside world

Base stations

Several base stations are installed on top of buildings or towers and are interconnected either via fibre or radio

Customers

At the customer site a transceiver is installed which is connected to one or multiple NIUs (if more than one customer on the same site)



Acronyms: ADM – Add/Drop Multiplexer; NIU – Network Interface Unit

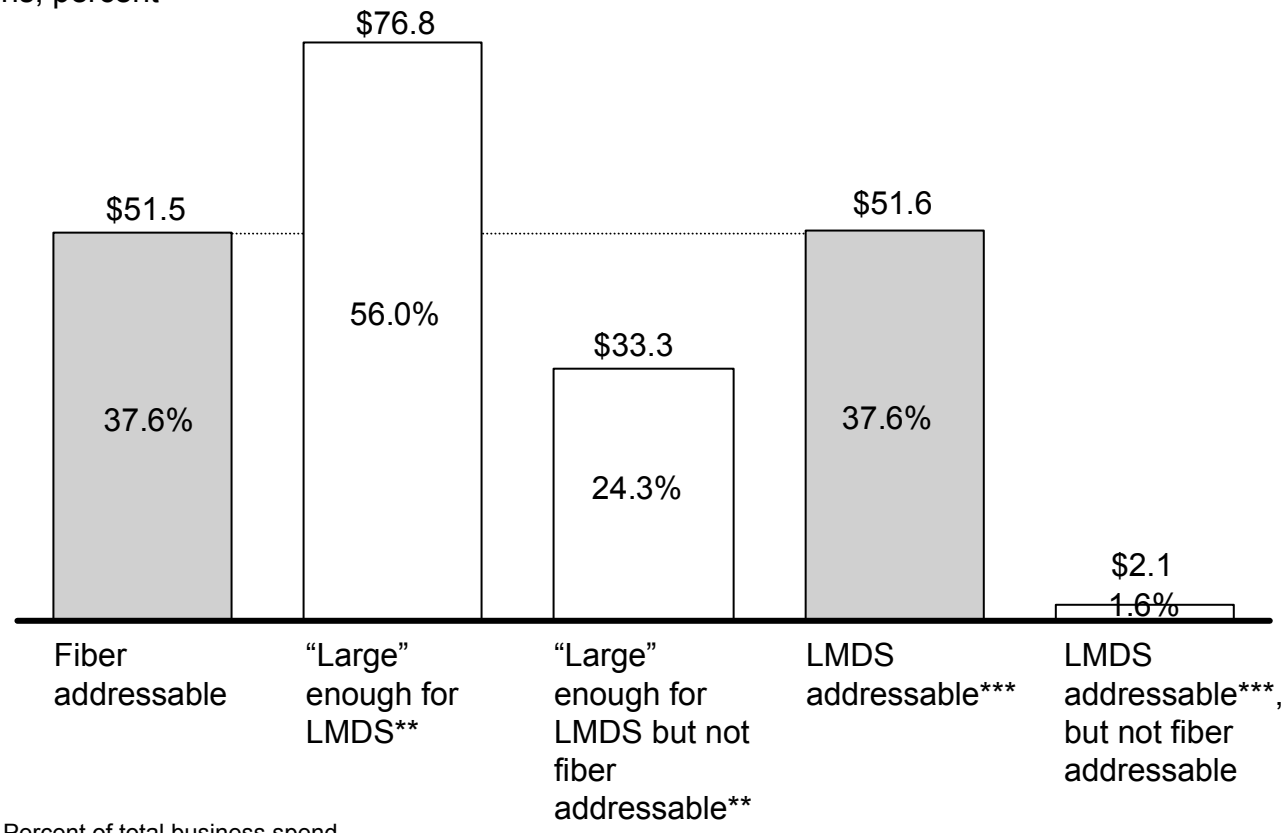
Source: Lucent; Nortel

LMDS – FACTORS DETERMINING ADDRESSABLE MARKET SIZE

Terrain	• Topography, foliage, and buildings can disrupt line-of-sight. LMDS requires customers to have strict line of sight between CPE and base station
Rooftop access	• Customers in MTUs/MDUs may not have rooftop access • Landlords may charge high-rates for access
Availability of wireline access	• Hassles of rooftop installation may lead customers to choose wireline technologies (xDSL, fiber) over LMDS • On the other hand, in order to provide backhaul connectivity, base-stations cannot be too far from fiber
Datacom Spend	• High cost of CPE limits service to customers/MTUs with high-levels of datacom spend

LMDS' MTU-ADDRESSABLE BUSINESS SPEND IS VERY SIMILAR TO FIBER'S

$ Billions; percent*



* Percent of total business spend

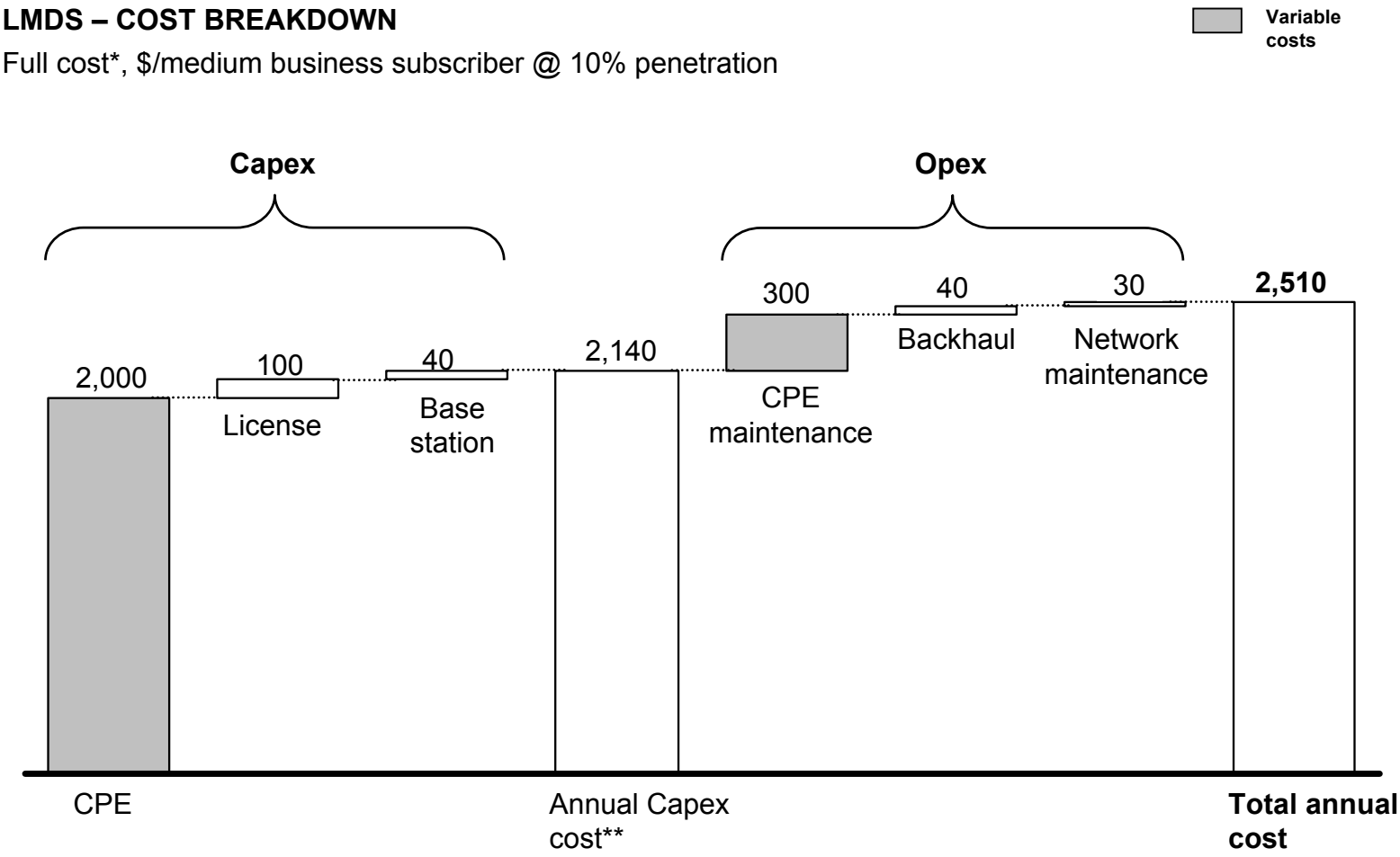
** "Large" = $7,500 total business monthly spend in building; based on LMDS model discussed in Broadband 2001

*** LMDS addressable = "Large" and within 2 miles of fiber node; fiber nodes include buildings with $55,000 monthly business spend, CO's and POPs

Source: McKinsey Telecom Database; JP Morgan; McKinsey analysis

LMDS – COST BREAKDOWN

Full cost*, $/medium business subscriber @ 10% penetration



* Cost to provide the local connection, including network cost (no other costs included, e.g. marketing, churn, …)

** All capex depreciated over 10 years, except CPE depreciated over 3 years

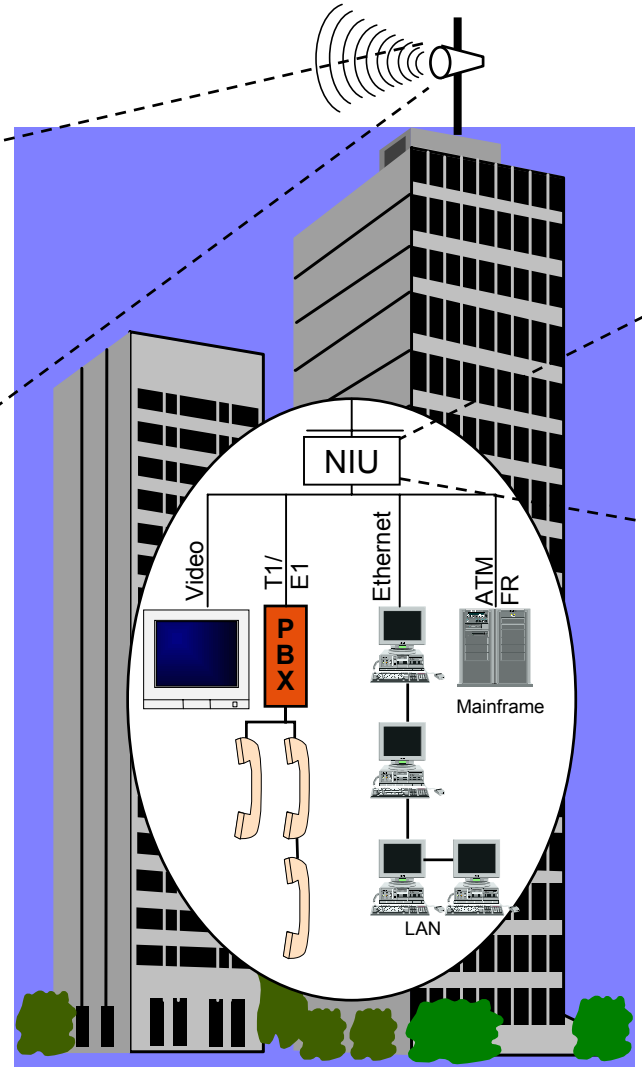
Source: McKinsey analysis

LMDS – A CLOSER LOOK AT CPE

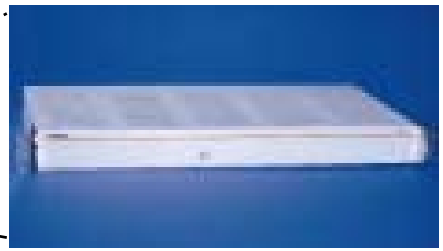
BACK-UP

Customer transceiver

- Small (~30 cm) roof-mounted antenna pointed directly at a base station transceiver
- Need only one transceiver per premise



Network interface unit (NIU)



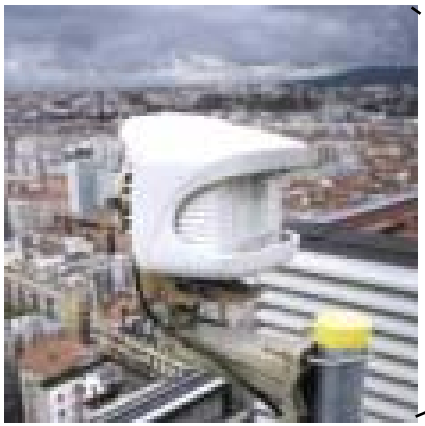
- Small rack-mounedt equipment with multiprotocol terminating jacks
- Exact configuration NIUs vary widely by vendor, each having its own characteristics
  - Nortel had models with 2 E1s and another with 4 E1s and a 10 Base T
  - Newbridge/Alcatel NIUs support T1/E1 or quadruple T1s, Ethernet, or OC-3

Source: Alcatel; Nortel; Lucent

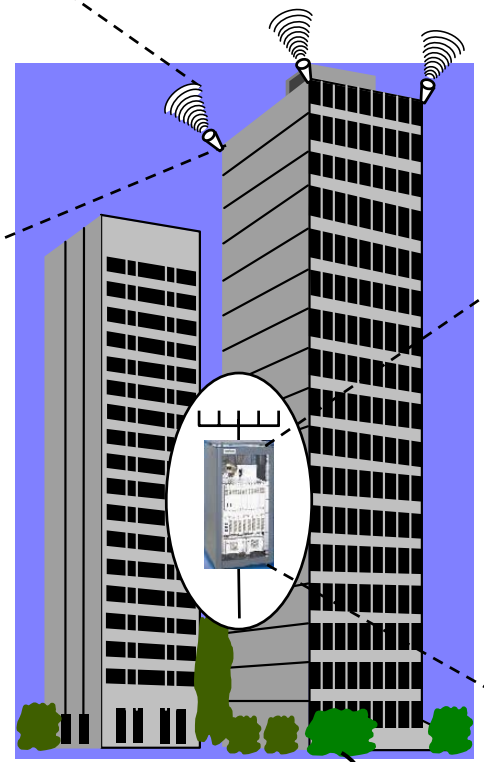
LMDS – A CLOSER LOOK AT BASE STATION EQUIPMENT

BACK-UP

Base station transceiver



- Most cell sites are divided into 90° (azimuth) sectors
- A separate transceiver is used for each individual sector
- Each transceiver (sector) can use the full spectrum allocation



To WAN via fibre or point-to-point radio link

Digital controller

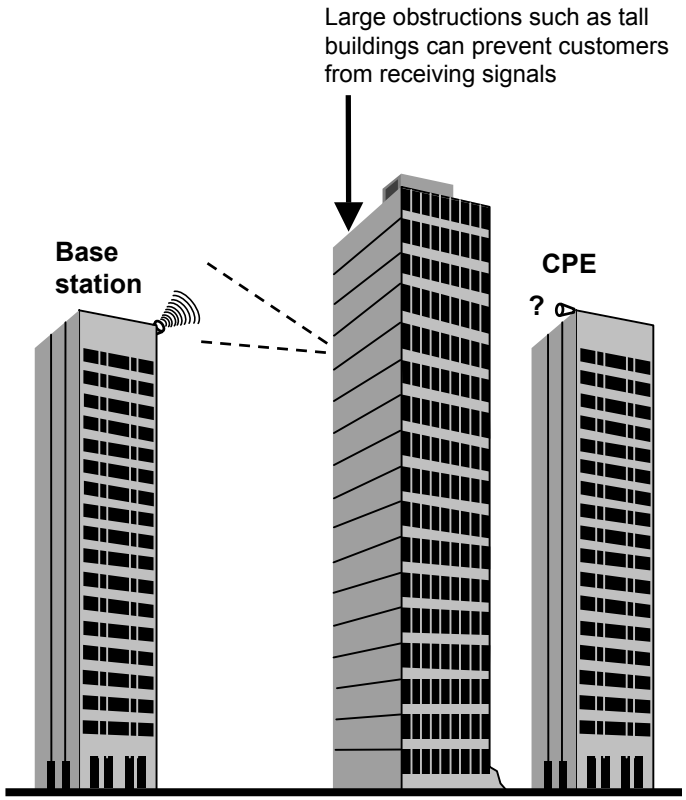
- Each digital controller manages a cell site – i.e., scrambling, redundancy, and bandwidth management
- It is interconnected to the network via fibre or radio

Source: Lucent; Nortel; McKinsey analysis

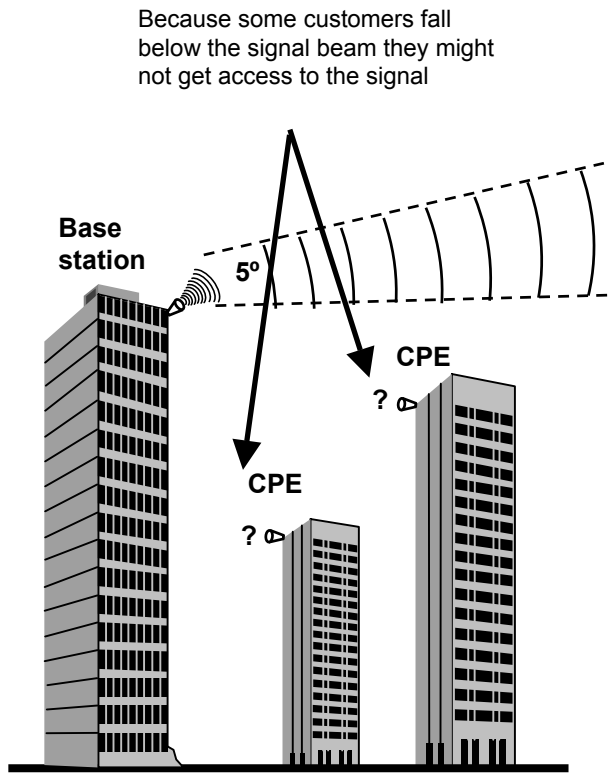
LMDS – LINE OF SIGHT CHALLENGES

BACK-UP

LMDS signals require that both transceivers be within direct visual range of one another



Beam aperture is limited to around 5º which limits vertical coverage*



Despite the use of repeaters, as much as 40% of customers could not receive LMDS signals in very dense urban areas with tall buildings

* Depends on manufacturer: Nortel ~5º, Lucent ~7º, Newbridge ~2º

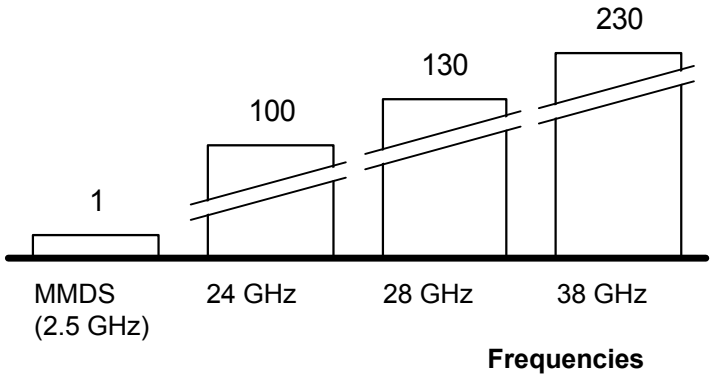
Source: McKinsey analysis

LMDS – FACTORS LIMITING RANGE

BACK-UP

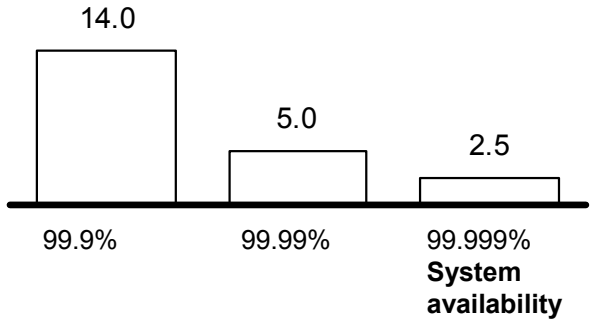
1. Higher frequencies dissipate faster over distance

Indexed signal decay over 1 mile distance
MMDS = 1



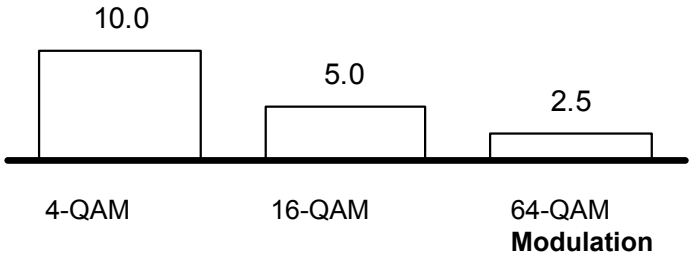
2. The higher the desired system availability, the smaller the cell size

Cell radius for given system availability
km



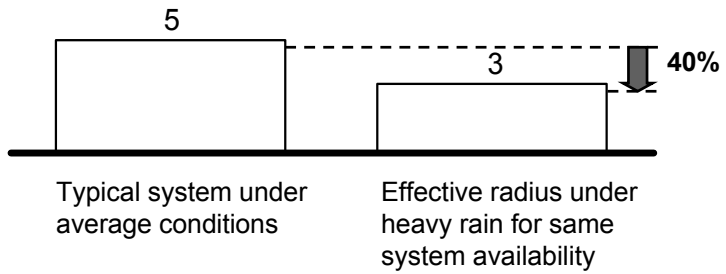
3. The modulation choice affects the cell size as well: the higher the modulation scheme, the smaller the cell

Cell radius for given system availability
km



4. The amount of rain and the size of the drops contribute to reducing cell radius

Cell radius variation in varying climatic conditions
km



Source: International Engineering Consortium; data over wireless – a primer

TECHNOLOGIES PROFILED

Wireline

Twisted Copper Pair
- xDSL
- Voice-over-DSL

Hybrid Fiber Coax
- Cable Modem/VoIP

Optical Fiber
- Gigabit Ethernet
- Passive Optical Networks

Powerline
- Powerline Telecommunications

Wireless

Fixed
- MMDS
- LMDS
- **Free-space optics**
- Unlicensed fixed wireless
- Wireless Mesh
- Satellite

Nomadic/mobile
- WLAN
- Next-Generation Mobile

FREE-SPACE OPTICS (FSO) – TALKING POINTS

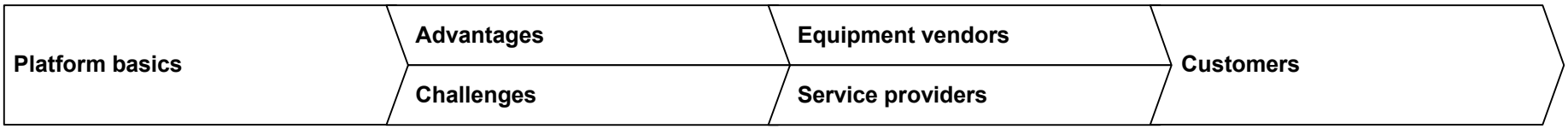
Basics

- FSO is an optical wireless platform providing point-to-point connections at data rates comparable to fiber-based technologies without the need to license spectrum
- Traditionally used to connect enterprise LANs across nearby buildings, now being marketed as a platform for Internet access and voice
- Market for FSO equipment was $51 million in 2000

Issues

- Requires perfect line of sight
- Signal can be interrupted by passing objects (such as birds) and weather

FREE SPACE OPTICS (FSO) – OVERVIEW



- Supports point-to-point connections at rates up to 1.25 Gbps. 10 Gbps equipment is expected to become available shortly
- A physical layer solution, FSO supports Ethernet and ATM
- Transmits information from point-to-point over beams of infrared laser light traveling through open-air
- Subject to network availability, supports full QoS and all voice and data applications
- Requires perfect line of sight. Availability depends on distance from PoP
- CPE consists of optical Tx/Rx placed near window or on rooftop
- Substitutes: Direct fiber to the building, LMDS

Advantages:
- Compared to other optical networking solutions
  - No need for expensive underground plant
  - Rapid provisioning
- Compared to other wireless solutions
  - Higher capacity
  - Roof access not necessary
  - 40% less expensive than comparable radio link
  - No spectrum license needed

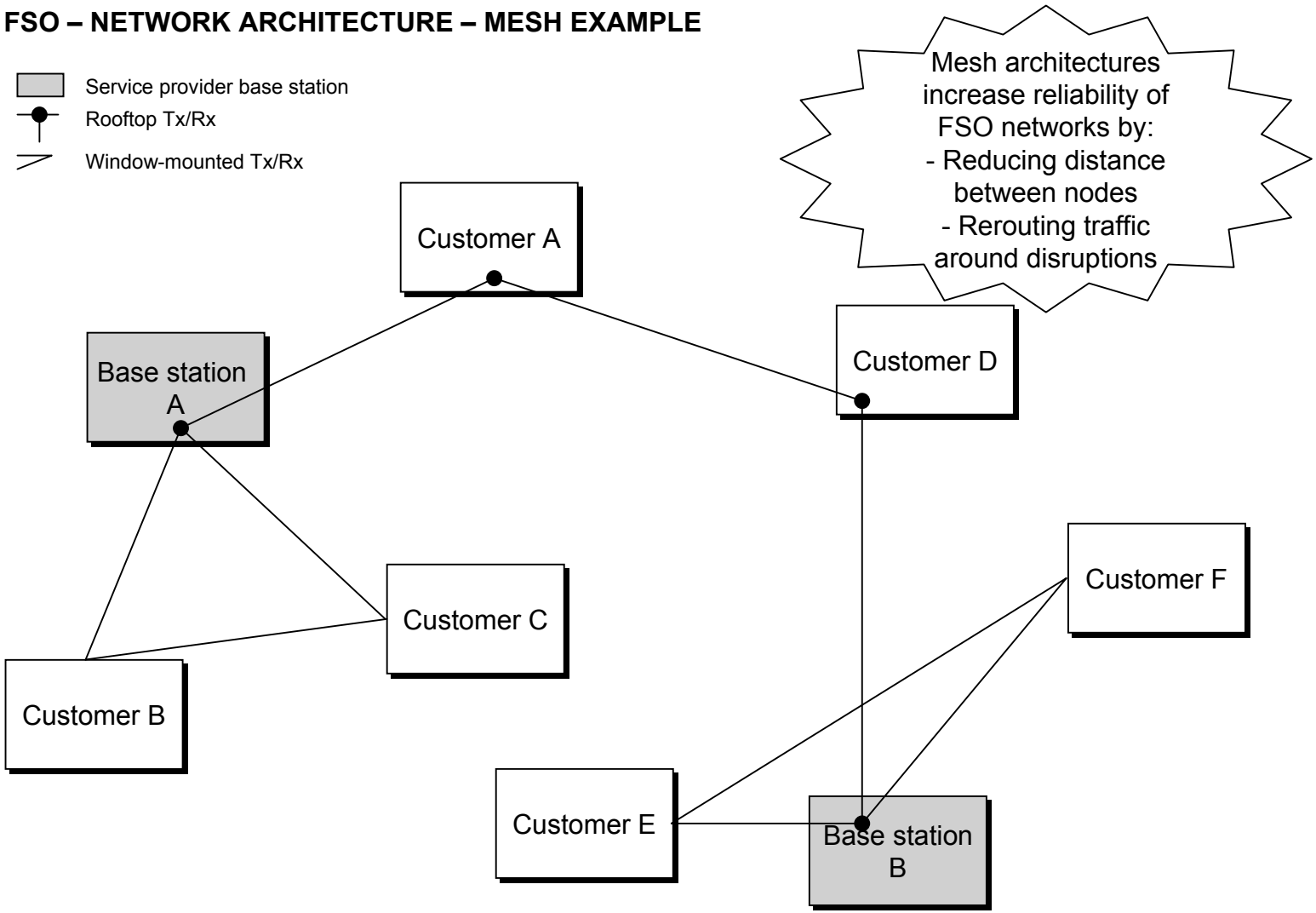
Disadvantages
- Strict line of sight requirements
- Inability to serve as primary access link due to disruption of signal due to weather, birds, building sway, cranes, etc.
- Expensive CPE
- Safety

Equipment vendors:
- Terabeam (partnered with Lucent)
- Air Fiber (partnered with Nortel)
- LightPointe
- Optical Access
- Canon
- PAV Data Systems
- CableFree
- fSONA

Service providers
- Terabeam

Promising customer segments:
- Large enterprises in dense metro areas
  - Back-up to wireline voice and data
  - Non-mission critical data services (additional capacity for Internet access)
- If equipment manufacturers reach scale, SMEs and households in dense areas
  - Internet access

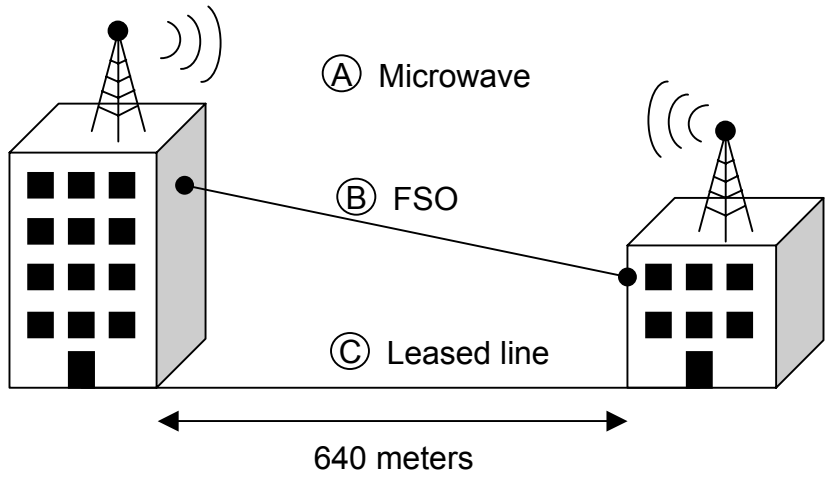
FSO – NETWORK ARCHITECTURE – MESH EXAMPLE



FSO – FACTORS DETERMINING ADDRESSABLE MARKET SIZE

Factor	Description
Terrain	• FSO requires perfect line of sight. Topography, foliage and buildings can block signal
Weather	• FSO's reliability and range depend strongly on weather patterns. Snow, rain, fog and extreme heat can disrupt signal
Density	• Determines the economically addressable number of users per base station
Telecom spend	• Since CPE is relatively expensive, only customers with high-levels of telecom spend would be interested in FSO
Data spend	• Since FSO is not 100% available, customers will be reluctant to rely on it for voice
Non-mission-critical data	• Since FSO is not 100% available, enterprises will not entrust it with mission critical data

FSO – CASE EXAMPLE – MOTLEY FOOL'S LAN-LAN CONNECTIVITY



Option	Price
Ⓐ Microwave (OC-3)	$38,000 for equipment only
Ⓑ FSO (OC-3)	$26,000 for equipment and installation, no monthly fee
Ⓒ Leased line (OC-3)	$9,000 per month plus equipment

Source: ASAP

FOS– BACKUP PAGES

- Distance sensitivity
- Key players

TECHNOLOGIES PROFILED

Wireline

Twisted Copper Pair
- xDSL
- Voice-over-DSL

Hybrid Fiber Coax
- Cable Modem/VoIP

Optical Fiber
- Gigabit Ethernet
- Passive Optical Networks

Powerline
- Powerline Telecommunications

Wireless

Fixed
- MMDS
- LMDS
- Free-space optics
- **Unlicensed fixed wireless**
- Wireless Mesh
- Satellite

Nomadic/mobile
- WLAN
- Next-Generation Mobile

UNLICENSED FIXED WIRELESS – TALKING POINTS

Basics

- Unlicensed fixed wireless networks provide Internet access over unlicensed spectrum, using technologies similar to those employed by wireless LANs
- Unlicensed FW technology is being deployed by smaller ISPs as an alternative to T1, fractional T1, or dial-up access
  - Smaller ISPs cannot provide high speed access over cable
  - Reselling ILEC DSL is not attractive to many ISPs, and CLEC DSL is fading as an alternative
- Current market size is hard to determine because there is no licensing requirements and smaller ISPs are usually privately held

Issues

- Cost of customer qualification and provisioning
- Base station site acquisition and backhaul cost
- Viable business model to provide public fixed wireless Internet access service
- Risk of “tragedy of the commons” as competing unlicensed spectrum applications proliferate
- Stability of manufacturing base in current economy

UNLICENSED FIXED WIRELESS – OVERVIEW

Platform basics | **Advantages** / **Challenges** | **Equipment vendors** / **Service providers** | **Customers**

- Spread Spectrum and OFDM technologies are used
  - Operates in ISM (2.4GHz) or UNII (5.8GHz) unlicensed band
  - Theoretical shared data rates up to 11Mbps for ISM and 54 Mbps for UNII. Effective throughput per user up to several Mbps
  - Base station reach of up to several miles
  - Near line-of-sight required, except for short range
- Point-to-point and point-to-multipoint architectures
- Uses standard Internet infrastructure for core network
- UFW supports Internet access and private corporate networks

Advantages:

- No spectrum acquisition costs nor leased circuit costs
- Capital for customer connections only installed as ordered
- Meets needs of ISPs for alternative last-mile high-speed access to DSL or cable modem

Challenges:

- Obtaining satisfactory coverage can be challenging and expensive
- Interference: risk of “tragedy of the commons” of unlicensed spectrum
- Lack of stable manufacturing base
- Customer installation
  - Connection from outside to inside
  - Antenna location
- Cost-effective and scalable operations systems, in particular RF design systems for engineering and customer acquisition
- Site acquisition

Equipment Vendors

- Western Multiplex
- Cisco
- WiLan
- Adaptive Broadband

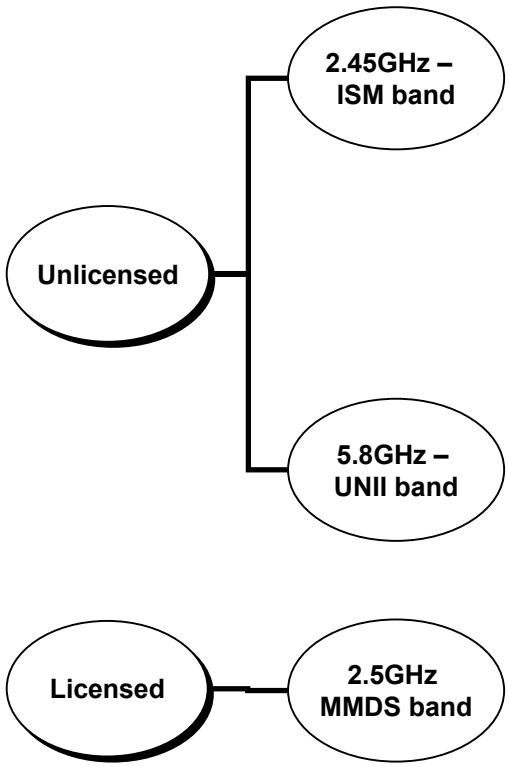
Internet Service Providers

- Polarcom
- Air2Lan
- Tele2 (UK)
- PSINet
- NetVoice

Promising customer segments:

- SMEs
  - Not serviceable by DSL
- Private corporate networks
  - Campus environment
  - Multi-location within metro
- Residential
  - Not DSL addressable
  - No high speed cable modem service

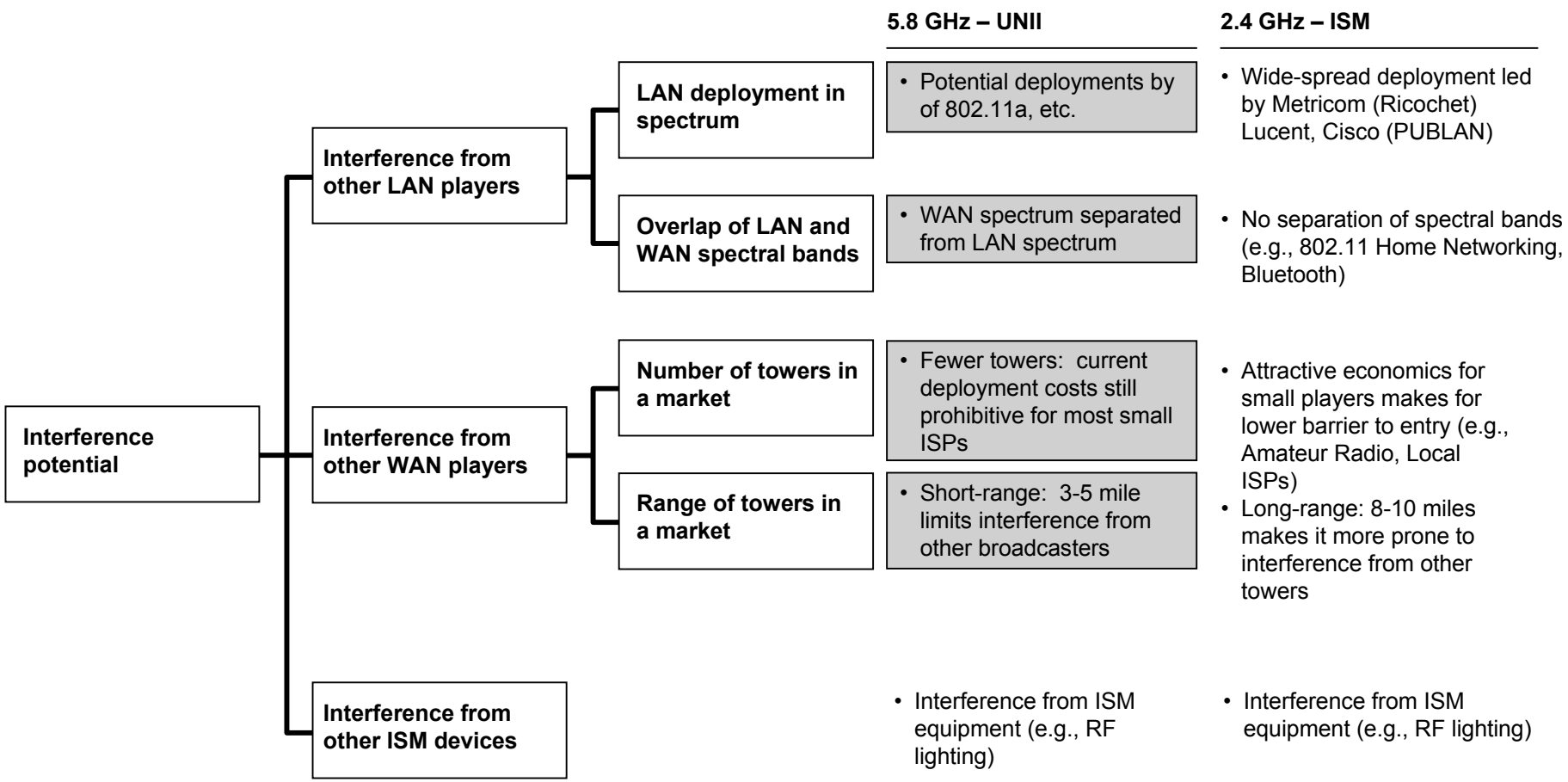
FIXED WIRELESS OPTIONS IN THE 1-7 GHZ RANGE



	Available bandwidth	Maximum effective radius	Advantages	Limitations
2.45GHz – ISM band	~80MHz	8-10 miles assuming line-of-sight	• Cheaper equipment than for MMDS • No licensing cost • Wide coverage range • CPE antenna does not necessarily need rooftop access if close enough to base station	• Limited bandwidth • Multiple sources of interference – Bluetooth, 802.11 Home Networking – Amateur video/radio broadcasting – Other operators
5.8GHz – UNII band	~100MHz	3-5 miles assuming line-of-sight	• Fewer sources of interference • Burst rates of 25Mbps possible	• Limited cell size
2.5GHz MMDS band	~156MHz	Up to 30 miles assuming line of sight	• Licensed spectrum – interference control • Backed by large players WCOM/Sprint/ADC/Cisco • Burst rates of up to 10Mbps possible	• Expensive equipment $147k/Tower • Added license cost ($200-$300/SME in 2nd and 3rd tier markets) • Fractured blocks of spectrum that make implementation challenging

RISK OF SPECTRUM DEGRADATION IS LOWER FOR THE 5.8 GHZ BAND

Lower risk of spectrum degradation



COST STRUCTURE FOR COMPETING TECHNOLOGIES (2000 NUMBERS)

	2.4 GHz–-ISM	5.8 GHz – UNII
	Breezecom	**Adaptive broadband**
• Tower cost	$30k	$33k
• Tower installation	$98k	$98k
• Spectrum licensing costs	0	0
• CPE cost	$600	$600
• CPE installation	$500	$500
• Maximum no. of subs/tower*	168	1,220
• Range (miles)	8.5	3-5

* Assuming 10x oversubscription
Source: Adaptive broadband; Breezecom

INCREMENTAL TOWER ECONOMICS – (2000 NUMBERS)

	2.4 GHz–-ISM	5.8 GHz – UNII
	Breezecom	**Adaptive broadband**
• No. of customers served	220	220
• Total set-up costs (excluding license costs)	$370k	$373k
• Spectrum/licensing costs	0	0
• Break-even time*	2-3 years	2-3 years
• Effective bandwidth**	273k	3.5 Mbps

* Discount rate of 15% assumed
** Assumes 5x oversubscription
Source: Team Analysis, Breezecom, Adaptive Broadband

TECHNOLOGIES PROFILED

Wireline

Twisted Copper Pair
- xDSL
- Voice-over-DSL

Hybrid Fiber Coax
- Cable Modem/VoIP

Optical Fiber
- Gigabit Ethernet
- Passive Optical Networks

Powerline
- Powerline Telecommunications

Wireless

Fixed
- MMDS
- LMDS
- Free-space optics
- Unlicensed fixed wireless
- **Wireless Mesh**
- Satellite

Nomadic/mobile
- WLAN
- Next-Generation Mobile

WIRELESS MESH* – TALKING POINTS

Basics

- Wireless mesh networks deliver broadband access (voice and data) to customers through routed networks of connected CPE. Each end-user's CPE, consisting of a transceiver, modem and router, is a node of the network, routing its neighbors' traffic in addition to sending and receiving its own content
- Wireless mesh networks maximize the addressable market of a wireless base station by easing line-of-sight restrictions and expanding its coverage area.
- Wireless mesh networks broadband access is targeted at households and SMEs
- Wireless mesh networks have been deployed to only a few hundred customers in test markets

Issues

- Difficulty in attaining sufficient subscription density to guarantee reliable service and reap the benefits of mesh architecture
- Difficulties common to fixed-wireless platforms: line-of-sight and installation

* Wireless mesh is an architecture, not a specific access technology, like HFC or 802.11b. This document describes fixed wireless mesh solutions providing broadband access to the home and small business. It does not consider mobile mesh or "*ad hoc* networks" providing voice and data services to PDAs and handsets

WIRELESS MESH – OVERVIEW

Platform basics | **Advantages** / **Challenges** | **Equipment vendors** / **Service providers** | **Customers**

- In a wireless mesh network, each customer's CPE receives, transmits and routes data
- Wireless mesh is not a specific platform (like 802.11b or HFC), but an emerging network architecture
- Existing wireless mesh technologies operate over a number of licensed and unlicensed spectral bands including LMDS and 2.4 GHz
- Nokia's system offers typical data rates of 384-768 Kbps. Radiant Networks' system delivers 2Mbps to the subscriber
- CPE consists of a rooftop antenna, radio, modem and router
- Each customer location must have line-of-sight to either the service provider's base station or another customer
- Nokia system supports IP data only. Radiant system supports voice and data over ATM-switched TDM circuits
- Substitutes: satellite, MMDS, HFC, xDSL

Advantages:
- Increases addressable market size for each base station by:
  - Increasing density of addressable customers (eased line-of-sight restrictions)
  - Increasing size of covered area (a customer beyond the direct reach of a base station can access the network through nearby customers within the base stations reach)
- Network reliability increases as more users join network
- Enables wide coverage with unlicensed spectrum without a dense population of base stations

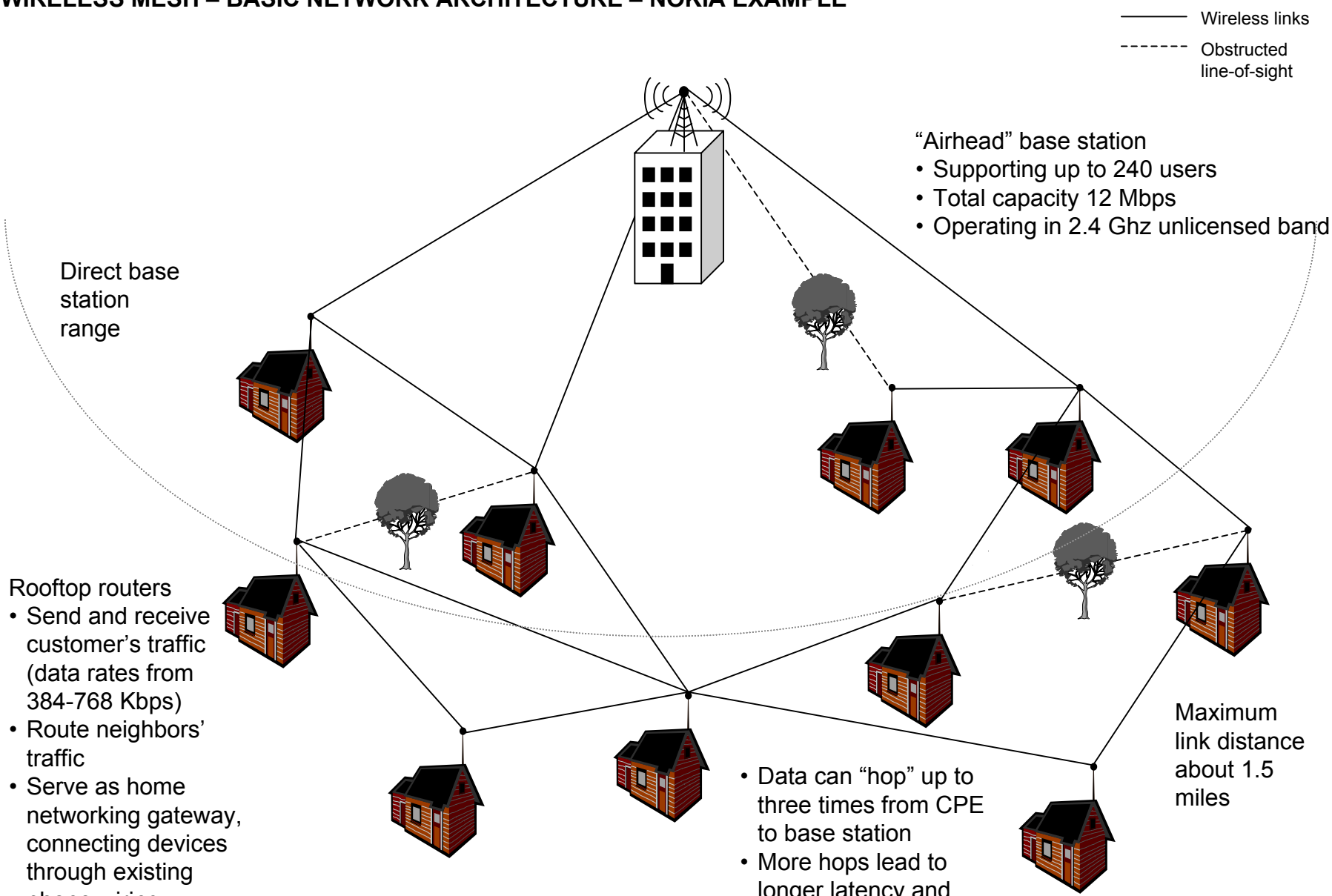
Challenges:
- Line-of-sight required between either CPE and base-station or CPE and another customer's on-net CPE
- Roof-top installation can be difficult
- Guaranteeing QoS and network availability
- Interference: unlicensed plays face risk of "tragedy of the commons" in unlicensed spectrum

Equipment vendors:
- Nokia (2.4 GHz)
- Sky Pilot (5.8 GHz)
- Cowave Networks (<11 GHz)
- Radiant Networks (LMDS)
- CALY Networks (LMDS)

Service providers
- Nokia's test markets:
  - Advanced TelCom Group, Santa Rosa, CA
  - Meer.net, Mountain View, CA
- Radiant test market:
  - Virginia Tech

Promising customer segments:
- Internet access to households, SOHOs and SMEs in neighborhoods unaddressed by xDSL, HFC and communities owned/controlled by a single entity (e.g. garden-style apartment and condominium complexes)

WIRELESS MESH – BASIC NETWORK ARCHITECTURE – NOKIA EXAMPLE



Source: Nokia; Trade Press

WIRELESS MESH – FACTORS DETERMINING ADDRESSABLE MARKET SIZE

Factor	Description
Terrain	• Topography, foliage, and buildings can disrupt line-of-sight (to varying degrees depending on frequency and intensity of carrier)
Density	• Affects ability to create a robust mesh
Rooftop access	• Customers in MTUs/MDUs may not have access to rooftops
Availability of wireline access	• Hassles of rooftop installation may lead customers to choose wireline technologies (xDSL or HFC) over wireless technologies

Source: Team analysis

TECHNOLOGIES PROFILED

Wireline

Twisted Copper Pair
- xDSL
- Voice-over-DSL

Hybrid Fiber Coax
- Cable Modem/VoIP

Optical Fiber
- Gigabit Ethernet
- Passive Optical Networks

Powerline
- Powerline Telecommunications

Wireless

Fixed
- MMDS
- LMDS
- Free-space optics
- Unlicensed fixed wireless
- Wireless Mesh
- **Satellite**

Nomadic/mobile
- WLAN
- Next-Generation Mobile

SATELLITE BROADBAND DATA SERVICE – TALKING POINTS

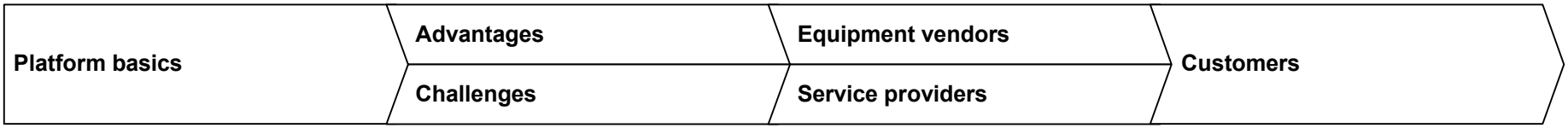
Basics

- Satellite data services allow a service provider to reach the entire US from a single earth station (effective coverage ~90% due to line-of-sight issues)
- 1-way systems (dial-up return) have been used for consumer Internet access since 1997 and 2-way VSAT service has been offered to enterprises for several years
- 2-way broadband satellite data service was introduced to the consumer and SME market in 2000

Issues

- Cable and DSL offer superior service at lower price
- Limited bandwidth availability particularly in the upstream channel
- High per-subscriber CPE cost ($750-$1,000 equipment plus $200 installation)
- Market structure (only two primary suppliers)

OVERVIEW – SATELLITE BROADBAND DATA SERVICE



- Hybrid service (dial-up return) has been offered for consumer internet access since 1997
- 2-way satellite service for consumer and SME market has been recently introduced
- Satellite transponders typically have 40 Mbps shared capacity and can serve 10,000 to 20,000 subscribers
- Services available in 2001 offer up to 500Kbps down/128Kbps up to consumer market and up to 1,540Kbps/256Kbps to SME market
- Round trip delays of 500ms in GEO (geostationary earth orbit) satellite links
- Currently most satellites operate in the Ku frequency band (12-18 GHz) with the next generation to expand into the Ka frequency band (18-31GHz)
- CPE consists of outdoor receive/transmit dish.
  - Data-ready dish can support internet access and satellite TV
- Substitutes: cable modem, DSL, fixed-wireless

Advantages:
- Low initial investment lets service provider achieve instant coverage for entire US
  - Transponders can be leased from wholesaler as needed
- Simple operational requirements
  - Just one national operations center
- Bundling synergies with DBS video services
- Simple provisioning makes it easy to marketed nationally through strong retail channels

Challenges:
- High CPE cost
  - Modem plus Rx/Tx dish
  - Professional installation
- Poor performance on interactive services due to high latency
- Bandwidth, particularly in upstream channel
  - Limited transponder capacity shared by all subscribers
  - Transponder economics very sensitive to bandwidth usage
- Line-of-sight requirement

Equipment vendors:
- Hughes
- Gilat

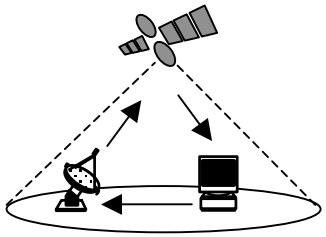
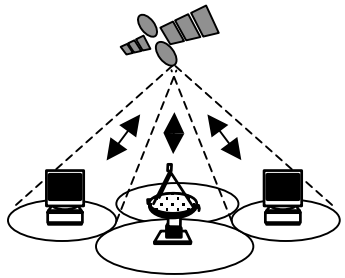
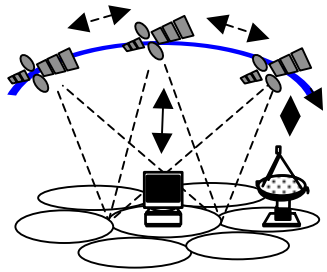
Service providers:
- Hughes
  - DirectPC/Directway for consumer/SME (3Q 2001)*
  - VSAT for enterprise market
  - Spaceway (2002)
- EchoStar joint ventures
  - Starband (4Q2000)
  - Wildblue (2002)
- Gilat
  - VSAT for enterprise market
  - Partner in Starband
- Tachyon (1999)
  - Business oriented service
- Astrolink (2003)
- Teledesic (2005)

Target customer segments:
- Mostly consumer market, but service capabilities may be adequate to some SMEs
- Satellite opportunity is in areas underserved by cable and DSL

Market size:
- Currently about 100,000 consumer/SME subscribers mostly of hybrid service
- Estimated 4 million consumer/SME subscribers of 2-way service by 2005
- About 300,000 VSAT terminals in 1999

* Hybrid service offered since 1997

BROADBAND SATELLITE DIRECT ACCESS – TECHNOLOGY

	Hybrid broadband GEO*	Two-way broadband GEO*	Two–way broadband LEO*
Architecture			
Core technology	Single GEO satellite Ku-band transponders	Single Ku-band GEO today Ka-band and spot-beams for next generation 1-8 GEOs for global coverage	40-300 LEO satellite constellation Ku or Ka-band transponders Spot-beams, inter-satellite links
Required CPE	Fixed receive-only dish PC-card/modem or TV set-top box PSTN/ISDN modem	Fixed receive/transmit dish PC-card/modem or TV set-top box	Steered receive/transmit antenna PC-card/modem or TV set-top box
Example player	Hughes DirectPC	StarBand SES Astra Hughes Spaceway Hughes DirecPC	Teledesic Skybridge

* GEO = Geostationary Earth Orbit at 36,000 km Altitude, LEO = Low-Earth Orbit at 700-1400 km altitude

Source: McKinsey analysis

SATELLITE – FACTORS DETERMINING ADDRESSABLE MARKET SIZE

Factor	Description
Line-of-sight	• Antenna must have clear line-of-sight towards the satellite (without buildings mountains in the way) • Major issue in MDUs where only part of the tenants face the satellite • Service downgrade during heavy rain make it inappropriate to some areas of the country
Requires outside antenna	• Regulations restrict the installation of dishes in MDUs and even in entire neighborhoods • May require roof rights
Service performance	• In general, data rates and service reliability are not adequate for medium and large businesses • Exceptions are high-end VSAT solutions used by large corporations for point-to-multipoint communications and to reach remote places without viable wireline alternative
Availability of wireline alternatives	• DSL and cable offer higher downstream and upstream bandwidth without the latency problems inherent to GEO satellite service • CPE for DSL or cable costs $125-$200 vs. $750-$1,000 satellite (plus $200 professional installation) and monthly service is $40-$50 vs. $70 for satellite

BROADBAND SATELLITE OFFERS SUPERIOR PERFORMANCE TO DIAL-UP ACCESS BUT CURRENTLY LAGS CABLE AND DSL ON PRICE AND PERFORMANCE

	xDSL	Cable	Satellite
Typical downstream	640-1,540 kbps	500 kbps-1 Mbps	• 150-400 kbps
Typical upstream speed	256-384 kbps	256-500 kbps	• 40-128 kbps
Suitability for nonbursty applications	High	Medium	• Medium/low
CPE cost	$160-$200*	$120-$160*	• $750-$1000*
Monthly fee	$50	$40-50	• $70

* CPE is typically subsidized by service provider
Source: J. P. Morgan – McKinsey; company web sites

ANNUALIZED CAPITAL EXPENDITURE PER TRANSPONDER

Million per year of life, per 38 Mbps equivalent transponder capacity

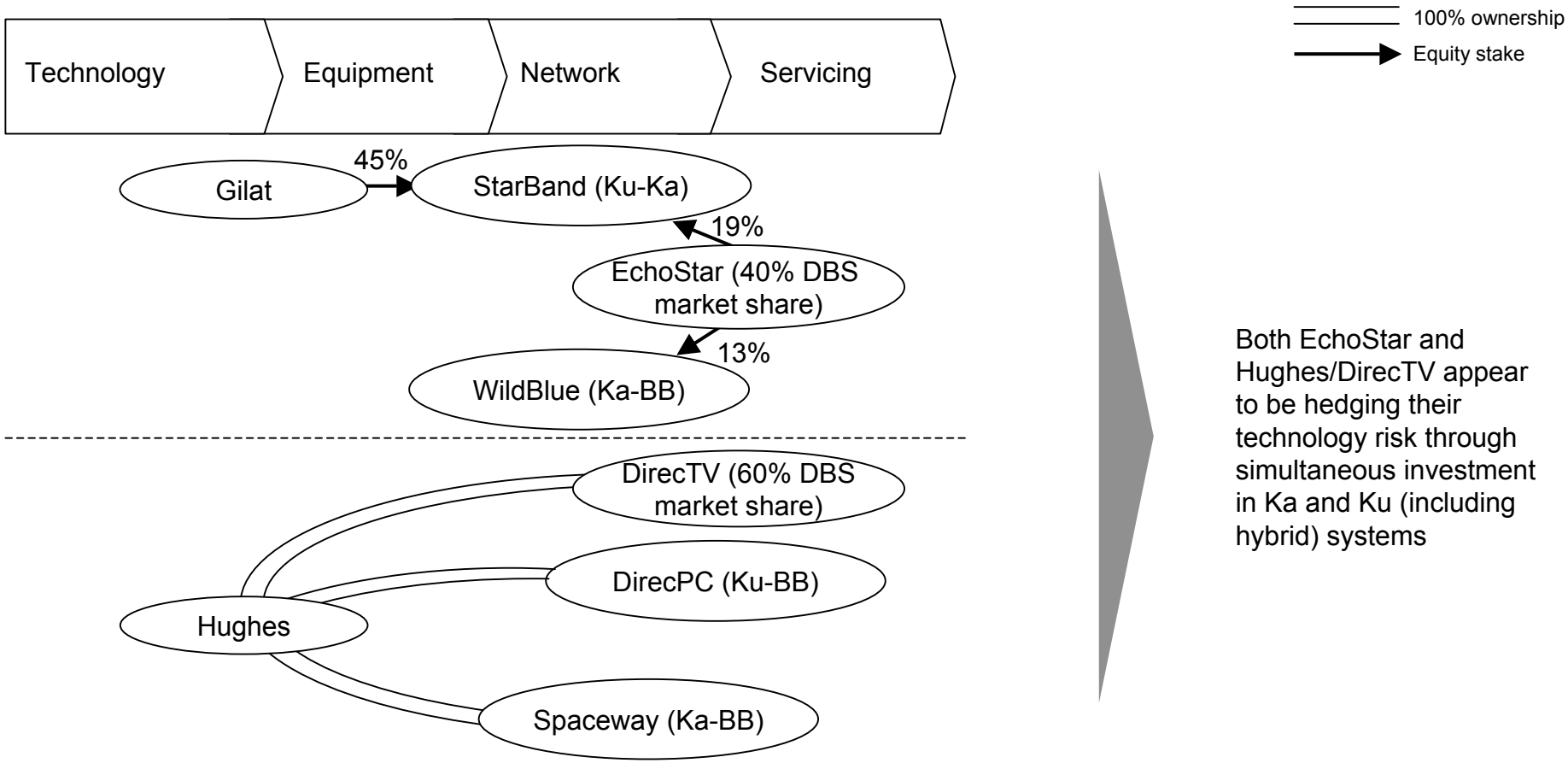
System	Cost	Satellite Lifetime	Down-link Throughput		Cost per 38 mbps per year
	Millions	*Years*	*Gbps*	*38 Mbps equivalent*	
Current GEO Ku	• 250	• 10	• 0.9	• 24	• 1.0
Spaceway					
• First 2	• 1400	• 10	• 12	• 316	• 0.4
• Full 8	• 4000	• 10	• 35	• 926	• 0.4
• Skybridge	• 6100	• 7	• 215*	• 5658	• 0.15 – 0.4*
• Teledesic	• 9000-15000	• 7	• 560**	• 14737	• 0.1 – 0.15

*Unclear if simultaneous service capacity or total satellite throughput; lower number adjusted for assumption that only 40% of theoretical capacity can be used over inhabited areas for LEO constellations

** Total combined satellite throughput is 2880 Gbps but actual simultaneous capacity available to users is limited to 14x2Mbps per coverage cell for 20.000 cells, i.e. 14x2x20.000=560 Gbps

Source: Industry reports, web pages, literature search, McKinsey analysis

MAJOR SERVICE PROVIDERS ARE BACKED BY POWERFUL SATELLITE INDUSTRY PLAYERS



Both EchoStar and Hughes/DirecTV appear to be hedging their technology risk through simultaneous investment in Ka and Ku (including hybrid) systems

Source: Company web sites; analyst reports

TECHNOLOGIES PROFILED

Wireline

Twisted Copper Pair
- xDSL
- Voice-over-DSL

Hybrid Fiber Coax
- Cable Modem/VoIP

Optical Fiber
- Gigabit Ethernet
- Passive Optical Networks

Powerline
- Powerline Telecommunications

Wireless

Fixed
- MMDS
- LMDS
- Free-space optics
- Unlicensed fixed wireless
- Wireless Mesh
- Satellite

Nomadic/mobile
- **WLAN**
- Next-Generation Mobile

WLAN – TALKING POINTS

Basics

- Wireless LAN (WLAN) technology has been widely-deployed for corporate, campus and home networking, with over 1.7M users worldwide in 2000. IBM, Dell and Toshiba are shipping 802.11b antennae and cards as standard equipment in new laptops
- Two services have recently emerged to extend the applicability of WLAN beyond the private setting.
  - Nomadic Internet access and VPN in hot-spots (e.g. airports, hotels) targeted at mobile professionals carrying laptops
  - Mobile Internet access in hot-spots (e.g. shopping malls, amusement parks) to the mass market through PDAs and handsets

Issues

- Developing a viable business model to provide public WLAN service
- WLAN's short-range limits its applicability to nomadic and mobile applications in hot-spots
- Power consumption issues will delay adoption for mobile applications

WLAN – OVERVIEW

Platform basics | **Advantages** / **Challenges** | **Equipment vendors** / **Service providers** | **Customers**

- 802.11b (a.k.a. WiFi) is the most common WLAN platform:
  - Operates in 2.4GHz unlicensed band
  - Theoretical data rates up to 11Mbps. Typical data rates around 5.5 Mbps, shared by up to 60 users per access point
  - Access point reach of less than 90m indoors and 360m outdoors
  - Existing antennae/modems for laptops (PCMCIA). PDA equipment should be available this year. Handset equipment in 2002
- 802.11a operates in the 5.8 GHz unlicensed band and supports data rates up to 54 Mbps
- WLANs have a point-to-multipoint architecture
- WLANs support Internet access and access to corporate networks through VPN

Advantages:

- No need for spectrum license
- Access points are inexpensive and local network capacity can be increased economically
- WiFi certification ensuring interoperability (80+ vendors)
- 802.11b is well-proven with over 1.7M users worldwide

Challenges:

- Short range limits applicability beyond hot-spots
- Battery life: WLAN will reduce cell-phone battery life from days to hours and PDA battery life from weeks to days
- Interference: risk of “tragedy of the commons” of unlicensed spectrum
- Security issues may delay adoption

802.11b Equipment Vendors

- Nokia
- Lucent
- Cisco
- 3com

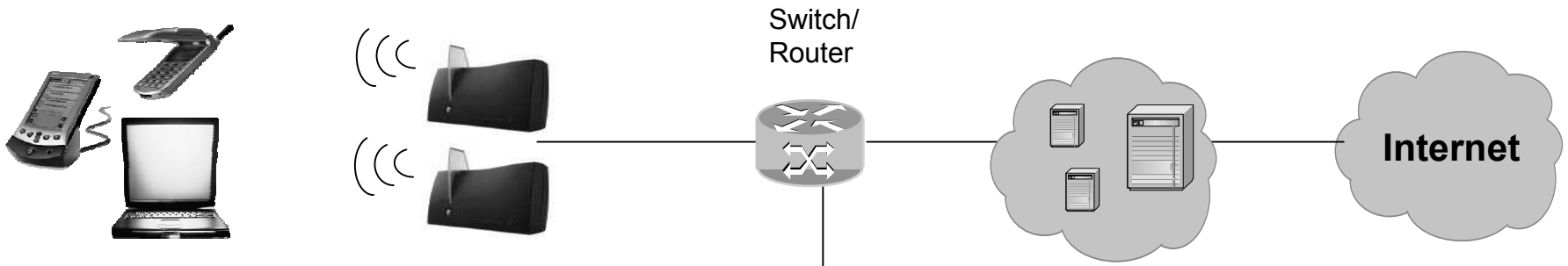
802.11b Service Providers

- Pure plays (Wireless ISPs)
  - Telia Homerun (Sweden)
  - Wayport (U.S., Canada)
  - MobileStar (U.S.)
- Cellular operators
  - Sonera (Finland)
- User-operated networks
  - Seattle Wireless
  - Consume (London)
  - Guerilla (Cambridge, MA)

Promising customer segments:

- Nomadic Internet access and VPN to mobile professionals carrying laptops in:
  - Hotels
  - Convention centers
  - Airports/rail stations
- Mobile Internet access and location based apps to consumers carrying PDAs and handsets in:
  - Shopping malls
  - Sports arenas
  - Banks
  - Theme parks
  - Museums/libraries

WLAN ISP ARCHITECTURE



Wireless station
- Accesses the WLAN through a PC card or an embedded module in non-PC clients

Access Point
- Acts as a wireless bridge to the local area network
- Usually provides basic access control and encryption
- Handles handover with other access points

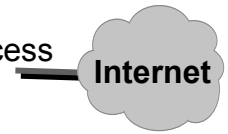
Service provider core network
- Provides billing capabilities

Example:
Telia Home Run,
Mobile Star

Local server
- Stores locally relevant content
- Provides additional access control
- Interfaces with the billing system

THE COST FOR THE BASIC WLAN ACCESS POINT IS LOW

802.11b CASE
SINGLE ACCESS POINT

Element	Investment dollars*	Product
Access point 	1,564	• Lucent 802.11b access point for corporate LANs
Router 	2,392	• Cisco 2610 Ethernet Router (combines routing and HDSL signalling)
Modem 		
Internet access 	211 per month	• 2 Mbps HDSL circuit from European telco**

- 60 concurrent users within 90 meters from access point share a resource that requires***
  - $4,000 investment
  - $211 per month running cost

* Based on solutions available on the Italian Market; does not include installation and maintenance costs

** A 2 Mbps leased line is currently used by Telia Home Run to connect its public access sites to Telia's core network.

*** 33 Kbps per user; semi-open environment (e.g. indoor with no through walls)

Source: Lucent; literature search; Telia; McKinsey analysis

PURE-PLAY WLAN ISP OPPORTUNITY IS LIKELY SMALL OR NON-EXISTENT

WLAN ISPs face many challenges

- Network effects
  - Nomadic applications require providers to have wide-coverage – creating large upfront capital requirements
- Expense of customer acquisition
  - WLAN ISP is not a mass-market play
  - Target market is fragmented across geographic and professional segments
- Expense of site acquisition
  - Hot-spot property owners will have a strong bargaining position
- Competition
  - Competition from cellular operators, WLAN ISPs and public wireline data providers (e.g. Laptop Lane) could be intense

- WLAN ISPs will have difficulty reaching scale
- WLAN ISPs with large roll-outs will be weighed-down by SG&A

802.11b ISPs

BACK-UP

Service provider	Countries	Location	Pricing	Partners
Telia Homerun	• Sweden	• Airports, train station and conference facilities • Around 100 hot-spots in Sweden/300 planned for the end of 2001	• Initial fee: 280 Eur • Subscription fee: Eur 170/ month • Soon to be launched pre-paid time-limited access	• Equipment-Symbol • Roaming (planned) -Mobile Star • Servers-Service Factory
Wayport	• US • Canada	• Airports – 3 • Hotels – 170	• $35.00 per 10 connections (each connection valid for the entire day in one location)	• Equipment – Lucent, Cisco • Bandwidth – Broadwing, Level3, UUNet, MCIWorldCom, Time Warner, Winstar • Software – LodgeNet
MobileStar	• US	• Airports – 28 • Hotels – ~100 • Coffee outlets (under development)	• Subscription – $59.95/month, unlimited use – $34.95/month, 500 minutes – 15.95/month, 200 minutes • Per use – $2.50 first 15 minutes, $.10 each additional minute	• Location – American Airlines, Starbucks, Hilton • Technology - Microsoft

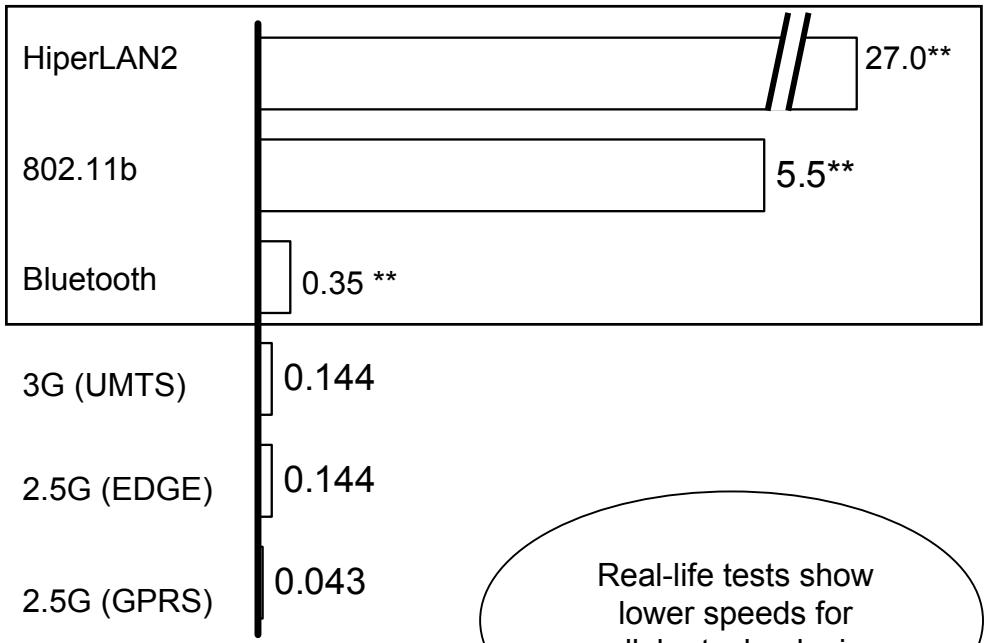
Source:Websites; interviews; WLAN Forum

WLANs OFFER SUPERIOR SPEED AND ECONOMICS OVER 3G FOR HOT-SPOT COVERAGE

BACK-UP

Single user handset data rates ("best case")

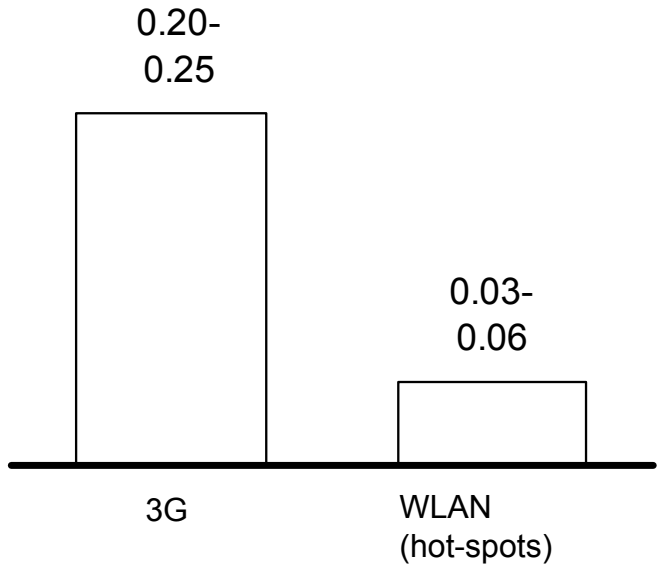
Mbps



Real-life tests show lower speeds for cellular technologies

Average cost of data traffic

$ per MByte



Assumptions for 3G cost

- WCDMA upgrade from existing GSM network
- Cell cost is around $400,000, amortized over 8 years and includes all shared network costs***
- Cell capacity of 6,075 Mbytes per day ****

* Downlink only, Symmetrical link speed is 432 kbps

** Single user data rates are 50% of theoretical

*** Network backbone, PDSN, PDGN, RNC, transceiver/transcoders, servers, OS, software licenses

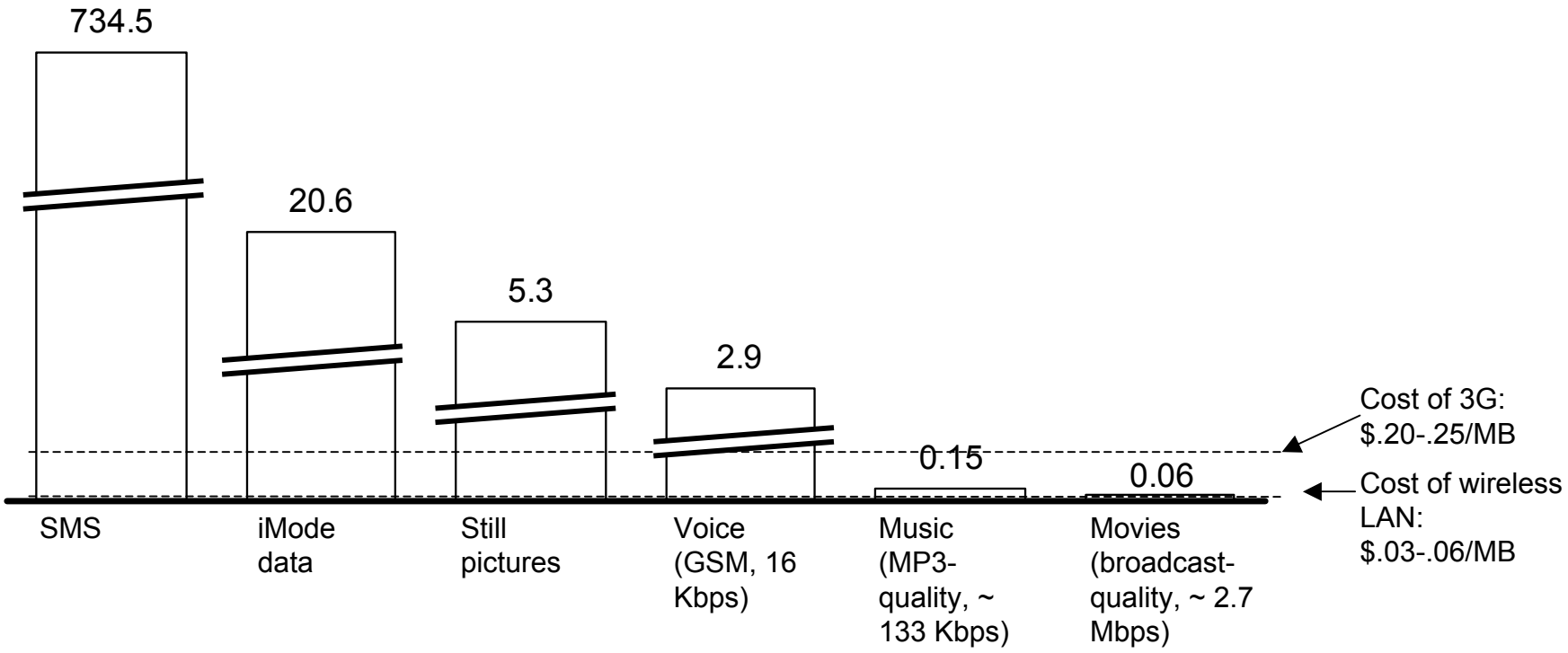
**** 15MHz of spectrum deployed, 3 sectors per cell, 0,2 bits/second/Hz/sector, 50% peak hour utilization rate, peak hour traffic 30% of total traffic

Source: Literature search, adapted from "New Generation Wireless Networks" knowledge effort

WLANs CAN COST EFFECTIVELY SUPPORT DATA HEAVY APPLICATIONS THAT ARE UNECONOMICAL IN 3G NETWORKS

BACK-UP

End-user willingness to pay
$ per MByte



Source: GS Research, Merrill Lynch; McKinsey analysis

TECHNOLOGIES PROFILED

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- Free-space optics
- Unlicensed fixed wireless
- Wireless Mesh
- Satellite

Nomadic/mobile
- WLAN
- **Next-Generation Mobile**

NEXT-GENERATION MOBILE – TALKING POINTS

Basics

- Next generation wireless technologies support higher bit rates, packet-switched connections and provide substantial improvement in spectral efficiency (bits/Hz/sector)
- Often referred to as 2.5G and 3G, they are fundamentally two CDMA-based platforms: CDMA One and WCDMA
- 2.5G often refers to different steps in multiple migration paths (GPRS, EDGE, 1XRTT, 1Xevdo/HDR, 1Xevdv)

Issues

- Multiple technology problems – ranging from network capacity to handset battery lifetime – will limit performance and range of applications supported
- End-user willingness to pay for different applications is unclear; situation is further complicated by likely limitations of infrastructure which will support only bursty data exchanges and low resolution/short video and pictures
- Operators ability to generate attractive returns on capital required to upgrade networks and obtain licenses is highly uncertain
- Carriers do not have business skills (marketing, sales, customer management), IT processes (billing, customer profiling), content and application aggregation experience to deploy data services effectively

NEXT-GENERATION MOBILE – OVERVIEW

Platform basics | **Advantages** / **Challenges** | **Equipment vendors** / **Service providers** | **Customers**

- Two CDMA-based technologies CDMAOne and WCDMA

- **WCDMA**
  - Requires clean 5MHz (paired) of clean spectrum
  - Designed to meet requirements of UMTS standard, e.g., up to 2 Mbps data throughput to stationary end-users outdoors, packet and circuit switched connections
  - Upgrade path includes GPRS and EDGE
  - No backward compatibility between WCDMA and GSM/GPRS/EDGE

- **CDMA One**
  - Natural upgrade path for IS-95 players
  - 1XRTT is backward compatible with IS-95 and doubles voice capacity
  - 1Xevdo and 1Xevdv can be deployed incrementally with 1.25MHz carriers

Advantages
- Improved voice capacity due to increased spectral efficiency
- Support of data services: circuit and packet switched
- Increased data throughput

Challenges
- Network will only support typical throughputs of 50-100Kbps over the next 3-4 years
- Handset availability likely to be delayed – limited functionality in the near term
- Large amount of capital required to deploy infrastructure and subsidize handsets
- Inadequate IT/back-office and business processes to support roll-out of data services
- Lack of spectrum for deployment of WCDMA

Equipment vendors:
- Ericcson
- Nokia
- Siemens
- Nortel
- Lucent
- ArrayCom
- Samsung

Service providers:
- Verizon
- Sprint
- AT&T Wireless
- Cingular
- Nextel
- Voicestream
- Vodafone
- NTT DoCoMo
- Telefonica
- KPN
- BT

- Mass consumer market
- Professionals
- Enterprises
- MVNOs (wholesale)
  - Virgin
  - Coke
- System Integrators (wholesale)
  - IBM
  - EDS
  - Brience
- Value added service providers (wholesale)
  - Onstar
  - Tracking applications

2.5G WILL DOMINATE FOR SEVERAL YEARS WHILE UMTS DEPLOYMENT LAGS BEHIND PROJECTIONS

Upgrade path through 2.5G

- **Cingular and AT&T:**
  - Need to overlay/deploy GSM, then GPRS just to get to 2.5G (capex and time investment)
- **Sprint and Verizon:**
  - Upgrading to 2.5G (1xRTT) during next 12-18 months
  - Technology sound for 3G migration beginning in 2002-2003
  - Verizon announced vague plans for GSM/GPRS overlay to comply with Vodafone
- **Voicestream:**
  - Still building GSM (2G) network, 2.5G launch in mid-late 2002
- **Nextel:**
  - Will take 2-3 years to migrate from iDEN to 3G upgrade path; probably will migrate to1XRTT

Spectrum limitations

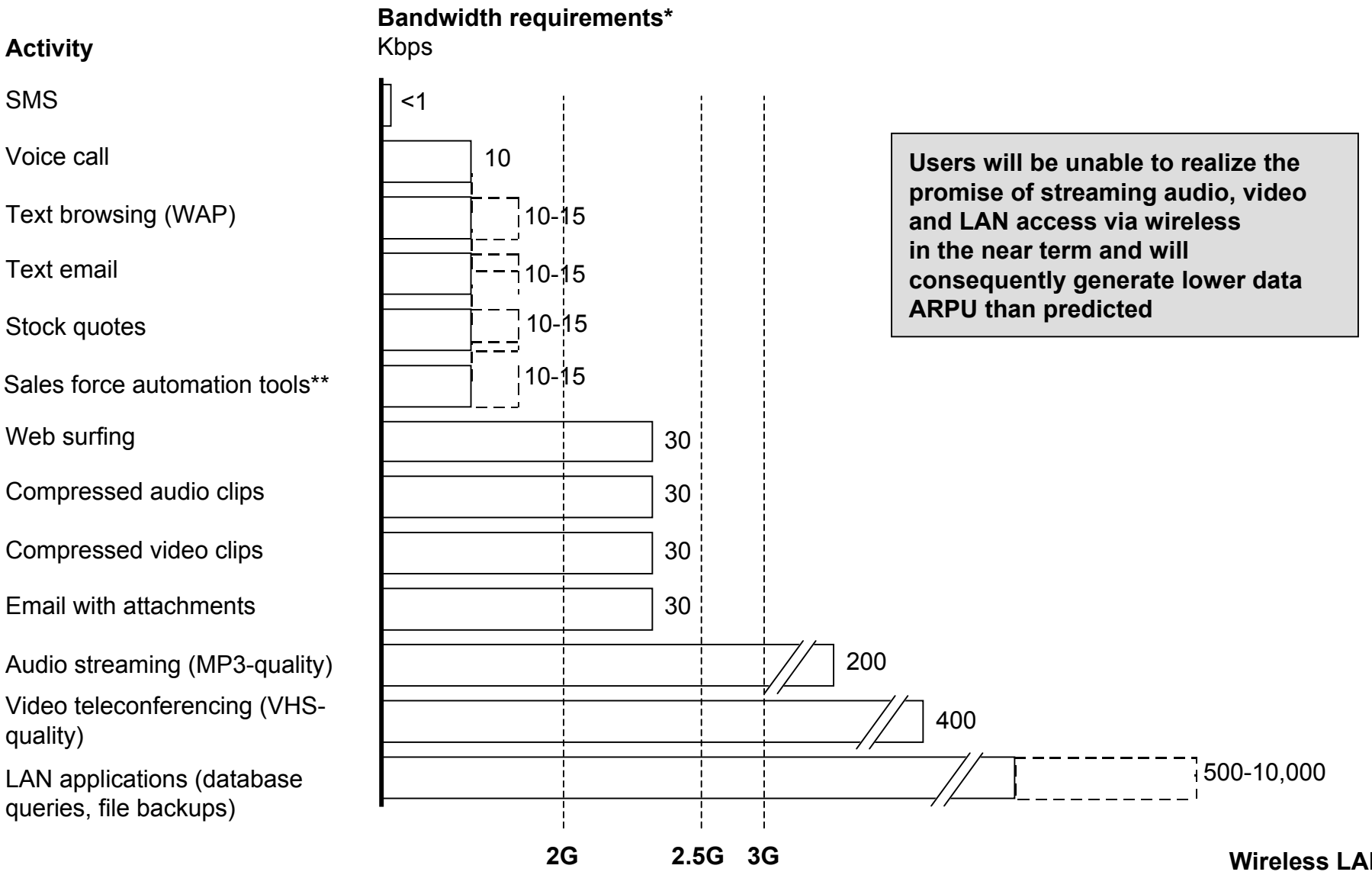
- 3G spectrum unlikely to be available before 2005
- W-CDMA requires 5MHz of clear, paired spectrum
- CDMA2000 1xEV-DO requires 1.25 MHz of clear, paired spectrum and only supports data – may create problems for PCS and Verizon in some markets with limited capacity

Technology readiness

- Availability of 3G handsets/devices questionable before 2H02/1H03
- 3G infrastructure unlikely to be available to begin network construction before 2002

Source: IEEE; CTIA; press releases; McKinsey

EARLY DATA NETWORKS CANNOT ENABLE CONTENT-RICH APPLICATIONS, WHICH WILL LIMIT DATA ARPU



* Based on existing applications

Source: Analyst reports; web sites

ACTUAL DATA THROUGHPUTS OF 3G NETWORKS LAG EXPECTATIONS

Kbits/sec

		Constraints		
Technology	**Expectation***	**Current network**	**Single user handset**	**Field tests, real life**
• GPRS	172	172	43	Under 25 kbps
• EDGE	474	172	96-144	Actual rates will vary typically in tens of Kbps per user
• CDMA 2000 1x	614	144	-	
• W-CDMA	2,048**	384	96-144	1. Radio connection (user location, interference, etc.)
• 1xEV-DO	2,458	-	-	2. Number of users per sector per MHz
• 1XEV-DV	5,180	-	-	

"*You will not see any carrier selling 384 Kbps for file transfers*"
– Mobile carrier

"*With the launch of W-CDMA, the actual speed will depend on traffic. We would like to provide several tens of kbps per user to support high numbers of users*"
– Mobile carrier

* Theoretical downlink speed
** Fixed applications
Source: Interviews; literature search