Access Networks:

Connecting the 'final mile' to homes and small businesses

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Requirements

- more bandwidth & reduced latency
  - avoiding the world wide wait
    - e-commerce
  - better quality audio/video
    - VOD, special interest TV
  - IP telephony/video conferencing
- “always-on”
  - remote access to home servers
  - instant messaging

Connectivity options

- conventional modems / ISDN
- xDSL
- cable modems
- fixed wireless : microwave/laser
- fiber to the home/kerb
- satellite : LEO/GEO/HAA
- mobile wireless : GSM/GPRS/3G & 802.11

Telephone Network

- conventional modems
  - digital-analogue-(digital)-analogue-digital
    - more advanced modulation techniques
    - 9.6, 14.4, 28.8, 36.4 Kbps
  - use direct digital connection at ISP
    - 56Kbps downlink (still 36KBps uplink)
- ISDN digital telephone line
  - 64+64 Kbps with rapid connection setup
  - requires fairly good quality line

xDSL: Digital Subscriber Line

- Use existing twisted pair copper plant
  - point-to-point link
- but, not a great transmission medium:
  - single pair, long, gauge & material changes
  - high freq loss, bridge taps and load coils
- interference sources
  - RF pickup/egress, thermal noise, reflections
  - Near End crosstalk (NEXT), Far End (FEXT)
- Throw DSP at the problem...

xDSL variants

- HDSL: 1.5Mbps, symmetric, 2 pair, no POTS, up to 12kft
  - T1/E1 delivery (old)
- SDSL: 1.5Mbps, symmetric, 1 pair, up to 18kft
- ADSL: 640-8Mbps ds, 64-800kbps us, 1 pair, POTS/ISDN, up to 18kft
- ADSL G.Lite: as above but 1.5Mbsp ds, 512Kbps us
  - “self install” splitter-less ADSL
- VDSL: 6-52Mbps ds, 2Mbps us, 1pair, POTS, 1-16Kft
  also 1,2,4,6,8,12Mbps symmetric
- Bandwidth negotiation and noise monitoring
- Asymmetric variants to reflect current traffic patterns

Competing xDSL technologies

- CAP/QAM
  - single "carrier"
  - lower symbol (baud) rate by encoding multiple bits per symbol
- DMT – current winner
  - many carriers e.g. ADSL has 249 x 4kHz channels with 15bit QAM = 249 x 60kbps
  - poor channels can be discarded/down-coded
    - Reduce symbol rate, fewer bits; more FEC
  - requires lots of DSP

xDSL regulatory issues

- Incumbent Local Exchange Carrier (ILEC) e.g. BT vs. Competitive LEC (CLEC)
- How to ‘open-up’ the market?
  - Physical level vs. DSL level vs. ISP level
  - issues of maintenance responsibility, exchange access etc
- Maintaining ‘life-line’ phone service

Cable Modems

- Uses CATV coax *tree* from Head End
  - serves 1000's of customers
    - rapid rollout -- can split tree later
- 30-40 Mb/s shared downstream bw
  - single 6MHz channel (same as a TV station)
  - 64/256 QAM encoding
  - head-end scheduled

Cable Modems

- Upstream channel is harder (320-10Mbps)
  - 16 QAM
  - need MAC protocol for Collision Detect and retransmission, fair bandwidth sharing
  - large distances require *ranging* optimizations
  - DOCSIS 1.1
- Encryption necessary for both channels
  - DES block cipher

Fixed Wireless

- Microwave and free-space laser
  - line-of-sight between rooftop antennas
    - avoids multi-path interference, lower power
- Free-space laser systems
  - 2-155Mbps and up
  - relatively narrow beam requires stable fixtures
  - Wavelength Division Multiplex systems

Fixed Wireless

- Microwave
  - point-to-point and multi-point systems
  - MMDS: 2GHz, 20-50km, 0.2-2Mbps
  - LMDS: 28GHz, 5km, 1-20MBps
  - MVDS: 40GHz, 3km, 100MBps+
- Free spectrum above 5GHz
  - but, limited propagation, ‘rain-fade’, requires high-speed electronics…

Satellite

- GEO stationary
  - 36,000km orbit
  - e.g. 2x 120ms RTT
- LEO constellations
  - 20+ in 1,500km orbits (2hr)
  - latency typically sub 100ms, 300Mbps+
  - interconnect options:
    - 1. forward to ground station
    - 2. Uplink to a GEO network
    - 3. LEO to LEO laser

“Near-satellite”

- Avoid LEO roll-out costs
  - target your market audience
- Fuel efficient planes
  - 55,000 ft, 2 pilots on 8hr shifts
  - NASA Helios : solar-powered wing
- high-altitude balloons
  - above most weather systems
  - use ion engines to stay in place

Fiber to the kerb / home

- A reasonable solution for new properties
  - fiber is cheap, termination costs dropping
- Digging up the street is very expensive
  - Especially into every home
- Fiber to the ‘kerb-side box’
  - remaining short length of existing copper good for 100’s of Mbps.

Public mobile wireless

- GSM currently provides 9600 and 14400bps circuit data service
  - Slow connection setup, no stat-mux gain, 600ms RTT
- GPRS – packet data over GSM
  - 32Kb/s - 100Kb/s, 900-1500ms RTT!
  - HTTP/TCP behaves very poorly
- UMTS “3G” services optimized for data
  - 384kbps quoted for pedestrians
- Public mobile b/w capabilities look set to remain poor & expensive in contrast to fixed

802.11 : three physical layers

- 802.11 FHSS (Freq. Hopping Spread Spectrum)
  - 2.4GHz, 2Mbp/s
  - Freq. Hop between 75 1MHz channels every 20ms
- 802.11b DSSS : now popular
  - 2.4GHz, 11Mb/s, 20-100m
  - Code Division Multiple Access. 13 channels, 3 distinct
- 802.11a : new standard
  - 5GHz, 54Mb/s, 5-30m
  - OFDM (DMT) – better multipath rejection
  - 48 sub carriers, varying coding, symbol rate & FEC

802.11 : MAC

- CSMA/CD doesn't work
  - Can't receive while TX'ing
- Use CSMA/CA Collision Avoidance
  - RX'er ACKs every packet else retransmit
  - Still have *hidden node* prob. Use 4-way HS:
    1. Listen. Wait for IFS (50ms). Send RTS (containing dest & duration). [If media busy, wait random back off]
    2. Destination sends a CTS (visible to hidden node)
    3. Sender sends data
    4. Destination sends ACK after 10ms. [If no ACK, retransmit]
  - Also, reserve some time for Base Station polled access

802.11

- WEP encryption
  - Network rather than per-user key
  - Need other schemes to control access etc
- Simple power management
  - Wake up periodically, AP buffers packets
- 802.11b deployed in homes, offices, hotels, coffee shops, shopping centres, auditoriums
  - Can a public service be built over this?