

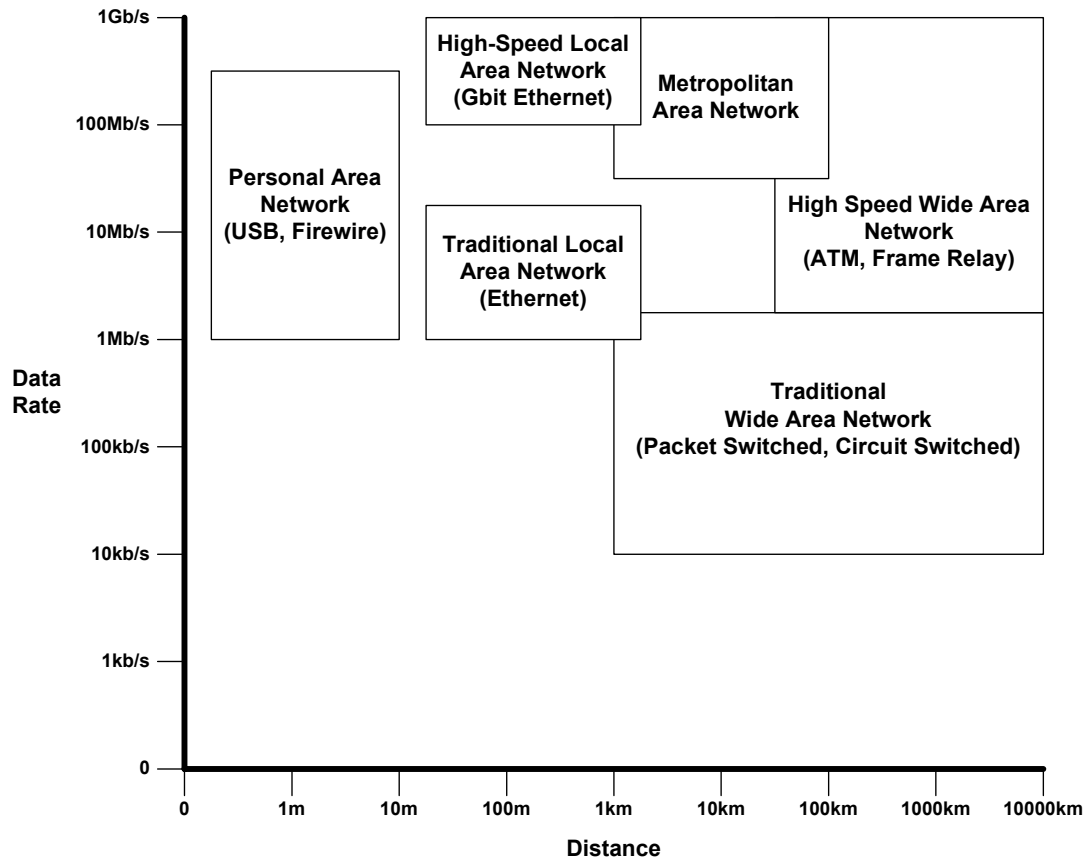
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Wireless Data Networks

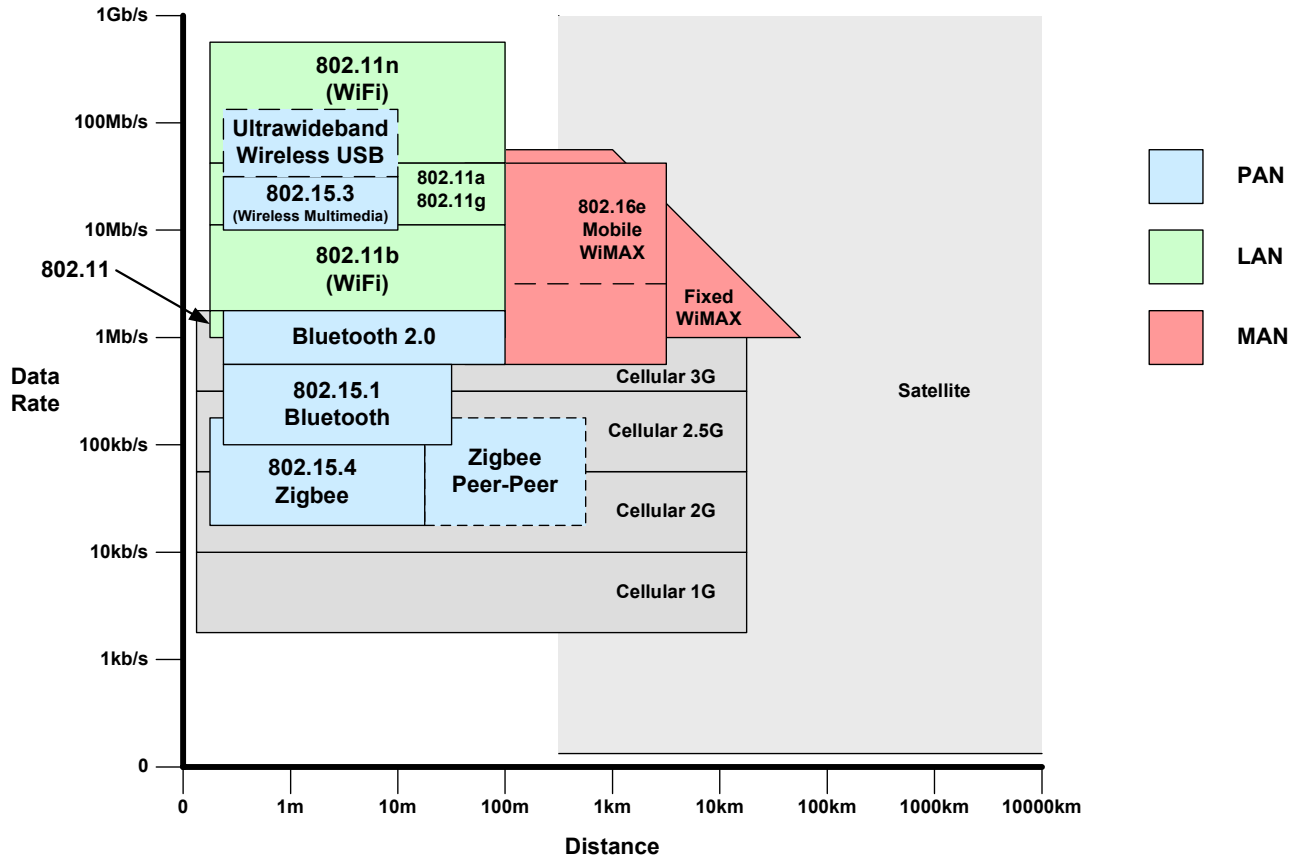


Nick Massey
VA7NRM

Wired Networks



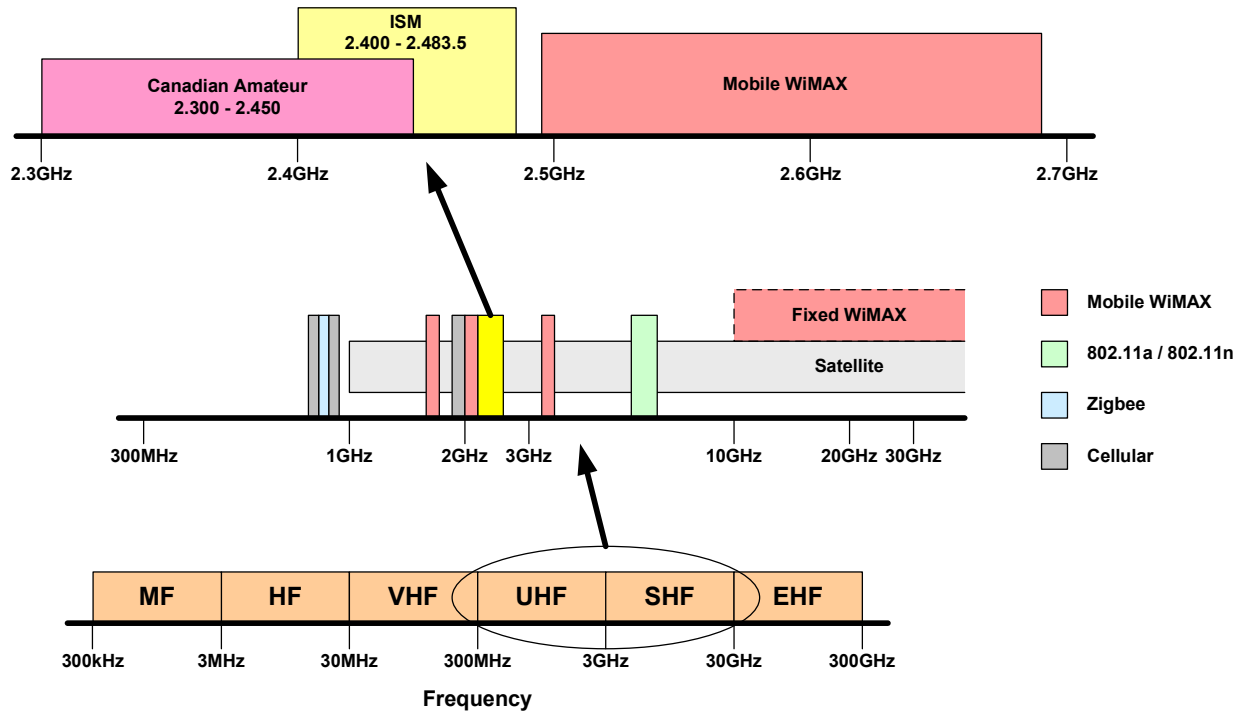
Wireless Networks



Frequencies



802.15.4 - Zigbee (2.4 GHz)
 802.15.1 - Bluetooth
 802.15.3 - Wireless Multimedia
 802.11, 802.11b, 802.11g, 802.11n
 Microwave ovens, Cordless phones +++



Bluetooth (802.15.1)



- Short range "wire replacement"
- Bluetooth 1.0 - 1999
- Bluetooth 1.1 - 2001
- Bluetooth 1.2 - 2003
- Bluetooth 2.0 - 2004
- 1 billion units shipped - November 2006
- 50 million units per month
 - but ... are they used?

Bluetooth Applications



- Keyboards, Mouse Devices
- Wireless Headsets (Phone or Stereo Music)
- Hands-free Telephony
- Cordless Telephony, Intercom
- Printing
- Network bridge – LAN, WAN, Fax
- File transfer and object exchange (OBEX)
- Wire replacement (Serial and Parallel I/O ports)
- Wireless Control (Wii, PlayStation3, Lego)

Bluetooth Radio



— • — • — • — • • • — • — • • • — • • • • — •

■ 2.4 GHz ISM Band

■ (Adaptive) Frequency Hopping

- 79 channels (most countries), 1 MHz spacing, 1.6 hop/s

■ Modulation

- Bluetooth 1.x GMSK 1 Mb/s in 1 MHz bandwidth
- Bluetooth 2.0 QPSK 2 Mb/s in 1 MHz bandwidth
- 8PSK 3 Mb/s in 1 MHz bandwidth

■ 3 Classes

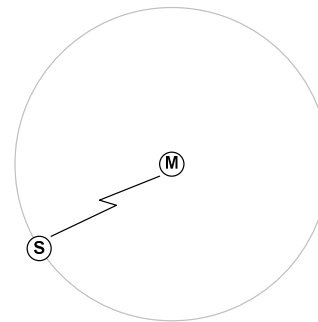
- Class 1 100 mW ~100 m
- Class 2 2.5 mW ~20 m
- Class 3 1 mW ~10 m

Piconets and Scatternets

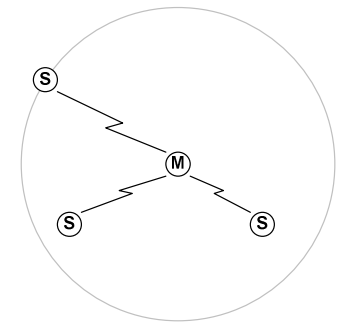


- Piconet has one Master and up to 7 Slaves
- Slave hopping sequence is synchronised to Master
- Master schedules Slave transmissions
- Master can assign assymmetric and unbalanced bandwidth to Slaves

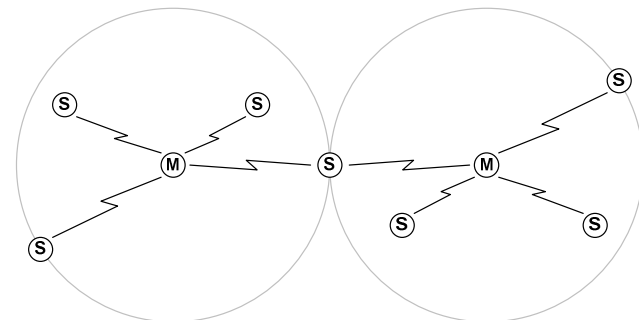
Point - Point



Point - Multipoint



Scatternet



Bluetooth Profiles



- . - . - - . - - . . . - . - - . . . - - .

■ Profiles – Strength

- Define interoperability between equipment

■ Profiles – Weakness

- Need to ensure unit supports required Profile

■ Example Profiles (There are many others)

- Headset
- A2DP (Stereo Headphones)
- Serial Port
- LAN Access
- Object Exchange

Zigbee (802.15.4)



- . - . - . - . . . - . - - . . . - - . - .
- Embedded applications using low data rates
 - Low Power – long battery life
 - Zigbee 1.0 – December 2004 (Public, June 2005)
 - Certified devices are now available

 - Self configuring Mesh Networks
 - Low duty cycle (devices can "sleep")

Zigbee Applications



- . - . - . - - . - - . . . -
- HVAC
 - Home Automation
 - Industrial Automation
 - Alarm/Status Monitoring (e.g. Smoke alarms)
 - Medical Monitoring

Zigbee Radio



- 868 MHz, 915 MHz and 2.4 GHz ISM Bands
- Direct Sequence Spread Spectrum
 - 868 MHz 1 channel 600 kHz wide
 - 915 MHz 10 channels 1.2 MHz wide
 - 2.4 GHz 16 channels 4.0 MHz wide
- Modulation
 - 868 MHz BPSK 20 kb/s
 - 915 MHz BPSK 40 kb/s
 - 2.4 GHz 16PSK 250 kb/s
- Tx Power: ~1 mW Range: Up to 100m

Zigbee Devices



— • — • — — • — — • • • — • — — • • • — • • • • • — •

■ FFD and RFD

- FFD Full Function Device On when idle
- RFD Reduced Function Device Off when idle

■ Coordinator (FFD)

- One per Network, controls the network

■ Router (FFD)

- Optional, extends network range

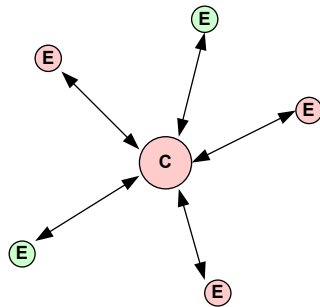
■ End (FFD or RFD)

- Performs monitoring or control functions

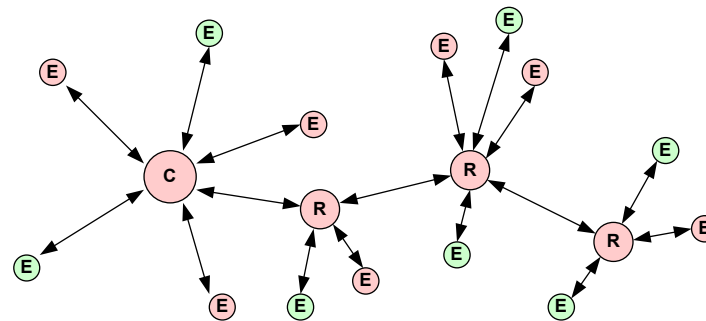
Star, Cluster Tree and Mesh Networks



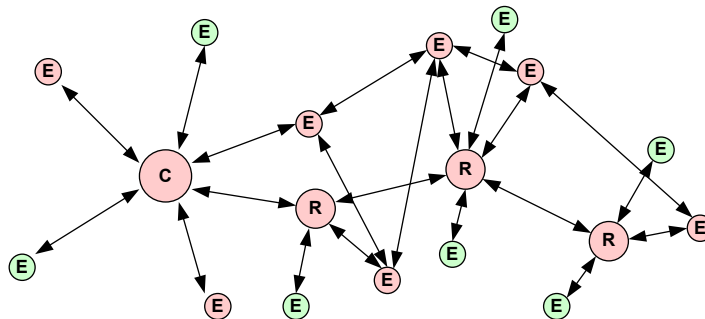
Star Network



Point - Multipoint



Mesh Network



(E) Full Function Device

(E) Reduced Function Device

Networks are CSMA/CA and can be:
Synchronised ("Beacon")
Unsynchronised ("Non-Beacon")

WiFi (802.11 Family)



- • — • — • — • • • — • — • • • — • • • • — •
- **Wireless Local Area Network**
 - **IEEE 802.11 – 1997 2.4 GHz 2 Mb/s**
 - **IEEE 802.11a – 1999 5.8 GHz 54 Mb/s**
 - **IEEE 802.11b – 1999 2.4 GHz 11 Mb/s**
 - **IEEE 802.11g – 2003 2.4 GHz 54 Mb/s**
 - **IEEE 802.11n – 2008? 2.4 GHz 540 Mb/s**
 - **2002 – 16 million units shipped**
 - **2006 – 160 million units projected**

WiFi Applications



- • — • — • — • • • — • — • • • — • • • • • — • • • • • — •
- **Wireless LANs**
 - LAN Extension
 - Building to Building Interconnect
 - Nomadic Access (Hotspots)
 - Ad Hoc Networks
 - **VoIP Phones (and "Cell" Phones)**
 - **Home Entertainment (Audio/Video Streaming)**
 - **Microsoft Zune (Song exchange)**

 - **Generally require some "Administration"**

802.11a Radio



- 5.150 – 5.250, 5.250 - 5.350 and 5.725 – 5.825 GHz
 - Indoor, Indoor/Outdoor, Outdoor (shares Amateur band)
- Four 20 MHz spaced channels in each band
- 52 carrier (48 data + 4 pilot carrier) OFDM
- 250 ksym/s
 - BPSK $\frac{1}{2}$ code - 6 Mb/s $\frac{3}{4}$ code - 9 Mb/s
 - QPSK $\frac{1}{2}$ code - 12 Mb/s $\frac{3}{4}$ code - 18 Mb/s
 - 16-QAM $\frac{1}{2}$ code - 24 Mb/s $\frac{3}{4}$ code - 36 Mb/s
 - 64-QAM $\frac{2}{3}$ code - 48 Mb/s $\frac{3}{4}$ code - 54 Mb/s
- 40 mW (USA Indoors) – 800 mW (USA Outdoors)
 - Indoor range ~ 30 m

802.11b Radio



- 2.400 – 2.483.5 GHz (USA/Canada)
- 11 overlapping channels on 5 MHz spacing
- Channels 1, 6 & 11 Recommended
- DSSS 11MHz chip rate - 22 MHz bandwidth
 - 11-bit Barker DBPSK 1 Msym/s 1 Mb/s
 - 11-bit Barker DQPSK 1 Msym/s 2 Mb/s
 - 8-bit CCK (4) DQPSK 1.375 Msym/s 5.5 Mb/s
 - 8-bit CCK (64) DQPSK 1.375 Msym/s 11 Mb/s
- 200 mW (Europe), 1000 mW (USA), Typically less
 - Indoor range ~30 m @ 11 Mb/s, ~100m @ 1 Mb/s

802.11g Radio



- 2.400 – 2.483.5 GHz (USA/Canada)
- 802.11a Scheme (OFDM) at 802.11b Frequencies
- Backwards compatible/interoperable with 802.11b
 - Beacons and Channel Access use 802.11b
 - Data can be either DSSS or OFDM
- Throughput less than 802.11a (can be 50%)
- Indoor range ~30 m @ 11 Mb/s, ~15m @ 54Mb/s

802.11n Radio

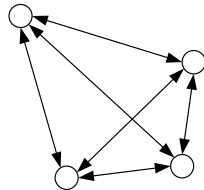


- Future – 540 Mb/s! – Ratification in 2008?
 - "Pre-n" or "Draft-n" products are available
 - Some manufacturers guarantee final compatibility
- Wider channels (40 MHz rather than 20 MHz)
 - Regulatory issues
- More efficient MAC and Aggregation
- Optional backwards compatibility
- Multiple-In/Multiple-Out (MIMO)
 - Many transmitters and receivers working together
 - 2x2 mandatory but more can be used
 - Probably ~150 Mb/s (2x2, 20MHz) or ~300 Mb/s(2x2, 40MHz)

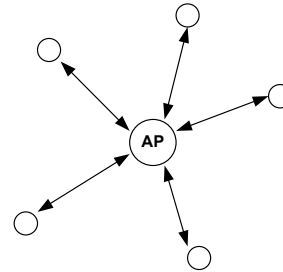
802.11 Networks



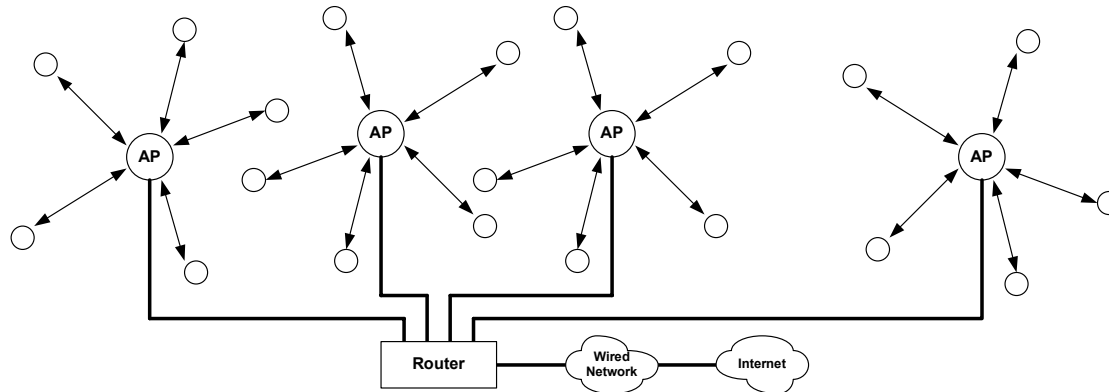
Independent BSS



Infrastructure BSS



Extended Service Set



802.16 (Mobile) WiMAX



- Provide Wireless Local Loop ("Last Mile") communications
- 802.16 – 2002
 - 10 – 66 GHz (Depending on licensing)
- 802.16d (Fixed) WiMAX – 2004
 - 2 – 11 GHz (Depending on licensing), NLOS
- 802.16e Mobile WiMAX – 2005
 - Licensed at 2.3/2.5, 3.5 or 5 GHz, NLOS
- "pre-WiMAX" equipment is in use
 - Canada – Inukshuk Wireless (Rogers/Bell) 2.5 GHz
 - USA – Sprint Nextel investing heavily
- Certified Mobile WiMAX products just becoming available

Inukshuk



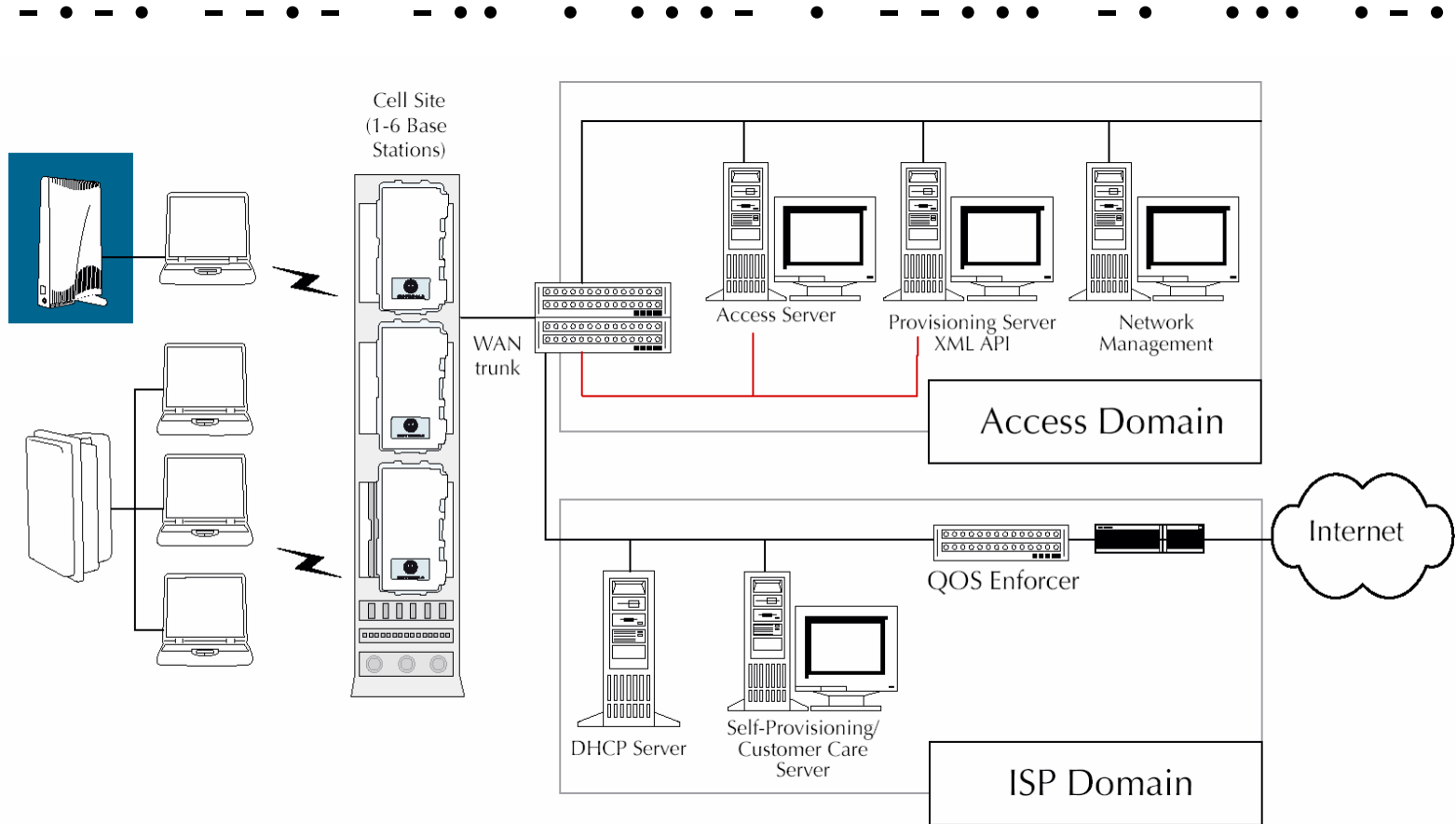
- Licensed 2.5 GHz
- Major Cities, coverage expanding
- Motorola (NextWave) Modem
 - 3.0 Mb/s download, 384 kb/s upload

802.16e Radio



- Scalable OFDM, MIMO support
- 1.25 – 20 MHz Channels
- 128 – 2048 carrier OFDM
- Adaptive Modulation, Coding and UL/DL Assignment
- 9.6 ksym/s (Examples for 512 carriers, 5MHz)
 - QPSK $\frac{1}{2}$ code x 6 - ~1 Mb/s $\frac{3}{4}$ code - ~8 Mb/s
 - 16-QAM $\frac{1}{2}$ code - ~11 Mb/s $\frac{3}{4}$ code - ~16 Mb/s
 - 64-QAM $\frac{2}{3}$ code - ~16 Mb/s $\frac{3}{4}$ code - ~27 Mb/s
- 2 W Typical
 - Typical range ~3 km

Mobile WiMAX Network



Wireless Local Loop?



- 802.16e Supports
 - Quality of Service
 - Circuit Switching
 - Broadcast/Multicast
- ... and allows for
 - Base Station Hand-off
 - Fractional Frequency Reuse
- WiMAX Consortium working to standardise
 - Roaming
 - Billing

Amateur HSMM



— • — • — • — • • • — • — • • • — • • • • — •

■ ARRL sponsored project

- Introduce high-speed data (≥ 56 kb/s) to Amateur Radio
- 2001
- A number of sub-projects including 70 kb/s at HF !

■ One technique is to use consumer 802.11 gear

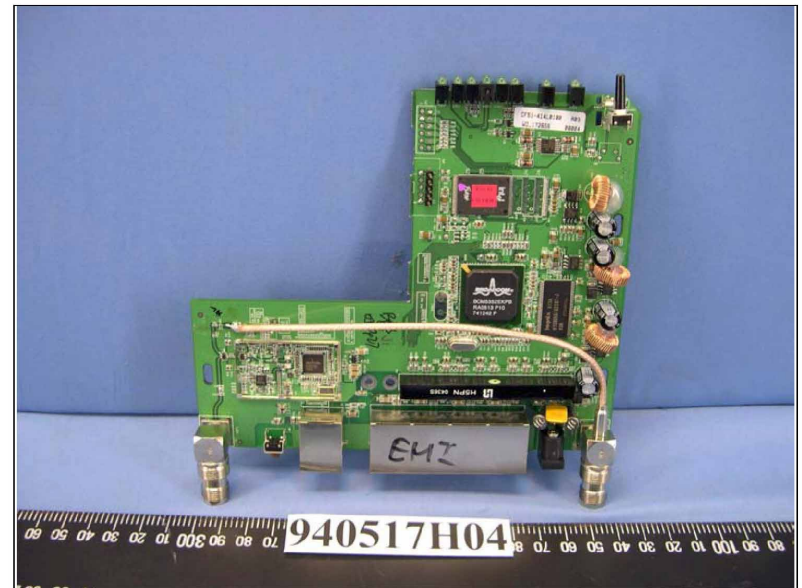
- Use "as is"
- Upgrade with open-source firmware
- Use high-gain antennas



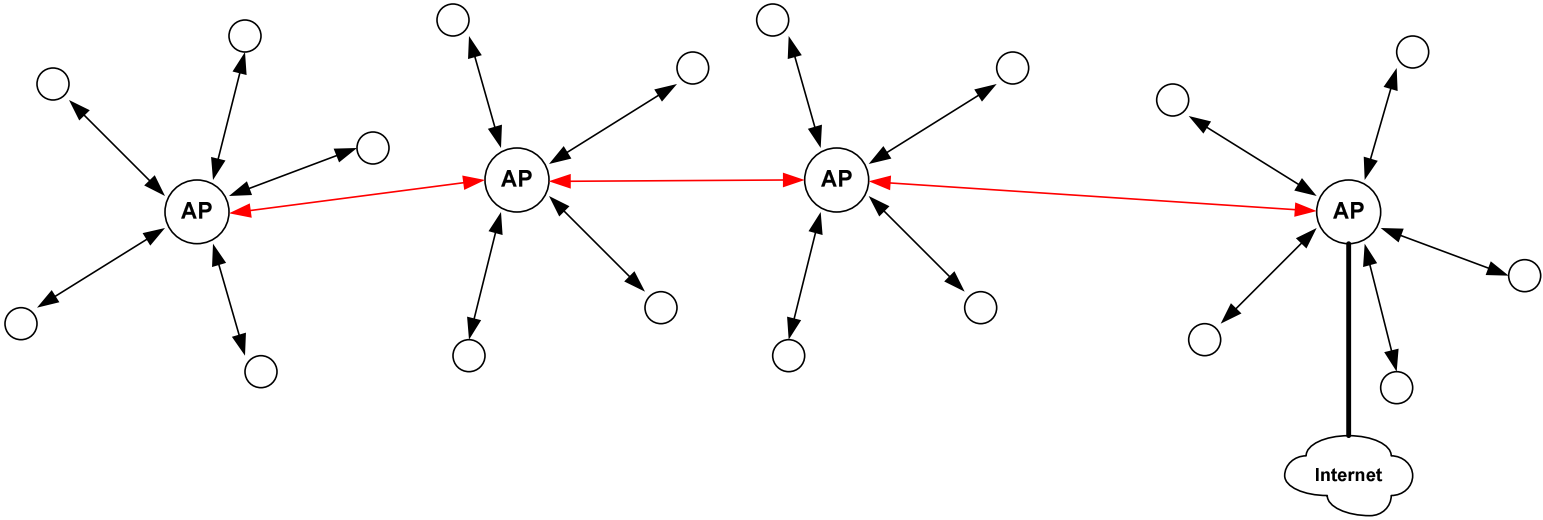
Linksys WRT54G



- Linux – Open Source
 - Newer versions VxWorks
- WRT54GL
 - L for Linux
 - Available online
- 3rd Party Firmware
 - Extra functionality
 - Higher Tx Power



802.11 WDS Wireless Distribution System



References



- **Wireless Communications and Networks, 2nd Ed.**
William Stallings
Pearson Prentice Hall, ISBN 0-13-191835-4

- **www.n5oom.org/hsmm**