WiFi Overview

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Radio Based Computer Networking for Research and Training in Developing Countries

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WiFi Overview
Agenda

- 802.11 Standards
- 802.11 Terminology
- DSSS Channel Allocation
- Medium Access Control
- Power Considerations
- Scanning
- Configuration
- Interference

Wireless Data Transmission flavors

- Packet Radio over VHF or HF
- Wireless Local Area Networks (WLAN)
- Wireless Local Loop (WLL, LMDS)
- Free Space Optics
- Satellite Transmission

Wi-Fi Technology Overview

- Wireless networks where borne as LANs, but for developing countries' applications they are more useful as MANs or even WANs
- The enormous success of this technology has led to a dramatic price reduction of the radios +modem, from $750 in 1992 to $30 in 2004, while transmission speed has increased up to 108 Mbps on the same 20 MHz channel

Wi-Fi Technology Overview: Standards

- IEEE 802.11

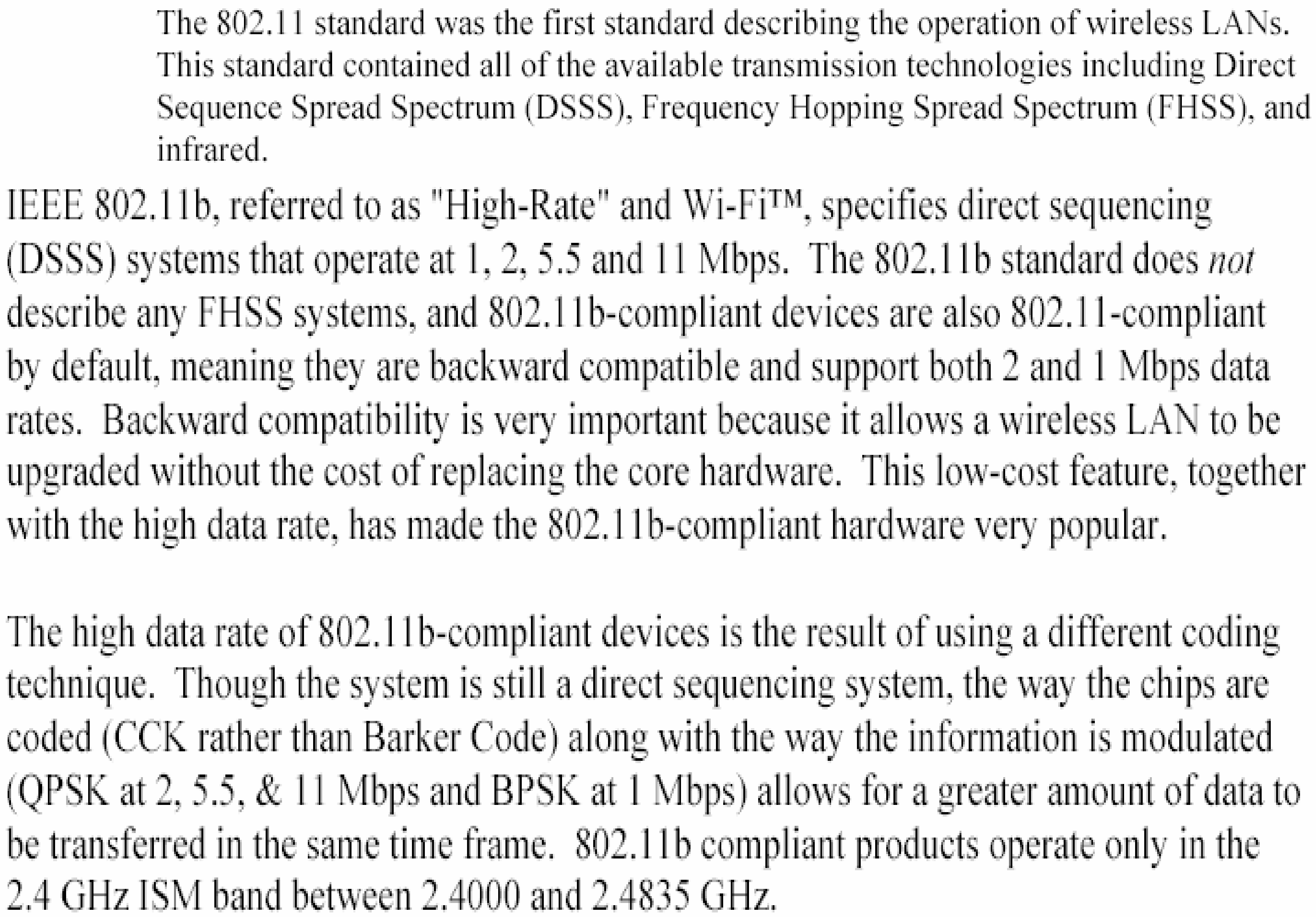
  1 and 2 Mbps, Frequency Hopping, DSSS (915 or 2400 MHz) or IR, Ratified in 1977

- IEEE 802.11 a up to 54 Mbps, 5 GHz, OFDM
- IEEE 802.11 b up to 11 Mbps, 2.4 GHz, DSSS

  Both ratified in 1999

- IEEE 802.11g up to 54 Mbps, 2.4 GHz, OFDM, downward compatible with 802.11b, Ratified in 2003

IEEE 802.11

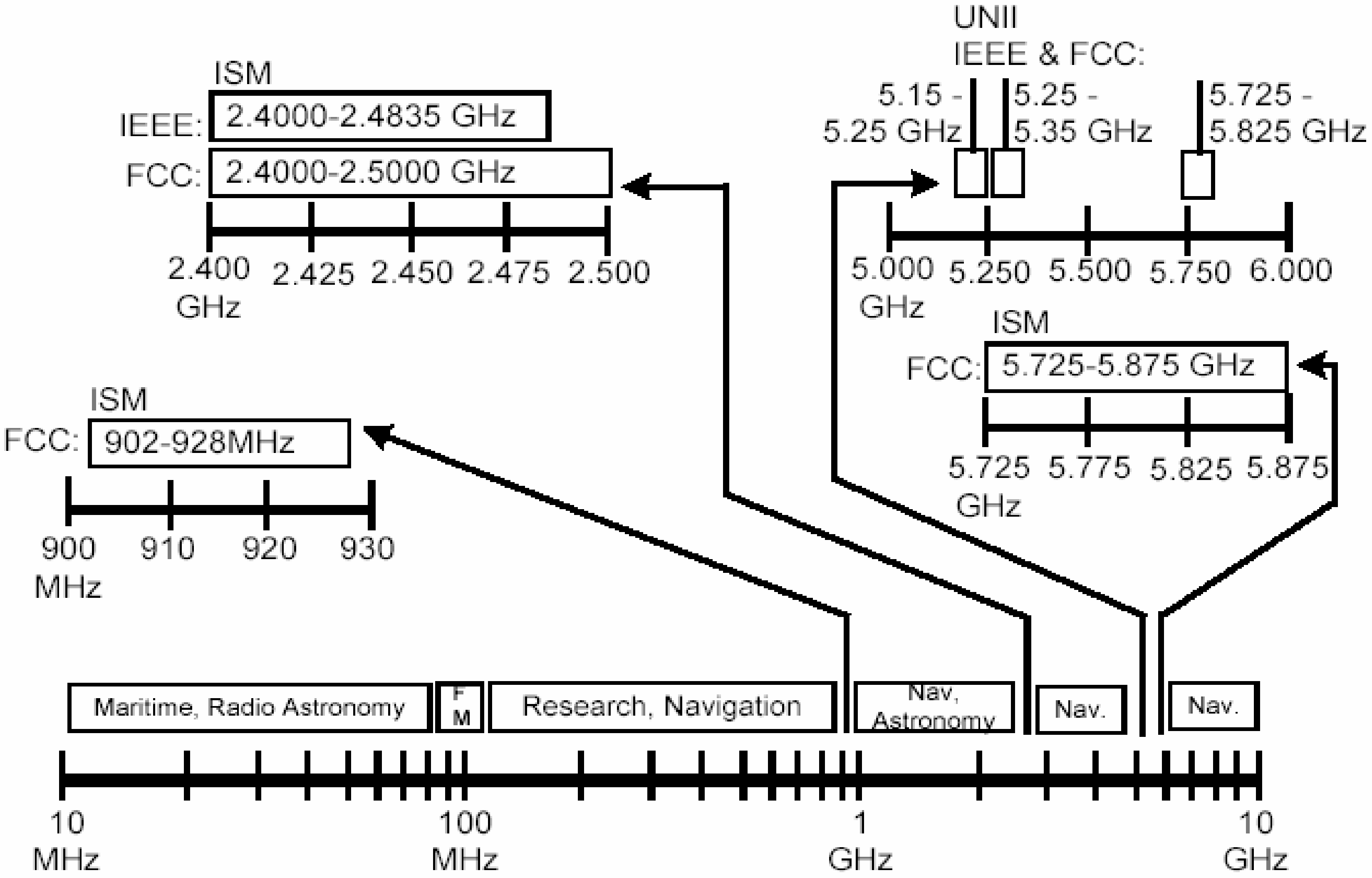


The 802.11 standard was the first standard describing the operation of wireless LANs. This standard contained all of the available transmission technologies including Direct Sequence Spread Spectrum (DSSS), Frequency Hopping Spread Spectrum (FHSS), and infrared.

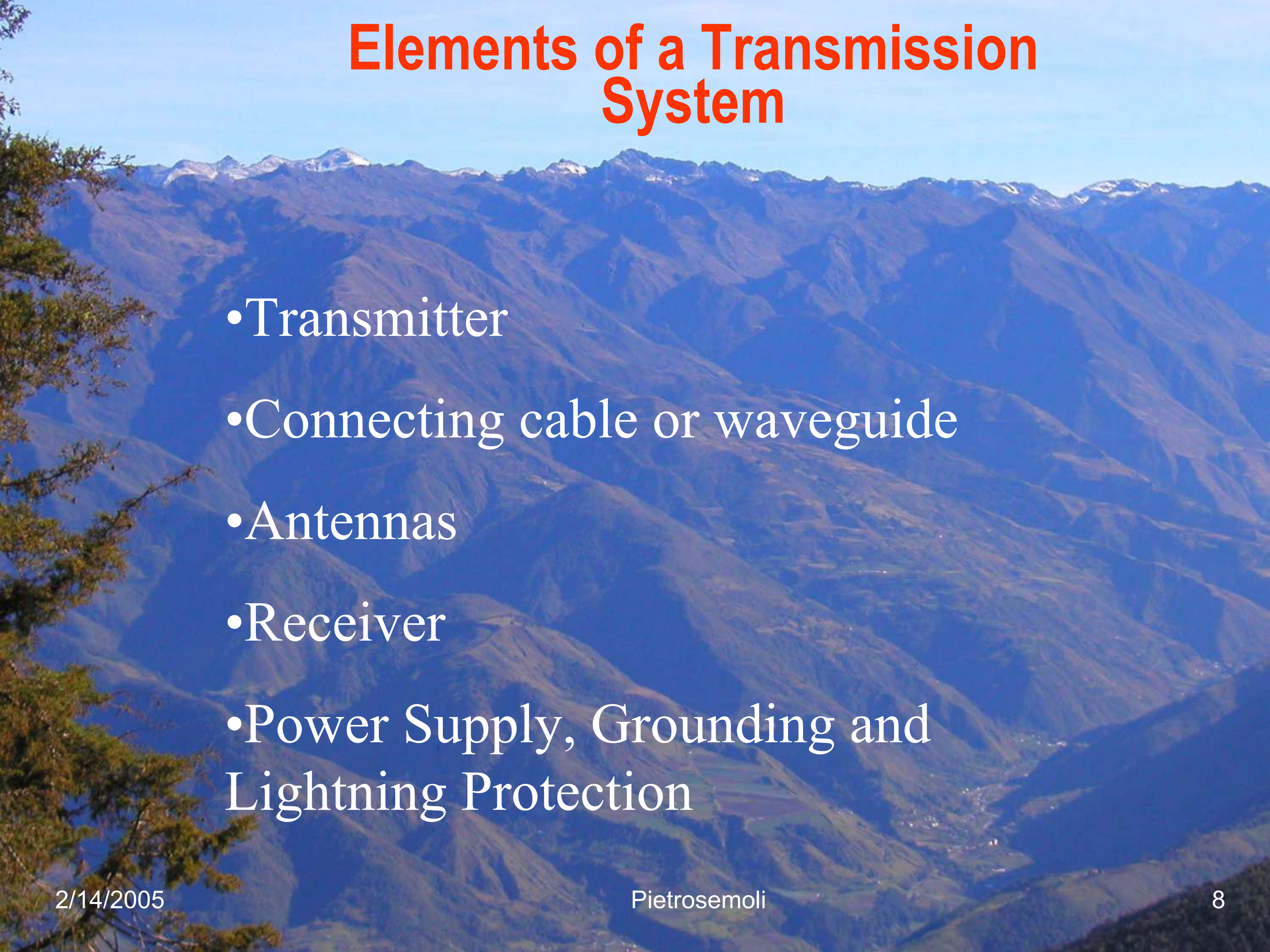
IEEE 802.11b, referred to as "High-Rate" and Wi-Fi™, specifies direct sequencing (DSSS) systems that operate at 1, 2, 5.5 and 11 Mbps. The 802.11b standard does *not* describe any FHSS systems, and 802.11b-compliant devices are also 802.11-compliant by default, meaning they are backward compatible and support both 2 and 1 Mbps data rates. Backward compatibility is very important because it allows a wireless LAN to be upgraded without the cost of replacing the core hardware. This low-cost feature, together with the high data rate, has made the 802.11b-compliant hardware very popular.

The high data rate of 802.11b-compliant devices is the result of using a different coding technique. Though the system is still a direct sequencing system, the way the chips are coded (CCK rather than Barker Code) along with the way the information is modulated (QPSK at 2, 5.5, & 11 Mbps and BPSK at 1 Mbps) allows for a greater amount of data to be transferred in the same time frame. 802.11b compliant products operate only in the 2.4 GHz ISM band between 2.4000 and 2.4835 GHz.

ISM and UNII Spectra

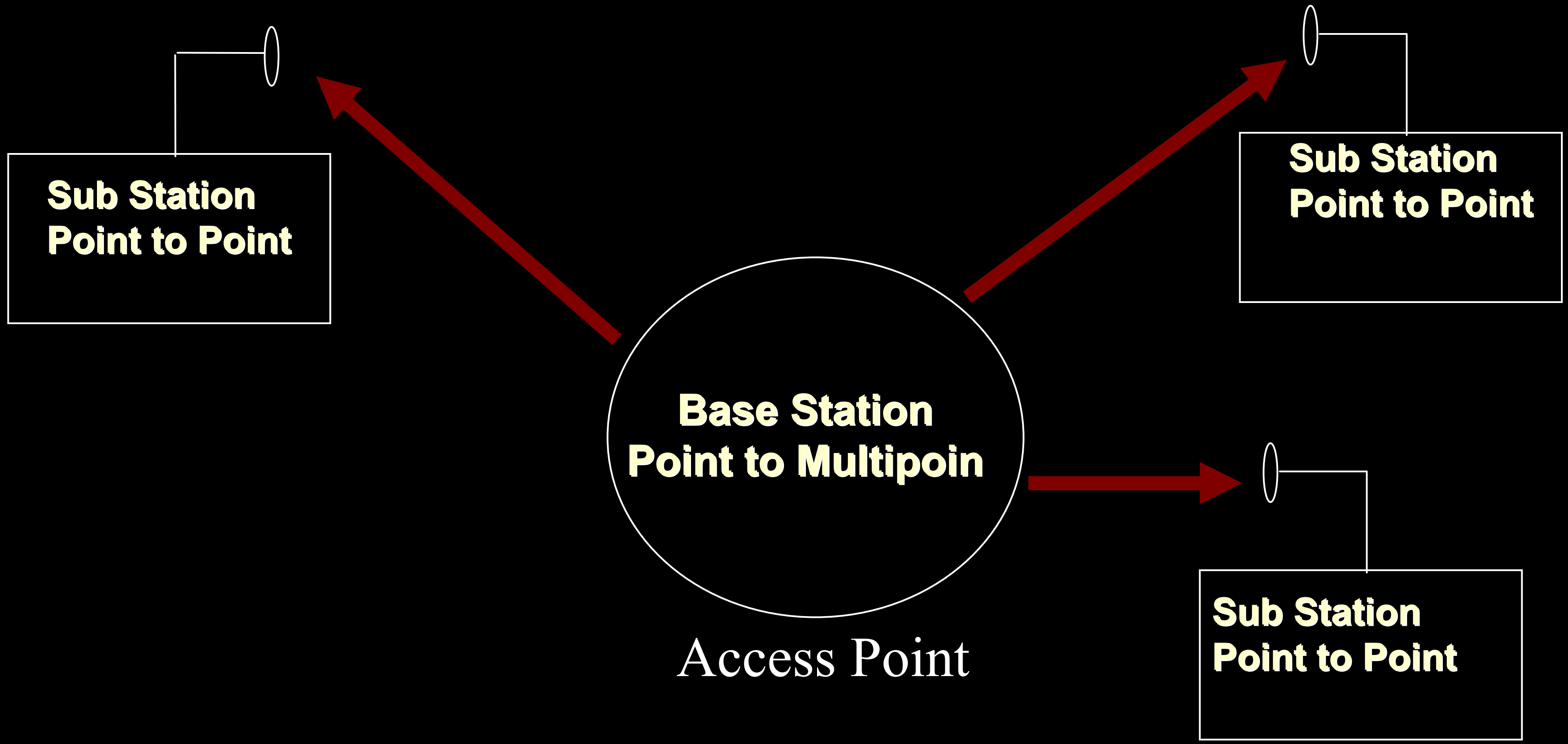


Elements of a Transmission System



- Transmitter
- Connecting cable or waveguide
- Antennas
- Receiver
- Power Supply, Grounding and Lightning Protection

System Configuration



Sub Station
Point to Point

Sub Station
Point to Point

Base Station
Point to Multipoin

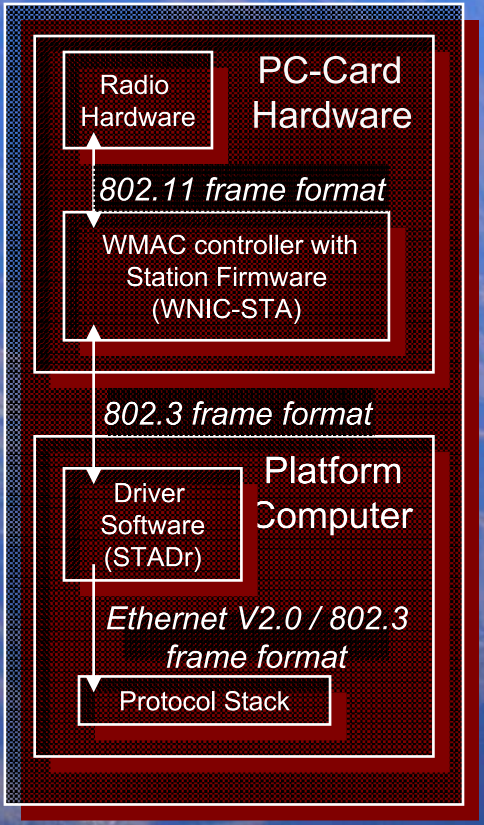
Access Point

Sub Station
Point to Point

IEEE 802 .11 Terminology

Station (STA) Architecture:

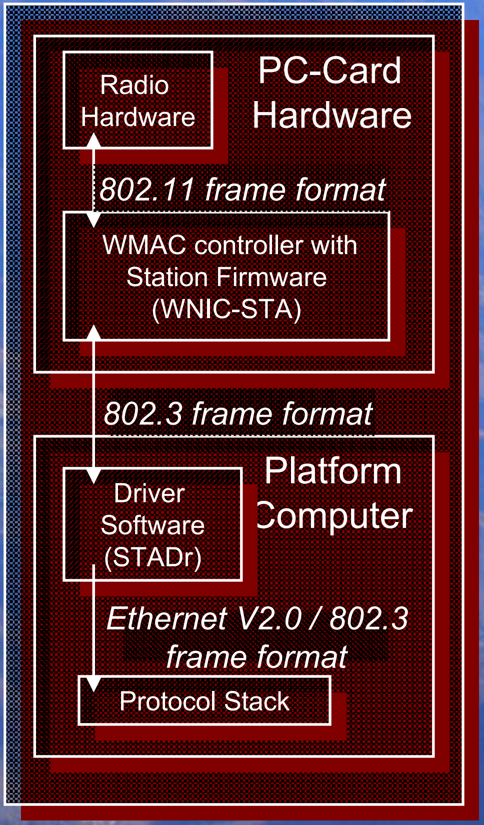
- Device that contains IEEE 802.11 conformant MAC and PHY interface to the wireless medium, but does not provide access to a distribution system
- Most often end-stations available in terminals (work-stations, laptops etc.)



IEEE 802 .11 Terminology

Access-Point (AP) Architecture:

- Device that contains IEEE 802.11 conformant MAC and PHY interface to the wireless medium, and provide access to a distribution system for associated stations
- Most often infra-structure products that connect to wired backbones

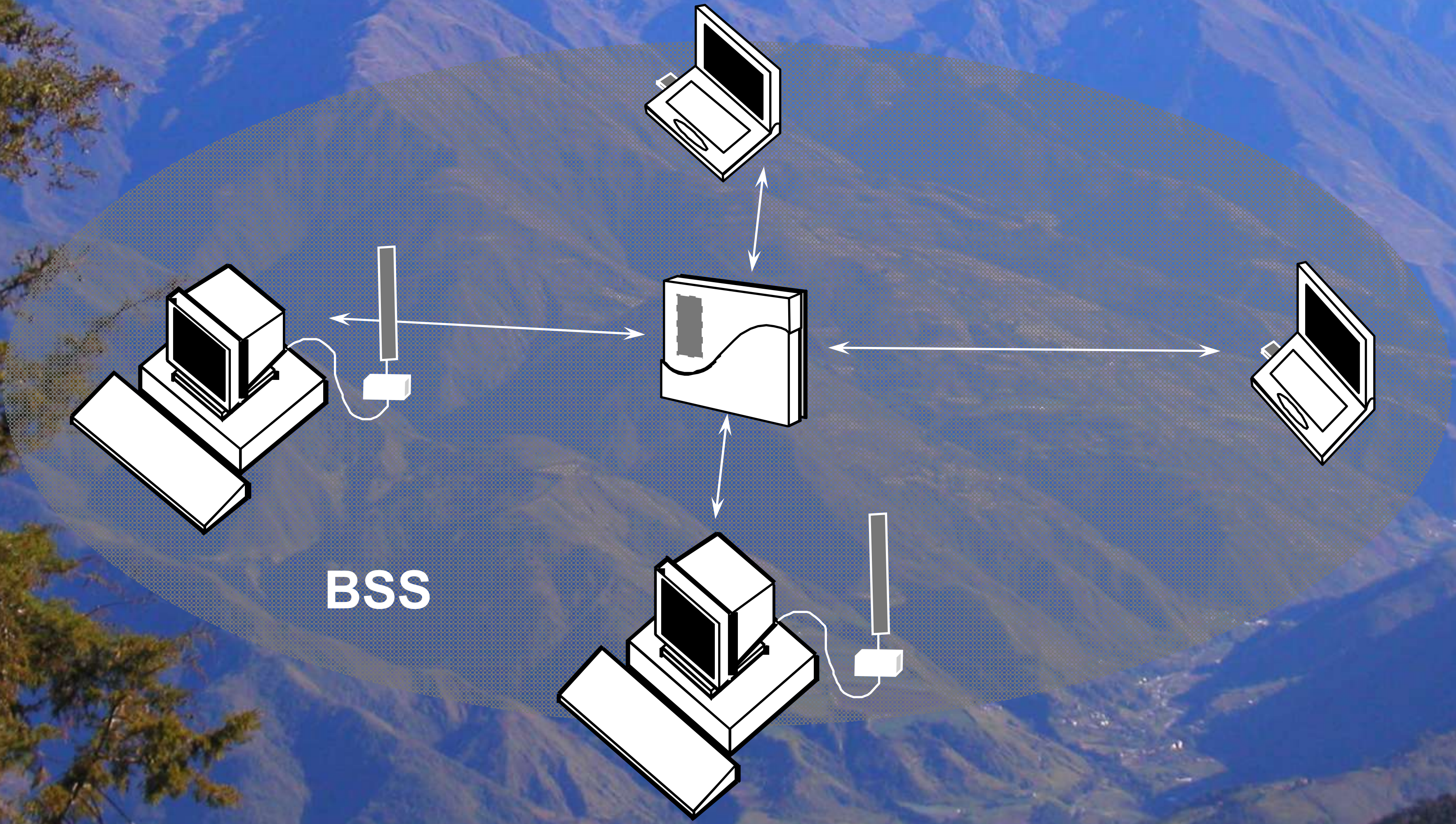


IEEE 802 .11 Terminology

BSS

- A set of stations controlled by a single “Coordination Function” (the logical function that determines when a station can transmit or receive)
- Similar to a “cell” in mobile phone terminology
- A BSS can have an Access-Point (both in standalone networks and in building-wide configurations), or can run without and Access-Point (in standalone networks only)
- Diameter of the cell is app. twice the coverage-distance between two wireless stations

Basic Service Set (BSS)

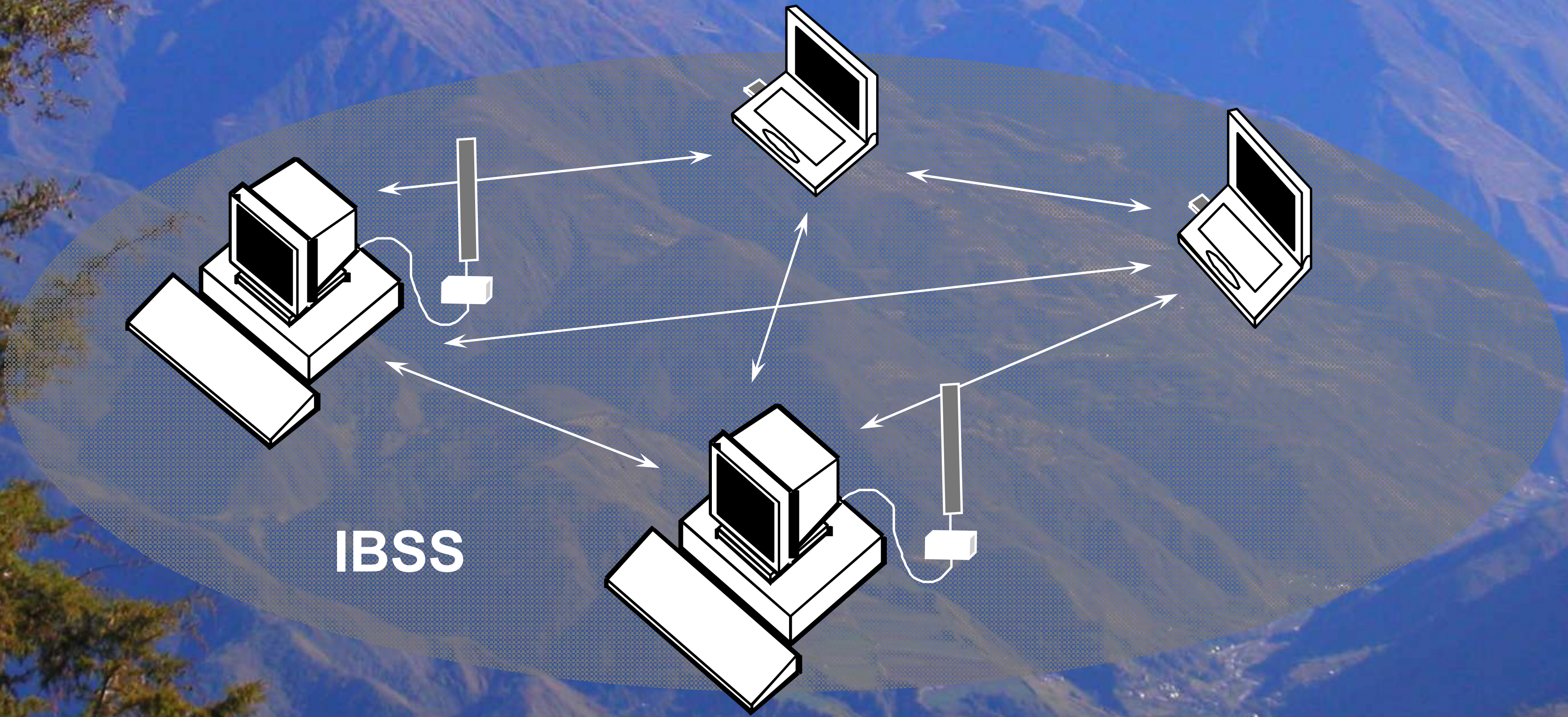


IEEE 802 .11 Terminology

Independent Basic Service Set (IBSS):

- A Basic Service Set (BSS) which forms a self-contained network in which no access to a Distribution System is available
- A BSS without an Access-Point
- One of the stations in the IBSS can be configured to “initiate” the network and assume the Coordination Function
- Diameter of the cell determined by coverage distance between two wireless stations

Independent Basic Service Set
(IBSS)



IEEE 802 .11 Terminology

Extended Service Set (ESS):

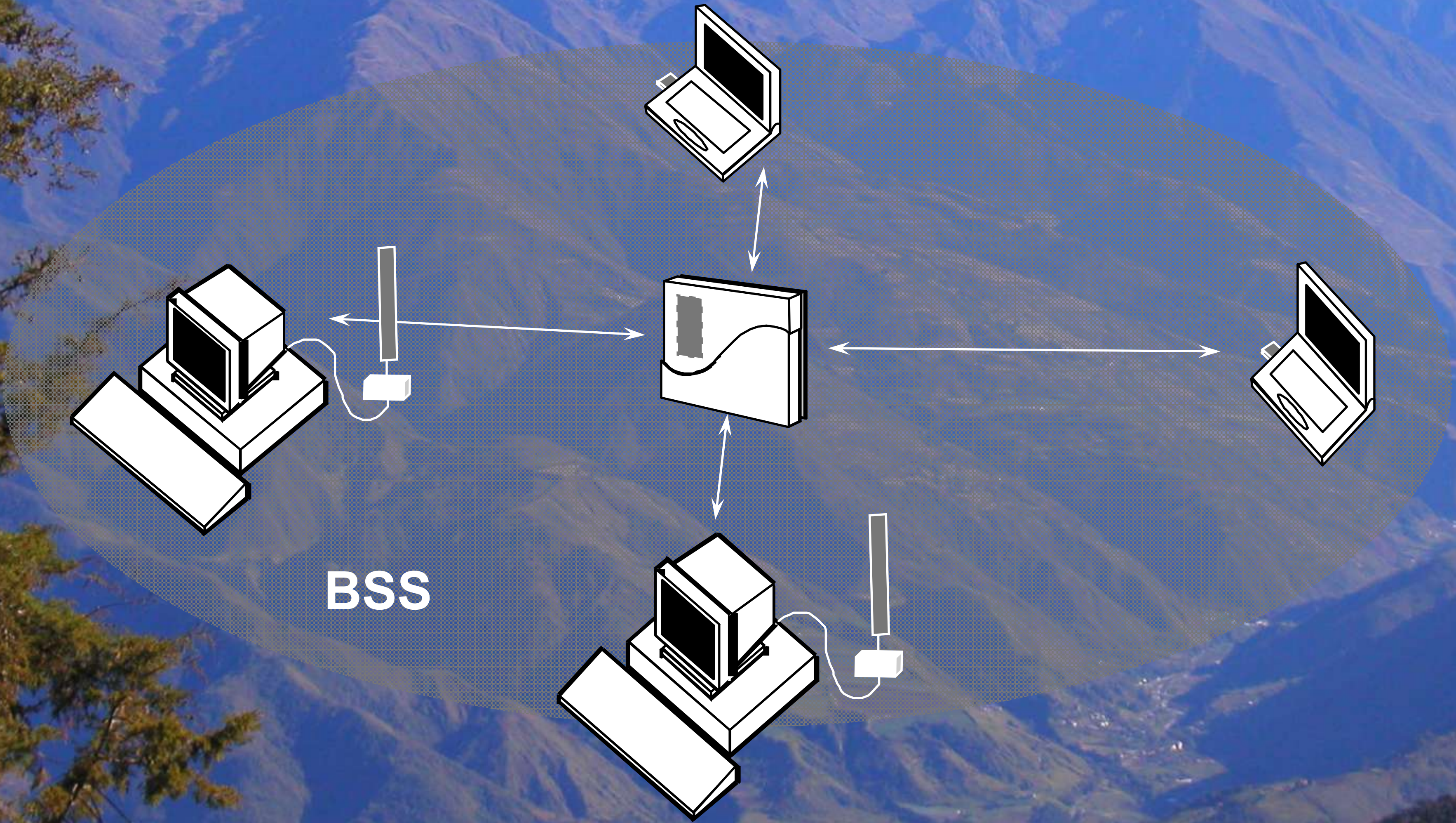
- A set of one or more Basic Service Sets interconnected by a Distribution System (DS)
- Traffic always flows via Access-Point

Distribution System (DS):

- A system to interconnect a set of Basic Service Sets
  - Integrated; A single Access-Point in a standalone network
  - Wired; Using cable to interconnect the Access-Points
  - Wireless; Using wireless to interconnect the Access-Points

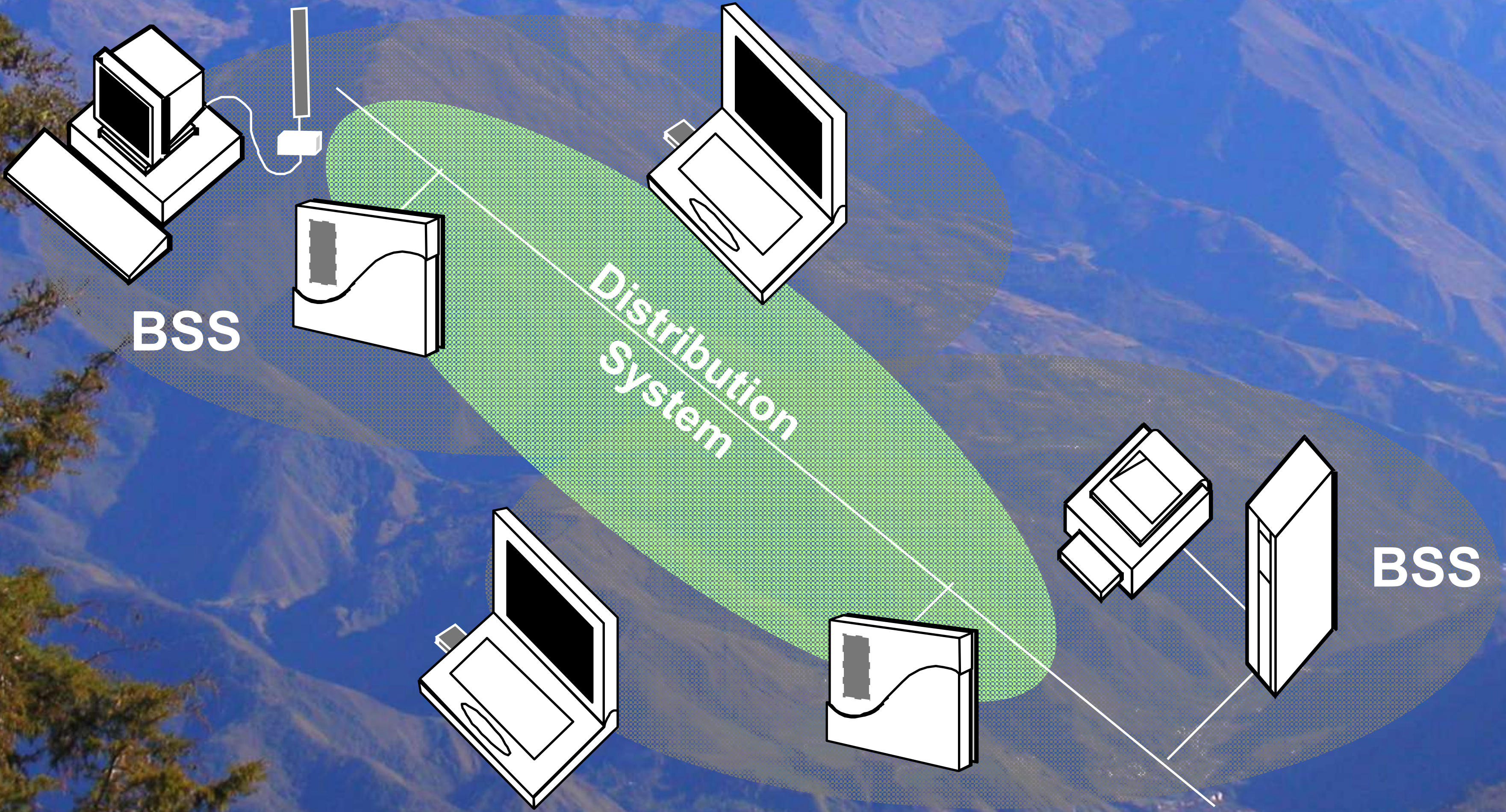
Extended Service Set (ESS)

single BSS (with integrated DS)



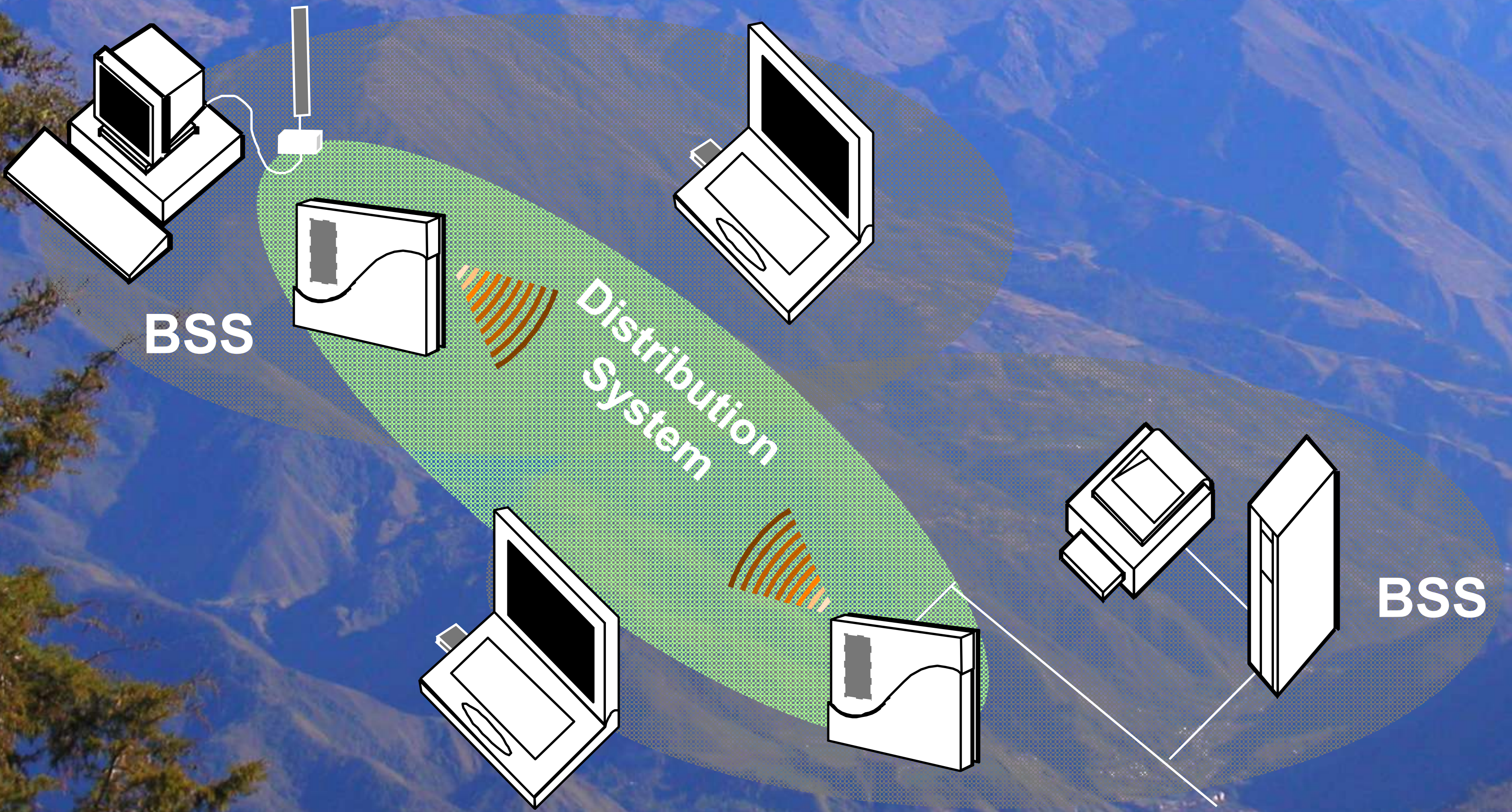
Extended Service Set (ESS)

BSS's with wired Distribution System (DS)

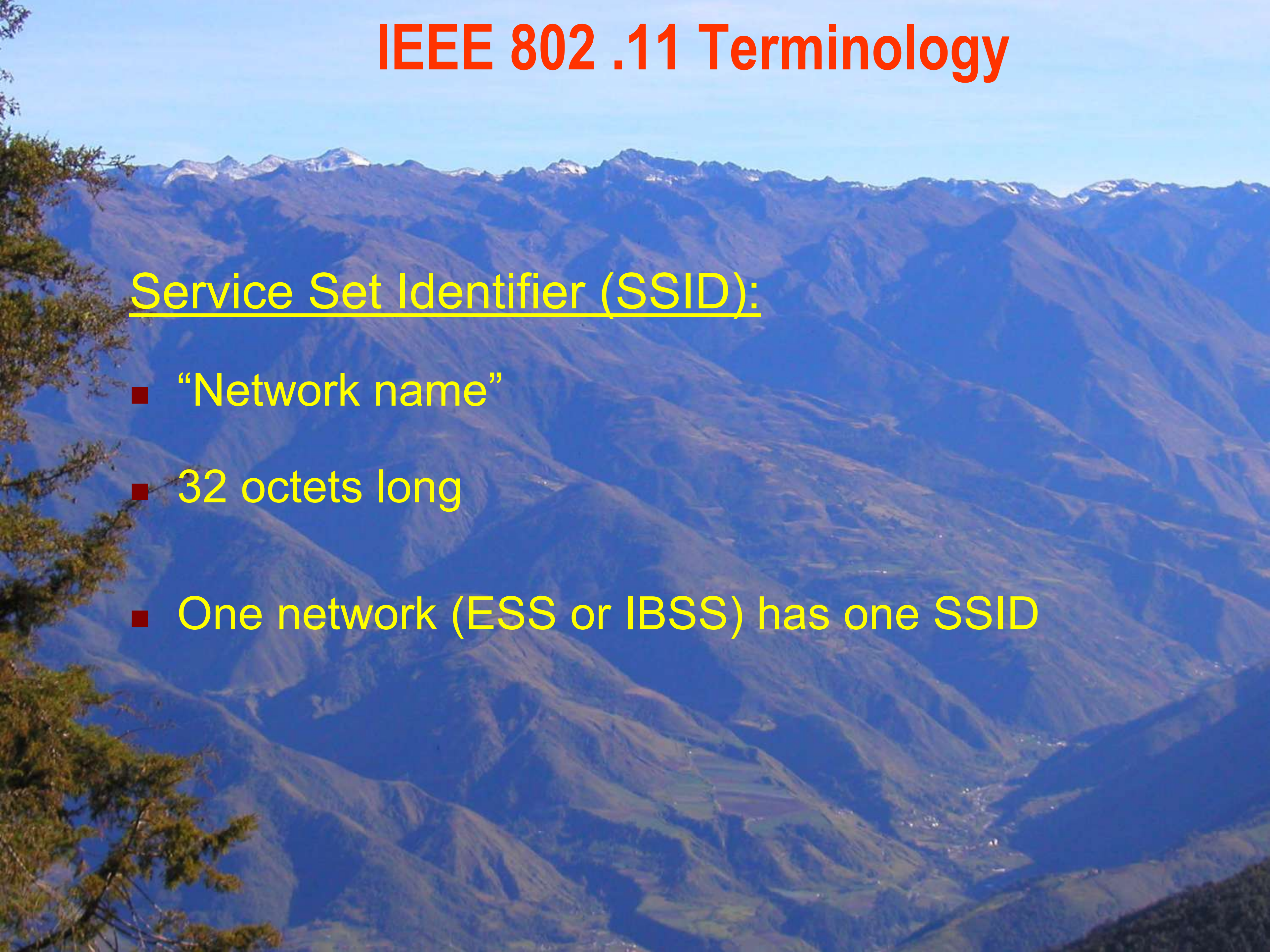


Extended Service Set (ESS)

BSS's and wireless Distribution System (DS)



IEEE 802 .11 Terminology



Service Set Identifier (SSID):

- "Network name"
- 32 octets long
- One network (ESS or IBSS) has one SSID

IEEE 802 .11 Terminology

Basic Service Set Identifier (BSSID)

- “cell identifier”
- 6 octets long (MAC address format)
- One BSS has one SSID
- Value of BSSID is the same as the MAC address of the radio in the Access-Point

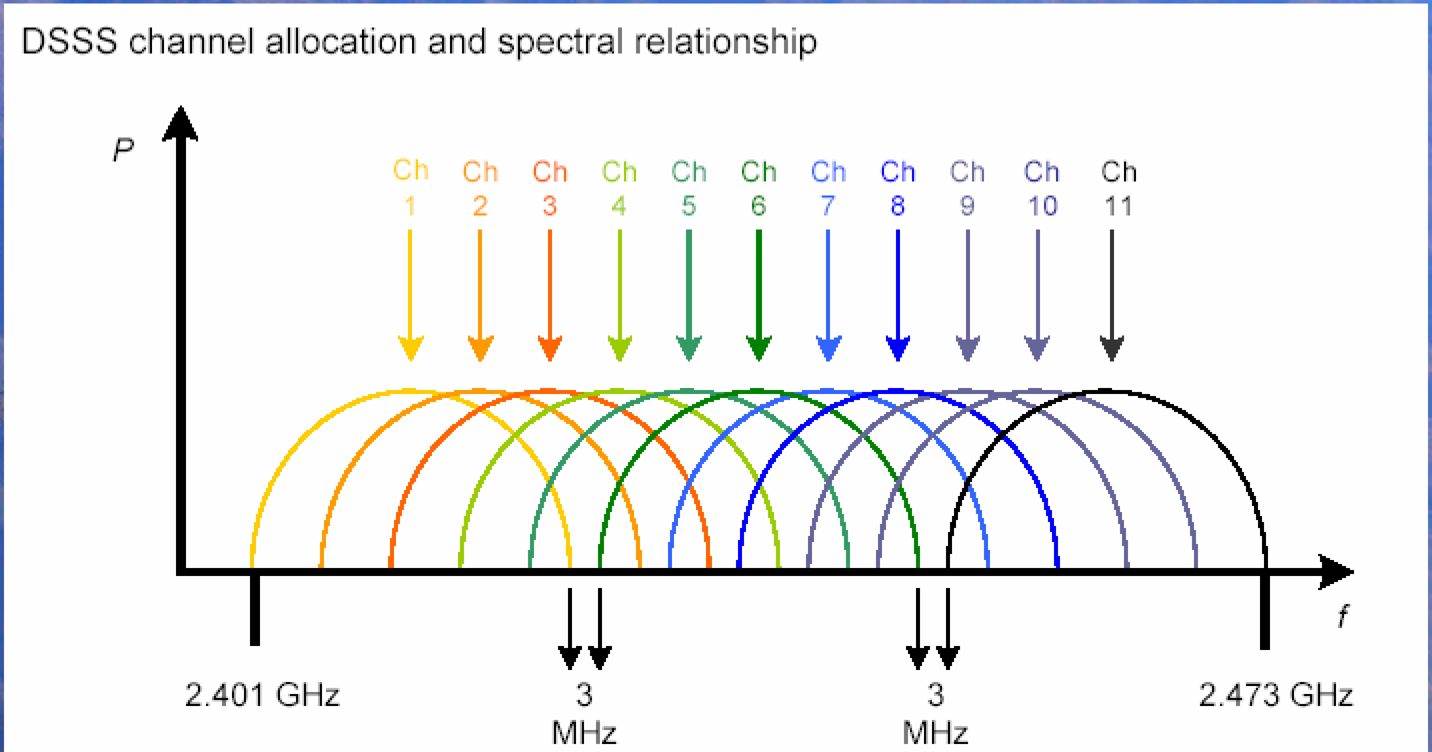
MAC Management Frames

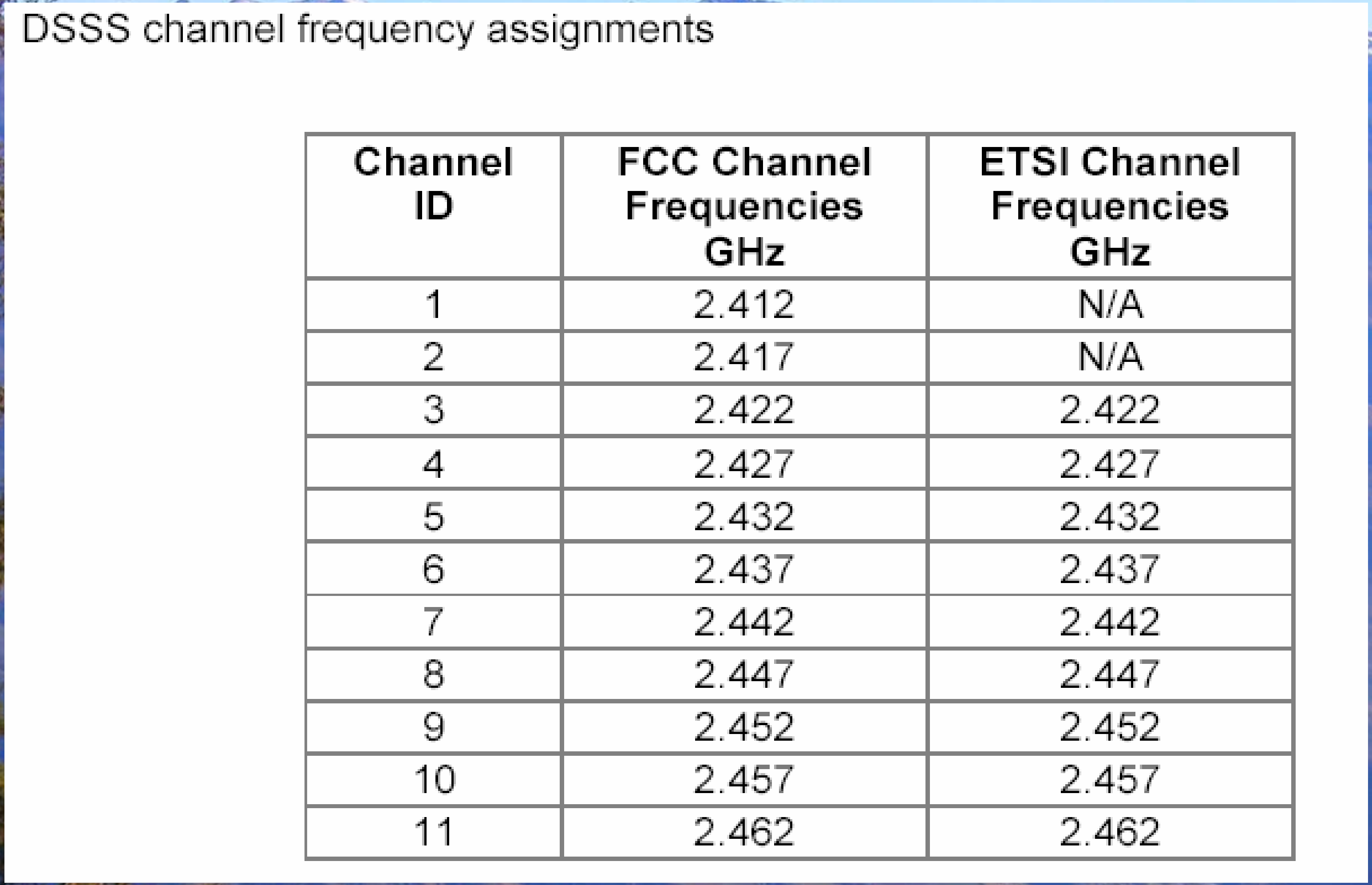
- Beacon
  - Timestamp, Beacon Interval, Capabilities, SSID, Supported Rates, parameters
  - Traffic Indication Map
- Probe
  - SSID, Capabilities, Supported Rates
- Probe Response
  - Timestamp, Beacon Interval, Capabilities, SSID, Supported Rates, parameters
  - same for Beacon except for TIM

MAC Management Frames (cont’d)

- Association Request
  - Capability, Listen Interval, SSID, Supported Rates
- Association Response
  - Capability, Status Code, Station ID, Supported Rates
- Re-association Request
  - Capability, Listen Interval, SSID, Supported Rates, Current AP Address
- Re-association Response
  - Capability, Status Code, Station ID, Supported Rates

Channel Overlapping

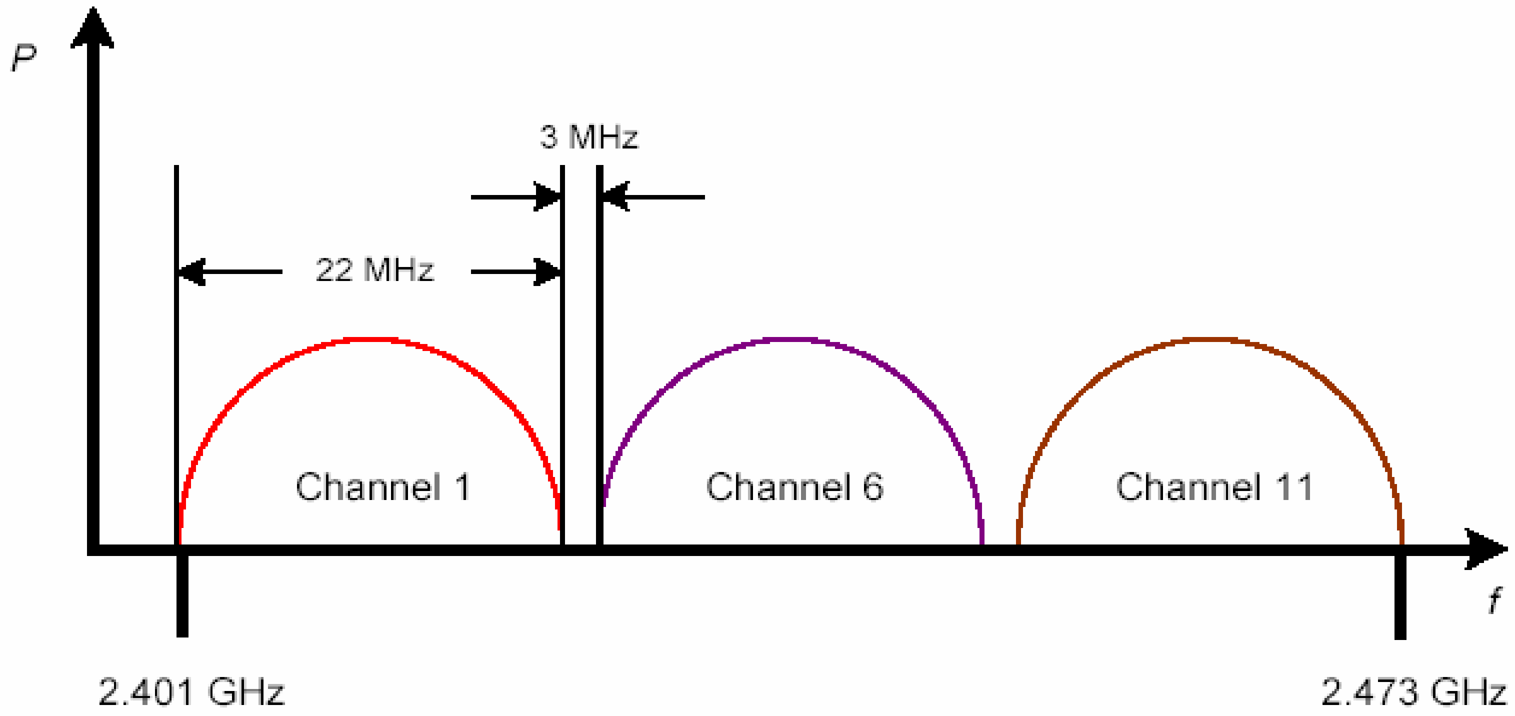




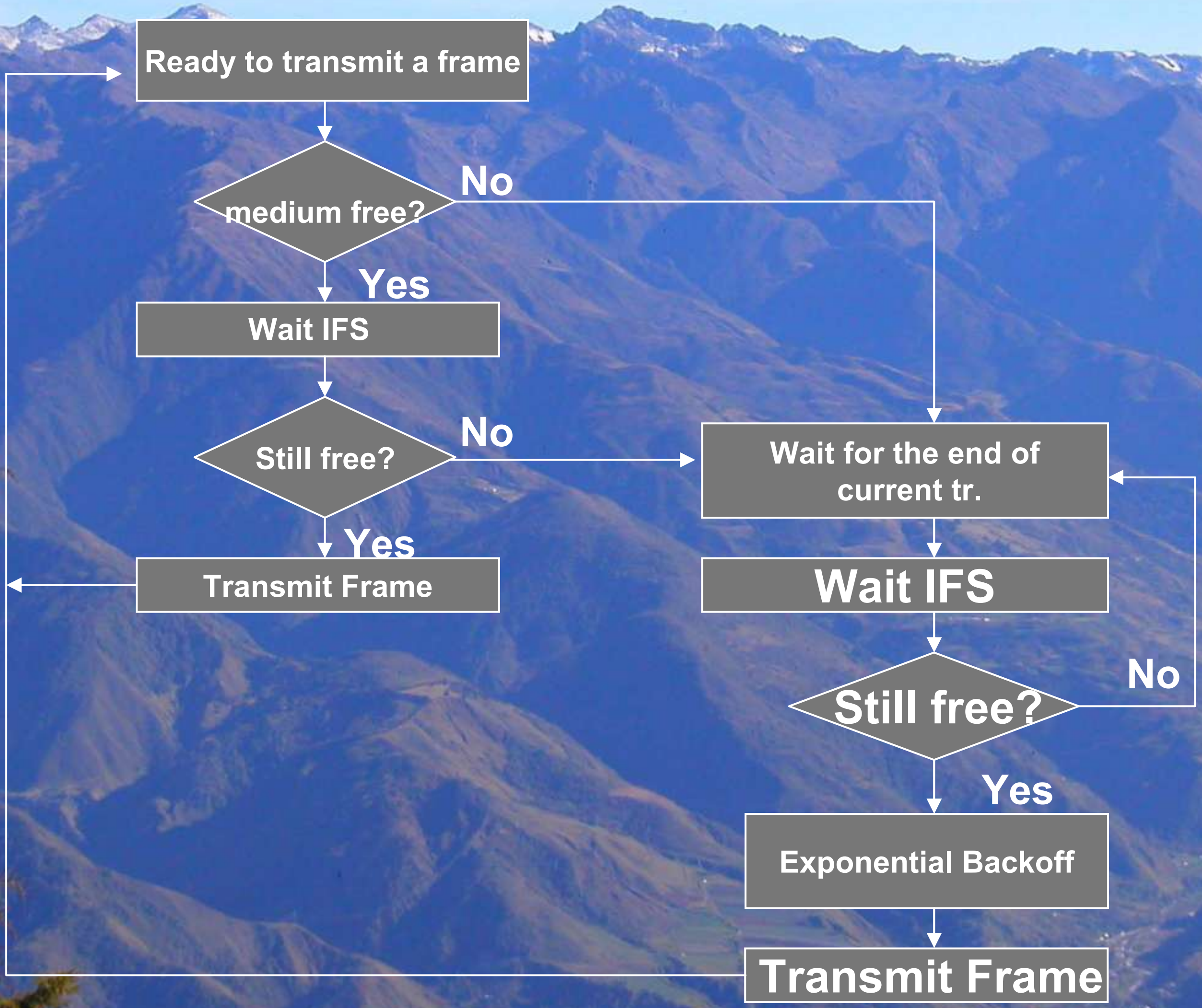
DSSS channel frequency assignments

Channel ID	FCC Channel Frequencies GHz	ETSI Channel Frequencies GHz
1	2.412	N/A
2	2.417	N/A
3	2.422	2.422
4	2.427	2.427
5	2.432	2.432
6	2.437	2.437
7	2.442	2.442
8	2.447	2.447
9	2.452	2.452
10	2.457	2.457
11	2.462	2.462

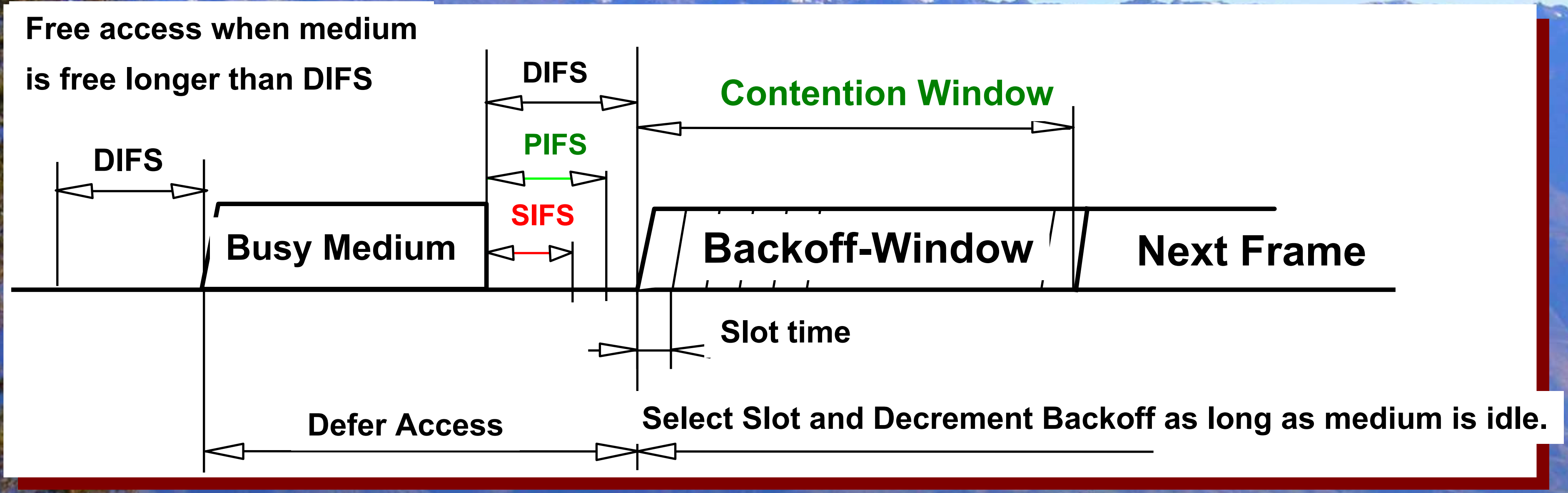
DSSS non-overlapping channels



IEEE 802.11 Medium Access Control Logic

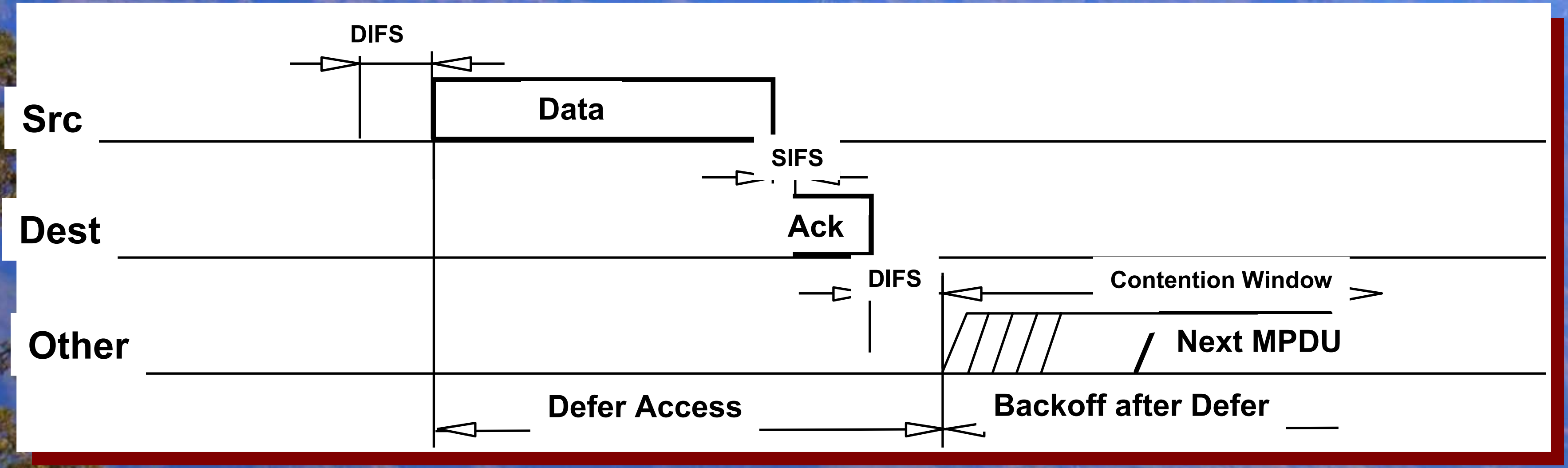


Operational processes
Inter-Frame Spacing



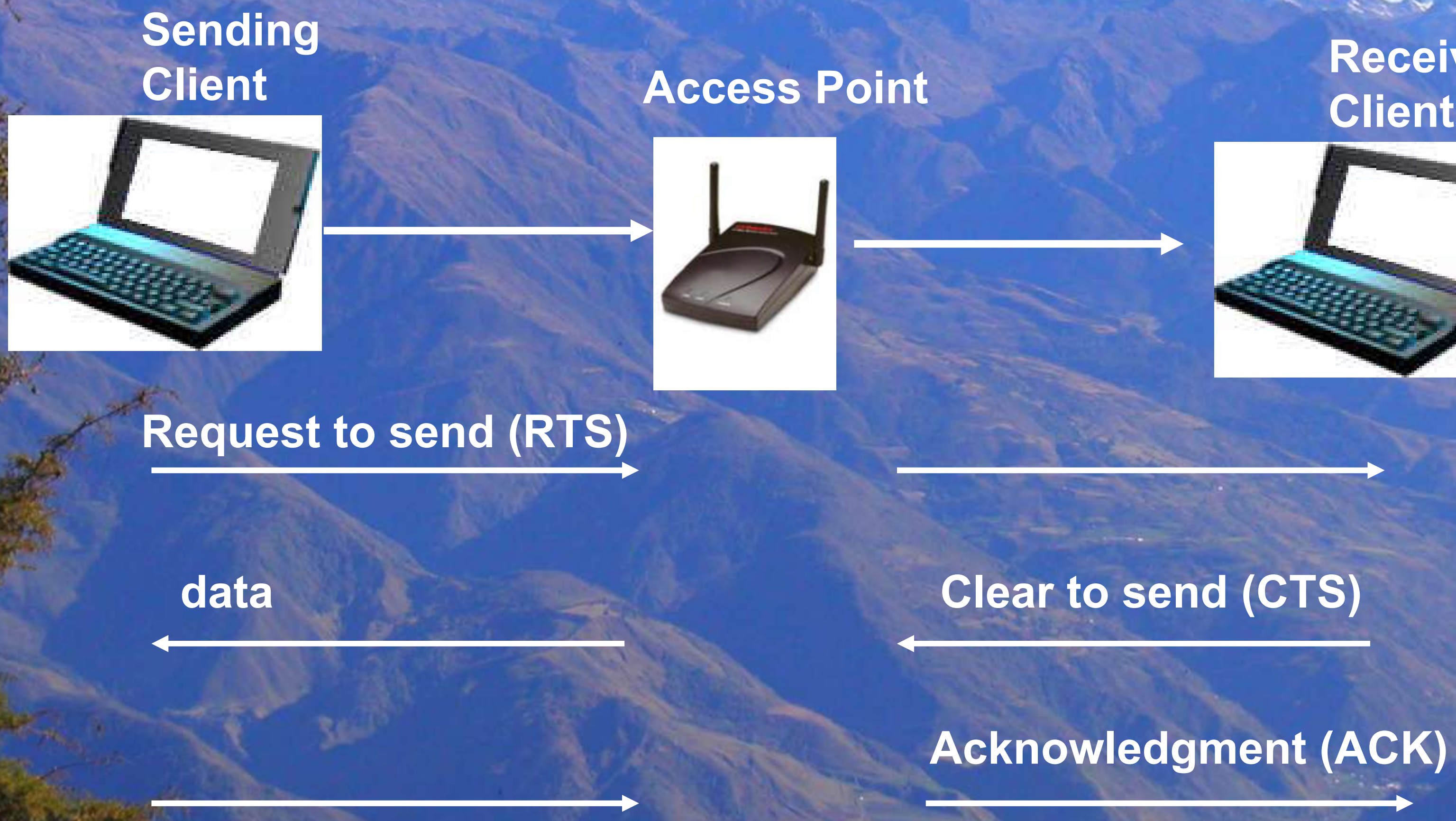
- Inter frame spacing required for MAC protocol traffic
  - SIFS = Short interframe space
  - PIFS = PCF interframe space
  - DIFS = DCF interframe space
- Back-off timer expressed in terms of number of time slots

Operational processes
Data Frames and their ACK



- Acknowledgment are to arrive within the SIFS
- The DCF interframe space is observed before medium is considered free for use

Channel Reservation



Sending Client

Access Point

Receiving Client

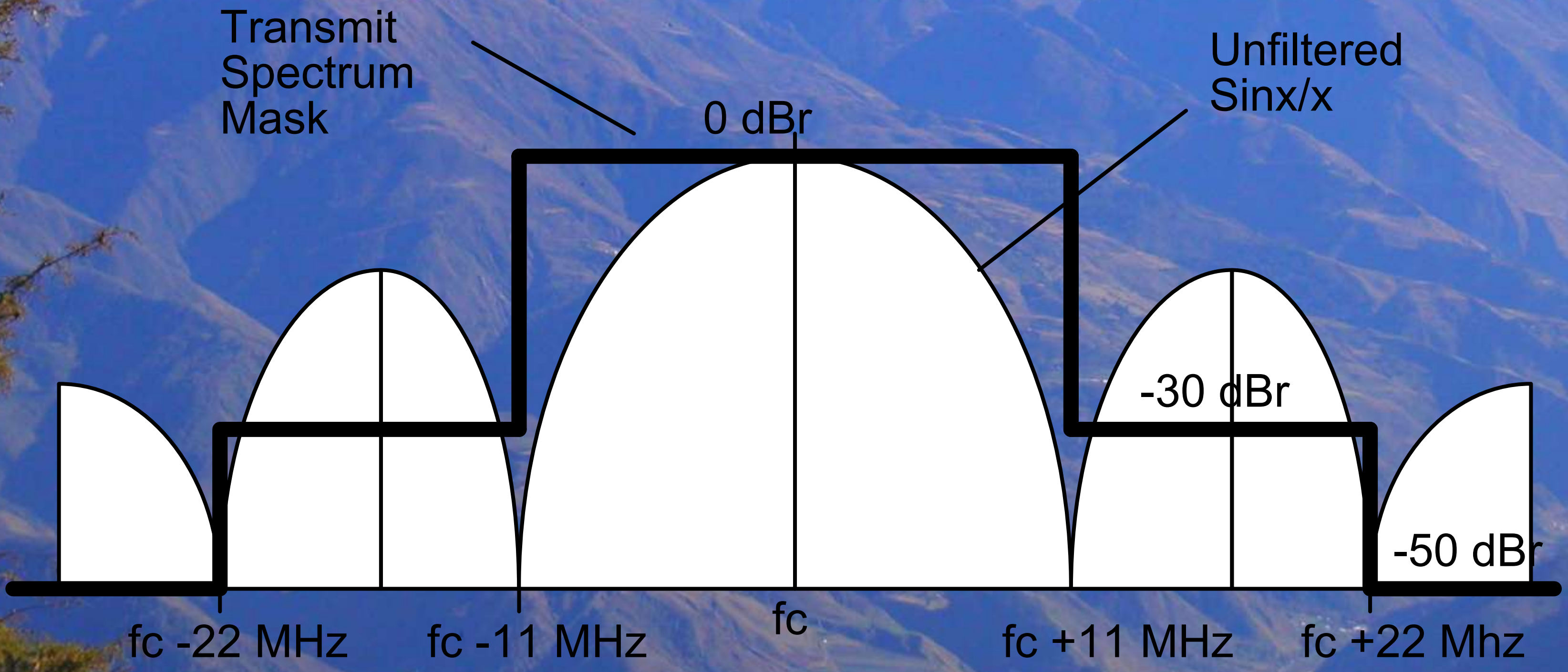
Request to send (RTS)

data

Clear to send (CTS)

Acknowledgment (ACK)

802.11b spectral mask

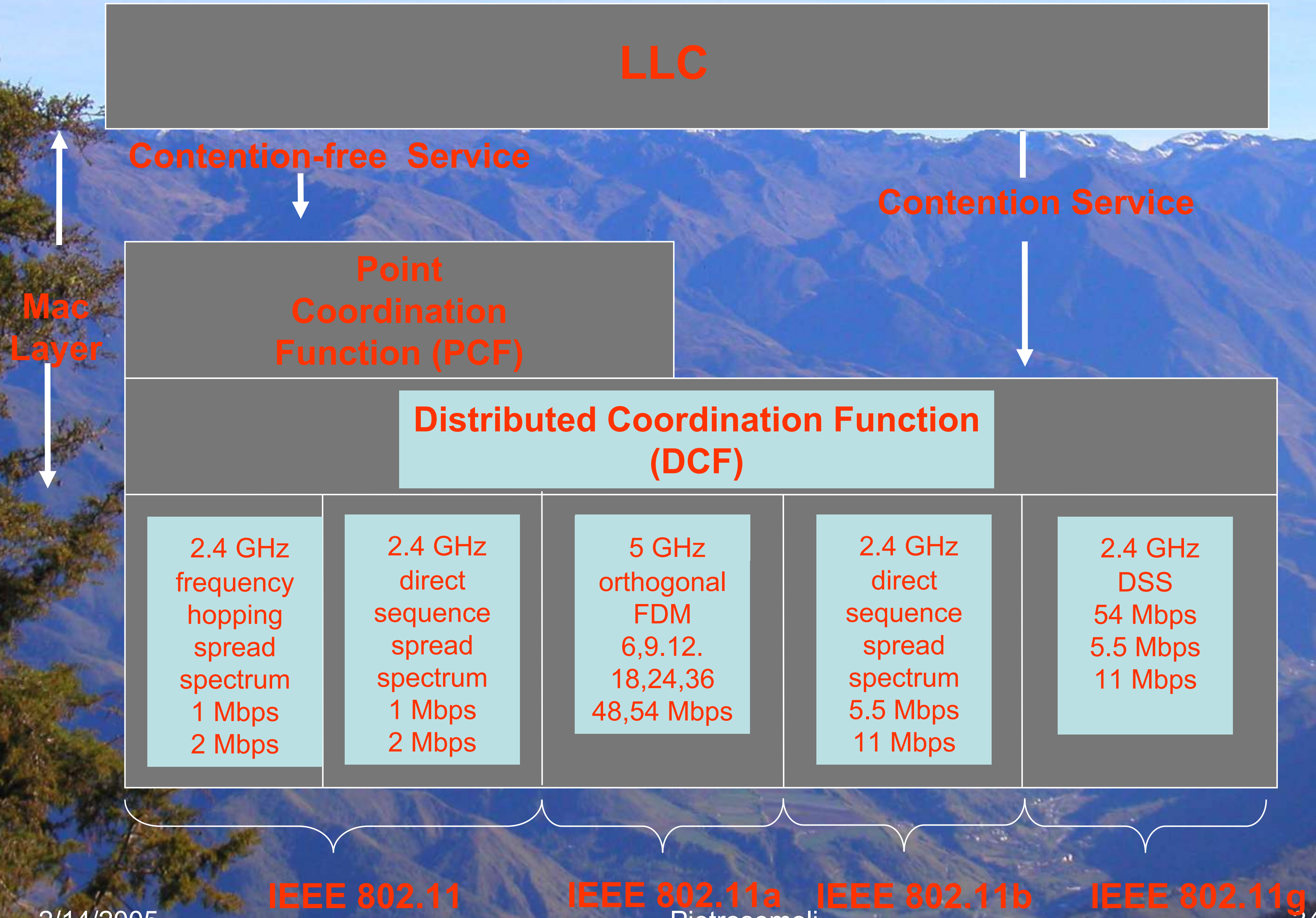


Control Frames

- Request to send (RTS)
- Clear to send (CTS)
- Acknowledgement (ACK)
- Power-Save Poll (PS Poll)
- Contention-Free End (CF End)
- CF End + CF Ack

Management Frames

- Association request frame
- Association response frame
- Reassociation request frame
- Reassociation response frame
- Probe request frame
- Probe response frame
- Beacon frame
- ATIM frame
- Disassociation frame
- Authentication frame
- Deauthentication frame



LLC

Contention-free Service

Contention Service

Mac Layer

Point Coordination Function (PCF)

Distributed Coordination Function (DCF)

2.4 GHz frequency hopping spread spectrum 1 Mbps 2 Mbps

2.4 GHz direct sequence spread spectrum 1 Mbps 2 Mbps

5 GHz orthogonal FDM 6,9.12. 18,24,36 48,54 Mbps

2.4 GHz direct sequence spread spectrum 5.5 Mbps 11 Mbps

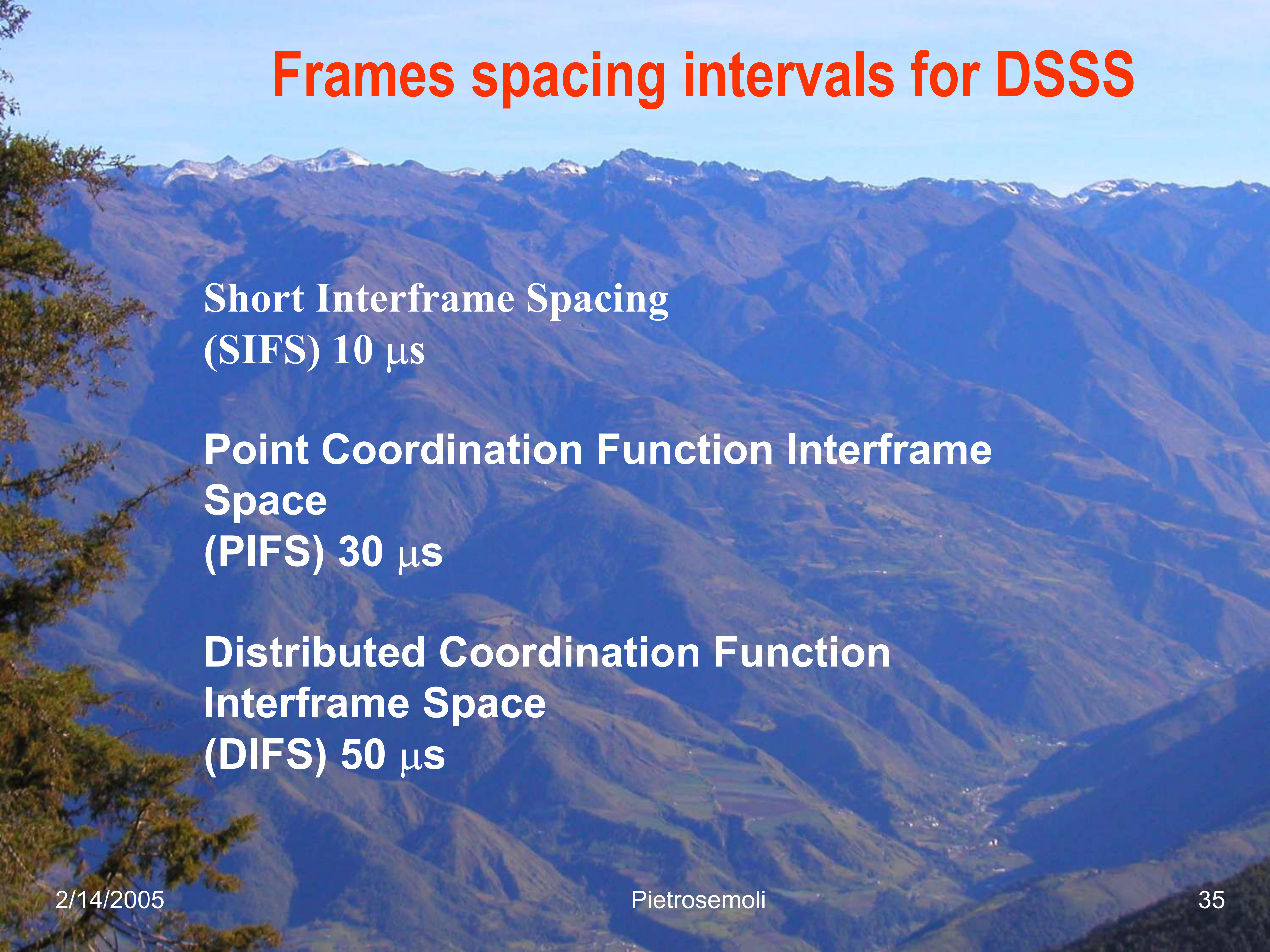
2.4 GHz DSS 54 Mbps 5.5 Mbps 11 Mbps

IEEE 802.11

IEEE 802.11a

IEEE 802.11b

IEEE 802.11g



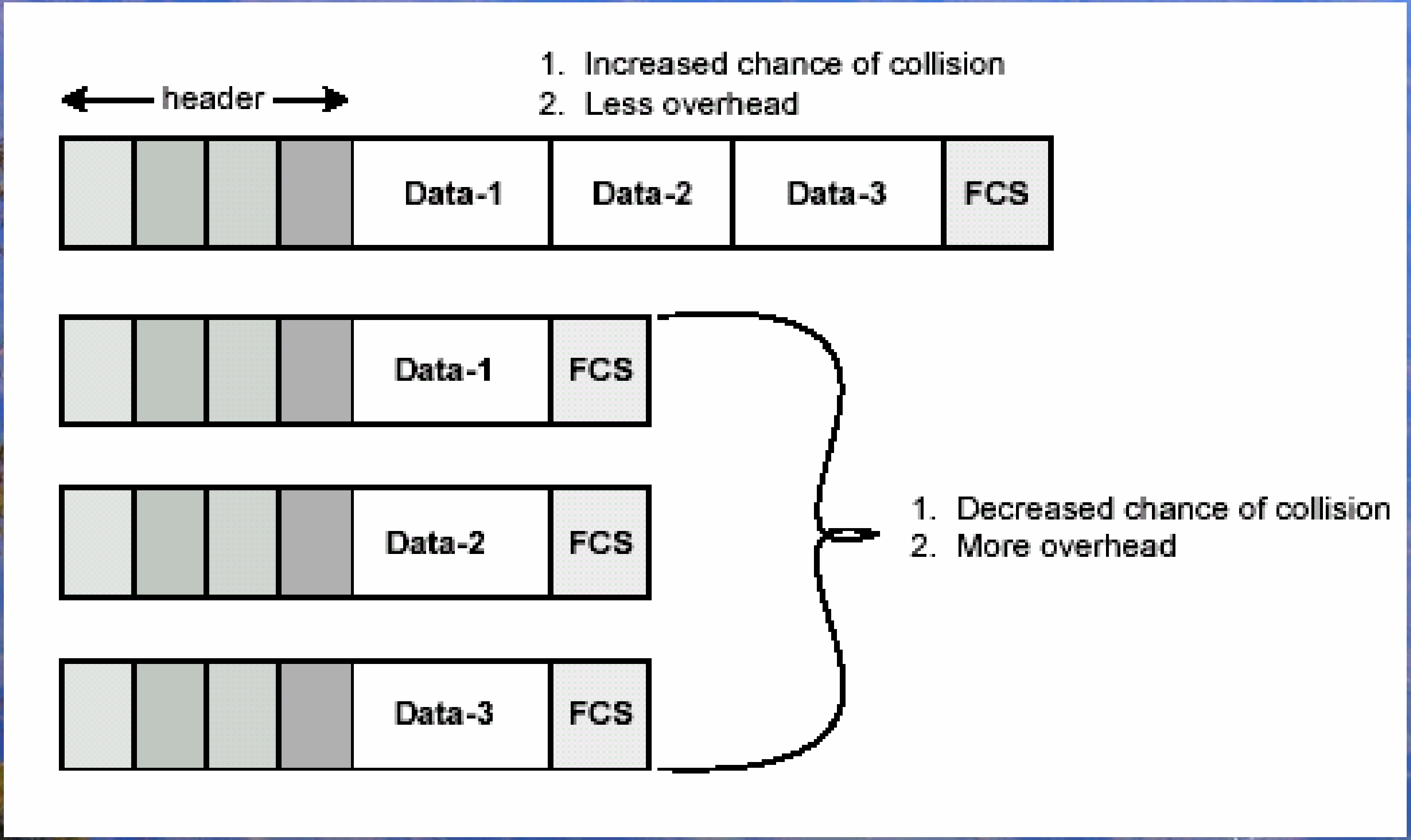
Frames spacing intervals for DSSS

Short Interframe Spacing
(SIFS) 10 μs

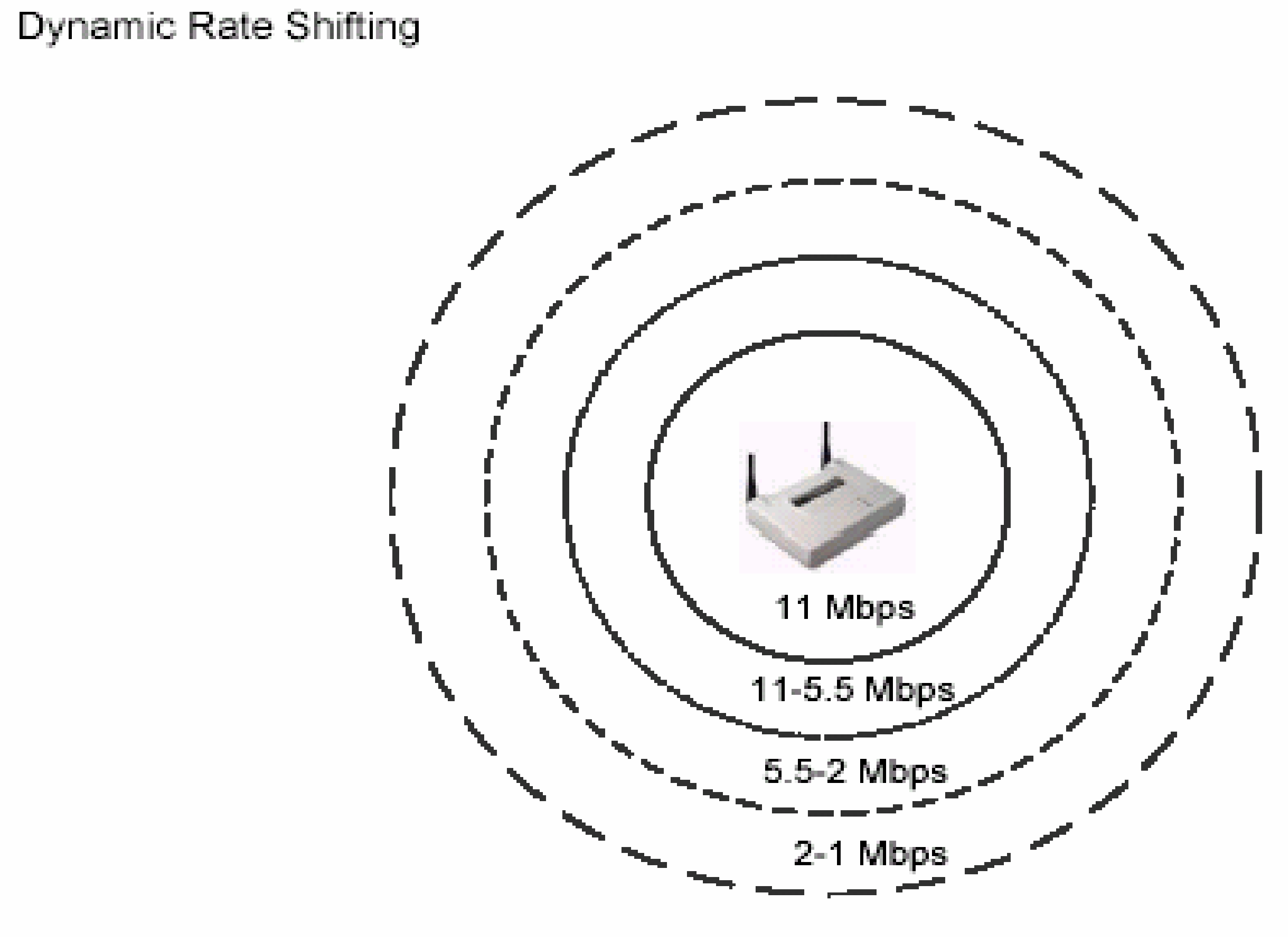
Point Coordination Function Interframe
Space
(PIFS) 30 μs

Distributed Coordination Function
Interframe Space
(DIFS) 50 μs

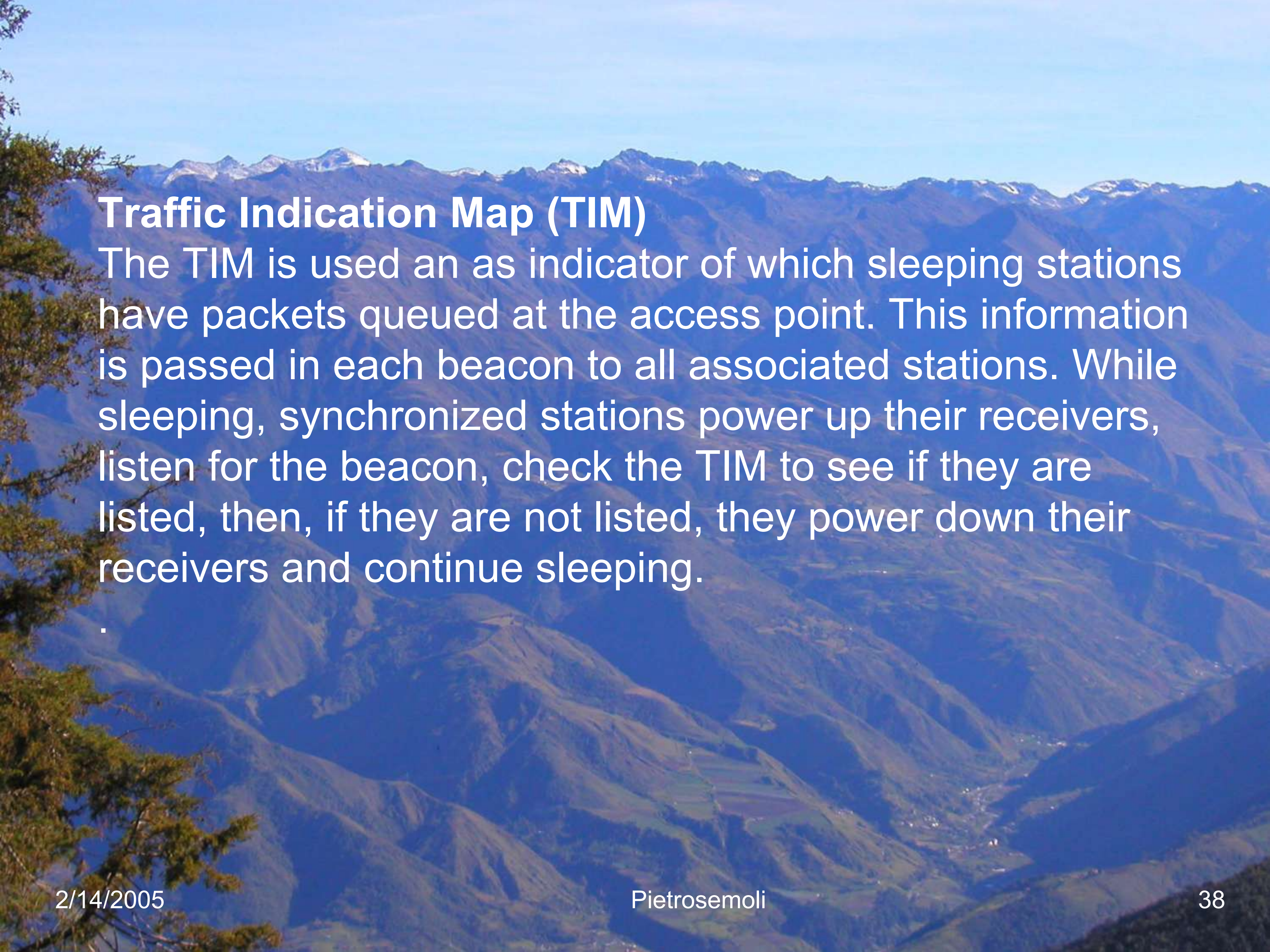
Fragmentation



Dynamic transmission rate



Dynamic Rate Shifting



Traffic Indication Map (TIM)

The TIM is used an as indicator of which sleeping stations have packets queued at the access point. This information is passed in each beacon to all associated stations. While sleeping, synchronized stations power up their receivers, listen for the beacon, check the TIM to see if they are listed, then, if they are not listed, they power down their receivers and continue sleeping.

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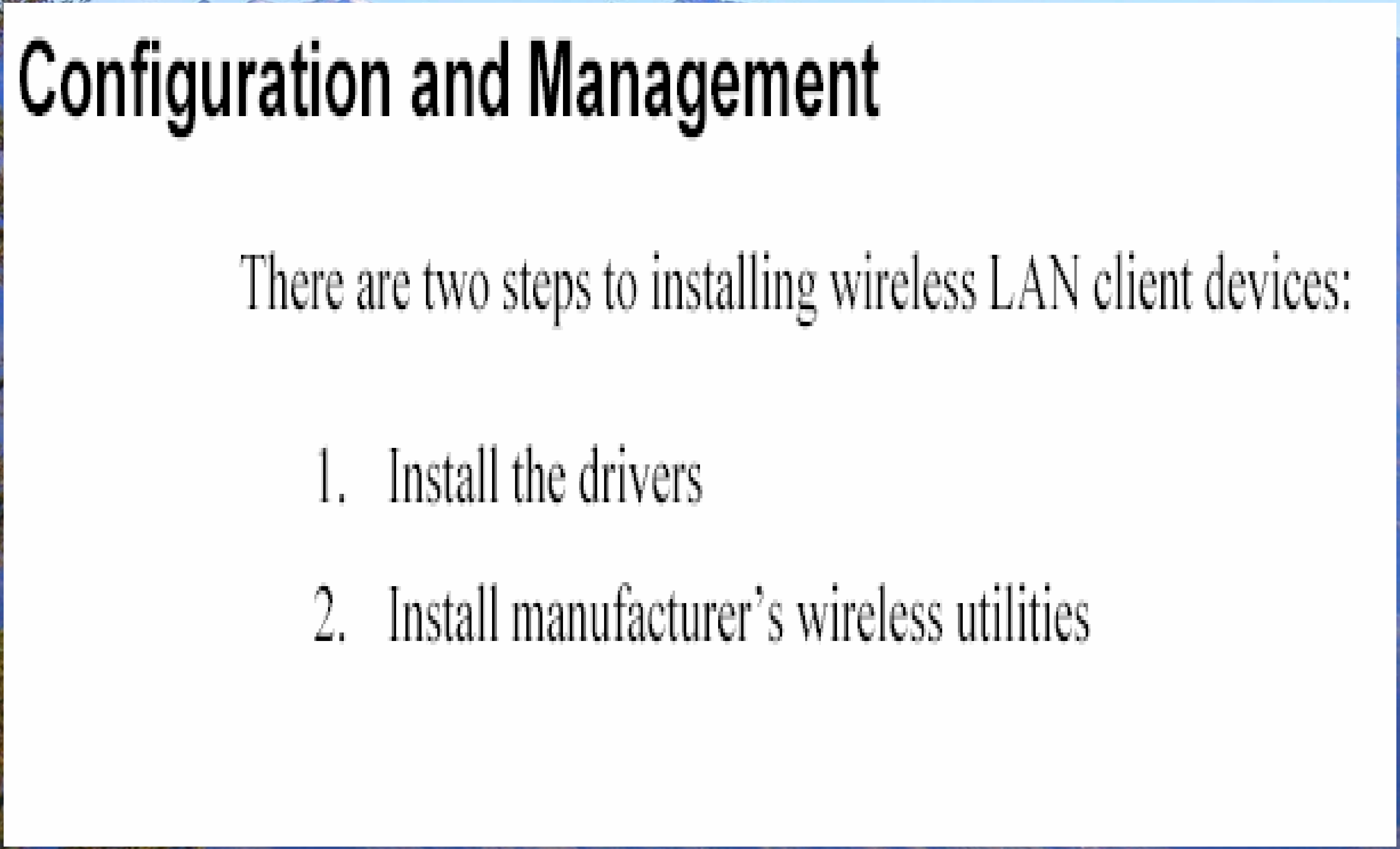
Operational processes
Association

- To establish relationship with Access-Point
- Stations scan frequency band to and select Access-Point with best communications quality
  - Active Scan (sending a “Probe request” on specific channels and assess response)
  - Passive Scan (assessing communications quality from beacon message)
- Access-Point maintains list of associate stations in MAC FW
  - Record station capability (data-rate)
  - To allow inter-BSS relay
- Station’s MAC address is also maintained in bridge learn table associated with the port it is located on



Configuration and Management

There are two steps to installing wireless LAN client devices:

1. Install the drivers
2. Install manufacturer's wireless utilities

Configuration Parameters
Basic parameters (Station)

Network Name (SSID)

- ASCII string to identify the network that the station wants to connect to.

Station Name (SSID)

- ASCII string to provide a user friendly station identification, when used in diagnostic purposes (in Windows systems: equal to “computer name”)

Type of Operation

- To identify the kind of network that the station will be part of
  - Network centered around APs
  - IBSS (peer-to-peer network)

Configuration Parameters
Advanced parameters (Station)

MAC Address

- Physical address of the card:
  - Universal; factory installed (default)
  - Local; user-defined (6 Hexadecimal characters)

Distance between APs

- To specify the coverage of a “cell” in terms of the distance between the Access-Points
  - Large
  - Medium
  - Small

Configuration Parameters

Advanced parameters (Station)

Interference Robustness

- Check box to enable/disable data-rate fallback delay-mechanism to allow improved performance in presence of microwave ovens or other interference signals

RTS/CTS Medium Reservation

- Check box to enable/disable the RTS/CTS handshake.

Card Power Management

- Check box to enable/disable Power Management

Configuration Parameters
Encryption parameters (Station)

Enable Encryption

- To enable/disable Encryption

Encryption keys

- Four fields to store up to four different encryption keys
- Entries take up to 5 ASCII or 10 hexa-decimal values (when using 64 WEP)

Encryption key index

- Index identifying which of the four keys is the active one

Configuration Parameters
Basic parameters (AP)

Network Name (SSID)

- ASCII string to identify the network that the Access-Point is part of (similar to Domain-ID in WaveLAN pre-IEEE). Only available in “Access Point” mode.

Frequency (channel)

- To indicate the frequency channel that the AP-500/1000 will use for its “cell”. The channel is selected from the set that is allowed in the regulatory domain.

Configuration Parameters

Advanced parameters (AP)

Interference Robustness

- Check box to enable/disable data-rate fallback delay-mechanism to allow improved performance in presence of Interference

DTIM

- Power Management related parameter to specify the timing of the delivery of multicast traffic to stations that have indicated to receive multicast messages while under power management.

  Example:

  - DTIM=1 means multicast traffic when it arrives at the AP is passed through after every beacon
  - DTIM=3 means multicast traffic is passed through after every 3rd beacon message

Configuration Parameters
Security parameters

Closed System (AP)

- To enable rejection of association requests from stations with *Network Name* set to “ANY”

Enable Encryption

- To enable/disable Encryption

Encryption keys

- Four fields to store up to four different encryption keys

Encryption key index

- Index identifying which of the four keys is the active one

Configuration Parameters
Advanced parameters

Medium Reservation

- To enable/disable the RTS/CTS handshake.
  - Threshold value 0-2346 (value=2347 disables Medium Reservation)

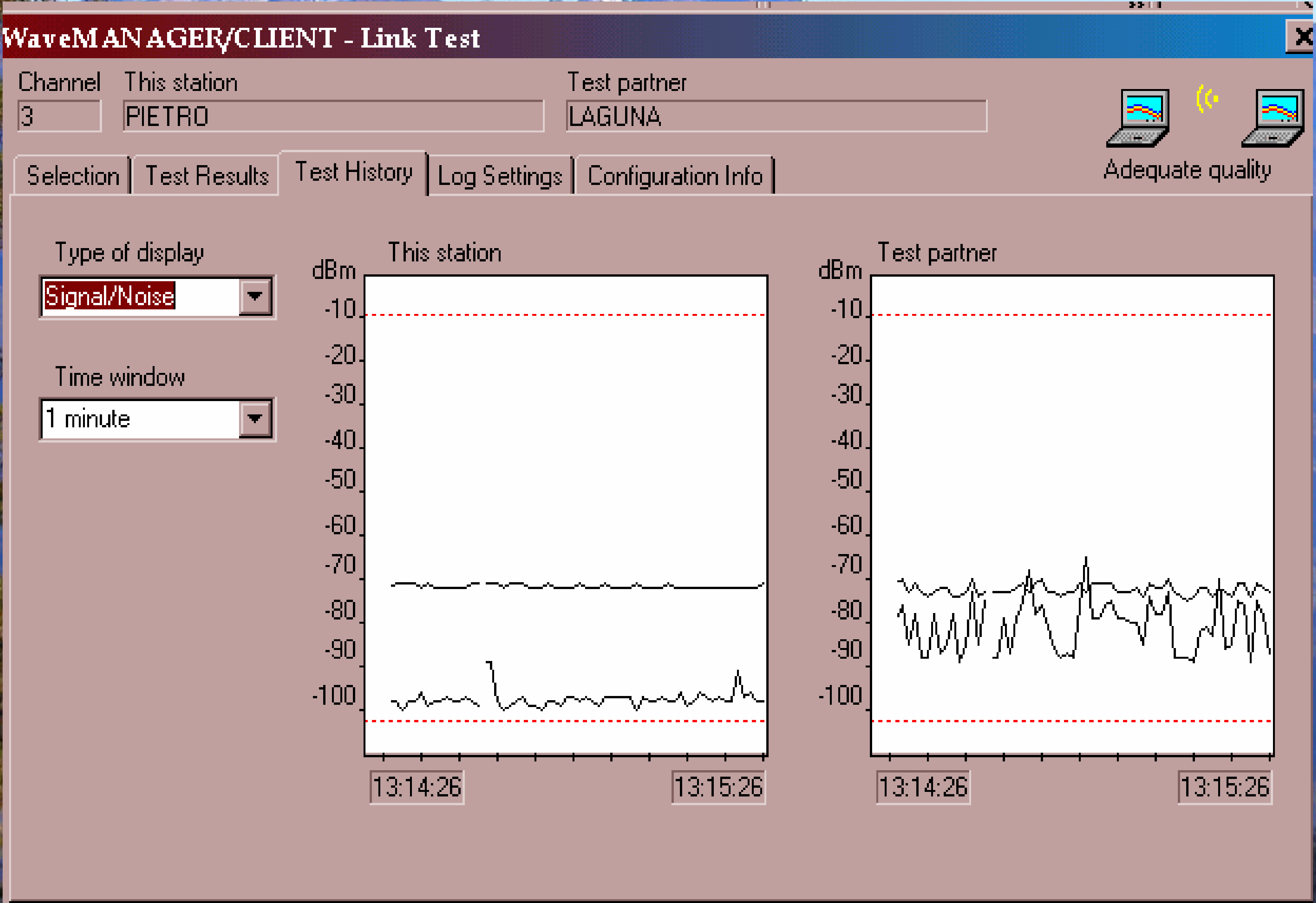
Distance between APs

- To specify the coverage of a “cell” in terms of the distance between the Access-Points
  - Large
  - Medium
  - Small

Multicast Rate

- To specify data-rate used for transmitting Multicast frames

Interference



WaveMANAGER/CLIENT - Link Test

Channel: 3

This station: PIETRO

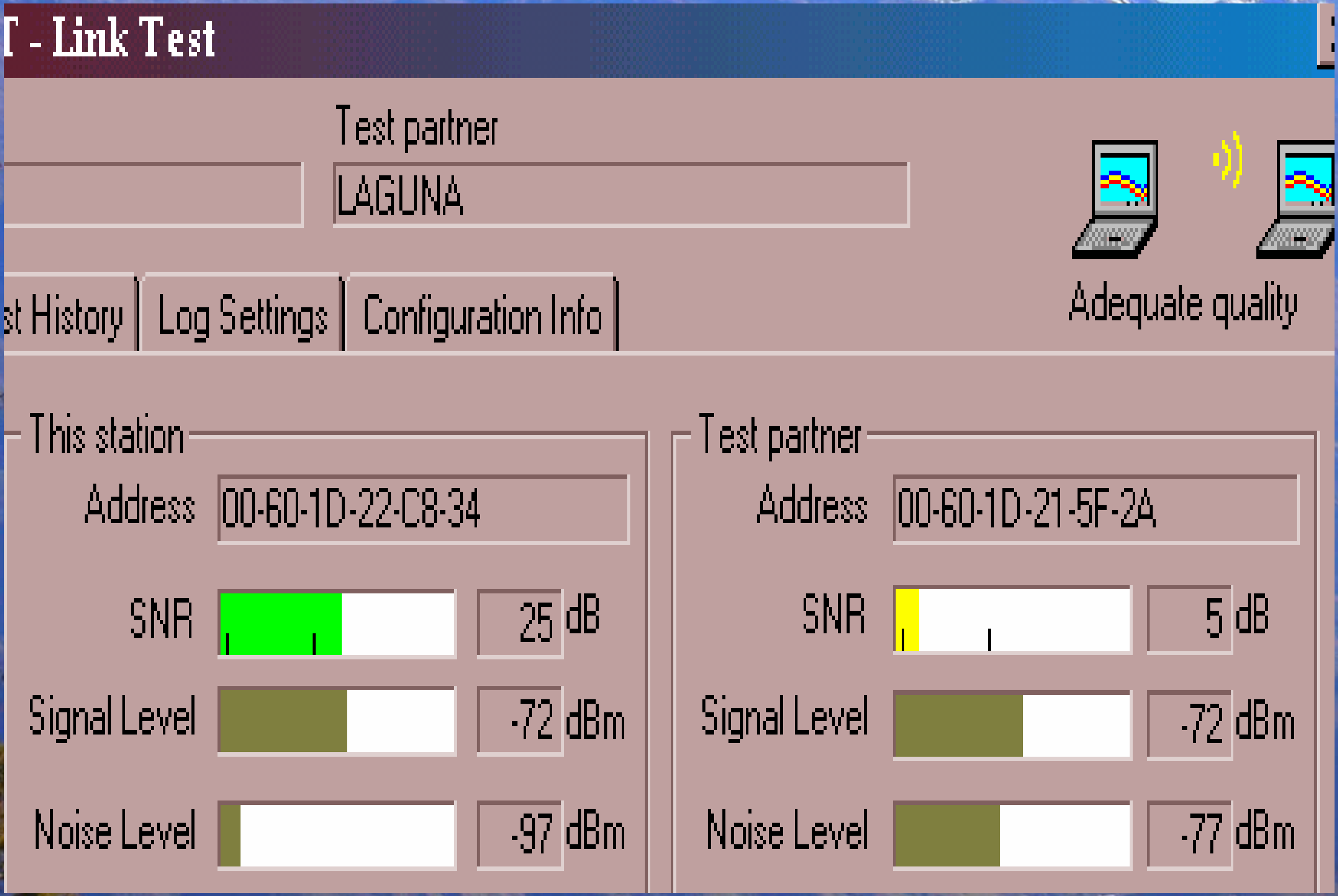
Test partner: LAGUNA

Adequate quality

Type of display: Signal/Noise

Time window: 1 minute

Interference



T - Link Test

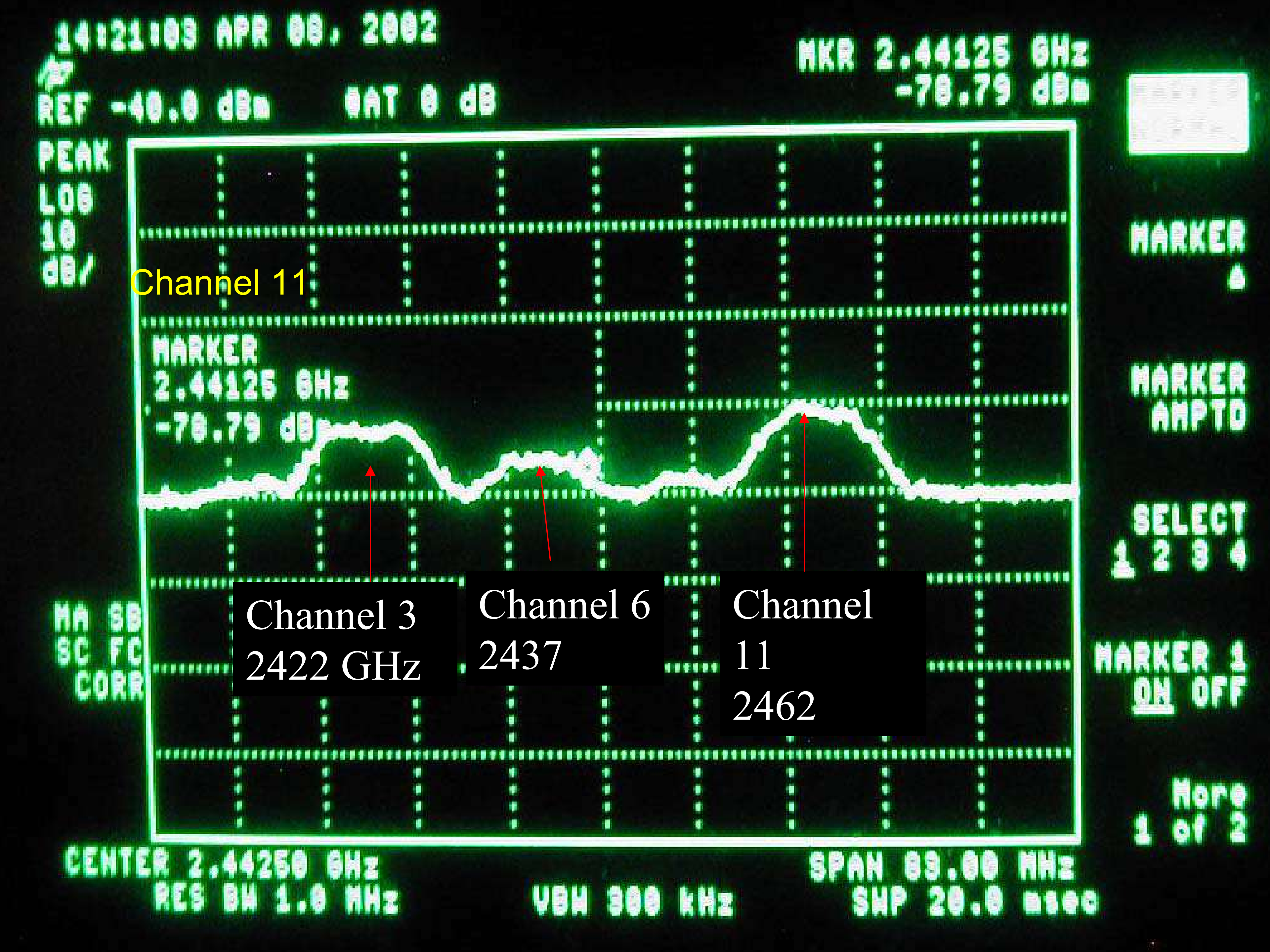
Test partner

LAGUNA

st History | Log Settings | Configuration Info

Adequate quality

	This station		Test partner	
Address	00-60-1D-22-C8-34		00-60-1D-21-5F-2A	
SNR	25	dB	5	dB
Signal Level	-72	dBm	-72	dBm
Noise Level	-97	dBm	-77	dBm



Channel 11

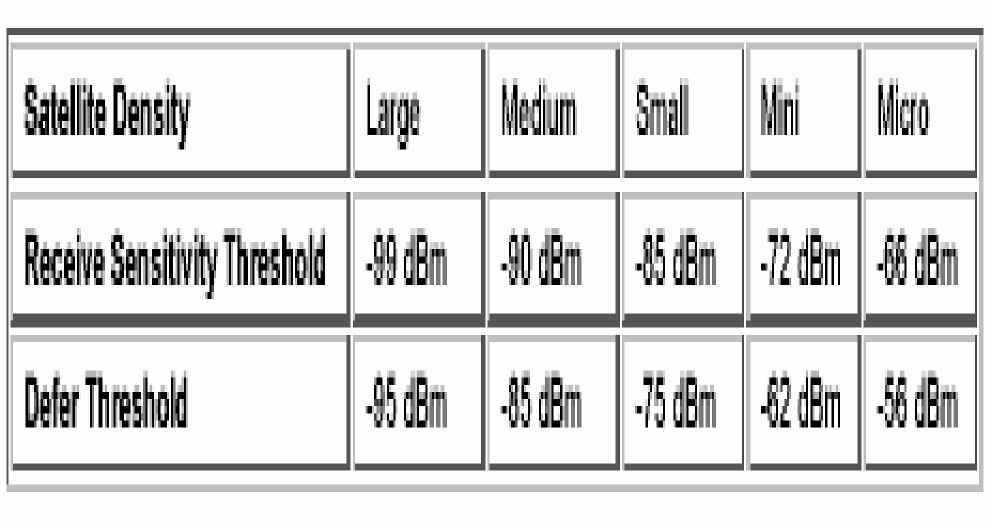
Channel 3
2422 GHz

Channel 6
2437

Channel
11
2462

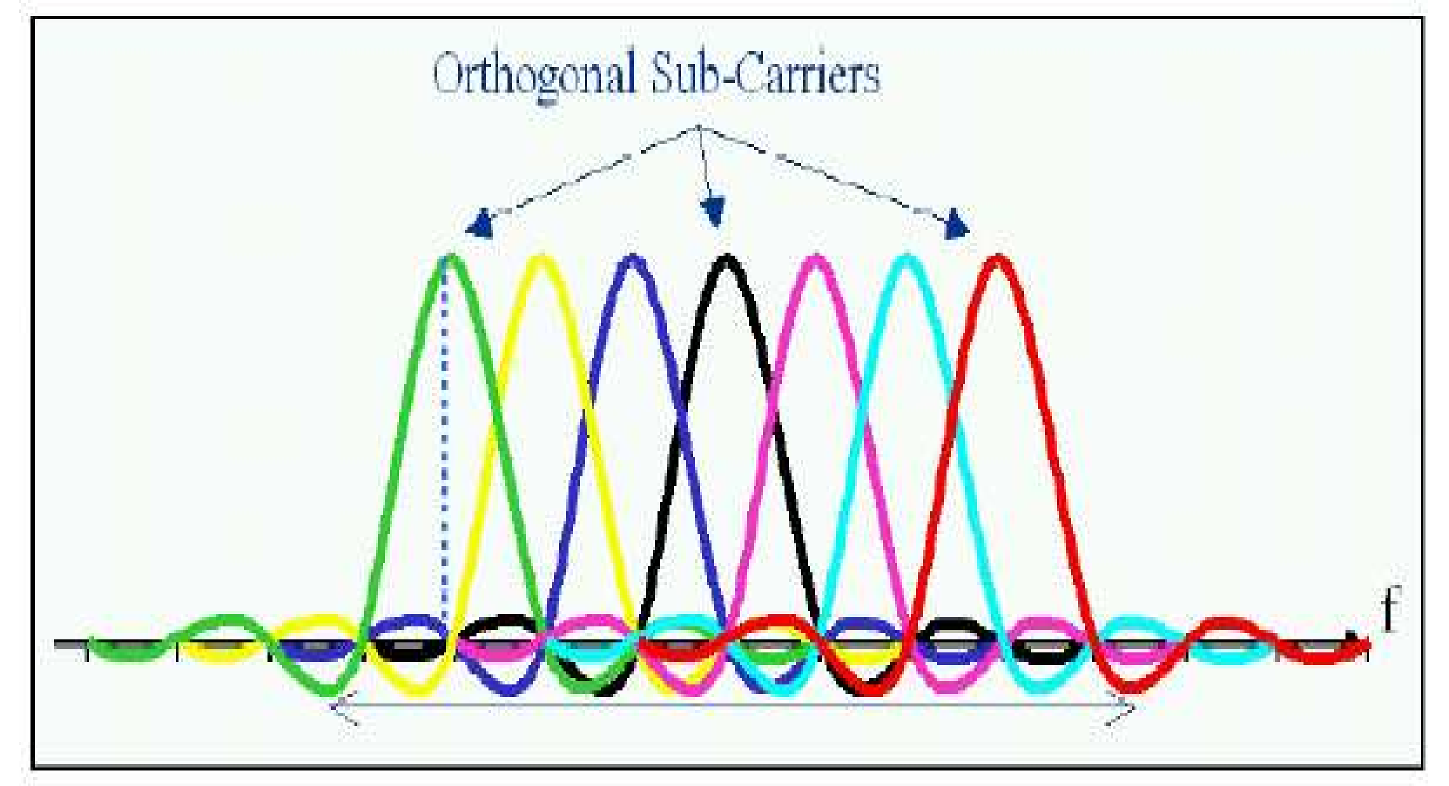
Proxim Mp11.a

Power over Ethernet
Max 36 W, Typ. 7.5W
Turbo mode gives 108 Mbps
rate adaptive to 6 Mbps
Max Out 18 dBm
Built in attenuator to control int.
Spanning tree protocol included
Radius support

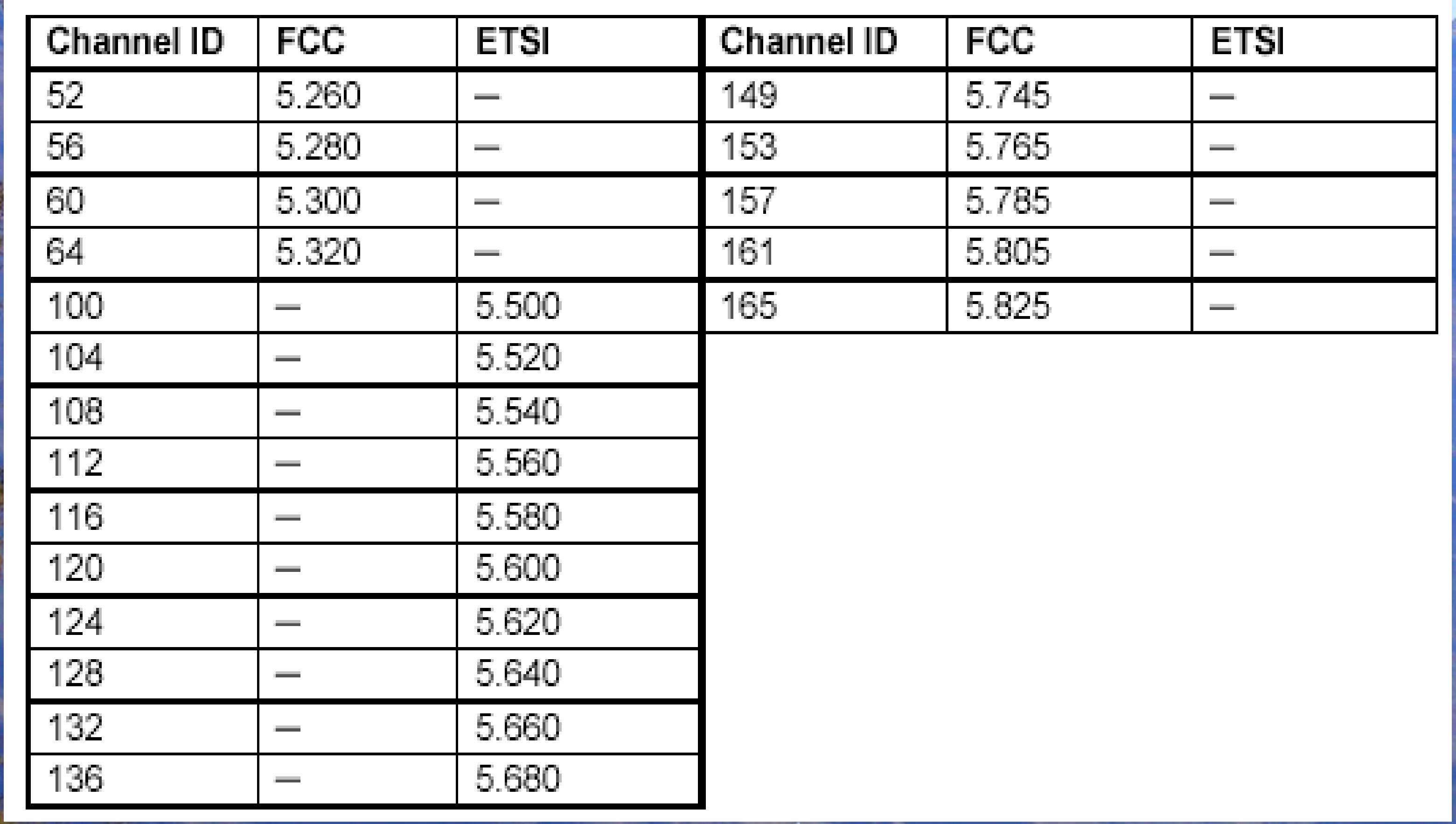


Satellite Density	Large	Medium	Small	Mini	Micro
Receive Sensitivity Threshold	-99 dBm	-90 dBm	-85 dBm	-72 dBm	-68 dBm
Defer Threshold	-95 dBm	-85 dBm	-75 dBm	-62 dBm	-58 dBm

OFDM



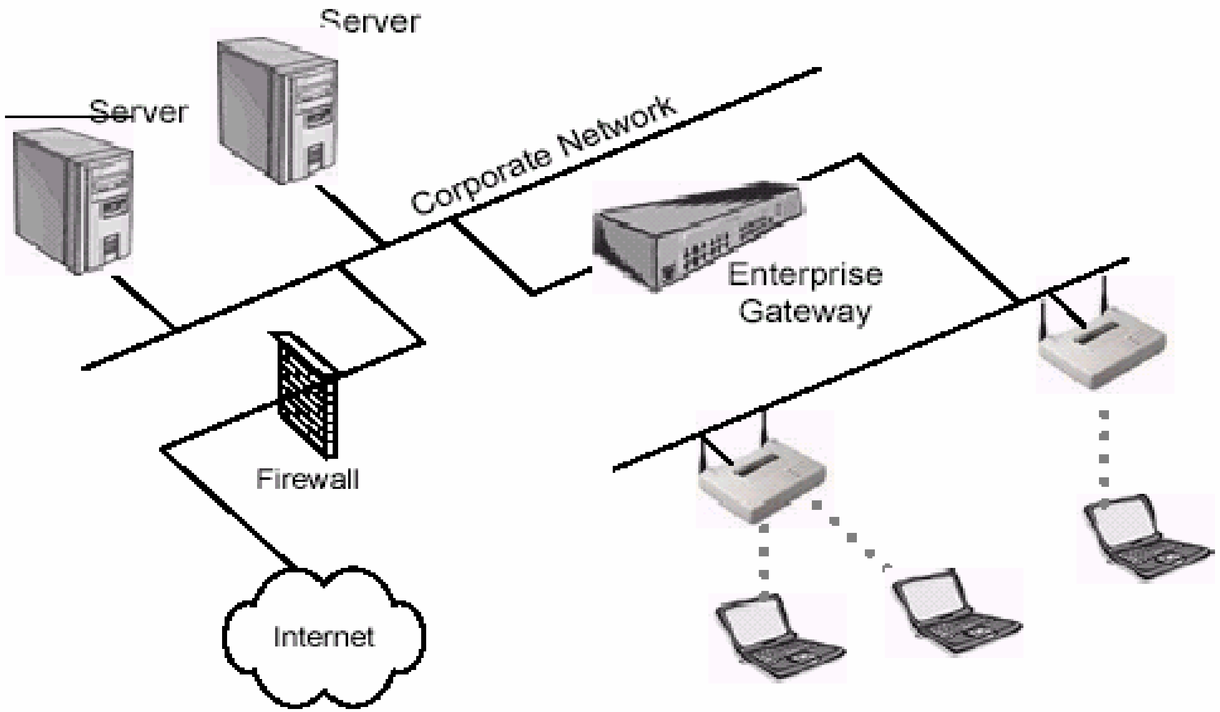
Supported Channels for 802.11a

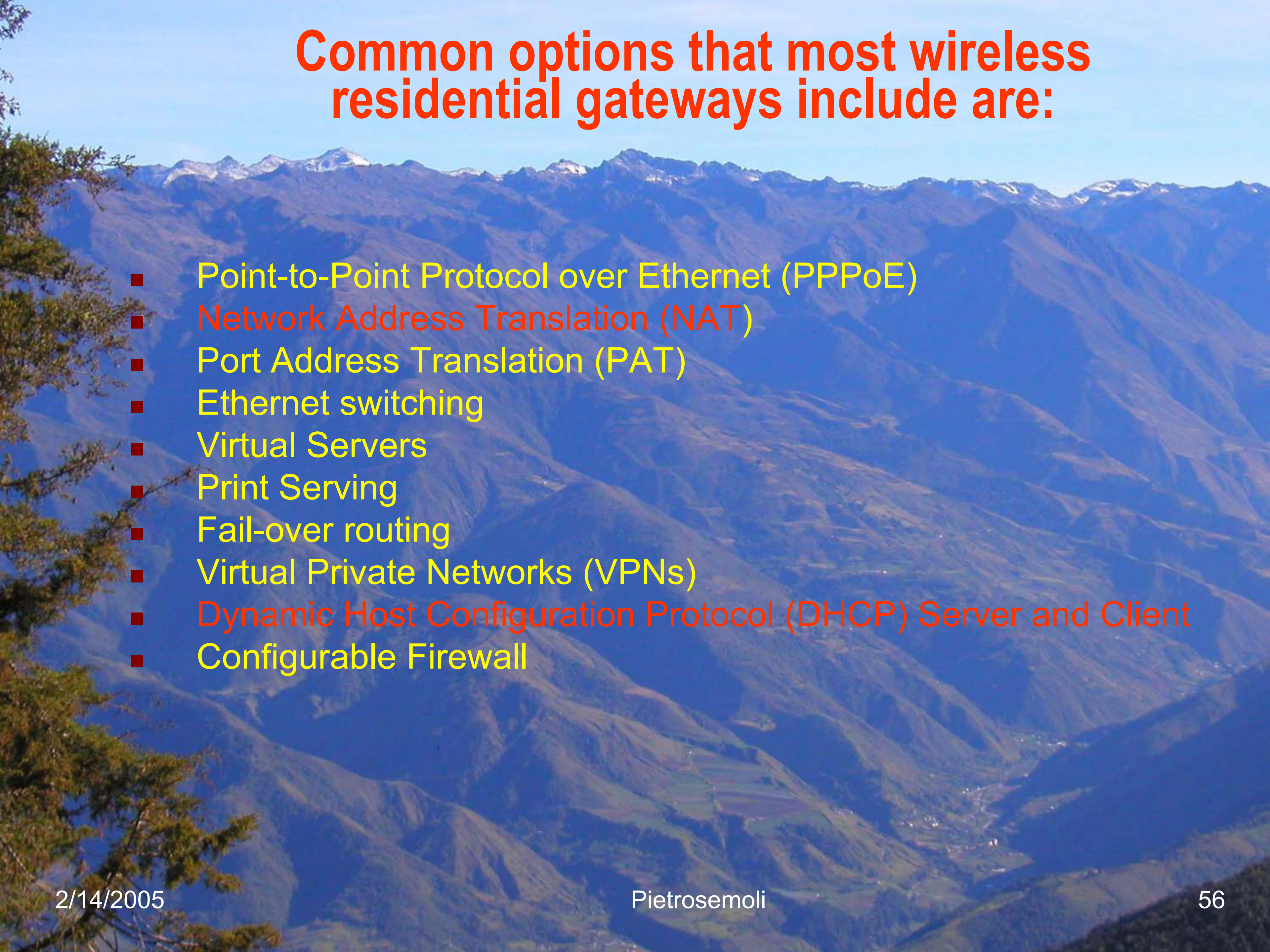


Channel ID	FCC	ETSI
52	5.260	—
56	5.280	—
60	5.300	—
64	5.320	—
100	—	5.500
104	—	5.520
108	—	5.540
112	—	5.560
116	—	5.580
120	—	5.600
124	—	5.620
128	—	5.640
132	—	5.660
136	—	5.680
149	5.745	—
153	5.765	—
157	5.785	—
161	5.805	—
165	5.825	—

Enterprise Gateway

An enterprise wireless gateway installed on a network





Common options that most wireless residential gateways include are:

- Point-to-Point Protocol over Ethernet (PPPoE)
- Network Address Translation (NAT)
- Port Address Translation (PAT)
- Ethernet switching
- Virtual Servers
- Print Serving
- Fail-over routing
- Virtual Private Networks (VPNs)
- Dynamic Host Configuration Protocol (DHCP) Server and Client
- Configurable Firewall

Enterprise Gateway Features

Enterprise wireless gateways do have features, such as Role-Based Access Control (RBAC), that are not found in any access points. RBAC allows an administrator to assign a certain level of wireless network access to a particular job position in the company. If the person doing that job is replaced, the new person automatically gains the same network rights as the replaced person. Having the ability to limit a wireless user's access to corporate resources, as part of the "role", can be a useful security feature.

Enterprise Gateway Features

Class of service is typically supported, and an administrator can assign levels of service to a particular user or role. For example, a guest account might be able to use only 500 kbps on the wireless network whereas an administrator might be allowed 2 Mbps connectivity.

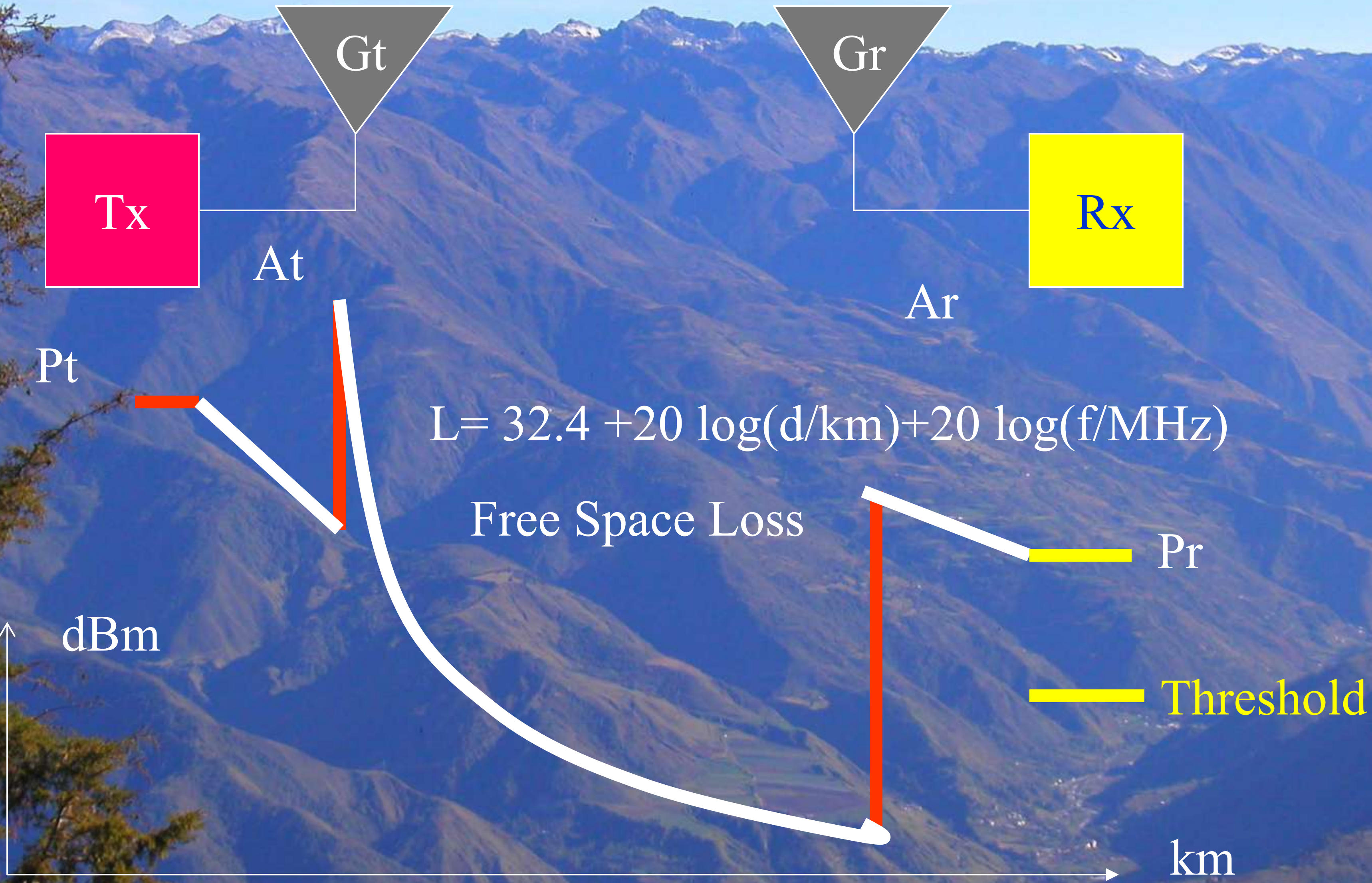
Configuration and Management **of EG**

- Enterprise wireless gateways are installed in the main data path on the wired LAN segment just past the access point(s)
- They are configured through console ports using telnet, internal HTTP or HTTPS servers, etc.
- Centralized management of only a few devices is one big advantage of using enterprise wireless gateways. An administrator, from a single console, can easily manage a large wireless deployment using only a few central devices instead of a very large number of access points.

Configuration and Management **of EWG**

Enterprise wireless gateways are normally upgraded through use of TFTP in the same fashion as many switches and routers on the market today. Configuration backups can often be automated so that the administrator won't have to spend additional management time backing up or recovering from lost configuration files. Enterprise wireless gateways are mostly manufactured as rack-mountable 1U or 2U devices that can fit into your existing data center design.

Power over distance



L= 32.4 +20 log(d/km)+20 log(f/MHz)

Power Limits

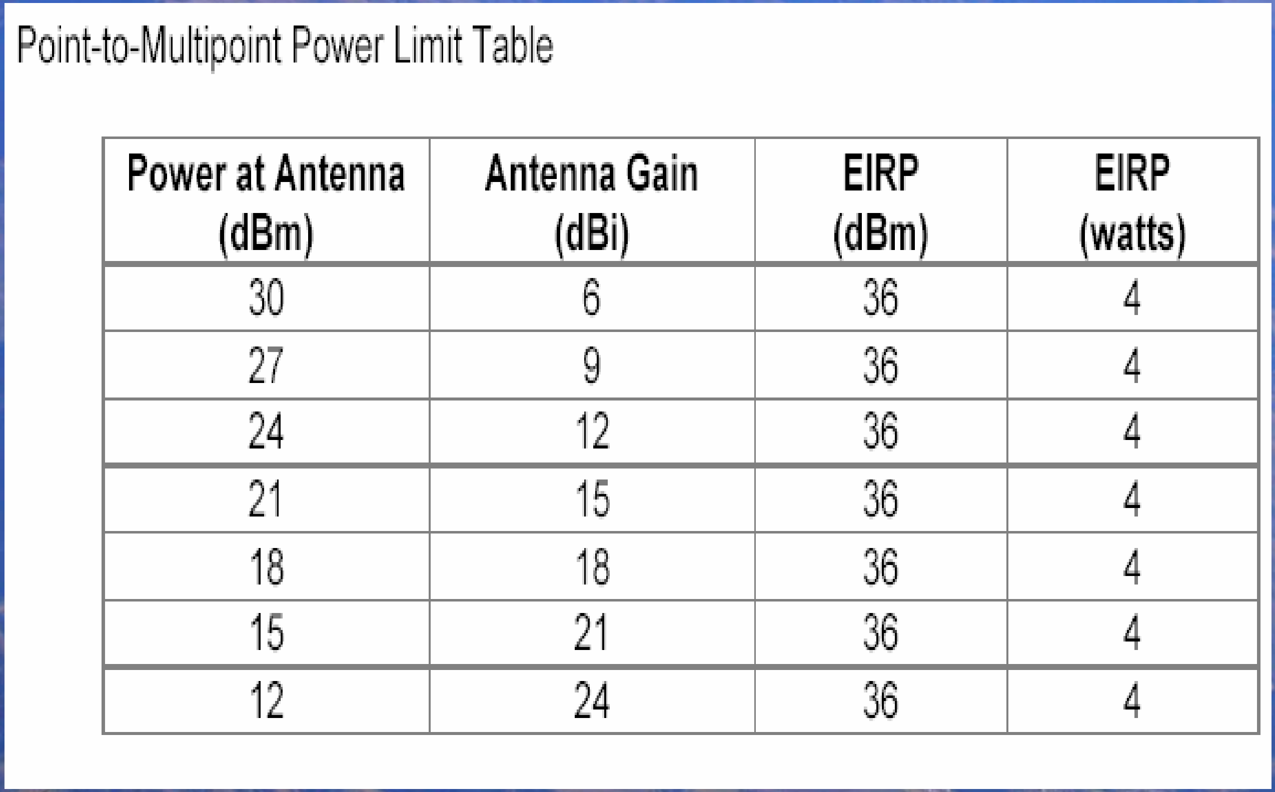
PtMP links have a central point of connection and two or more non-central connection points. PtMP links are typically configured in a star topology. The central connection point may or may not have an omnidirectional antenna It is important to note that when an omnidirectional antenna is used, the FCC automatically considers the link a PtMP link.

Regarding the setup of a PtMP link, the FCC limits the EIRP to 4 Watts in both the 2.4 GHz ISM band and upper 5 GHz UNII band. The power limit set for the intentional radiator (the device transmitting the RF signal) in each of these bands is 1 Watt. If the transmitting wireless LAN devices are adjustable with respect to their output power, then the system can be customized to the needs of the user.

Power Limits

Suppose a radio transmitting at 1 Watt (+30 dBm) is connected directly to a 12 dBi omnidirectional antenna. The total output power at the antenna is about 16 Watts, which is well above the 4 Watt limit. The FCC stipulates that *for each 3 dBi above the antenna's initial 6 dBi of gain, the power at the intentional radiator must be reduced by 3 dB below the initial +30 dBm*. For the example, since the antenna gain is 12 dBi, the power at the intentional radiator must be reduced by 6 dB. This reduction will result in an intentional radiator power of +24 dBm (30 dBm – 6 dB), or 250 mW and an EIRP of 36 dBm (24 dBm + 12 dBi), or 4 Watts. The power at the intentional radiator must never be more than 1 Watt and the EIRP must never be above 4 Watts for a PtMP connection.

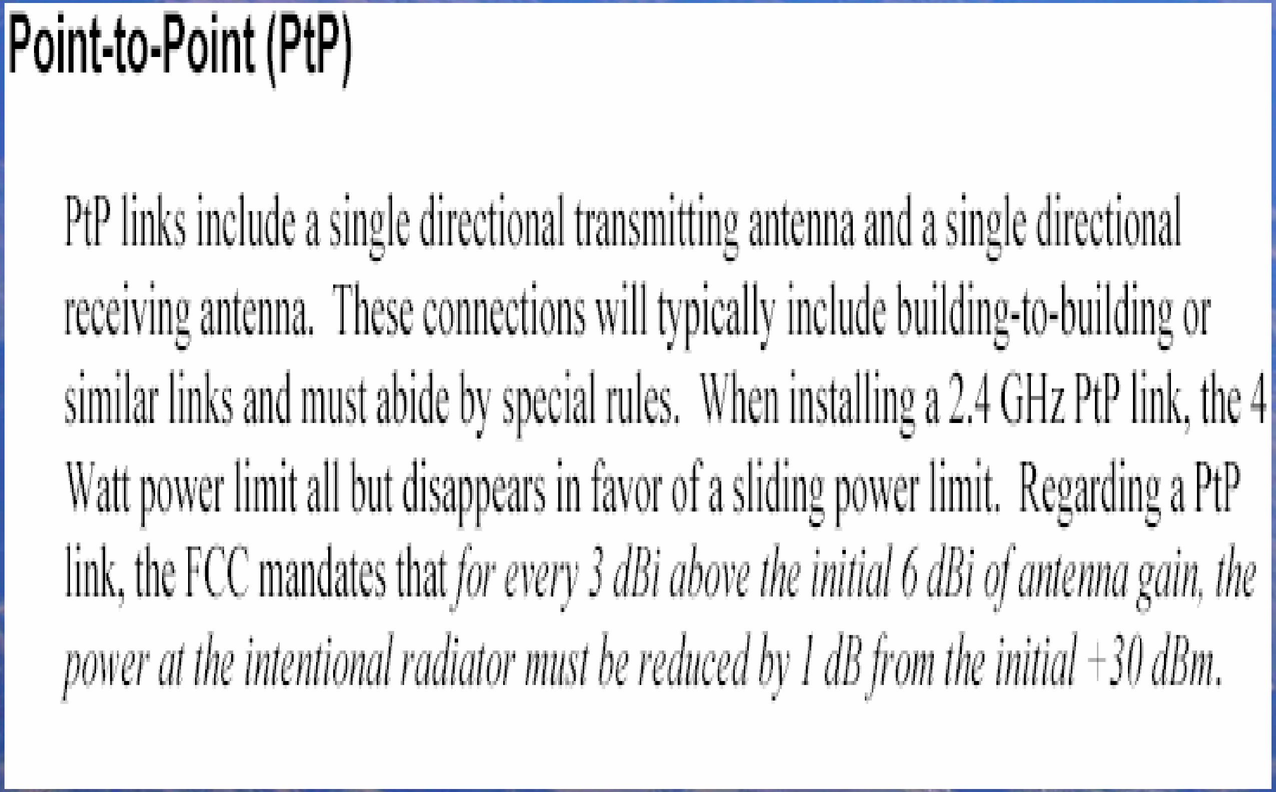
Power Limits



Point-to-Multipoint Power Limit Table

Power at Antenna (dBm)	Antenna Gain (dBi)	EIRP (dBm)	EIRP (watts)
30	6	36	4
27	9	36	4
24	12	36	4
21	15	36	4
18	18	36	4
15	21	36	4
12	24	36	4

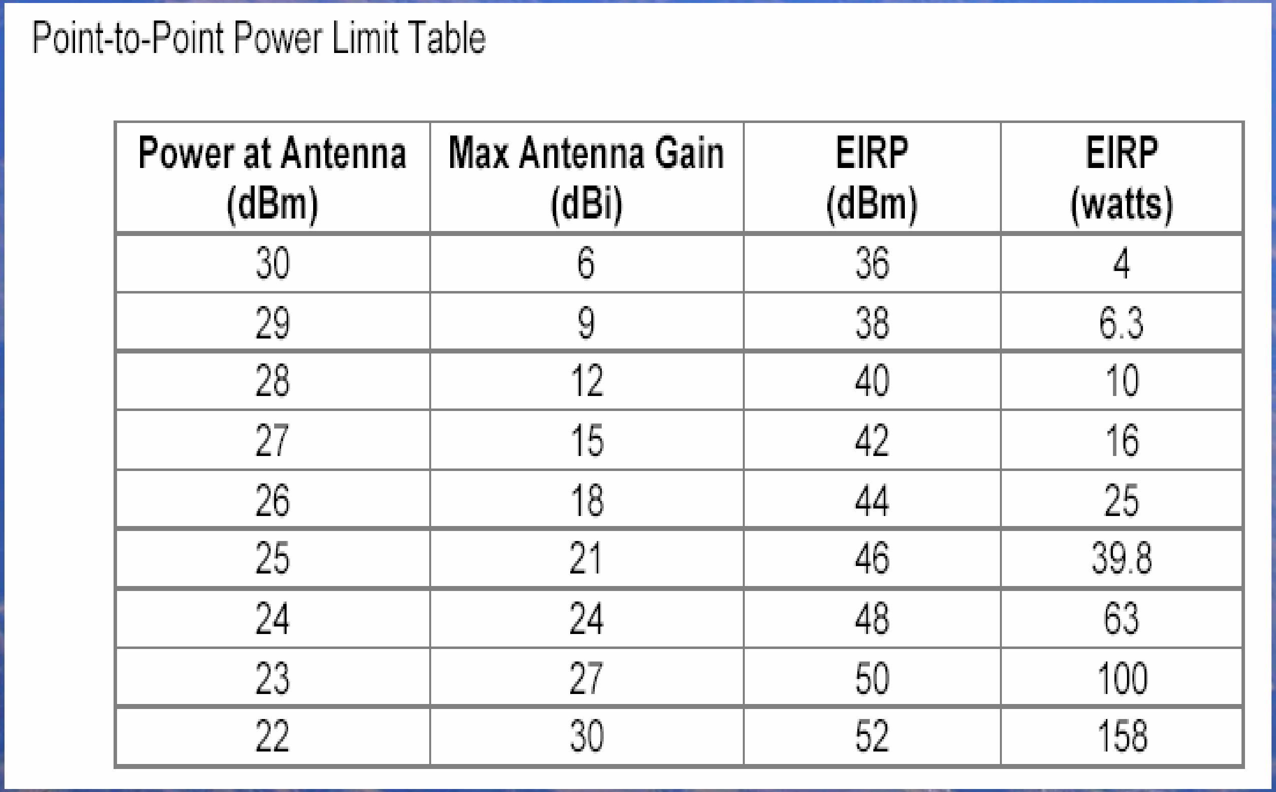
Power Limits



Point-to-Point (PtP)

PtP links include a single directional transmitting antenna and a single directional receiving antenna. These connections will typically include building-to-building or similar links and must abide by special rules. When installing a 2.4 GHz PtP link, the 4 Watt power limit all but disappears in favor of a sliding power limit. Regarding a PtP link, the FCC mandates that *for every 3 dBi above the initial 6 dBi of antenna gain, the power at the intentional radiator must be reduced by 1 dB from the initial +30 dBm.*

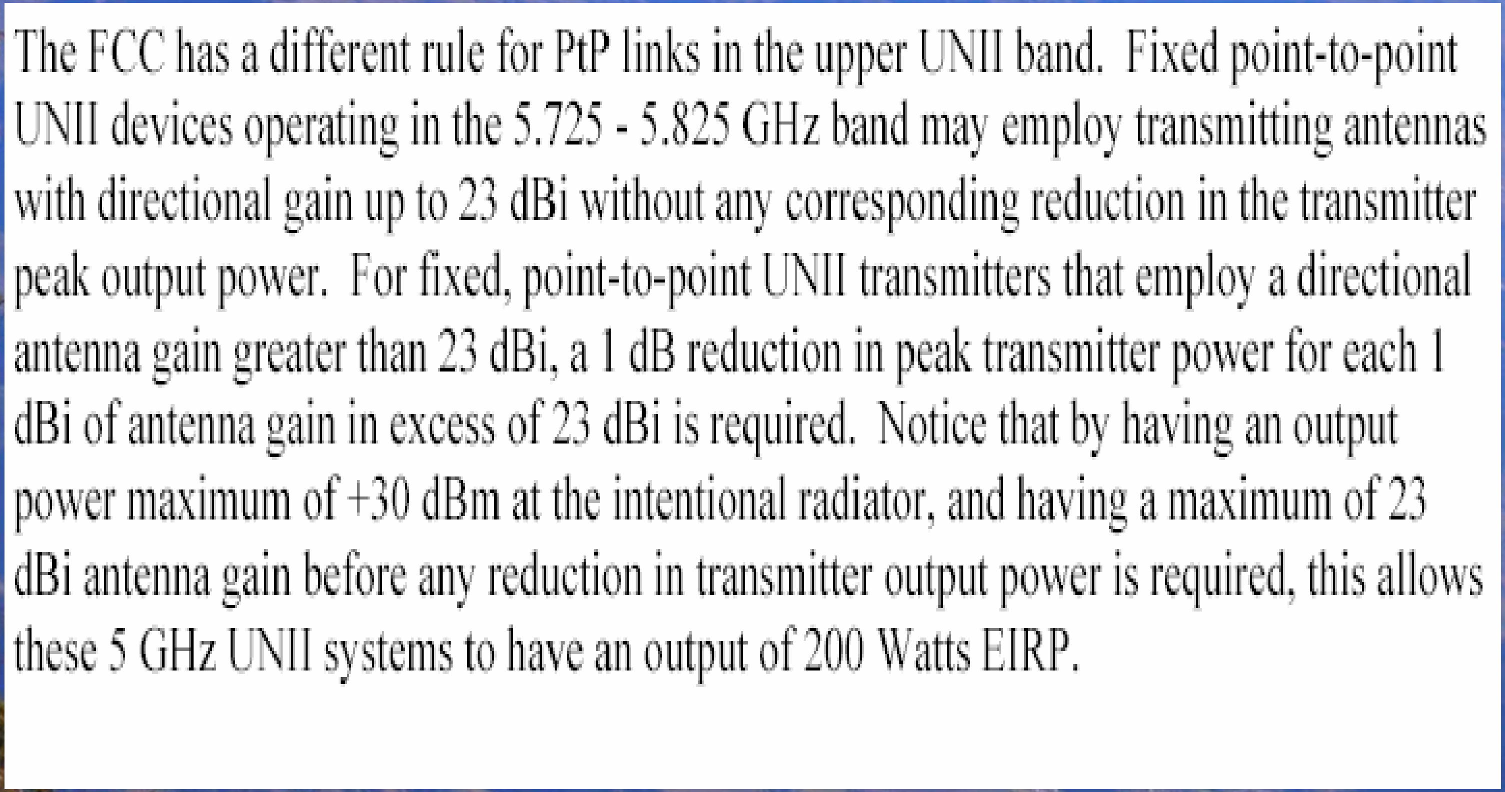
Power Limits



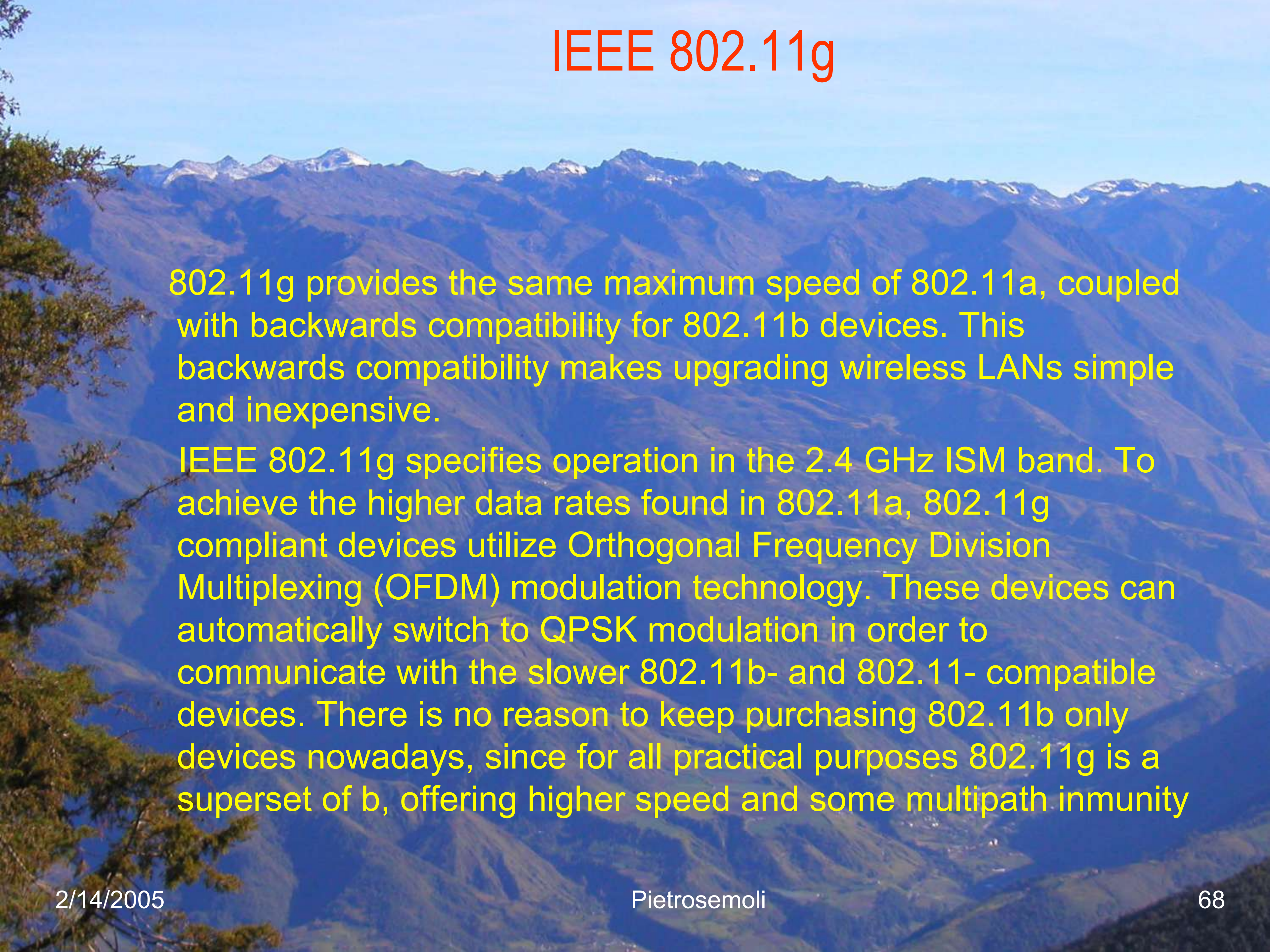
Point-to-Point Power Limit Table

Power at Antenna (dBm)	Max Antenna Gain (dBi)	EIRP (dBm)	EIRP (watts)
30	6	36	4
29	9	38	6.3
28	12	40	10
27	15	42	16
26	18	44	25
25	21	46	39.8
24	24	48	63
23	27	50	100
22	30	52	158

Power Limits



The FCC has a different rule for PtP links in the upper UNII band. Fixed point-to-point UNII devices operating in the 5.725 - 5.825 GHz band may employ transmitting antennas with directional gain up to 23 dBi without any corresponding reduction in the transmitter peak output power. For fixed, point-to-point UNII transmitters that employ a directional antenna gain greater than 23 dBi, a 1 dB reduction in peak transmitter power for each 1 dBi of antenna gain in excess of 23 dBi is required. Notice that by having an output power maximum of +30 dBm at the intentional radiator, and having a maximum of 23 dBi antenna gain before any reduction in transmitter output power is required, this allows these 5 GHz UNII systems to have an output of 200 Watts EIRP.

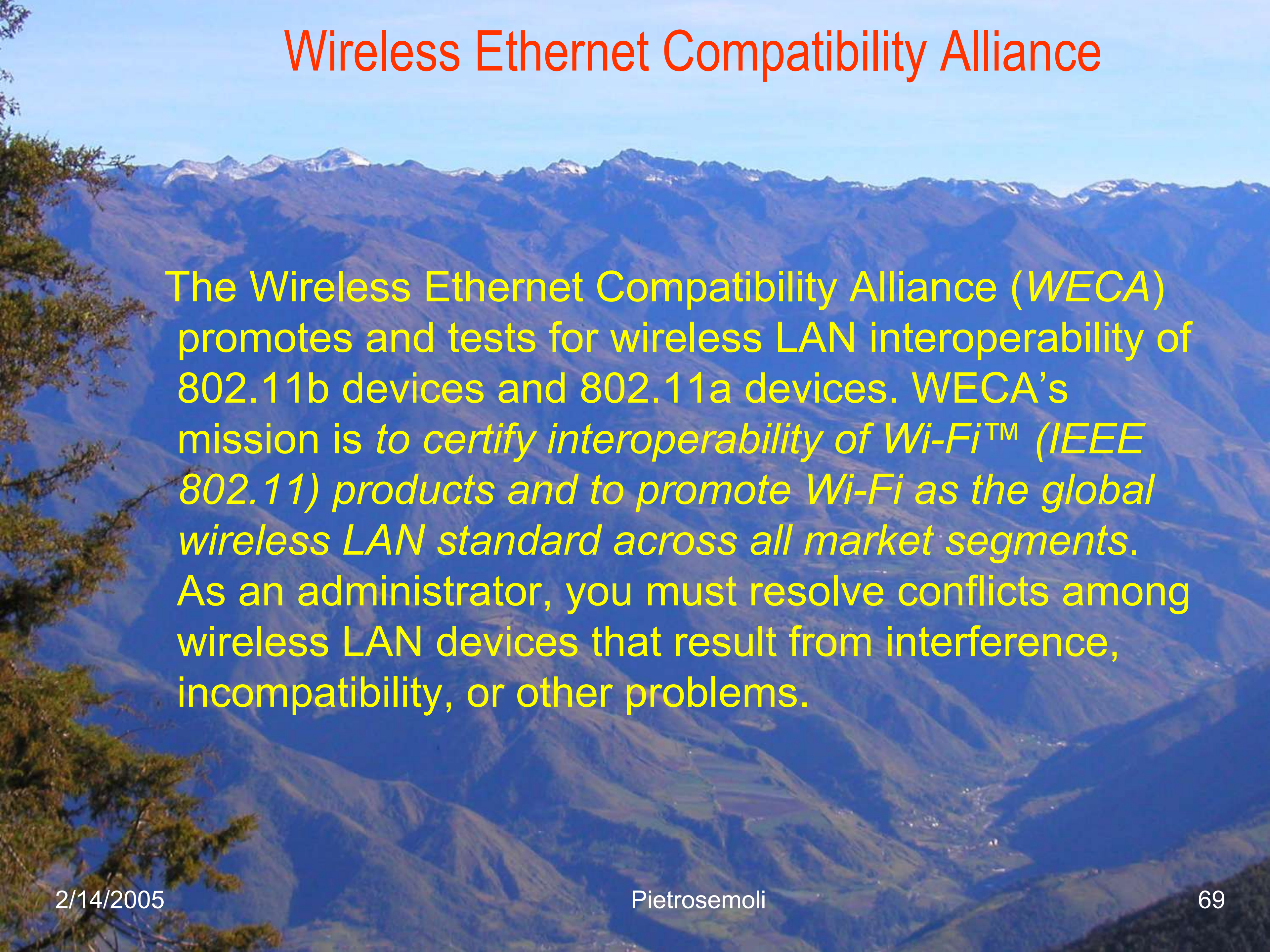


IEEE 802.11g

802.11g provides the same maximum speed of 802.11a, coupled with backwards compatibility for 802.11b devices. This backwards compatibility makes upgrading wireless LANs simple and inexpensive.

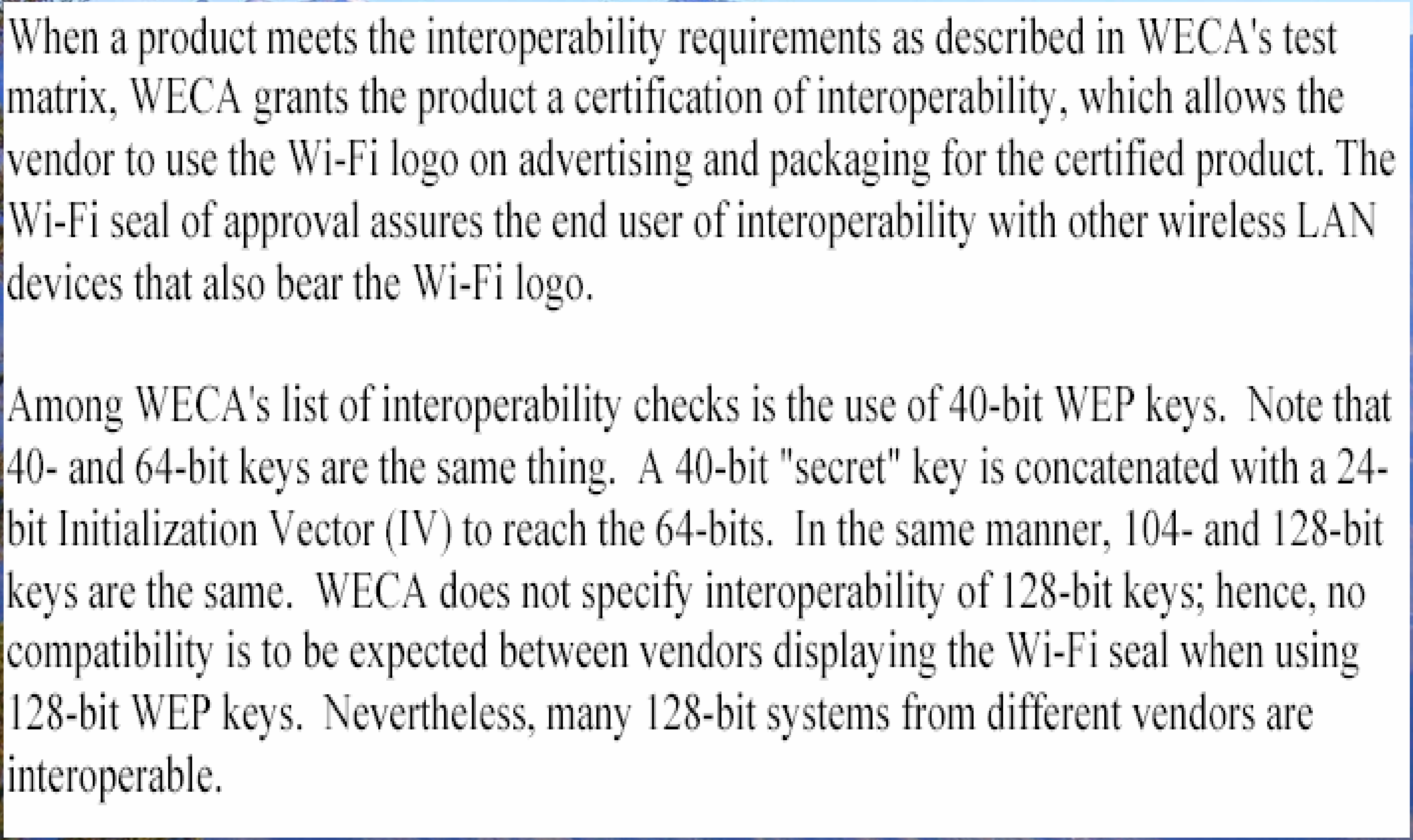
IEEE 802.11g specifies operation in the 2.4 GHz ISM band. To achieve the higher data rates found in 802.11a, 802.11g compliant devices utilize Orthogonal Frequency Division Multiplexing (OFDM) modulation technology. These devices can automatically switch to QPSK modulation in order to communicate with the slower 802.11b- and 802.11- compatible devices. There is no reason to keep purchasing 802.11b only devices nowadays, since for all practical purposes 802.11g is a superset of b, offering higher speed and some multipath inmunity

Wireless Ethernet Compatibility Alliance



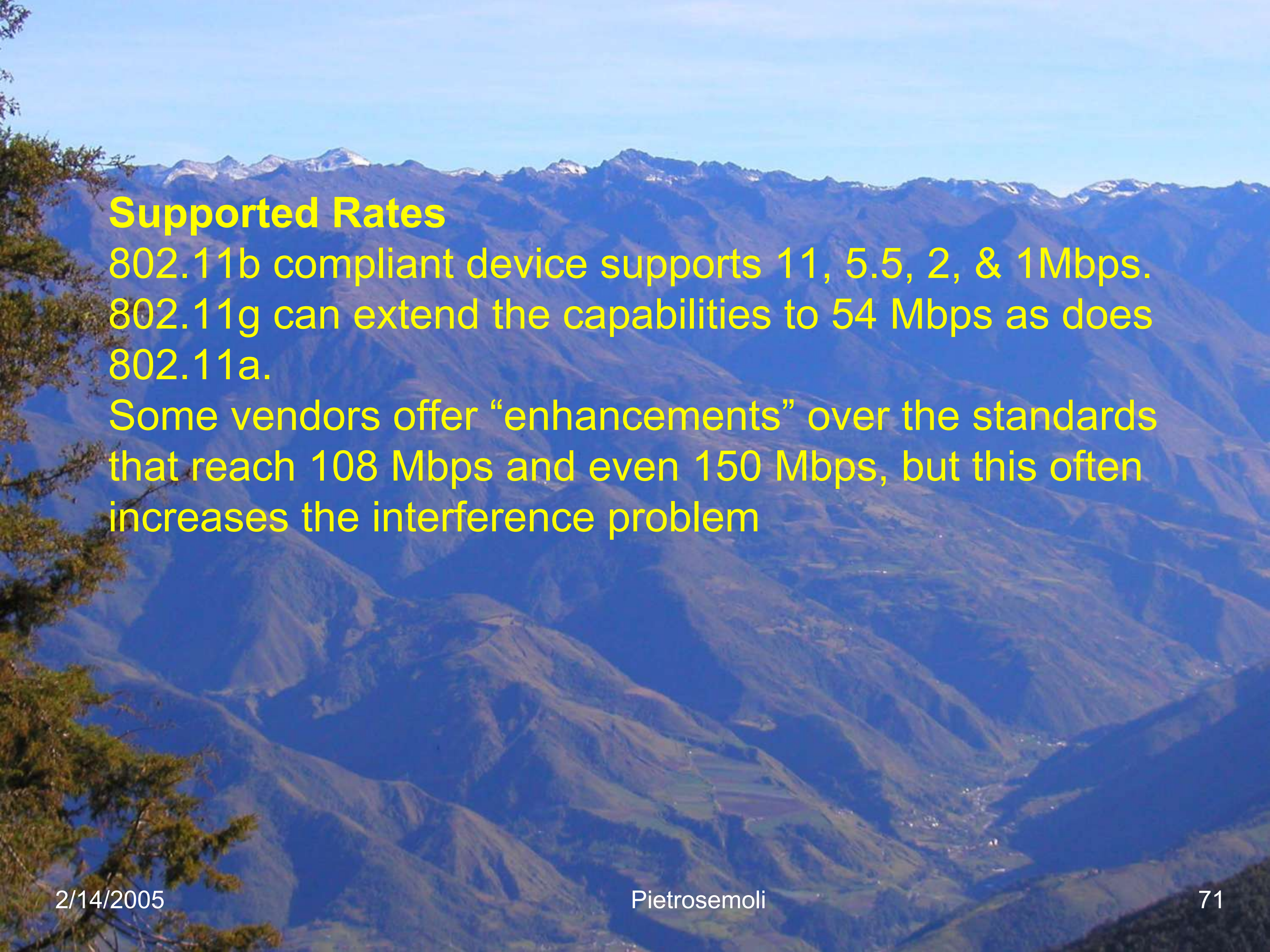
The Wireless Ethernet Compatibility Alliance (*WECA*) promotes and tests for wireless LAN interoperability of 802.11b devices and 802.11a devices. WECA's mission is *to certify interoperability of Wi-Fi™ (IEEE 802.11) products and to promote Wi-Fi as the global wireless LAN standard across all market segments*. As an administrator, you must resolve conflicts among wireless LAN devices that result from interference, incompatibility, or other problems.

Wireless Ethernet Compatibility Alliance



When a product meets the interoperability requirements as described in WECA's test matrix, WECA grants the product a certification of interoperability, which allows the vendor to use the Wi-Fi logo on advertising and packaging for the certified product. The Wi-Fi seal of approval assures the end user of interoperability with other wireless LAN devices that also bear the Wi-Fi logo.

Among WECA's list of interoperability checks is the use of 40-bit WEP keys. Note that 40- and 64-bit keys are the same thing. A 40-bit "secret" key is concatenated with a 24-bit Initialization Vector (IV) to reach the 64-bits. In the same manner, 104- and 128-bit keys are the same. WECA does not specify interoperability of 128-bit keys; hence, no compatibility is to be expected between vendors displaying the Wi-Fi seal when using 128-bit WEP keys. Nevertheless, many 128-bit systems from different vendors are interoperable.



Supported Rates

802.11b compliant device supports 11, 5.5, 2, & 1Mbps.

802.11g can extend the capabilities to 54 Mbps as does 802.11a.

Some vendors offer “enhancements” over the standards that reach 108 Mbps and even 150 Mbps, but this often increases the interference problem

Thanks for your attention