Using Multiple Channels with the IBM High Rate Wireless LAN[1]

IBM High Rate Wireless LAN (IEEE 802.11b compliant) products offer users the ability to operate on several frequency channels within the 2.4 GHz band. The number of channels available for the user depends on local regulations and can vary from 1 to 13.

This capability allows the user to increase the capacity of the network, and it provides a mechanism for avoiding portions of the 2.4MHz band where interference is encountered. However, in order to fully exploit this capability, it is essential that the user be aware of certain behavioral aspects of RF systems. This report will increase the user's understanding of these issues, and to give guidance and recommendations on how to configure the network best when using multiple channels. The following aspects are considered:

- Channel assignments in each regulatory domain
- Use of two Wireless LAN cards in one Access Point
- Effects of adjacent channels on the current choice
- Guidelines for radio-cell planning

Channel Assignments per Regulatory Domain

The following channels are available (the 4-digit numbers in this table represent the center frequencies in MHz):

Channel ID	FCC	ETSI	France	Japan
1	2412	2412	-	-
2	2417	2417	-	-
3	2422	2422	-	-
4	2427	2427	-	-
5	2432	2432	-	-
6	2437	2437	-	-
7	2442	2442	-	-
8	2447	2447	-	-
9	2452	2452	-	-
10	2457	2457	2457	-
11	2462	2462	2462	-
12	-	2467	2467	-
13	-	2472	2472	-
14	-	-	-	2484

Factors That Impact the Use of Multiple Channels

Deferring – IBM Wireless LAN systems implement a Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA) mechanism, which means that an IBM Wireless LAN transmitting station will ensure that the medium is free (not in use by another station that uses Direct Sequence Spectrum Spread) prior to initiating its transmission. If the medium is not free, the station will defer its transmission until the medium is free. Deferring reduces available bandwidth, since the same medium is now shared with other stations. Deferring only occurs if the station is capable of recognizing the other transmission as a modulated signal and not as just RF energy. This is true when the stations share the same frequency sub-band or when they operate in two adjacent sub-bands. When a station is more than one channel away but still at such close proximity that it can be sensed, it is classed only as an interference source.

Interference – When a receiving IBM Wireless LAN station experiences RF disturbance from another source, which cannot be recognized as an RF-modulated signal that conforms to IEEE 802.11 Direct Sequence Spread Spectrum signaling, it is seen as interference. Interference can block transmissions depending on relative physical distances. Users may experience the effects of interference as a reduction in range.

Adjacent Channel Rejection – This is a measure of a receiver's ability to recognize a signal from an adjacent frequency sub-channel, reject it, and receive only the signal in the sub-channel it was meant to receive. It is expressed as the strength of the received adjacent channel's signal that will be rejected related to the signal strength of the "in-band" signal in terms of dB.

Example: Measurements indicate that the 802.11b PC-Card shows adjacent channel rejections of 35 dB if the adjacent channel is 25 MHz away. This means that if the signal from the adjacent channel is detected by the receiver with 35dBm more signal strength than the signal in the "tuned" band, it will be rejected. Otherwise, the signal from the adjacent channel is seen as noise and thus deteriorates the quality of the in-band signal.

Near-Far Behavior - This term describes the relationship of the distance between two devices that effectively communicate with each other using 802.11b adapters and the distance between one of those devices and a source of interference that degrades the signal. The presence of a source of interference close to the receiving station will negatively impact the quality of the received signal and will manifest itself to the user as a noticeable reduction in distance covered. As with adjacent channel rejection, this near-far behavior is expressed as the degree to which the interfering signal is stronger then the intended signal in terms of dB.

Channel Separation – For there to be minimal interference between two frequency sub-bands, there must be sufficient frequency spacing between them. Due to near-far behavior, the effects of a neighboring station (the source of interference) are more pronounced if it is close to the receiving station. Maximizing the frequency separation between the sub-bands used will result in the best communications quality.

Example: Station A operates on Channel 1 and communicates to its Access Point, which is 20 meters away. Station B operates on another channel and communicates with its Access Point. The table shows the minimum distances between Station A and Station B that would allow good communication between the station A and its Access Point for different channels assigned to Station B.

Station A's Channel	Station B's Channel				
Channel 1	Chan. 3	Chan. 4	Chan. 5	Chan. 6	Chan. 7
Distance between Station A and Station B	5-10 meter	1-4 meter	1-2.5 meter	1-2 meter	1-1.5 meter

Distance Between Access Points – As mentioned previously, the distance between access points can impact the quality of the communications path between a wireless LAN client station and its access point. If the access points are too close to each other and there is insufficient channel separation, either interference or defer situations can occur, which lead to reductions in coverage or bandwidth as sensed by the wireless LAN client station.

Distance Between Access Points Parameter (Defer Thresholds, Carrier Detect Thresholds) – With the IBM Wireless LAN System, access points can be configured to be more or less sensitive to neighboring cells, using the Distance Between Access Points (formerly called AP density) parameter. This parameter controls when roaming stations switch from one access point to another. When the "Distance Between Access Points" parameter is set to "small," the actual distance between the access points should be less then when it is set to "Large"). In fact, setting this parameter determines the values for two other thresholds:

- ***Defer Threshold*** – This is the value at which a signal, which is recognized by the receiving station as being a modulated signal, is to result in a deferral. If such an incoming signal is of lower strength than the defer threshold value, it does not result in a deferral, and the station will initiate its transmission.

- ***Carrier Detect Threshold*** – This is the signal strength value at which the signal from another station is accepted. It is a form of programmable receiver sensitivity.

The following matrix shows the relationship between the value for Distance between Access Points and the actual values of the two thresholds mentioned:

Distance Between Access Points	Defer Threshold	Carrier Detect Threshold
Small	-75 dBm	-85 dBm
Medium	-85 dBm	-90 dBm
Large	-95 dBm	-95 dBm

Using Two Wireless LAN Adapters in One IBM Access Point

Lab tests have been conducted that assess interactions between two wireless LAN adapters that reside in a single IBM access point. A variety of configurations were tested to find the best settings for channel selection and/or antenna placement. Recommendations were formulated based on the results. The three tested configurations were:

- Two IBM Wireless LAN PC Card adapters in one IBM access point

- One IBM Wireless LAN PC Card Adapter and one non-IBM pre-IEEE 2.4 GHz PCMCIA adapter in one IBM access point

- One IBM Wireless LAN PC Card Adapter and one non-IBM pre-IEEE 915 MHz PCMCIA adapter in one IBM access point

Two IBM Wireless LAN PC Card Adapters in one IBM Access Point

Based on the tests the following guidelines were formulated:

- Using two IBM Wireless LAN PC Card Adapters in one IBM access point will not operate satisfactorily without the use of the external range-extending antenna.

- One range-extending external antenna, connected to one of the adapters through a one-meter cable, is sufficient to allow the use of two IBM Wireless LAN PC Card Adapters in one IBM access point.

- To minimize interference between the two adapters, the frequency sub-channels used need to be at least 8 channels apart. Therefore, this configuration cannot be used in the Japan or France regulatory domain.

- The following tables indicate the possible combinations for channel assignments of both IBM Wireless LAN PC Card Adapters inside the IBM access points based on the considerations for channel separation as described above:

ETSI Domain

Adapter-1's Channel #	**Adapter-2's Channel #**												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1									□	□	□	□	□
2										□	□	□	□
3											□	□	□
4												□	□
5													□
6													
7													
8													
9	□												
10	□	□											
11	□	□	□										
12	□	□	□	□									
13	□	□	□	□	□								

Note: A □ symbol indicates a channel combination that can be used.

FCC Domain

Adapter-1's Channel #	**Adapter-2's Channel #**										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1									□	□	□
2										□	□
3											□
4											
5											
6											
7											
8											
9	□										
10	□	□									
11	□	□	□								

Note: A □ symbol indicates a channel combination that can be used.

Distances Between IBM Access Points

Building-wide or campus-wide Wireless LAN networks often involve the deployment of multiple IBM access points to assure that there is sufficient coverage for stations that are fitted with Wireless LAN Adapters. Use of multiple access points also provides additional capacity by using overlapping radio cells with different frequency sub-channels. When multiple access points are used, questions arise concerning which frequencies need to be used and concerning the distances that should be maintained between the access points in order to maximize the isolation between neighboring cells, thus maximizing the capacity of the network. To address these questions, lab tests and measurement were conducted which yielded the following guidelines for IT managers who install wireless LAN networks:

- Ensure sufficient channel separation between adjacent cells. The following matrices can help in the selection of channel combinations. Access point A controls the cell that is adjacent to the cell that is driven by access point B.

ETSI Domain

Channel # of Access Point B	**Channel # of Access Point A**												
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**
1						□	□	□	□	□	□	□	□
2							□	□	□	□	□	□	□
3								□	□	□	□	□	□
4									□	□	□	□	□
5										□	□	□	□
6	□										□	□	□
7	□	□										□	□
8	□	□	□										□
9	□	□	□	□									
10	□	□	□	□	□								
11	□	□	□	□	□	□							
12	□	□	□	□	□	□	□						
13	□	□	□	□	□	□	□	□					

Note: A □ symbol indicates a channel combination that can be used.

FCC Domain

Channel # of Access Point B	**Channel # of Access Point A**										
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
1						□	□	□	□	□	□
2							□	□	□	□	□
3								□	□	□	□
4									□	□	□
5										□	□
6	□										□
7	□	□									
8	□	□	□								

9	□	□	□	□							
10	□	□	□	□	□						
11	□	□	□	□	□	□					

Note: A □ symbol indicates a channel combination that can be used.

- Even though channels are separated according to the tables above, some level of RF interference between the cells can occur. This can lead to a reduction in receiver sensitivity and therefore a reduction in coverage distance between an IBM Wireless LAN client station and its access point. To improve this condition, increasing the distance between access points may be necessary. ***If maximum receiver sensitivity (coverage) is required*** with regard to the connection between the IBM Wireless LAN client station and the access point, the following spacings between the access points apply ("external antenna" refers to the optional range-extending antenna):

Distance between APs	Receiver Sensitivity	Without External Antenna	With External Antenna
Small	-85 dBm	18 meters	32 meters
Medium	-90 dBm	32 meters	55 meters
Large	-95 dBm	55 meters	100 meters

- However, if the spacing between the access point is fixed at 1 meter (if no range-extending antennas are used) or 2 meter (when using external- antennas), the receiver sensitivity on the link between a client station and its access point will be reduced, due to another nearby access point. The following table contains values of receiver sensitivity that result from the presence of neighboring cells, as determined during lab testing.

Distance between Access Points	1 meter spacing	2 meter spacing
Small	-60 dBm	-61 dBm
Medium	-60 dBm	-61 dBm
Large	-60 dBm	-61 dBm

- To determine what the coverage (and associated cell-size) would be with the above receiver sensitivity values, the following matrix can be consulted. The distances listed are based on modelling and collected data. They represent maximum distances in different environments with different values for receiver sensitivity.

	-60 dBm	-85 dBm	-90 dBm	-95 dBm
Open Environment	45 meters	400 meters	625 meters	900 meters
Semi-Open	22 meters	140 meters	190 meters	270 meters

Closed	15 meters	52 meters	65 meters	80 meters
Open Warehouse	38 meters	320 meters	550 meters	800 meters
Supermarket	25 meters	150 meters	200 meters	290 meters
Open office	17 meters	68 meters	93 meters	130 meters
Department store	34 meters	65 meters	78 meters	88 meters

Radio-Cell Planning Guidelines

This is the recommended approach to cell planning:

1. Classify the environment by comparing it to one of those listed. This roughly determines the physical dimensions of a cell.

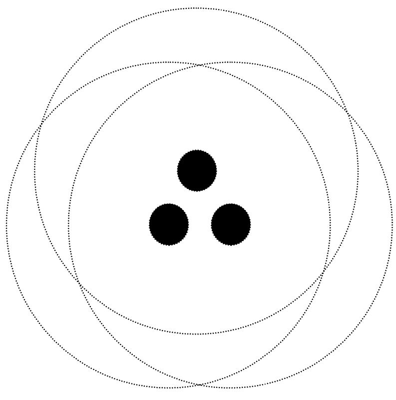
2. Determine the average network bandwidth requirement per user.

3. Determine the number of users per cell.

4. Determine the total amount of bandwidth required per cell (number of users times bandwidth per user).

5. If total bandwidth exceeds the capacity of a single cell, additional co-located cells are required. Select the smallest cell size. This will reduce the number of stations per cell, as well as increase available capacity for each user in the cell. Smallest cells are created by selecting AP density = high and by positioning the co-located access points at one meter from each other. Maximum aggregate capacity can be attained by using 3 access points positioned at 1 meter from each other and by using channel 1, channel 6, and channel 11 (see the following diagram).

The black dots symbolize the three access points with the dotted circles representing the cell boundaries.



6. To force load balancing and to keep roaming stations from associating with more than one access point, the co-located access points must be assigned three different network names. The stations in the covered area should be evenly distributed over these three networks.

7. To avoid any near-far problems, minimum distances between stations must be observed. In the above scenario, a minimum distance of 1-2 meters between stations is acceptable.

[1]Original content from Lucent Orinoco™