... WDS (Wireless Distribution System)

ORiNOCO Technical Bulletin 046/ A February 2002

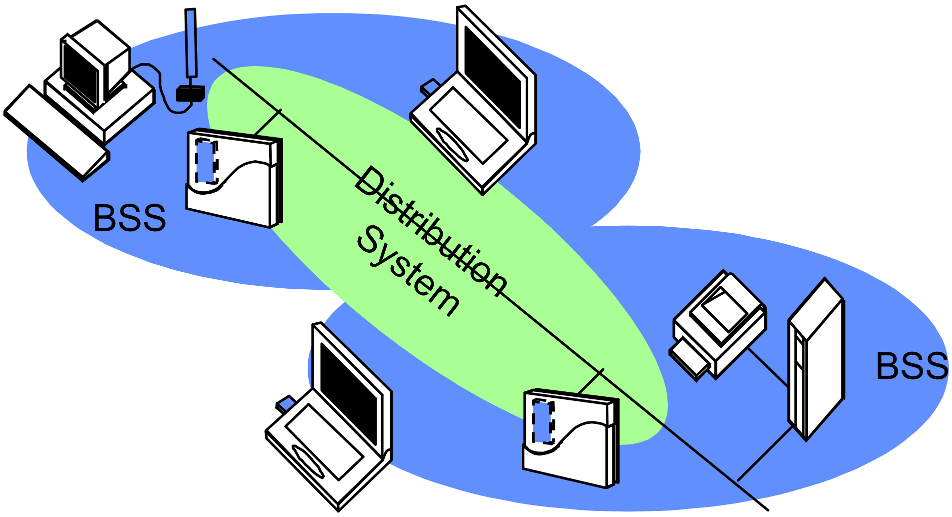
Introduction

With the arrival of the AP-2000 Access Points, WDS operation as defined by the IEEE802.11 standard has been made available. Using WDS it is possible to wirelessly connect Access Points, and in doing so extend a wired infrastructure to locations where cabling is not possible or inefficient to implement. This bulletin explains the concept of WDS, and shows how an AP-2000 can be configured to use it. In addition some throughput data will be provided that is obtained from evaluation testing.

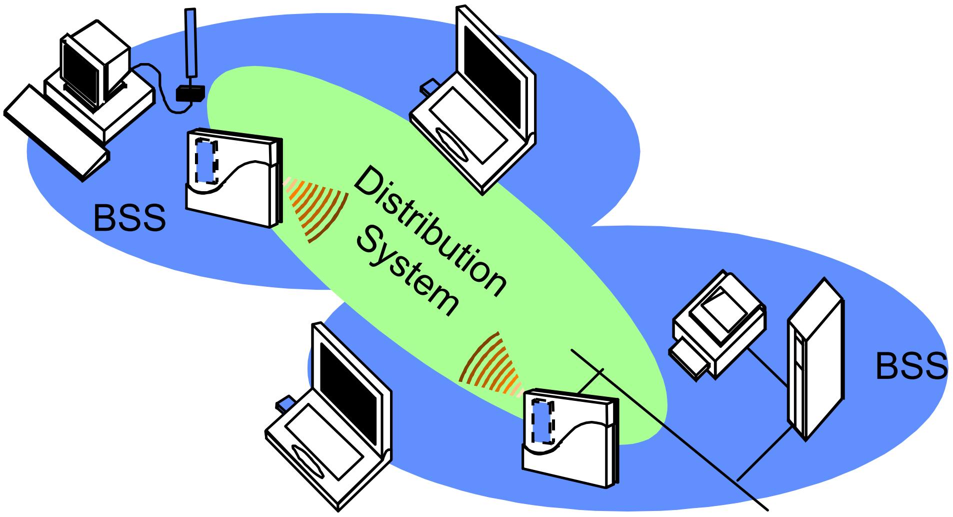
WDS – what is it?

In IEEE 802.11 terminology a "Distribution System" is system that interconnects so-called Basic Service Sets (BSS). A BSS is best compared to a "cell", driven by a single Access Point (one of those circles in the diagram below). So a "Distribution System" connects cells in order to built a premise wide network which allows users of mobile equipment to roam and stay connected to the available network resources.

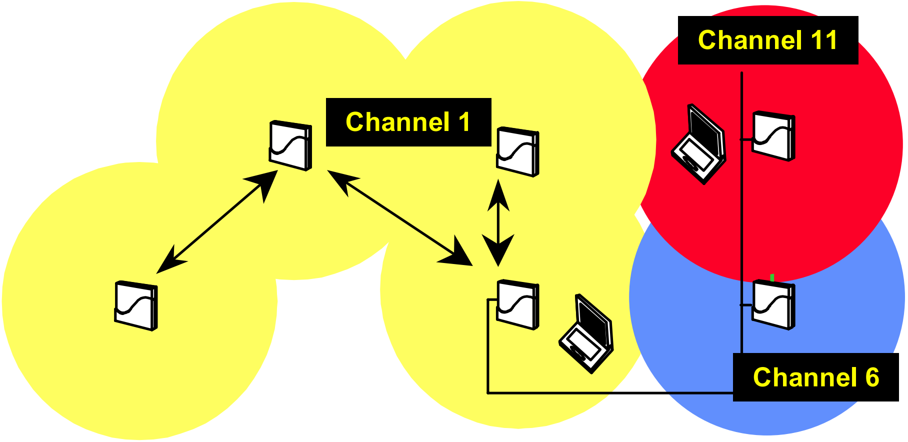
A distribution system can Wired (typically Ethernet), or Wireless (using the radio device inside the Access Point). The following diagram shows a wired distribution system.



If no cable is used but the connection between the APs is established using the PC card a wireless distribution system is created as shown in the next figure:



In the diagram below the three access points on the right hand side of the picture are connected by Ethernet cable and hence use a wired distribution system, while the four access points in the left portion are wirelessly connected, and are said to use WDS.



One important aspect of WDS (this in contrast to other existing wireless AP to AP connection schemes used in for instance outdoor installations) is the fact that a single PC card in the Access Point can assume multiple roles at the same time. It can "drive" a cell (as in wired connected APs), and as such connects wireless clients to the infrastructure, and it can maintain up to six different wireless connections to other Access Points. For that to be possible the operational (frequency) channel will need to be the same for the cell that is controlled by the AP and for the wireless links to the other APs. In the diagram above this is illustrated by the four cells on the left hand portion of the picture all operating on channel 1.

How does it work? (for techies)

Addresses.

LAN devices (including wireless LAN devices) communicate which each other by using MAC addresses (which are hardware addresses uniquely assigned in the factory to each device). Each Wireless PC Card therefore has a unique MAC address that is used by the system to send data frames to it. If a LAN device transmits data, it will add its own MAC address to the frame as well in order to indicate to the recipient where the frame came from. In short all data frames transmitted over a LAN will contain a Destination and a Source MAC address as part of the frame header. If a data frame is transmitted over an Ethernet cable just those two MAC addresses are required. When data frames are to be transmitted between LAN end-stations, that are not connected to the same LAN segment, an intermediate device is required to "bridge" the frame from one segment to another. An access point is such a device also known as a bridge, that has the capability to relay traffic from one segment to another. It performs this task with the use of a "bridge learn table", where MAC addresses are stored in association with the LAN segment (or physical interface) where they reside (from the perspective of the bridge).

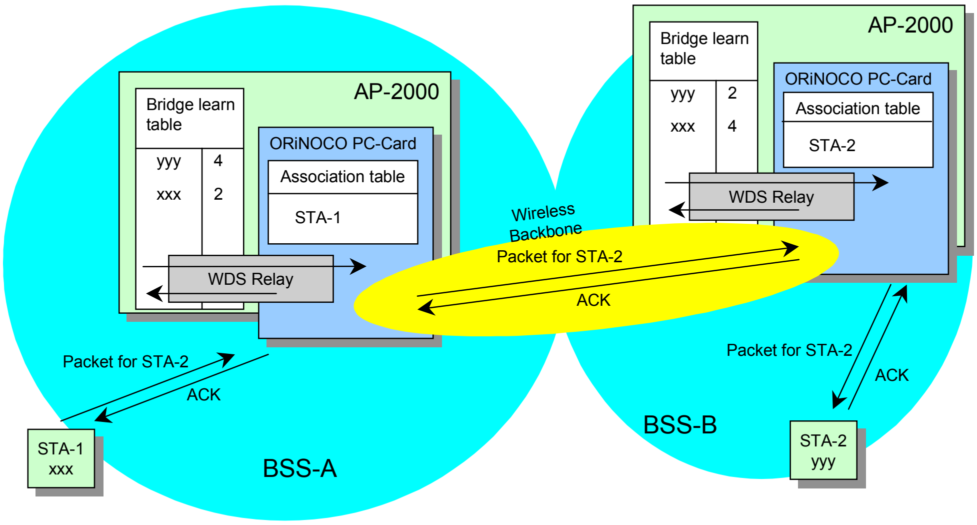
Traffic between wireless LAN devices that conform to the IEEE 802.11 standard require 4 MAC addresses instead of 2. When a wireless device is associated to an access point it will always direct its traffic to the access point by using the MAC address of the PC card in the access point as its direct destination address. The MAC address of the end station to which the frame was to be sent to is also included in the frame header, so that the PC card in the access point can determine where to relay the frame to. Finally the sending station's own MAC address is in the frame as the source address. So a total of three addresses is used.

When a WDS link is set up between two access points, all four available address fields in the MAC header are used:

- *the MAC address of the sender,*
- *the MAC address of the final destination,*
- *the MAC address of the sending PC card in the access point,*
- *MAC address of the receiving PC card in the other access point.*

Traffic flow

To illustrate the basic traffic flow between two stations that reside in two different cells that are interconnected by a WDS link, the following diagram might help.



In this figure Station1 (STA-1) in the left cell wants to transmit a frame to Station 2 (STA-2) in the right hand cell. The stations are associated to their respective access points, and are known in the bridge learn tables. Their MAC addresses "xxx" and "yyy" respectively are recorded in the bridge learn tables and related to a so called port number. As an AP-2000 has the capability to support two PC cards, and as there can be a maximum of 6 WDS links that a single PC card can support, a total of 15 different ports can be used:

Port #	*Meaning*
1	*Ethernet port*
2	*PC Card in slot A; BSS*
3	*PC Card in slot A; WDS link 1*
4	*PC Card in slot A; WDS link 2*
5	*PC Card in slot A; WDS link 3*
6	*PC Card in slot A; WDS link 4*
7	*PC Card in slot A; WDS link 5*
8	*PC Card in slot A; WDS link 6*
9	*PC Card in slot B; BSS*
10	*PC Card in slot B; WDS link 1*
11	*PC Card in slot B; WDS link 2*
12	*PC Card in slot B; WDS link 3*
13	*PC Card in slot B; WDS link 4*
14	*PC Card in slot B; WDS link 5*
15	*PC Card in slot B; WDS link 6*

So in the example diagram, STA-1 (MAC address xxx) is known in the left-hand AP-2000's bridge learn table as located on port 2. The bridge learn table also tells the AP-2000 that STA-2 (MAC address yyy) is located on port 4, meaning that they are both served by the served by the same PC Card (i.e. the one in slot A). A similar situation can be found in the right-hand AP-2000.

The steps in the traffic flow now are as follows:

1. *STA-1 sends its frame to the PC Card of its AP (because all its traffic goes in that direction); the frame includes the MAC address of the final destination, i.e. STA-2.*
2. *The PC Card in the left hand access point receives the traffic and acknowledges its correct reception to STA-1, converts the frame from an IEEE 802.11 format (with four addresses) to IEEE 802.3 format (Ethernet frame with two addresses, being the address of STA-1 as sender and STA-2 as destination). The PC Card then passes the frame to the AP-2000 bridge code.*
3. *The bridge code looks up the address of STA-2 in its bridge learn table and concludes that STA-2 is related to port 4, and port 4 itself is related to the same PC card. So the frame is passed on to the PC Card with the indication it is to be transmitted on port 4.*
4. *The PC Card itself maintains a table with the MAC addresses of the opposite end stations of the WDS links that it supports, so based on the port number the PC card will know the MAC address of the PC Card in the other AP.*
5. *The PC Card in the left-hand AP will now use the MAC address of the PC Card in the other AP as destination address, its own MAC address as source address, and will add the two addresses that were in the original frame received from the bridge. So now a total of 4 addresses are in the frame header.*
6. *The frame is transmitted on through the air and the PC Card in the other AP will receive the frame, send an acknowledgement back, convert the frame to a 2-address frame and passes it to its bridge.*
7. *De bridge will consult its bridge table, and passes the frame on to the PC card with indication to send it on port 2, being the BSS (cell) where the STA-2 is known to be.*
8. *Finally STA-2 accepts the frame and send an acknowledgement back to the PC Card in the AP.*

Roaming.

Roaming between cells that are interconnected by a WDS link works exactly the same as for cells that are interconnected via Ethernet. The effect of a relocation of a station from one cell to the other is that the bridge learn tables will be updated to reflect the new location of the station. This is done by the hand-over request messages that are part of the IAPP (Inter Access Point Protocol). For details on roaming and IAPP please consult the Tb on that matter (TB-021)

When to use WDS and when not

WDS offers great flexibility at low cost and as such can be applied in many useful situations. However there are also a few considerations that may lead a user to decide not to use WDS. This section will try to list the pro's and con's of the use of WDS.

Pro's

- ***Cost effective.*** *No additional expense in terms of adding a wireless link to an already installed AP-2000. Adding a WDS link merely requires a reconfiguration of the AP-2000, without having to pay the price for an additional PC Card*
- ***Flexible.*** *Expanding an existing wired infrastructure network by adding coverage for office space that is not adjacent to the existing office can be easily achieved, providing great flexibility.*
  - *For example connecting an office in the building across the street. Or connecting that location in the manufacturing area where cabling was hard (and expensive to install).*
  - *Another example could be the use of such an extension could be in an area where laying cable is not allowed because of historic nature of the building, or because of the presence of health hazardous material such as asbestos.*
  - *WDS is also an excellent solution to create a roaming network in an area where wired connections between the APs cannot be established. For example think of a convention in a hotel or resort, where a large area needs to be covered, and therefore multiple APs are needed.*

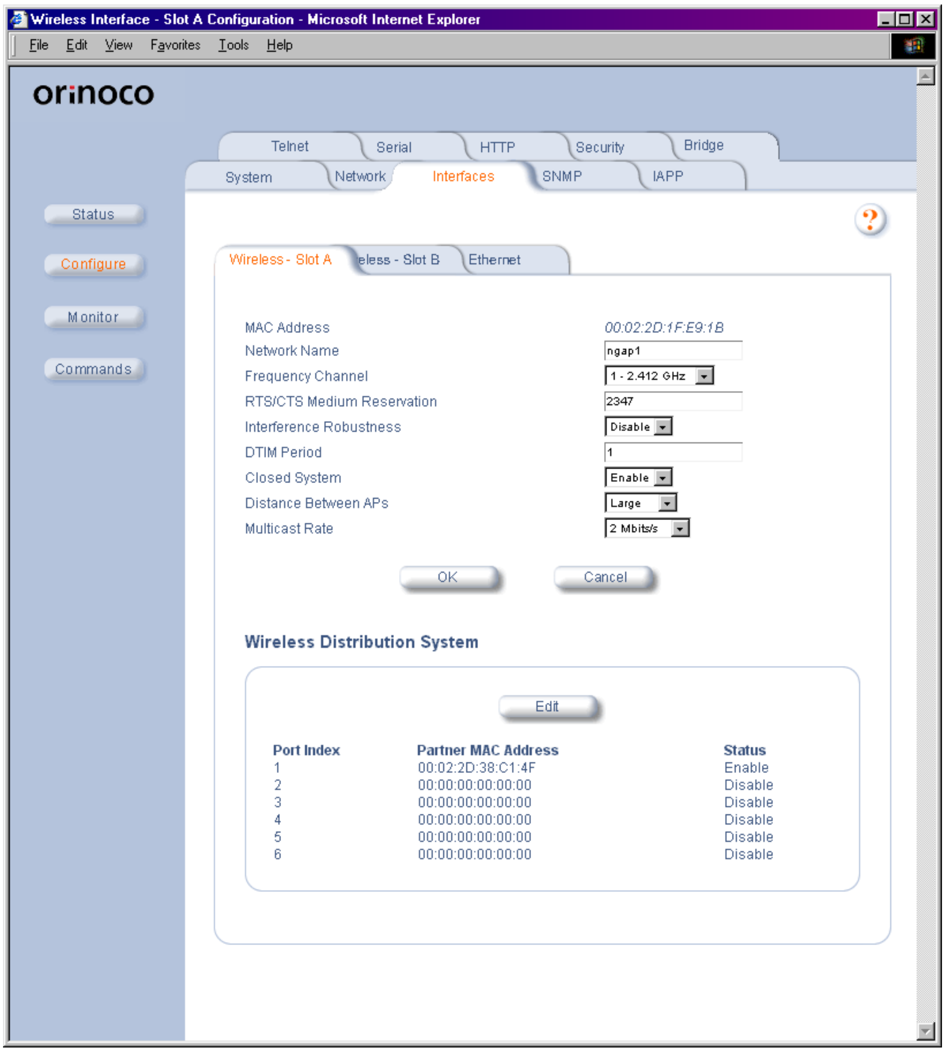
Drawbacks (current and/or temporarily)

- ***Encryption.*** *It is not possible to use encryption with dynamic assigned and rotating keys, on the WDS link. Only fixed assigned WEP keys can be used to provide encryption. In the current implementation of the AP-2000 this selection of fixed WEP keys for the WDS link also means that this is in effect for the BSS (and as such for all the client stations that are associated to the BSS). So in case the user wishes to use 802.1x to secure its operation for its wireless clients, at this moment it will not be possible to use an encrypted WDS link.*
- ***Performance.*** *As the traffic flow example shows the frame goes through the air three times, and because of the CSMA/CA technology used and the fact that a single PC Card (and a single channel) is used, the end-to-end throughput will be about one third of the maximum attainable value. Obviously using a second PC card can improve this situation but in that case the expense of a second card has to be accepted. Later in this bulletin different configurations are shown with associated throughput numbers.*
- ***Outdoor operation.*** *WDS allows creation of point to point connections, which would suggest that this could be applied to outdoor installations as well. Though in principle this is true, one has to remember that the IEEE802.11 standard has been devised primarily for LAN (indoor) operations, and that for use in outdoor situations (especially long distances and point to multi-point configurations) additional provisions are to be implemented. The outdoor product offering of the ORiNOCO family address these options and future releases of these products might be based on WDS technology.*

How to configure the AP

To create a WDS link the only thing that is needed, is to configure the access points at one end of the WDS link with the MAC address of the PC card in the access point at the other end of the link. The following screen captures show the GUIs that are to be manipulated to make this work.

1. *When accessing the AP-2000 using the web browser, proceed to the configuration tabs (by "pressing" the configuration button in the left portion of the screen).*
2. *Select the "Interfaces" tab and on sub folders displayed, select the one for the slot where the PC Card is inserted that needs to have a WDS link set up.*



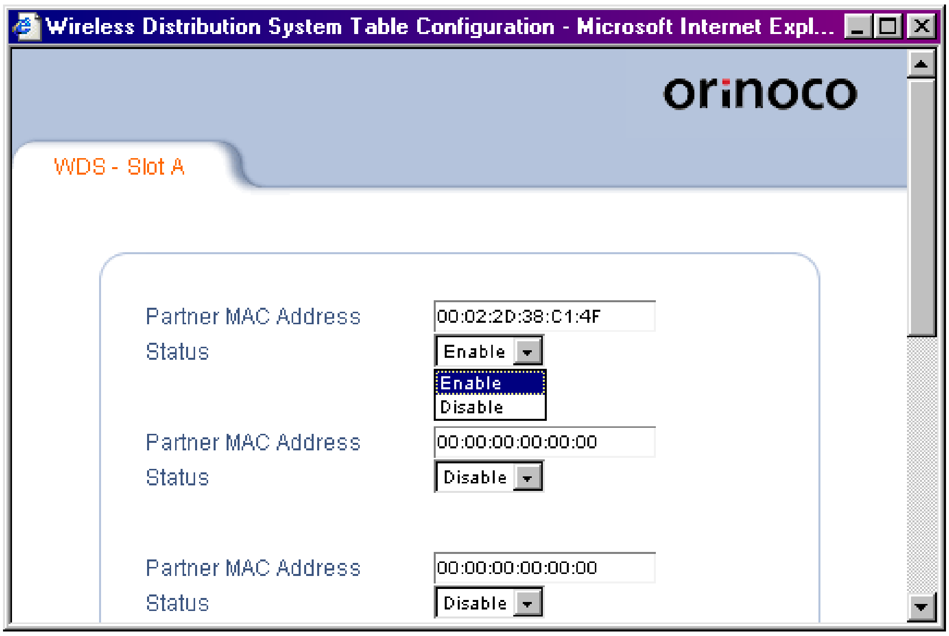
MAC Address 00:02:2D:1F:E9:1B
Network Name ngap1
Frequency Channel 1 - 2.412 GHz
RTS/CTS Medium Reservation 2347
Interference Robustness Disable
DTIM Period 1
Closed System Enable
Distance Between APs Large
Multicast Rate 2 Mbits/s

Wireless Distribution System

Port Index	Partner MAC Address	Status
1	00:02:2D:38:C1:4F	Enable
2	00:00:00:00:00:00	Disable
3	00:00:00:00:00:00	Disable
4	00:00:00:00:00:00	Disable
5	00:00:00:00:00:00	Disable
6	00:00:00:00:00:00	Disable

3. *The bottom portion of the screen shows the area dedicated to WDS setup, by listing 6 different ports and there settings. By default the ports will be disabled and the entries for the MAC address is set to all zero's.*

4. *By clicking the "Edit" button another window will be displayed that allows the user to enter MAC address information and change the state of a selected port to enable.. The MAC address to be entered is the address of PC Card in the access point at the opposite side of the WDS link. Clicking OK, will accept the entry and any change in state made.*



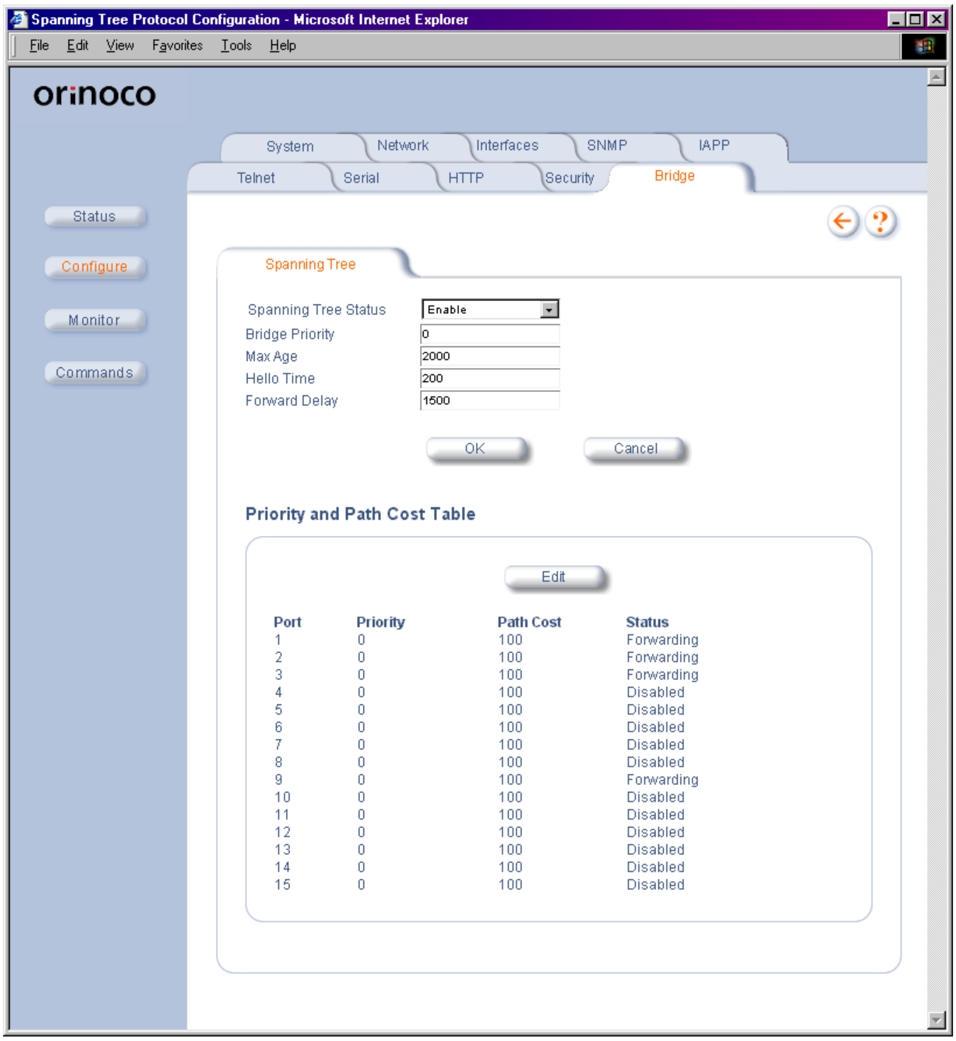
Wireless Distribution System Table Configuration - Microsoft Internet Expl...
orinoco
WDS - Slot A

Partner MAC Address 00:02:2D:38:C1:4F
Status Enable

Partner MAC Address 00:00:00:00:00:00
Status Disable
Partner MAC Address 00:00:00:00:00:00
Status Disable

5. *To make sure that the bridge will properly forward traffic to this WDS port, the port also has to be enabled on the spanning tree configuration. (should be done automatically, but a check is advised)*

6. By selecting the “Bridge” tab, and on the screen that is shown then clicking the “Spanning Tree” hyperlink, all port settings are shown as seen by the AP bridge software. The ports either have a state of forwarding or disabled. As the following screen capture illustrates, one WDS link is present and in forwarding state and is using port 3. The aother forwarding ports in this screen capture, ports 2 and 9 are both BSS ports for PC Cards in slot A and slot B respectively, while port 1 is the Ethernet port.



Spanning Tree Status: Enable
Bridge Priority: 0
Max Age: 2000
Hello Time: 200
Forward Delay: 1500

Priority and Path Cost Table

Port	Priority	Path Cost	Status
1	0	100	Forwarding
2	0	100	Forwarding
3	0	100	Forwarding
4	0	100	Disabled
5	0	100	Disabled
6	0	100	Disabled
7	0	100	Disabled
8	0	100	Disabled
9	0	100	Forwarding
10	0	100	Disabled
11	0	100	Disabled
12	0	100	Disabled
13	0	100	Disabled
14	0	100	Disabled
15	0	100	Disabled

Performance evaluations

As said earlier in this bulletin, there are some disadvantages in using WDS, one of them being the throughput reduction. However when deploying AP-2000 system it is possible to minimize the decrease in throughput, by making efficient use of the 2nd PC card slot. In this section information is provided on what performance can be achieved in different configurations.

Test platforms:

- *HP Omnibook 800 CT (166 MHz Pentium-I with MMX technology) notebook computer, running Windows 95 (wired connected to the AP)*
- *HP Omnibook 6000 laptop computer (700 MHz Pentium-III), with Win98*

Test Software:

- *Throughput test tool of "WhatsUpGold" (IPSwitch, Inc.)*
- *Tool uses TCP/IP protocols*

Test scenario:

- *Execute a test from notebook station to desktop station, using 50 packets with packet sizes that increase from 1024 Bytes to 8192 Bytes.*
- *Record lowest measured reading, highest measured reading and average measured reading.*
- *Execute the above test 5 times, and select the highest (best) reading and best average reading.*
- *Execute the above for the three configuration listed above.*
- *Adapters were using default settings (Auto-rate / high speed, WEP off, Fragmentation off, Medium Reservation off)*
- *Use different configurations as listed in the table below*

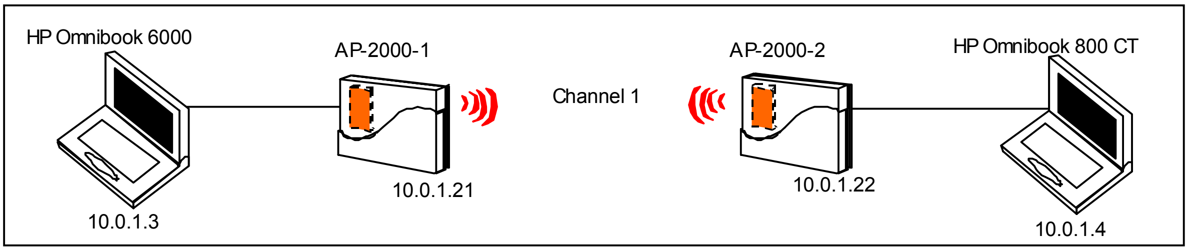
Test Results:

The following table contains the results of the tests executed as described above (readings are in Mbps):

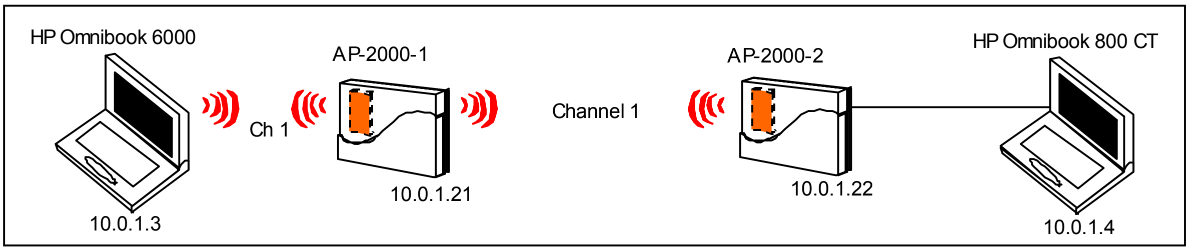
	ORiNOCO	
	Maximum	Average
1. Both clients wired connected to each AP	4.59	3.46
2. One client wired connected to one AP; other client wirelessly connected to other AP	2.22	1.90
3. Both clients wired connected to each AP; One PC Card used in AP	1.87	1.61
4. One client wired connected to one AP; other client wirelessly connected to other AP; latter AP uses two Radio cards on different channels.	3.64	2.79
5. Both clients wirelessly connected to each AP; two PC Card used in each AP; three different channels used.	3.19	2.28

The following diagrams provide additional clarification of the test configurations used. The sequence of these diagrams correspond to the rows in the table above.

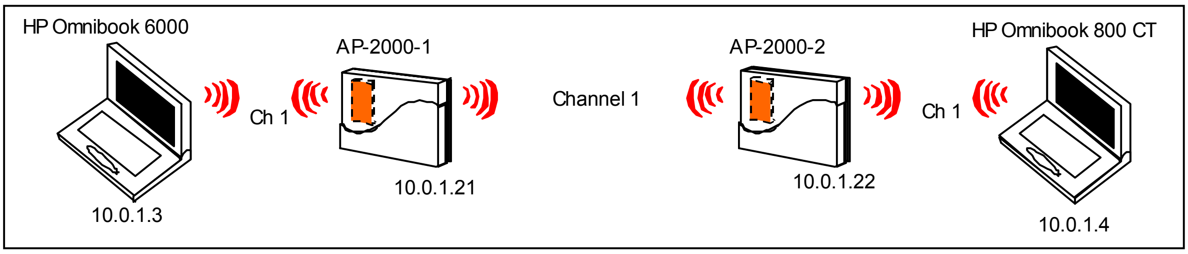
1. Both clients wired connected to each AP



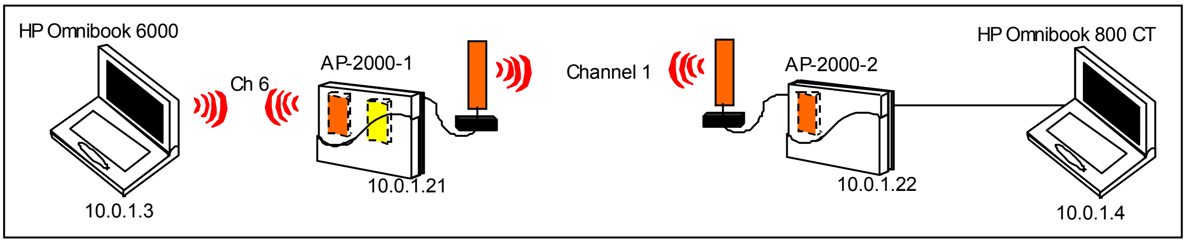
2. One client wired connected to one AP; other client wirelessly connected to other AP



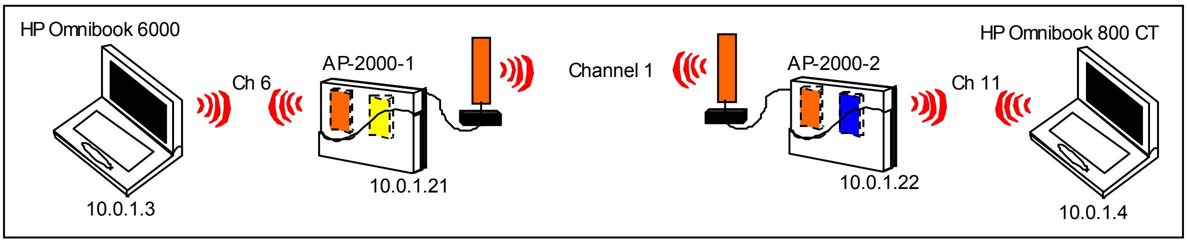
3. Both clients wirelessly connected to each AP; One PC Card used in AP



4. One client wired connected to one AP; other client wirelessly connected to other AP; latter AP uses two Radio cards on different channels.



5. Both clients wirelessly connected to each AP; two PC Card used in each AP; three different channels used.

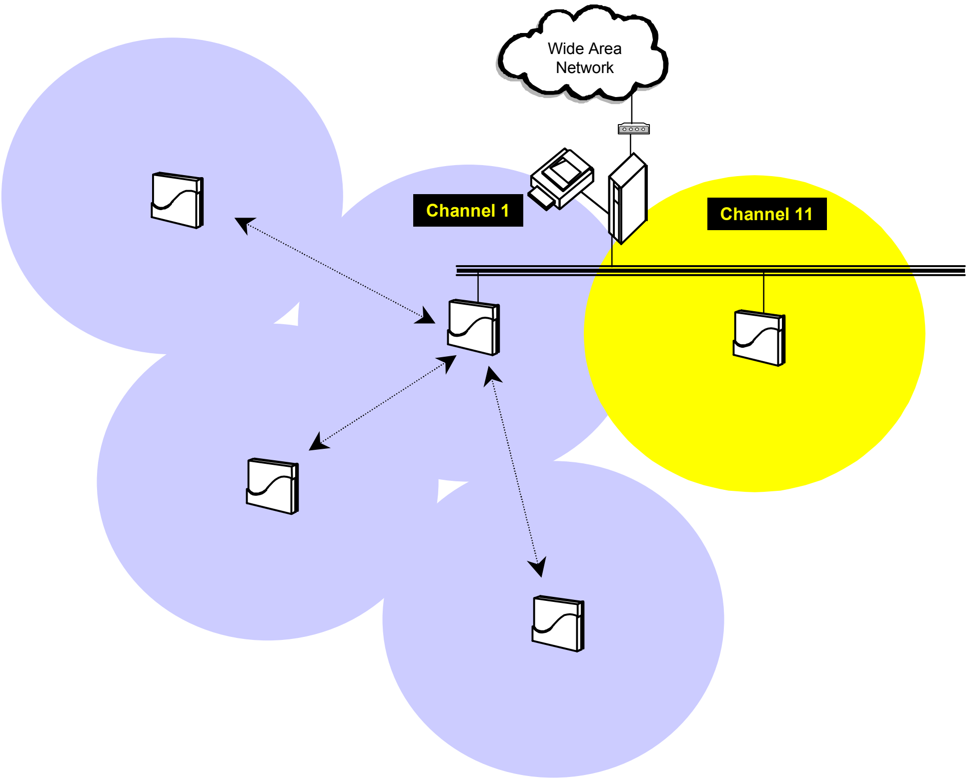


Advanced configurations

The flexibility that WDS offers, can yield numerous different configurations, each having significant operational benefits and limitations at the same time. A few of those configurations are shown here with some explanation on what issues to look out for.

Star configuration

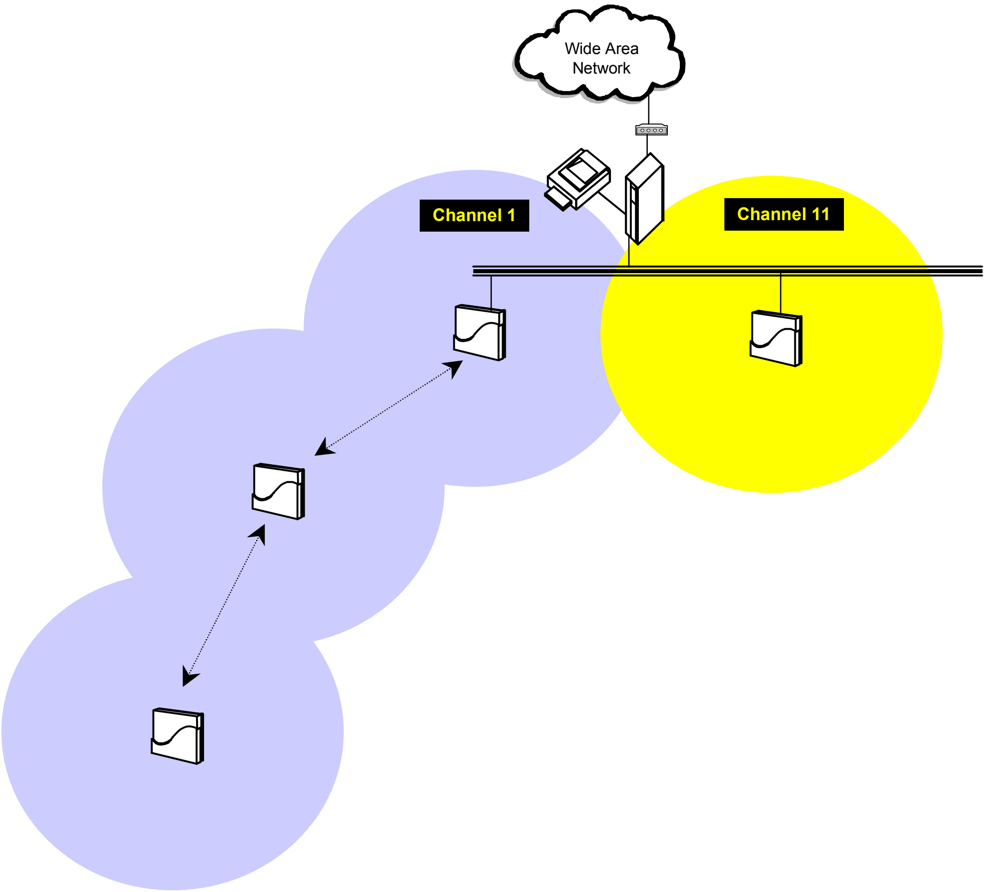
In a star configuration WDS links are established between one AP and several others, as illustrated by the picture below. The central AP could be part of a wired infrastructure network, while the “satellite” APs are positioned to cover an area which is larger than can be covered by a single cell.



In this set-up the root AP needs three WDS ports enabled for 3 different links while the three satellites each have one WDS port enabled. It is not required that the port-index number assigned to a given WDS link is the same as the port-index number on the other side of the WDS link. In other words at the root AP, the MAC addresses for the three satellites are assigned to ports 3, 4 and 5, while in the satellite APs the MAC address of the root-AP can be entered in any port position that is available.

Chain configuration

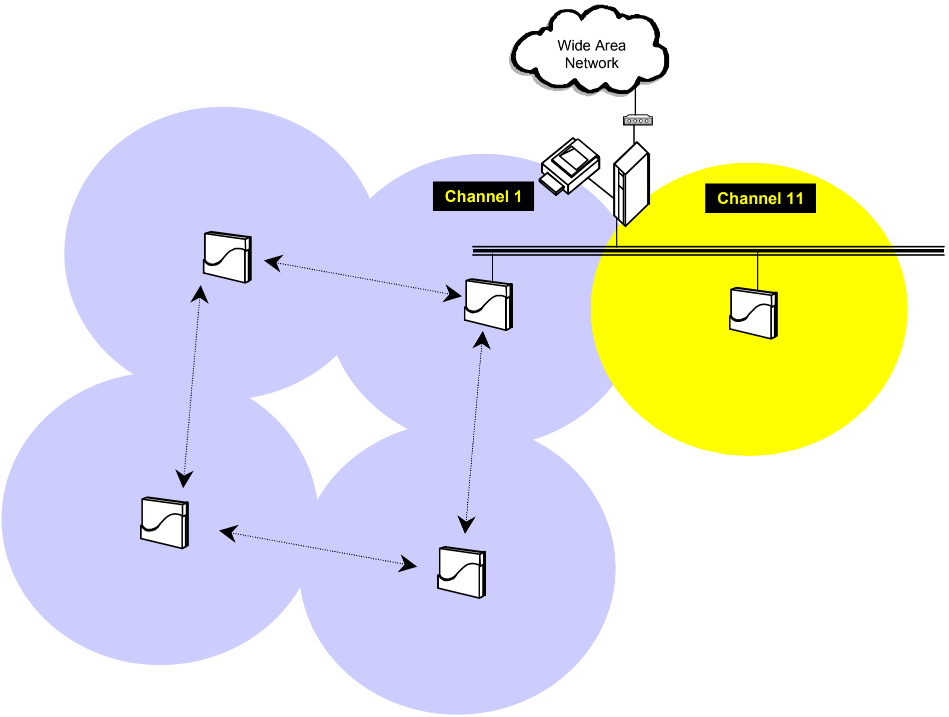
Where the Star configuration can cover a more rectangular or square area, a Chain configuration allows coverage of a longer shape (for instance a long corridor). The AP's are chained together, where the first AP for example could have a connection to the existing infrastructure (with all the network resources).



In this setup the AP's at either end of the chain will need one WDS port enabled while the AP's in the middle of the chain will require two WDS ports to be configured to point upward and downward in the chain. In a local setup a chain of 6 AP's has been created (which does not mean that 6 is the upper limit, but it indicates what possibilities exist).

Loop configuration

If the end points of a chain are connected to each other a loop is created. Normally it is advised to avoid loops involving bridges as it can lead to performance breakdowns, and broadcast and multi-cast storms. However if the bridges in the loop (in our case these bridges are the access points) support spanning tree protocols, a loop can be created adding connection redundancy that can be used in case one of the access points in the loop fails. For example when looking at the four access points in the left-hand picture of the diagram, the one in the top right hand will fail, the one just below that still has a connection to the backbone via the other access points.



The AP-2000 supports Spanning Tree and is expected to assure that the negative effects of a loop are prevented. In addition the user can configure the AP-2000's spanning tree operation by defining the preferred path that the traffic should follow, by setting different values for the path cost and priority fields.

General considerations

For all of the configurations sketched variations to the APs can be made:

- *The AP holds one PC Card for all WDS and all BSS related traffic*
- *The AP holds one PC Card for all the WDS traffic and another PC Card on a different channel to pick up wireless stations.*
- *The AP holds one PC Card for all WDS traffic and connects to a hub or switch to support wired connected (non-roaming) LAN devices.*
- *Combinations of the three variations above.*

Potential issues that may arise:

- *The area covered by the several APs is larger than the coverage area of a single AP. This can negatively impact the defer mechanism of the radios. (i.e. the APs maybe to far away from each other so that they cannot "hear" each others transmissions, which can result in excessive collisions and retransmissions)*
- *If a single PC card is used for all wireless traffic and wireless clients are operational as well, end-to-end throughput may be considered too low (depending on the applications).*
- *In the chain configuration, if the chain becomes very long end-to-end latency issue might come into play. At the moment of the draft of this bulletin no test data is available to verify what limitations in terms of length of the chain has to be observed, but there obviously will be a practical limit.*