The Innovation Behind Broadband Wireless

ASWipLL / AS3010 Systems

Wireless IP-Based Local Loop System

Release 5.2

System Description

Leading the World in Wireless DSL

The ASWipLL product bears the CE marking. This CE marking demonstrates ASWipLL's full compliance with applicable European Union (EU) directives:

The ASWipLL product bears the Underwriters Laboratories (UL) marking, demonstrating full compliance with UL's safety requirements:

ASWipLL products bear the Federal Communications Commission (FCC) marking, demonstrating compliance with FCC Part 15 regulations.

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Contents

1. Introduction 1-1
1.1. Main Features 1-3
1.2. Customer Benefits 1-4
1.3. System Architecture 1-5
1.3.1. Base Station Site 1-6
1.3.2. Subscriber Site 1-9
1.3.2.1. Outdoor Radio with Indoor Ethernet Switch/Hub ... 1-9
1.3.2.2. Indoor Radio Only 1-12
1.3.3. Network Management Tools 1-14
1.4. Applications 1-15
1.4.1. Broadband Data Access 1-15
1.4.2. High Speed Internet Access 1-16
1.4.3. Voice over IP 1-17
1.4.4. Traffic Engineering in Multi-Tenant Application 1-18
1.4.4.1. VLAN Tagging 1-18
1.4.4.2. Without VLAN Tagging 1-20
1.4.5. Repeater Solution 1-21
1.4.6. TDM over Packet Solution 1-22
1.4.7. ASWipLL Low-Speed Vehicle Solution 1-23

2. ASWipLL Radio Technology: Physical Layer 2-1
2.1. Frequency Hopping Spread Spectrum 2-2
2.2. Modulation 2-4
2.3. Operating Frequency Bands 2-6
2.4. Standards Compliance 2-8

2.5. RF Antennas 2-8
2.5.1. Dual Antenna Receive Diversity 2-10
2.5.2. ASWipLL 700 2-10
2.5.3. RF Planning Considerations for Band-C in FCC Markets .. 2-11
2.6. Radio Planning 2-12
2.6.1. Main Technical Parameters 2-13
2.6.2. System Coverage 2-14
2.6.2.1. Line of Sight 2-14
2.6.2.2. Link Budget 2-14
2.6.3. Interference Analysis: FDD vs. TDD 2-18
2.6.4. Frequency Allocation 2-20
2.6.4.1. Synchronized versus Unsynchronized Operation 2-20
2.6.4.2. Frequency Allocation 2-22
2.6.5. Capacity Considerations 2-23
2.6.5.1. General 2-23
2.6.5.2. VoIP Bandwidth and Simultaneous Calls 2-24
2.6.5.3. Data Bandwidth 2-24
2.6.5.4. Calculation Example 2-25
2.6.6. Selecting an Appropriate Operation Mode 2-25
2.6.6.1. ASWipLL Multiple Modes 2-25
2.6.6.2. System Range Considerations 2-26
2.6.6.3. Interference Rejection 2-29
2.6.6.4. System Capacity Calculations Based on FSK Modulation 2-30
2.6.6.5. Conclusion 2-32
2.6.7. Radio Planning Software Tool 2-33

3. ASWipLL's Air MAC Protocol 3-1
3.1. MAC Protocol Features 3-1
3.2. Preemptive Polling Multiple Access Protocol 3-2
3.2.1. Slotted Aloha Process 3-3
3.2.2. Packet Transmission 3-3

3.2.3. Polling Sequence 3-4
3.2.4. PPMA vs. CSMA 3-4

4. ASWipLL Networking 4-1
4.1. IP Routing 4-2
4.1.1. Multiple IP Subnets 4-3
4.1.2. Increased Network Efficiency - No Broadcast Packets 4-3
4.1.3. Support for DHCP Relay Agent 4-3
4.1.4. Eliminates Need for External Routers 4-4
4.1.5. Interoperability with Third-Party IP Routers 4-4
4.1.6. Efficient Air IP Subnet Addressing 4-4
4.1.7. RFC 1918 4-6
4.2. PPPoE Bridging 4-7
4.2.1. PPPoE Limitations 4-8
4.2.2. PPPoE Bridging and IP Routing Support 4-9
4.3. 802.1Q/p Support 4-9
4.3.1. IP Routing 4-11
4.3.2. PPPoE 4-11
4.4. Transparent Bridging 4-12
4.5. Quality of Service 4-13
4.5.1. ASWipLL End-to-End QoS 4-15
4.5.1.1. DiffServ/TOS 4-16
4.5.1.2. 802.1p 4-17
4.6. Bandwidth Management 4-18
4.6.1. MIR and CIR 4-18
4.6.1.1. MIR 4-19
4.6.1.2. CIR 4-20
4.6.2. CIR Proportional Degradation 4-21
4.6.3. ASWipLL CIR/MIR and VoIP 4-22
4.6.4. ASWipLL CIR/MIR and Modem Rate 4-23
4.6.5. Fairness 4-23

4.7. Security 4-25
4.7.1. Layer 1: Frequency Hopping 4-25
4.7.2. Layer 2 4-26
4.7.2.1. PPMA 4-26
4.7.2.2. Authentication (PPMA) 4-26
4.7.2.3. Encryption 4-27
4.7.2.4. PPPoE Bridging 4-27
4.7.2.5. 802.1Q 4-28
4.7.3. Layers 3 to 7 4-29
4.7.3.1. IP Filtering 4-29
4.7.3.2. Intracom 4-30
4.7.3.3. Management (SNMP) 4-30

5. ASWipLL Voice-over-IP Solution 5-1
5.1. Main Features 5-1
5.2. Interconnection with PSTN 5-2
5.3. Number of Supported VoIP Calls 5-2
5.4. VoIP Related Capabilities 5-3

6. ASWipLL TDMoP Solution 6-1
6.1. TDMoP Applications 6-1
6.1.1. Full E1/T1 Point-to-Point 6-2
6.1.2. Fractional E1 Point-to-Point 6-4
6.1.3. Point-to-Point V.35 6-4
6.2. SDA-E1 Device 6-5
6.2.1. Hardware Interfaces 6-6
6.2.2. Connector Pinouts 6-6
6.2.2.1. 15-Pin D-Type 6-7
6.2.2.2. 8-Pin RJ-45 (E1) 6-7
6.2.2.3. 8-Pin RJ-45 (LAN) 6-8
6.2.2.4. 9-pin D-type 6-8
6.2.3. LED Indicators 6-9

6.2.4. Network Management 6-10
6.2.5. Specifications 6-11

7. ASWipLL Base Station Devices 7-1
7.1. Base Station Radio (BSR) 7-3
7.1.1. BSR Models 7-5
7.1.1.1. BSR with Integrated, Flat-Panel Antenna 7-5
7.1.1.2. BSR with N-Type Connector for Third-Party External Antenna.. 7-6
7.1.2. Standard Accessories.. 7-7
7.1.3. Hardware Interfaces 7-8
7.1.4. Connector Pinouts 7-8
7.1.4.1. 15-pin D-type Connector (Ethernet) 7-8
7.1.4.2. 9-pin D-type Connector (Serial).......................... 7-10
7.1.5. Network Management 7-11
7.1.6. Technical Specifications 7-11
7.2. Base Station Distribution Unit (BSDU) 7-14
7.2.1. Hardware Interfaces 7-15
7.2.2. LED Indicators... 7-16
7.2.2.1. BSR's LEDs 7-16
7.2.2.2. 100Base-T LEDs... 7-17
7.2.2.3. Status LEDs 7-17
7.2.3. Network Management 7-18
7.2.4. Technical Specifications 7-18
7.3. Global Positioning Satellite Antenna 7-19
7.3.1. Configurations and Optional Hardware 7-20
7.3.2. Connector Pinouts 7-20
7.3.3. Technical Specifications 7-21
7.4. Base Station Power System (BSPS)... 7-22
7.4.1. Features 7-22
7.4.2. System Description 7-23
7.4.3. Main Unit 7-24

7.4.3.1. Rectifier Module ... 7-26
7.4.3.2. System Controller ... 7-30
7.4.4. DC Distribution Unit ... 7-33
7.4.4.1. Specifications ... 7-34
7.4.5. Battery Unit ... 7-36
7.5. Typical Base Station Configurations ... 7-36
7.5.1. Base Station with Single BSR ... 7-37
7.5.2. Multi-Layer Base Station ... 7-38

8. ASWipLL CPE Devices ... 8-1
8.1. Subscriber Premises Radio (SPR) ... 8-3
8.1.1. SPR Models ... 8-4
8.1.1.1. SPR with Integrated, Flat-Panel Antenna ... 8-4
8.1.1.2. SPR with N-Type Connector for Third-Party External Antenna ... 8-7
8.1.2. Standard Accessories ... 8-8
8.1.3. Hardware Interfaces ... 8-8
8.1.4. Connector Pinouts ... 8-9
8.1.4.1. 15-Pin D-Type Connector (Ethernet) ... 8-9
8.1.4.2. 15-Pin D-Type Connector (Serial) ... 8-10
8.1.4.3. 9-pin D-type Connector (for Previous SPR Models) ... 8-12
8.1.5. Network Management ... 8-12
8.1.6. Technical Specifications ... 8-13
8.2. Subscriber Data Adapter (SDA) ... 8-16
8.2.1. SDA Models ... 8-17
8.2.2. SDA-4S Models ... 8-17
8.2.2.1. Hardware Interfaces ... 8-20
8.2.2.2. Connector Pinouts ... 8-20
8.2.2.3. LED Indicators ... 8-22
8.2.2.4. Specifications ... 8-23

8.2.3. SDA-4H 8-25
8.2.3.1. Hardware Interfaces 8-26
8.2.3.2. Connector Pinouts 8-26
8.2.3.3. LED Indicators 8-28
8.2.3.4. Specifications 8-30
8.2.4. SDA-1 8-31
8.2.4.1. Hardware Interfaces 8-31
8.2.4.2. Connector Pinouts 8-32
8.2.4.3. Specifications 8-33
8.2.5. SDA-1/DC 8-34
8.2.5.1. Hardware Interfaces 8-35
8.2.5.2. Connector Pinouts 8-35
8.2.5.3. LED Indicator 8-37
8.2.5.4. Specifications 8-37
8.3. RSS LED Plug Adapter 8-38
8.3.1. Physical Dimensions 8-42
8.3.2. Hardware Interfaces 8-43
8.3.3. Connector Pinouts 8-43
8.3.3.1. Adapter-to-SPR Cabling 8-44
8.3.3.2. Adapter-to-SDA Cabling 8-47
8.3.4. LED Indicators 8-48
8.4. Indoor Data Radio (IDR) 8-49
8.4.1. IDR Models 8-51
8.4.1.1. IDR with Integrated, Flat-Panel Antenna 8-52
8.4.1.2. IDR with TNC-type Connector for Third-Party External Antenna 8-52
8.4.2. Hardware Interfaces 8-52
8.4.3. Connector Pinouts 8-52
8.4.3.1. 8-Pin RJ-45 Connector (Ethernet) 8-54
.8.4.3.2 RJ-11 Connector (Serial) 8-54
.8.4.3.3 6-Pin Molex Connector (Power) 8-55

8.4.4. LED Indicators 8-55
8.4.5. Technical Specifications 8-57

9. ASWipLL Point-to-Point Radio 9-1
9.1. PPR Models and Radio Coverage 9-3
9.1.1. PPR with Integrated, Flat-Panel Antenna 9-3
9.1.2. PPR with N-Type Connector for Third-Party External Antenna 9-4
9.2. Standard Accessories 9-5
9.3. Hardware Interfaces 9-5
9.4. Connector Pinouts 9-6
9.4.1. 15-Pin D-Type Connector (Ethernet) 9-6
9.4.2. 9-Pin D-Type Connector (Serial) 9-7
9.5. Network Management.. 9-7
9.6. Technical Specifications 9-8

10. ASWipLL AutoConnect 10-1
10.1. AutoConnect Process 10-1
10.1.1. Continual AutoConnect.. 10-2
10.1.2. AutoConnect with Redirection 10-3
10.2. Reliability 10-6

11. ASWipLL Redundancy 11-1
11.1. BSR Redundancy 11-1
11.1.1. Redundancy Based on AutoConnect.............................. 11-2
11.1.2. Redundancy Based on Duplicated Air MAC Addresses... 11-4
11.2. Power Redundancy 11-6
11.2.1. BSPS Unit 11-6
11.2.1.1. Battery Backup Power..................................... 11-6
11.2.1.2. Rectifier N + 1 Redundancy 11-7
11.2.2. UPS Unit 11-7

12. Management System ... 12-1

12.1. Main Features ... 12-2

12.2. WipManage ... 12-3

12.2.1. Network Topology ... 12-4

12.2.2. Alarm and Event Management ... 12-8

12.2.3. Configuration ... 12-10

12.2.4. Performance Monitoring ... 12-11

12.2.5. Security ... 12-12

12.2.6. ASWipLL Database ... 12-12

12.3. WipConfig ... 12-13

12.4. WipConfig PDA ... 12-14

12.5. WipAD ... 12-15

12.6. WipLL DB Upgrade ... 12-16

A. Glossary of Terms ... A-1

B. ASWipLL Product List ... B-1

C. ASWipLL Feature List ... C-1

D. IP Routing / PPPoE vs. Transparent Bridging ... D-1

E. ASWipLL MTBF Ratings ... E-1

F. ASWipLL Integrated Antenna Specifications ... F-1

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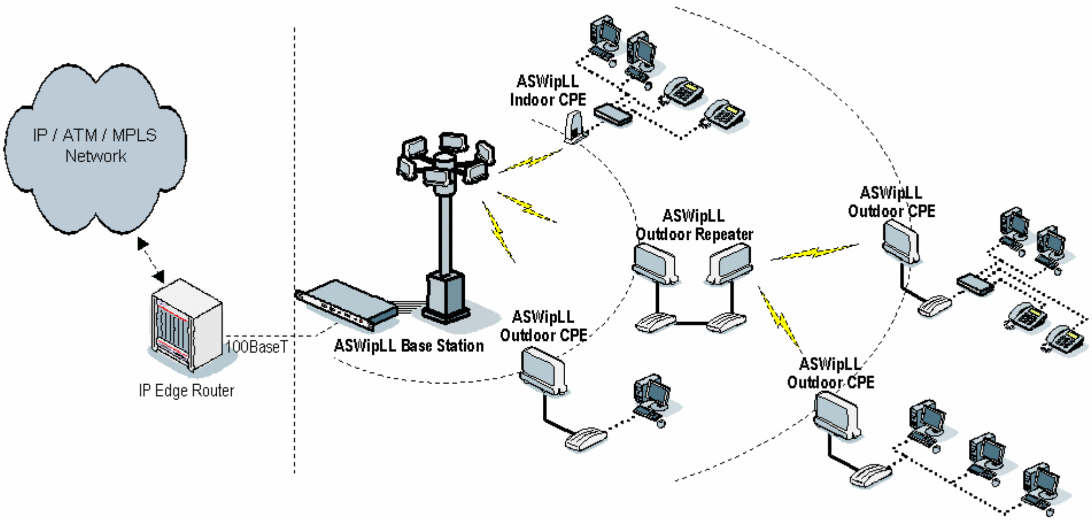
1

Introduction

Airspan's **ASWipLL** system provides a low-cost, high-performance point-to-multipoint frequency hopping- and IP-based broadband wireless access (BWA) solution. ASWipLL provides wireless local-loop (last-mile) connectivity designed to deliver high-speed data, Voice over IP (VoIP), and multimedia services to residential, SOHO, and small to medium enterprises. Delivering "always-on", high-speed Internet access and traditional voice services, ASWipLL offers service providers an integrated, scalable access solution providing quick-to-market deployment and low-market entry cost for broadband services.



ASWipLL operates in both the licensed bands (3.*x* GHz ranging from 3.3 to 3.8 GHz, 2.8 GHz, 2.5 GHz Multichannel Multipoint Distribution Services – MMDS, 2.3 GHz, 1.5 GHz, 925 MHz, and 700 MHz), and unlicensed bands (5.8 GHz, 2.4 GHz ISM, and 900 MHz).

Each **ASWipLL** Base Station can support thousands of subscribers, providing each sector with high connectivity speeds of up to 4 Mbps. **ASWipLL** utilizes air protocol technology for wireless packet switching using Frequency Hopping technology. **ASWipLL**'s in-house Preemptive Polling Multiple Access (PPMA) Air MAC protocol technology, which recognizes transmission type and allocates bandwidth, is highly efficient—80% throughput (i.e. 80% of 4 Mbps produces 3.2 Mbps net capacity)—allowing multiple concurrent subscribers to utilize bandwidth over only a 1.33-MHz channel.

ASWipLL enables interconnection with the Public Switched Telephone Network (PSTN) by using an IP-to-PSTN gateway. **ASWipLL** supports VoIP by offering interoperability with a wide range of third-party products such as residential gateways (RGW), access gateways, gatekeepers, and softswitches.

ASWipLL introduces real-time adaptive modulation (2-, 4-, 8-level FSK) and auto retransmission request (ARQ); features offering high quality services whilst maximizing spectrum utilization.

ASWipLL provides bandwidth management by supporting both asymmetric and aggregated committed information rate (CIR) and maximum information rate (MIR), guaranteeing bandwidth levels to subscribers.

ASWipLL supports broadband services such as VLANs and VPNs based on IEEE 802.1Q/p. **ASWipLL** supports IP routing and PPPoE bridging, as well as transparent bridging.

ASWipLL provides embedded security features such as IP (packet) filtering based on addresses, protocols, and applications.

The **ASWipLL** system supports SNMP-based management, allowing remote fault, configuration, performance, and security management of the entire ASWipLL system. This includes remote simultaneous software upgrade of multiple ASWipLL devices.

1.1. Main Features

The ASWipLL system provides the following main features:

- Low initial investment, maximum return on investment (ROI)
- Modular, scalable architecture, providing flexible deployment architectures
- Packet-based air interface supporting high-speed data, VoIP, and multimedia services
- Simultaneous high-speed data and telephony—up to 4 Mbps (3.2 Mbps net) per sector
- "Always-on" high-speed Internet
- Large cell coverage—up to 38 km
- Compact, integrated design allowing easy and quick deployment
- Advanced Quality of Service, supporting DiffServ and IEEE802.1p
- Simultaneous support of IP routing and PPPoE bridging
- Supports transparent bridging, allowing easy IP addressing schemes
- Sophisticated bandwidth management—symmetric/asymmetric CIR and MIR
- Supports 802.1Q for VLANs/VPNs
- Provides automatic connection and configuration of first-time powered-on, unconfigured subscriber devices
- Supports configuration files, allowing the same configuration settings to be applied to multiple ASWipLL devices
- Base Station (i.e. BSR) redundancy using ASWipLL's AutoConnect feature
- Power redundancy when using the BSPS unit
- Supports local and remote SNMP-based management, providing an intuitive GUI for easy management

1.2. Customer Benefits

The ASWipLL system offers the following customer benefits and advantages over competitors:

- No IF or RF cables required for indoor unit-to-outdoor unit (IDU-to-ODU) connectivity. Instead, ASWipLL uses standard CAT-5 Ethernet cables, providing cost-effective and easy installation.
- Scalability and modular Base Station architecture, allowing customers to add equipment when needed, thereby, allowing low initial cost entry and pay-as-you-grow strategy. Unlike competitors, the ASWipLL Base Station is not a chassis-based design, and, therefore, provides flexibility and space-saving at Base Stations.
- ASWipLL's open architecture allows interoperability with multi-vendor products such as residential gateways (RGW), access gateways, gatekeepers, and softswitches, thereby, operating seamlessly in multi-vendor environments.
- ASWipLL’s proprietary PPMA Air MAC protocol is highly efficient—80% throughput—allowing multiple concurrent subscribers to utilize bandwidth without network degradation (from collisions and high BER).
- Long-distance radio coverage of up to 38 km.
- Functions as both an IP router and a transparent bridge.
- Supports transparent bridging for easy implementation of IP addressing schemes.
- ASWipLL’s IP routing provides efficiency and eliminates the need for additional hardware.
- Enhanced QoS, based on IP addresses, protocols, and applications.
- End-to-end QoS based on DiffServ/TOS and 802.1p.
- Quick-and-easy installation and configuration using ASWipLL's AutoConnect feature.
- Embedded security features such as IP (packet) filtering based on addresses, protocols, and applications.
- Rich networking packages such as 802.1Q/p VLANs/VPNs.

1.3. System Architecture

The ASWipLL system architecture is composed of the following three basic areas:

- **Base Station site:** consists of ASWipLL access units that interface between the provider's backbone and the ASWipLL subscriber sites.
- **Subscriber site:** consists of ASWipLL customer premises equipment (CPE) that interfaces between the Base Station and the subscriber's network.
- **Network operations center (NOC) tools:** Windows- and SNMP-based programs, providing fault, configuration, performance, and security management.

Figure 1-1 displays a block diagram of the main areas of the ASWipLL system.

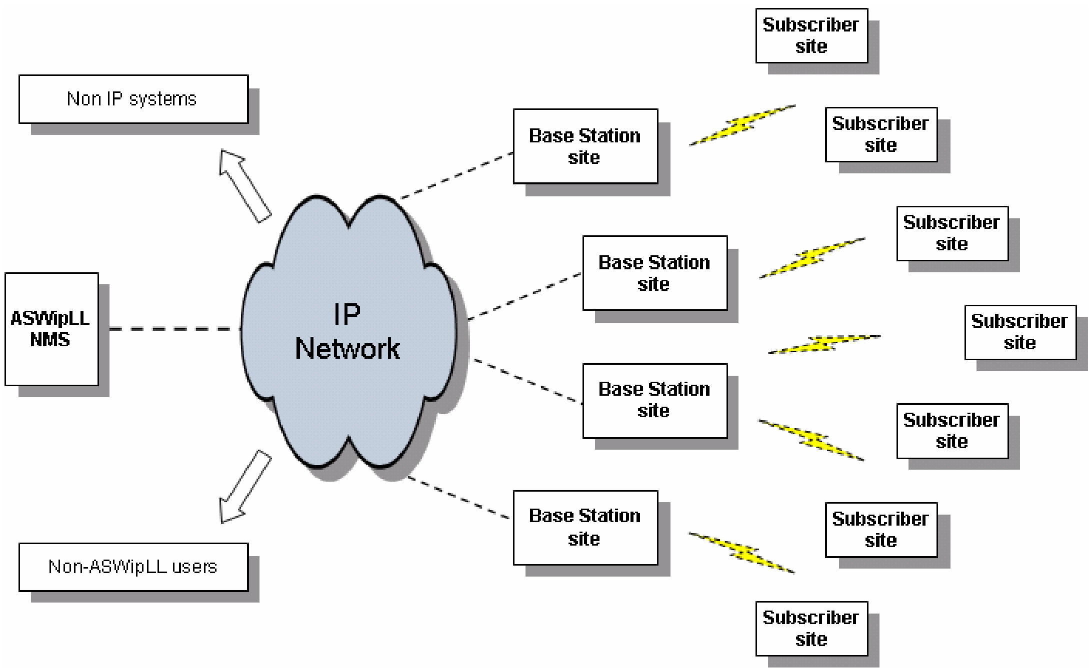


Figure 1-1: ASWipLL System Architecture

1.3.1. Base Station Site

The ASWipLL Base Station interfaces between the subscriber sites and the service provider's backbone, providing subscribers with high-speed data, Internet, and VoIP services.

The ASWipLL Base Station is comprised of the following units (some optional):

- **Base Station Radio** (BSR)**:**

  The BSR is an outdoor radio unit, typically mounted on a pole or wall, involved in providing a wireless link between the Base Station and subscribers. The standard BSR provides 60-degree radio coverage, serving up to 252 subscribers in a sector.

  The BSR is available in various models that either provides built-in antennas or N-type ports for attaching a third-party antenna(s) for increasing radio coverage or providing dual antenna diversity.

  For Base Stations consisting of multiple BSRs, the BSRs connect to the ASWipLL Base Station Distribution Unit (BSDU), which provides the interface to the provider's backbone, and power. For a Base Station consisting of a single BSR, the BSR is typically powered and connected to the provider's backbone by the ASWipLL Subscriber Data Adapter (SDA).

- **Point-to-Point Radio** (PPR):

  The PPR is similar to the BSR, but implemented in a point-to-point radio application, providing wireless communication with a single remote subscriber (i.e. ASWipLL Subscriber Premises Radio).

- **Base Station Distribution Unit** (BSDU)**:**

  The BSDU is an Ethernet switch implemented at Base Stations consisting of multiple BSRs. The BSDU provides 100Base-T interface between the BSRs and the provider's backbone. The BSDU is also responsible for providing BSRs with –48 VDC power supply and frequency hop synchronization for multiple BSDUs and BSRs.

  The BSDU is installed indoors in a standard 19-inch cabinet, connecting to the BSRs by standard CAT-5 cables. Each BSDU can service a maximum of six BSRs. In addition, up to four BSDUs can be daisy-chained at a Base Station, supporting up to 24 BSRs. Therefore, a Base Station at maximum configuration can serve up to 6,048 subscribers (i.e. 24 BSRs multiplied by 252 subscribers).

- **Subscriber Data Adapter** (SDA)**:**

  The SDA is typically implemented at the subscriber site; however, it is also implemented at Base Stations consisting of a single BSR. The SDA provides the BSR with -48 VDC power supply and Ethernet interface to the provider's backbone.

  The SDA is installed indoors and connected to the BSR by a CAT-5 cable.

- **Base Station Power Supply** (BSPS)**:**

  The BSPS is an optional unit that provides the ASWipLL Base Station with –48 VDC power supply and power redundancy. The BSPS is installed at the Base Station site in a standard 19-inch cabinet. The BSPS connects to, and services a maximum of four BSDUs.

- **Global Positioning System (GPS)** antenna**:**

  The GPS antenna is a rugged, self-contained GPS receiver and antenna that receives a universal GPS satellite clock signal. The GPS is an optional unit that connects to the BSDU. The GPS synchronizes frequency hopping of multiple Base Stations ensuring that the entire ASWipLL network operates with the same clock based on a universal satellite clock signal, and, thereby, eliminating radio frequency ghosting effects.

Figure 1-2 shows a Base Station configuration with daisy-chained BSDUs (i.e. 24 BSRs, 4 BSDUs, 1 BSPS, and 1 GPS).

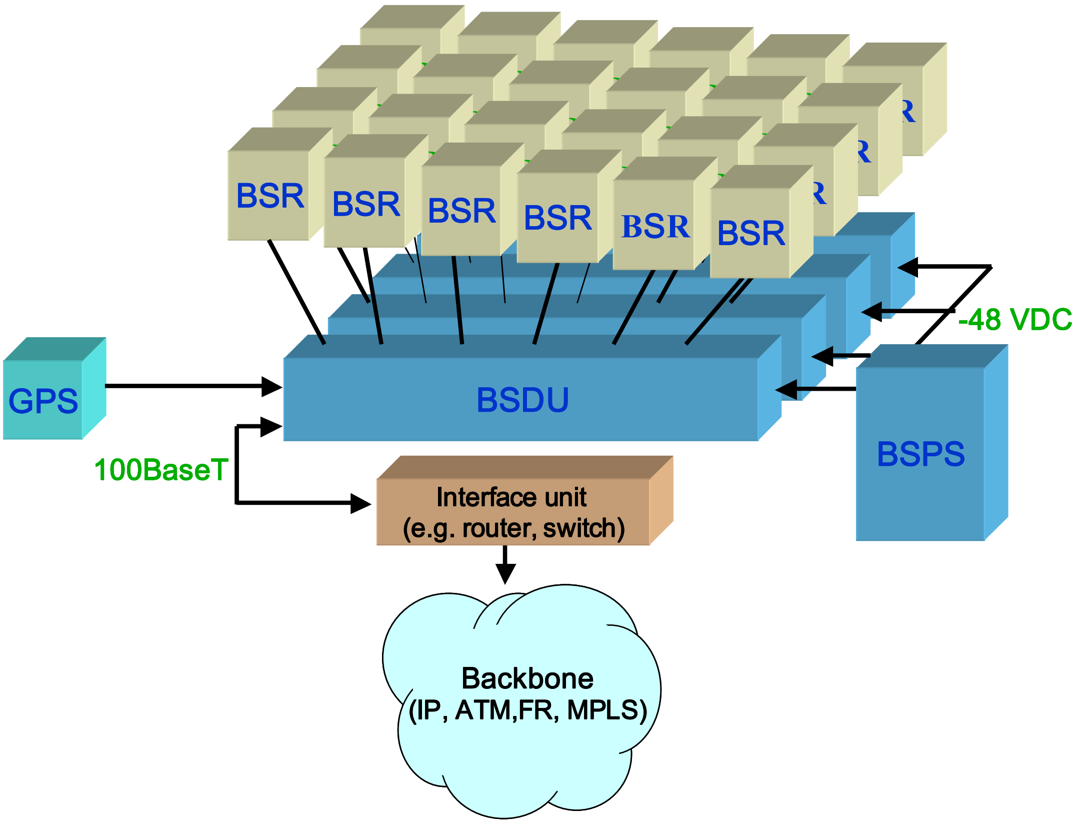


Figure 1-2: ASWipLL Base Station at maximum configuration

1.3.2. Subscriber Site

The ASWipLL subscriber site is located at the subscriber's premises. The ASWipLL subscriber site consists of a radio transceiver that receives and transmits signals from and to the Base Station. The radio transceiver provides the subscriber with high-speed data access, Internet access, and VoIP at up to 4 Mbps. The ASWipLL radios interface to the subscriber's Ethernet network either through a hub or switch, or directly, depending on the ASWipLL radio model.

Note: For VoIP support, Airspan can provide a third-party residential gateway (RGW). The RGW typically provides two POTS ports for telephony, a 10BaseT LAN port for subscriber PC/network, and a 10BaseT port for connecting to the SDA or IDR (depending on subscriber site configuration).

The ASWipLL system provides two different subscriber site configurations:

- Outdoor radio with indoor Ethernet switch/hub
- Indoor radio only

1.3.2.1. Outdoor Radio with Indoor Ethernet Switch/Hub

The outdoor radio with indoor Ethernet switch/hub configuration consists of the ASWipLL Subscriber Premises Radio (SPR) and the ASWipLL Subscriber Data Adapter (SDA), respectively. These two devices are described below:

- **Subscriber Premises Radio (SPR):**

  The SPR is the outdoor radio transceiver that provides a wireless link between the subscriber’s network and the Base Station.

  The SPR connects to the subscriber’s network through the ASWipLL SDA, an Ethernet hub or switch (depending on SDA model). The SDA provides the SPR with DC power, lightening protection, and Ethernet (10Base-T and/or 100Base-T) interface to the subscriber’s PCs/network (up to four PCs depending on SDA model). The SPR connects to the SDA by a standard CAT-5 cable.

  The SPR is mounted outside, typically on an external wall or on a pole to provide a clear line-of-site with the Base Station.

The SPR is available in various models that either provide built-in antennas or N-type ports for attaching a third-party antenna for increasing radio coverage (antenna gain).

- **Subscriber Data Adapter (SDA):**

  The SDA is a switch or hub (depending on model), providing the SPR with -48 VDC power supply (from AC power outlet), lightening protection, and 10/100Base-T interface to the subscriber's PCs/network.

  The SDA is installed indoors and can be mounted on a wall or simply placed on a desktop. The SDA connects to the SPR by a standard CAT-5 cable.

  The SDA is available in the following models:

  - **SDA-1:** hub that provides one 10BaseT interface to the subscriber's computer or LAN network if connected to another hub or a switch.
  - **SDA-1/DC:** adapter that provides Ethernet (one 10BaseT) and regulated –48 VDC power to the SPR. This model can be powered from a power source of 10 to 52 VDC (e.g. from a **solar panel** or car lighter, which typically provide 12 VDC). This model is typically implemented in mobile wireless applications, e.g. in a car or truck.
  - **SDA-4H:** hub that provides four 10BaseT interfaces to the subscriber's computers and/or networks. One of the 10BaseT ports provides crossover cabling for interfacing to another hub or LAN switch. Alternatively, it may be connected to another PC via a crossed Ethernet cable.
  - **SDA-4S:** integrated LAN switches, providing four 10/100BaseT interfaces to the subscriber's PCs/network. The ports of the SDA-4S models support **Auto Negotiation**, allowing automatic configuration for the highest possible speed link: 10BaseT or 100BaseT, and Full Duplex or Half Duplex mode. In other words, the speed of the connected device (e.g., a PC) determines the speed at which packets are transmitted through the SDA-4S port. For example, if the device to which the port is connected is running at 100 Mbps, the port connection will transmit packets at 100 Mbps. If the device to which the port is connected is running at 10 Mbps, the port connection will transmit packets at 10 Mbps.

The SDA-4S ports also support automatic **MDI/MDI-X** crossover detection, allowing connection of straight-through or crossover CAT-5 cables to any port.

The SDA-4S is available in the following models:

- **SDA-4S (standard):** standard integrated LAN switch, providing four 10/100BaseT interfaces to the subscriber's computers. This model is ideal for SOHO implementation.
- **SDA-4S/DC:** integrated LAN switch, providing four 10/100BaseT interfaces and especially designed for implementation where available power supply is DC (10 to 52 VDC), e.g. from a **solar panel** or car lighter, which typically provide 12 VDC. This model provides regulated –48 VDC power to the SPR.
- **SDA-4S/VL:** provides VLANs between ports and the SPR, ensuring privacy between LAN users of the different ports. For example, all users connected to Port 1 do not "see" users connected to Port 2. This model is ideal for multi-tenant (VLAN security) implementation.
- **SDA-4S/VLtag:** ideal for multi-tenant applications where traffic engineering and privacy is required. SDA-4S/VLtag assigns a specific VLAN ID to traffic, based on the SDA-4S/Vltag port at which the traffic arrives. The VLAN IDs are fixed (since SDA-4S/VLtag is not user configurable). SPR converts the four VLAN IDs tagged by SDA-4S/VLtag to four VLAN IDs configured through ASWipLL's network management system (WipManage). The tag conversion is performed by SPR before sending the traffic to the air and vice versa when coming from the air.
- **SDA-4S/1H3L:** provides a high priority port (left-most port) for VoIP traffic.
- **SDA-4S/VL/1H3L:** combines the functionality of the SDA-4S/VL and SDA-4S/1H3L models (i.e., VLAN for each port and a high priority port for VoIP).
- **SDA-E1:** integrated TDMoIP FE1/Ethernet converter with standard SDA features.

Figure 1-3 displays a typical setup at a susbcriber site implementing an ASWipLL outdoor radio unit (SPR) and an ASWipLL indoor Ethernet switch /hub (SDA).

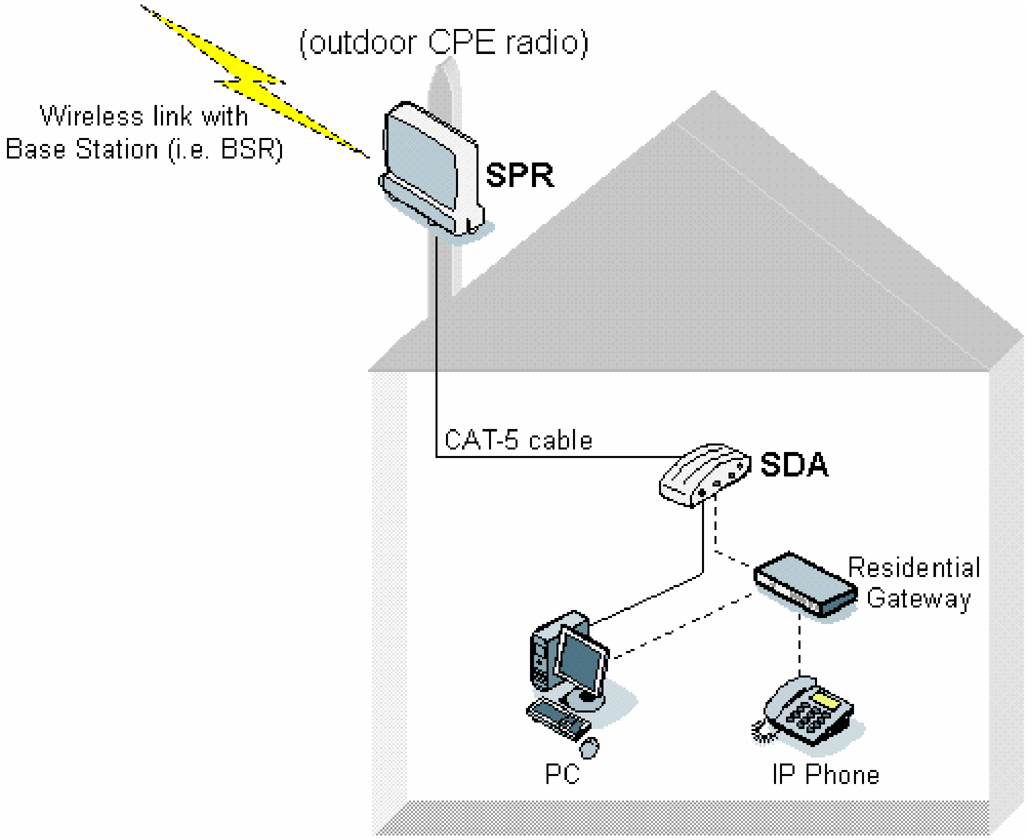


Figure 1-3: Subscriber site with SPR and SDA units (optional RGW)

1.3.2.2. Indoor Radio Only

The indoor radio configuration consists of the ASWipLL Indoor Data Radio (IDR). The IDR combines the functionality of the SPR and SDA, functioning as a transceiver and a hub. The IDR provides one 10Base-T Ethernet interface to the subscriber's network. The IDR receives its power from a separate power supply unit (AC-DC power adapter).

The IDR provides a built-in antenna and a TNC-type port for attaching a third-party antenna for increasing radio coverage (antenna gain) and ensuring line-of-site with the Base Station.

The IDR with a built-in antenna is typically mounted on an interior wall or on a desktop with line-of-site with the Base Station. The antenna of the IDR model with an external antenna is typically mounted outdoors to provide line-of-site with the Base Station.

The IDR can be used for data and voice transmissions. In the case of voice, the IDR uses a third-party RGW to interface with the subscriber's IP phone. Figure 1-4 displays a typical setup for data and voice at a susbcriber site implementing a the IDR.

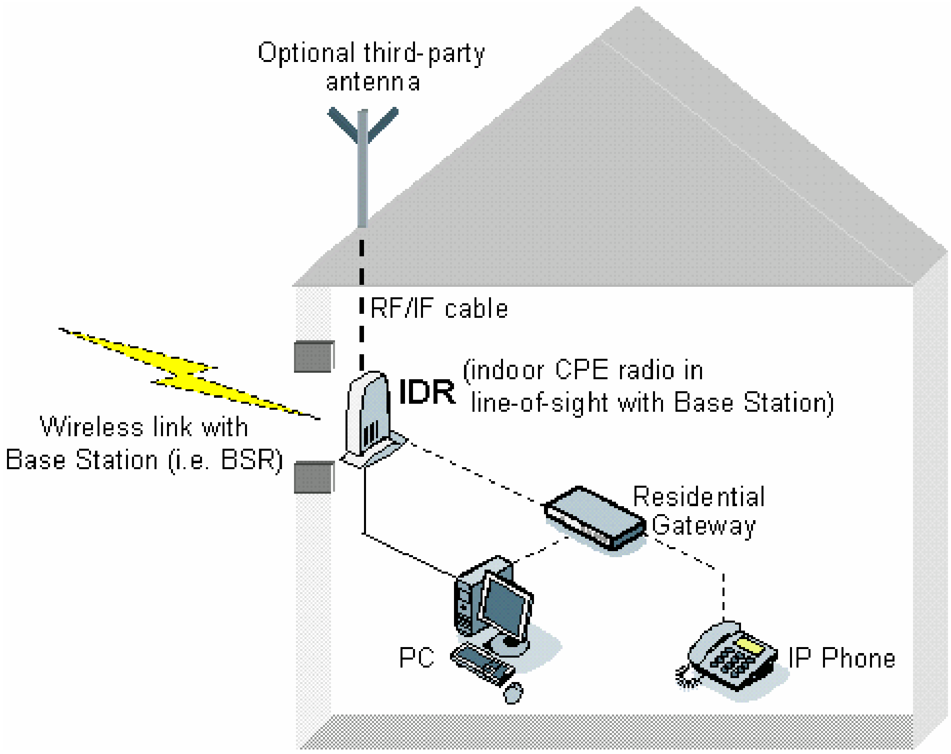


Figure 1-4: Subscriber site with IDR (optional third-party external antenna and RGW)

1.3.3. Network Management Tools

Airspan's ASWipLL system provides comprehensive set of state-of-the-art, use-friendly configuration and management tools for the ASWipLL system. These management tools provide fault, configuration, performance, and security management for the ASWipLL system.

The ASWipLL system provides the following management tools:

- **WipManage™:** Windows-based program, functioning as the ASWipLL network (element) management system (NMS) providing fault, configuration, performance, and security management.

  WipManage is based on Simple Network Management Protocol (SNMP), providing both local and remote network management.

- **WipConfig™:** Windows-based program, providing serial initial configuration (e.g. IP addresses) of the ASWipLL devices, used typically at the factory, or during installation. WipConfig also provides received signal strength indication (RSSI) for subscriber radios allowing accurate device orientation and positioning for optimal reception with Base Station. In addition, WipConfig provides a license-dependant Spectrum Analyzer that scans a user-defined frequency range, measuring RSSI values for each frequency, and therefore, allowing the operator to choose "clean" frequencies for operating the ASWipLL system.

- **WipConfig PDA™:** designed to run on a personal digital assistant (PDA), providing an alternative tool to WipConfig (described above) for performing initial configuration.

- **WipAD™:** Windows-based program, providing quick-and-easy automatic simultaneous downloading of software version files to multiple ASWipLL devices.

1.4. Applications

The following subsections provide examples of typical ASWipLL applications.

1.4.1. Broadband Data Access

In a non-ASWipLL environment, using a standard PSTN modem in circuit-switched networks, subscribers are limited to 56 Kbps of throughput, and in most cases, to 28.8 Kbps. From the provider's perspective, once a subscriber has dialed up with a PSTN modem, a full channel is occupied for as long as the session lasts.

In contrast, ASWipLL subscribers are limited only by their own configuration, with a maximum of 4 Mbps—70 times faster than the fastest PSTN modem. In addition, subscribers do not necessarily consume more bandwidth from the provider, since bandwidth is used only when a data packet is transmitted.

These characteristics of ASWipLL make it suitable for providing data access to subscribers while maintaining best usage of bandwidth and capacity.

1.4.2. High Speed Internet Access

One of the advantages of ASWipLL is the fact that subscribers are "always on" Internet. This means that there is no dialing process and no need for the hassle involved with dialup access. Subscribers need only to open their Web browser or e-mail to be instantly connected.

ASWipLL can also distinguish between applications and subscribers, thus, enabling the provider to provide different class of service to subscribers. For example, it can provide different services to Web browsing and e-mail by prioritizing Web browsing for ensuring best "Internet experience".

Figure 1-5 shows a typical ASWipLL application for high-speed Internet access.

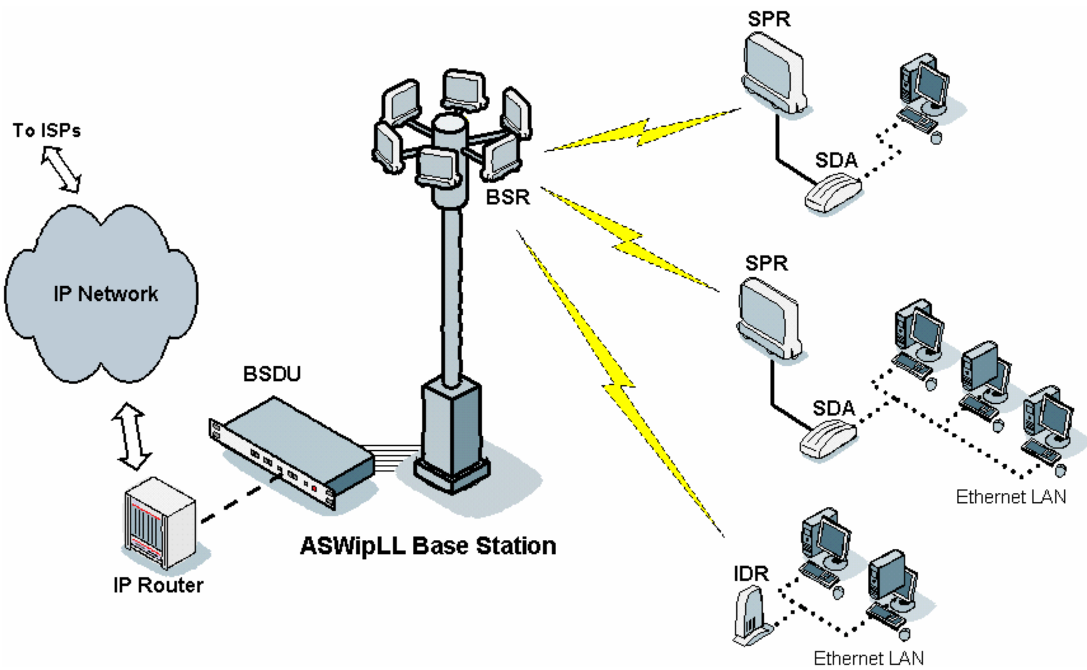


Figure 1-5: Typical ASWipLL Application for High-Speed Internet Access

1.4.3. Voice over IP

The ASWipLL system enables providers the flexibility of migration from a data-only network to an integrated Voice-over-IP and data network. The ASWipLL voice solution provides interoperability with any IP-to-PSTN network gateway. The use of the IP-to-PSTN gateway allows providers seamless PSTN connectivity such as SS7 (signaling network), G3-303, and V5.2 over E1, allowing deployment in multi-national markets.

Figure 1-6 shows a typical ASWipLL application for VoIP.

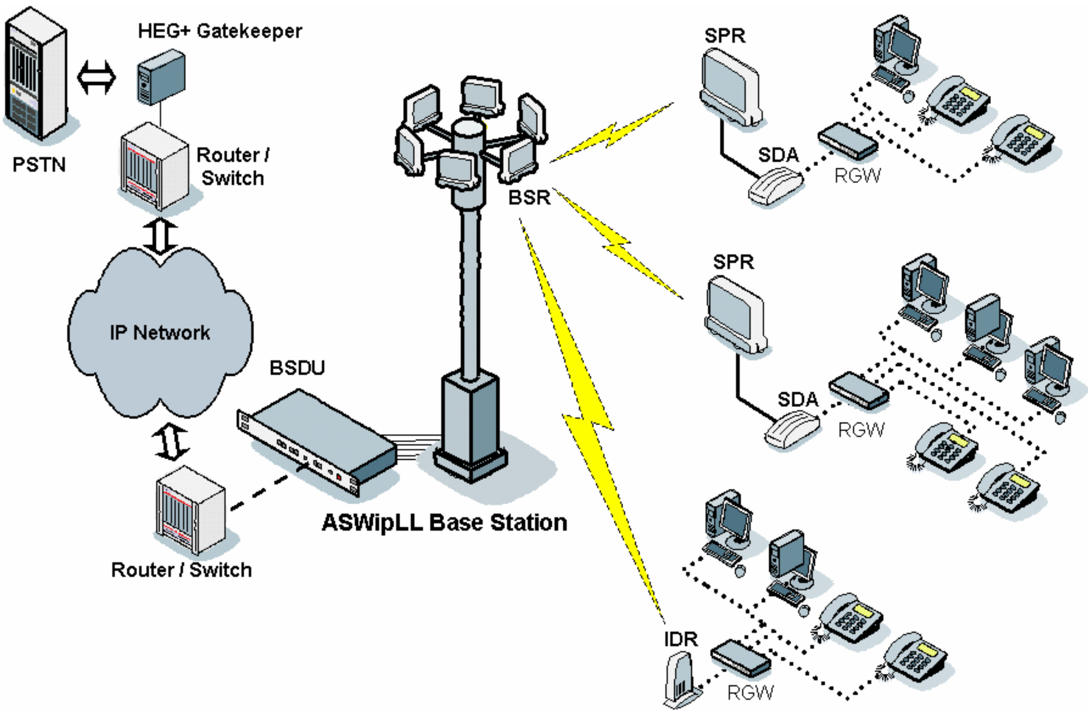


Figure 1-6: Typical ASWipLL Application for VoIP

1.4.4. Traffic Engineering in Multi-Tenant Application

The ASWipLL system provides high-speed wireless broadband (e.g., Internet) access for multiple-tenant units (MTU). ASWipLL provides a dedicated high-speed connection to the building, and then distributes that bandwidth among the tenants, providing them with a private, secure connection. ASWipLL's MTU solution supports both data and VoIP. When VoIP is required, a third-party VoIP gateway is implemented.

1.4.4.1. VLAN Tagging

The ASWipLL system provides VLAN tagging and traffic engineering in MTU applications in networks that connect to MPLS, ATM, or Frame Relay backbones. The ASWipLL hardware responsible for providing these MTU solutions is the SDA-4S/VLtag Ethernet switch serving up to four tenants, or an external integrated LAN switch (connected to the SDA-4S/VLtag) serving more than four tenants (e.g., 24 ports).

ASWipLL's SDA-4S/VLtag assigns a different VLAN ID (fixed) to traffic from each of its four ports. ASWipLL's SPR converts these four VLAN IDs, tagged by SDA-4S/VLtag, to four VLAN IDs configured by ASWipLL's NMS (WipManage). SPR performs this tag conversion before sending traffic to the air, and when receiving traffic from the air. This VLAN conversion is applicable only when SPR is used as a transparent bridge.

Figure 1-7 shows an example of how MTU works in an ATM environment.

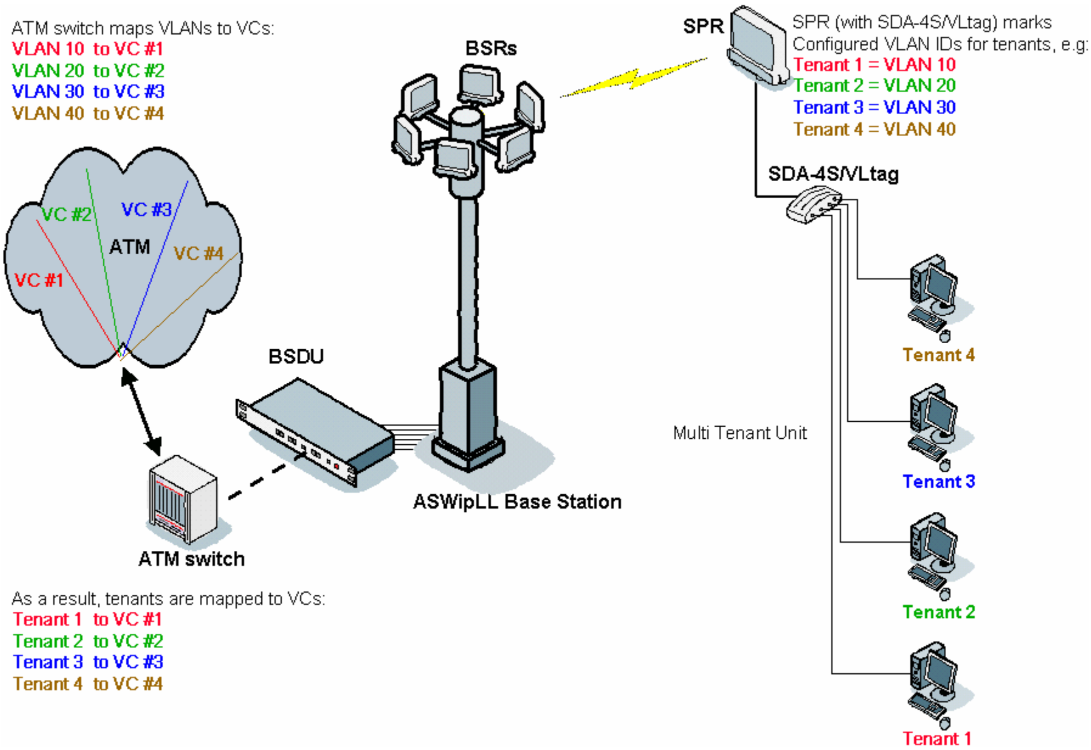


Figure 1-7: Multi-tenant solution (i.e., multiple VLANs) in an ATM environment

1.4.4.2. Without VLAN Tagging

The ASWipLL system also provides regular VLAN support (without VLAN tagging), providing privacy between tenants in MTU applications. The ASWipLL hardware responsible for providing these MTU solutions is the SDA-4S/VL Ethernet switch serving up to four tenants, or an external third-party integrated LAN switch (connected to the SDA-4S/VL) serving more than four tenants (e.g., 24 ports). The SDA-4S/VL provides VLANs between its ports and the SPR, ensuring privacy between users of different ports. For example, all users connected to Port 1 do not "see" users connected to Port 2.

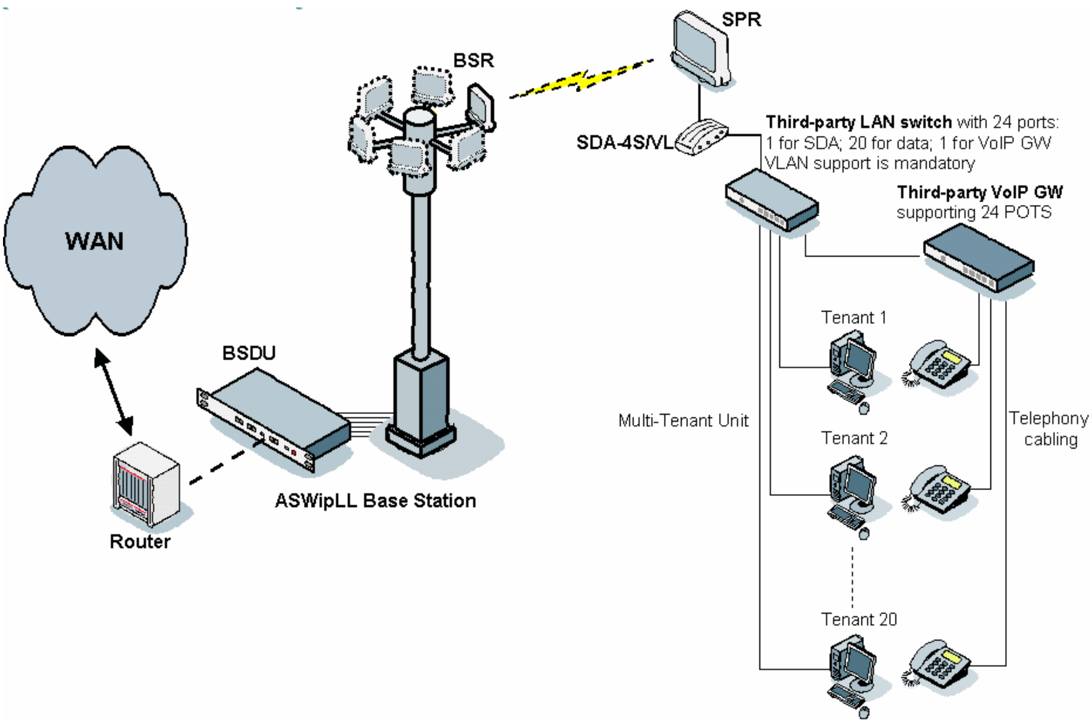


Figure 1-8: Multi-tenant solution without VLAN tagging, but ensuring privacy between tenants

1.4.5. Repeater Solution

ASWipLL units can be used to provide repeater functionality. This is implemented in scenarios where the BSR needs to be "extended" to remote subscriber sites that are blocked by obstacles such as trees, hills, and other typical line-of-sight obstructions or that the BSR-SPR (or BSR-IDR) transmission is out-of-range.

Back-to-back Ethernet connectivity of a BSR with an SPR/IDR provides the repeater capability, as illustrated in Figure 1-9.

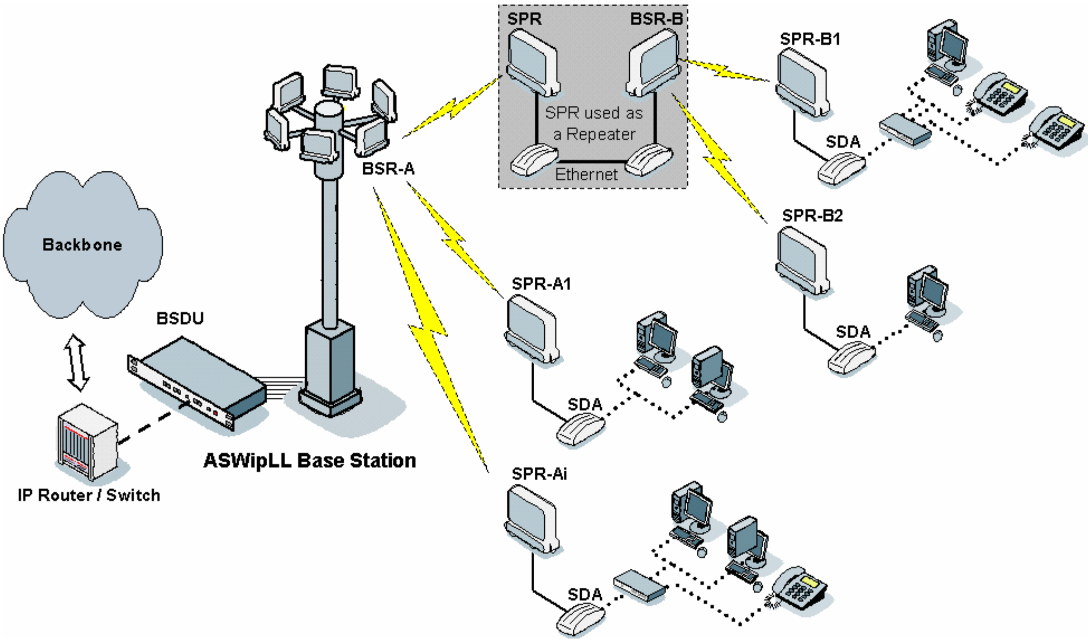


Figure 1-9: ASWipLL repeater solution

In Figure 1-9, BSR ***A*** is part of an ASWipLL Base Station connected to the service provider's backbone. BSR ***A*** serves multiple SPRs, marked as SPR **Ai**. Two SPRs—SPR ***B1*** and SPR ***B2***—cannot communicate directly with the Base Station. Therefore, an SPR acts as a repeater by connecting back-to-back with BSR ***B*** (SPR ***B1*** and ***B2*** are served by BSR ***B***).

Notes:
- Careful planning is required to cope with issues such as interferences and delay that are introduced by the repeater solution. For example, if the system is used as a frequency hopping system, GPS may be required at each base station.
- Space and frequency isolation between the "repeater SPR" and BSR *B* is required.
- Bandwidth management should be calculated to support the "repeater bandwidth".
- IP addressing and routing tables should be configured to support the repeater solution.

1.4.6. TDM over Packet Solution

ASWipLL supports TDM over packet (TDMoP) solutions, including the following E1/T1 and leased lines applications:

- Full E1/T1 PTP
- Fractional E1/T1 point-to-point (PTP)
- V.35 point-to-point

In these applications, ASWipLL transmits E1/T1 or V.35 traffic over a wireless Ethernet path established by the ASWipLL radios. E1/T1 over Ethernet (TDMoP) is accomplished using the ASWipLL SDA-E1 device, which is an E1/T1-Ethernet converter. V.35 over Ethernet is accomplished using a third-party V.35-Ethernet converter (manufactured by Arranto). These devices are located behind the ASWipLL radios. Thus, ASWipLL provides transparent E1/T1-over-Ethernet and V.35-over-Ethernet traffic conversion.

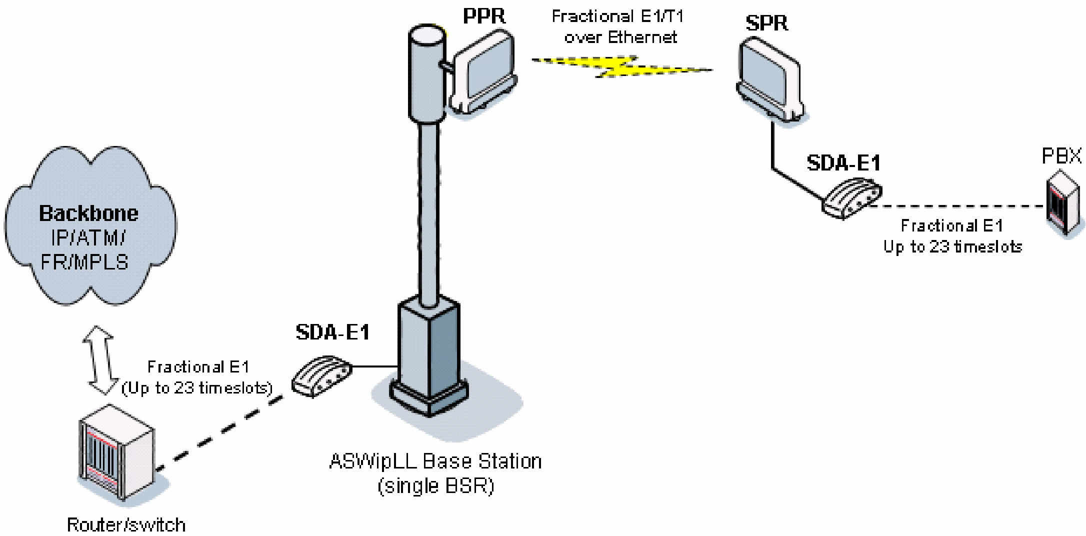


Figure 1-10: ASWipLL TDMoP solution

1.4.7. ASWipLL Low-Speed Vehicle Solution

ASWipLL offers wireless communication solutions for platforms consisting of low-speed vehicles. A typical example for this application is data connectivity between a harbour and ships in sea, river or lake environments. The harbour represents the static ASWipLL Base Station; the ships represent moving CPEs (i.e. SPR devices). In such an application, ASWipLL allows the ships to communicate with the harbor from up to 38 km away. This can offer a quick return on investment.

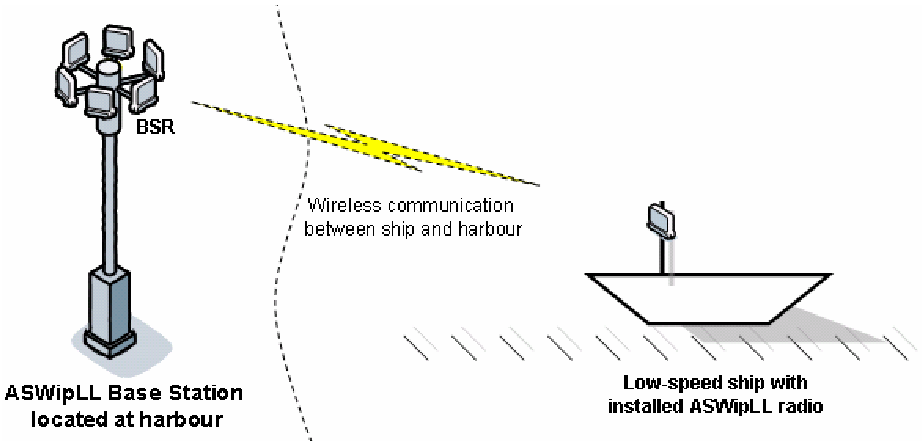


Figure 1-11: ASWipLL low-speed vehoicle solution

Highlights of the solution include:

- ASWipLL provides an alternative to CATV, xDSL and other wired services that are not provided over water
- ASWipLL can be used in a variety of frequency bands
- ASWipLL allows connectivity over large distances
- ASWipLL can be used for static platforms or low-speed mobile platforms as long as LOS is provided
- ASWipLL's SPR can be powered from 12 VDC source (typically from a solar panel) using SDA-1/DC
- ASWipLL offers a cost-effective solution

2

ASWipLL Radio Technology: Physical Layer

The ASWipLL system provides wireless, local-loop connectivity between the provider's IP-based backbone and the subscriber. This radio link is established using ASWipLL transceivers located at the Base Station and subscriber sites.

This chapter discusses the following radio frequency (RF) physical layer issues on which the ASWipLL system is based:

- Frequency Hopping Spread Spectrum
- Modulation
- Frequency Bands
- Standards Compliance
- ASWipLL RF Antennas
- Radio Planning

2.1. Frequency Hopping Spread Spectrum

The ASWipLL system implements frequency-hopping code division multiple access (**FH-CDMA**) spread spectrum modulation for digital signal transmission over the air between the Base Station and the subscriber site. The ASWipLL system's frequency hopping supports a channel bandwidth of 1 MHz or 1.33 MHz, and channel spacing of 1 MHz (or 1.75 MHz if operating in the 3.5 GHz band).

Frequency hopping is a basic modulation techniques used in spread spectrum signal transmission. Spread spectrum enables a signal to be transmitted across a frequency band that is much wider than the minimum bandwidth required by the information signal. The transmitter "spreads" the energy, originally concentrated in narrowband, across a number of frequency band channels on a wider electromagnetic spectrum.

In an FH-CDMA system, a transmitter "hops" between available frequencies according to a specified algorithm, which can either be random or predefined (see Figure 2-1). The transmitter operates in synchronization with a receiver, which remains tuned to the same center frequency as the transmitter. A short burst of data is transmitted on a narrowband signal. The transmitter then tunes to another frequency, and transmits again.

The receiver is capable of hopping its frequency over a given bandwidth several times a second (20 hops per second in the ASWipLL system), transmitting on one frequency for a certain period of time, then hopping to another frequency and transmitting again. The ASWipLL system supports a hopping speed of 50 msec hopping intervals.

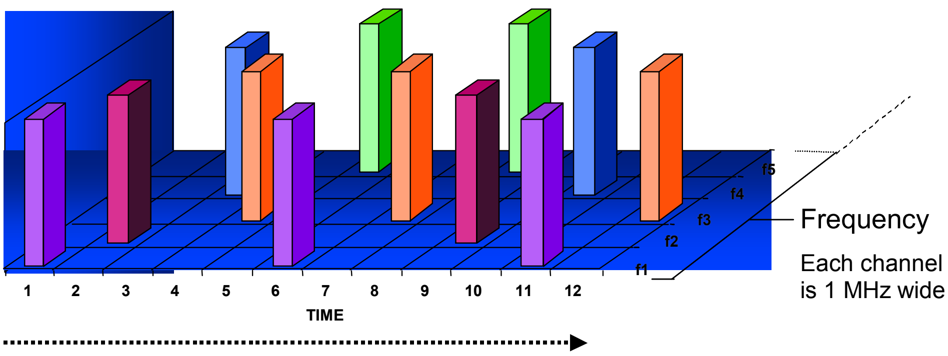


Figure 2-1: An example of Frequency Hopping Spread Spectrum

Implementing FH-CDMA in the ASWipLL system provides the following advantages:

- Frequency Hopping Spread Spectrum (FHSS) is based on interference avoidance. Narrow band interference that does not meet the signal-to-noise ratio (SNR) blocks only a few hops, decreasing the throughput only partially.
- The required spectrum for an FHSS system is flexible in that it does not have to be contiguous.
- FHSS can coexist with other systems in the same spectrum band.
- FHSS ensures security as to intercept transmission; a receiver must "know" the hopping sequence.
- Frequency diversity copes with the frequency selective fading and multipath.

The RF channel obtained by the ASWipLL operator is divided into ***n*** 1-MHz sub-channels, with center frequencies located at integer multiples of 1 MHz (see Figure 2-2). These sub-channels are organized into a set of orthogonal hopping sequences. Several methodologies are available for creating these sequences, depending on available spectrum and local regulations.

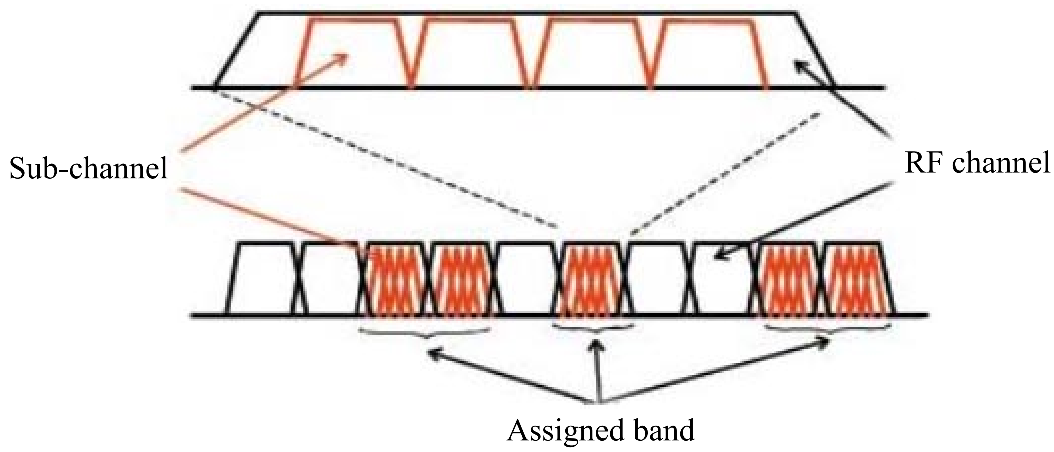


Figure 2-2: Relationship between "sub-channel", "RF channel", and "assigned channel"

Table 2-1 shows an example of six orthogonal sequences that can be derived from seven sub-channels.

Table 2-1: Example of six orthogonal FH sequences

Sequence No.	Sub-channels (frequencies)						
1	0	1	2	3	4	5	6
2	0	2	4	6	1	3	5
3	0	3	6	2	5	1	4
4	0	4	1	5	2	6	3
5	0	5	3	1	6	4	2
6	0	6	5	4	3	2	1

Up to 32 such sequences, each with up to 99 sub-channels can be pre-configured in the ASWipLL ROM. An additional 32 sequences can be configured by the ASWipLL operator in the RAM to provide further flexibility.

2.2. Modulation

The ASWipLL system is based on Continuous Phase Frequency Shift Keying (CPFSK) modulation. Frequency Shift Keying (FSK) uses ***m*** different frequencies for ***m*** symbols. The simplest FSK is binary FSK, where 0 and 1 correspond to different frequencies:

$$S(t) = \begin{cases} A_c Cos(2\pi f_1 t) & m(nT_b) = 1 \\ A_c Cos(2\pi f_2 t) & m(nT_b) = 0 \end{cases}$$

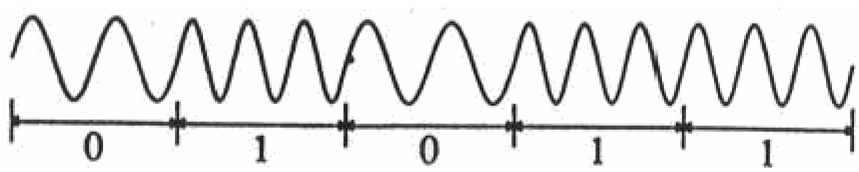


Figure 2-3: Graph displaying different frequencies for 0 and 1 bits

FSK is similar to non-linear analogue FM, but with digital modulation.

FSK provides the following benefits:

- Non-coherent detection is possible - no carrier synchronization is required.
- Immunities to non-linearity - the envelope contains no information and, therefore, can be hard-limited; information is carried by zero crossings:
  - Can be used with non-linear power amplifiers
  - Better efficiency

The FSK phase can be discontinuous or continuous (i.e. CPFSK), as displayed below.

Figure 2-4: FSK phase: discontinuous (left wave); continuous (right wave)

Continuous wave (implemented in ASWipLL) is more natural than discontinuous and provides the following advantages:

- Smaller bandwidth (discontinuous wave causes high frequency components)
- Operates better when transmission link has non-linearities

2.3. Operating Frequency Bands

ASWipLL operates in the numerous frequency bands, as listed in the table below.

Table 2-2: ASWipLL operating frequencies

Band type	ASWipLL product	ASWipLL radio	Operating frequencies
Licensed	**ASWipLL 700**	BSR; PPR; SPR; IDR	700 MHz (698 to 746 MHz; TDD)
	ASWipLL 925	BSR; PPR; SPR	925 MHz (910 to 940 MHz; TDD)
	ASWipLL 1.5	BSR; PPR; SPR	1.5 GHz (1427 to 1525 MHz; FDD; 49-MHz duplex separation)
	ASWipLL 1.9	BSR; SPR	1.9 GHz (1850 – 1910 and 1930 – 1990; FDD)
	ASWipLL 2.3	BSR; SPR	2.3 GHz (2300 to 2400 MHz; TDD)
	ASWipLL MMDS	BSR; PPR; SPR	MMDS 2.5 GHz (2500 to 2686 MHz; TDD)
	ASWipLL 2.8	BSR; PPR; SPR	2.8 GHz (2700 to 2900 MHz; TDD)
	ASWipLL 3.*x*	BSR; PPR; SPR; IDR	3.*x* GHz (3300 to 3810 MHz; TDD or FDD; 50- or 100-MHz duplex separation for FDD)
Unlicensed	**ASWipLL 900**	BSR; PPR; SPR; IDR	ISM 900 MHz (902 to 928 MHz; TDD)
	ASWipLL 2.4	BSR; PPR; SPR; IDR	ISM 2.4 GHz (2400 to 2500 MHz; TDD)
	ASWipLL 5.8	BSR; PPR; SPR	5.8 GHz (5725 to 5875 MHz; TDD)

Notes:

- For ASWipLL 1.5 (i.e. operating in the 1.5 GHz band), the duplex separation can be customized according to customer requirements, e.g. 60.5 MHz for Australia.
- ASWipLL 3.*x* includes numerous products, each operating in specific frequency ranges in the 3-GHz band (3300 to 3810 MHz).

- For a list of the ASWipLL products, see Appendix B, "ASWipLL Product List".

The figure below provides a graphical display of the operating frequency bands of the various ASWipLL products.

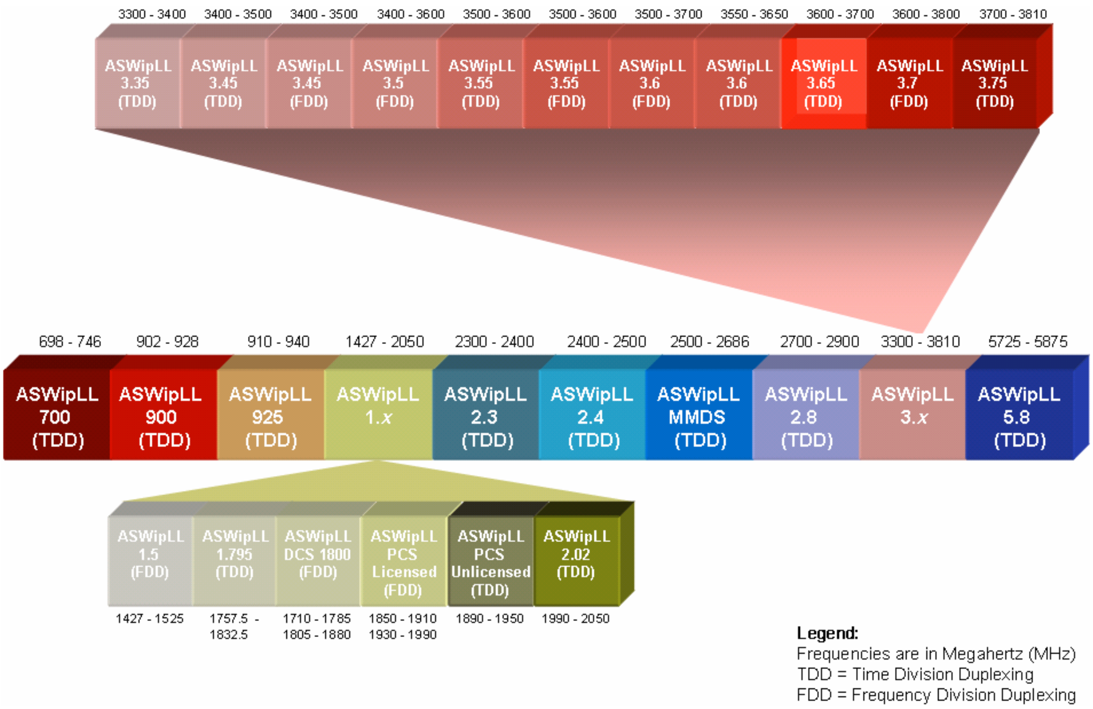


Figure 2-5: Graphical display of ASWipLL operating frequencies

2.4. Standards Compliance

Table 2-3 lists standards to which ASWipLL complies.

Table 2-3: ASWipLL standards compliance

Standard	Compliance
EMC	• **700 MHz:** FCC Part 27 • **900 MHz:** FCC Part 15 • **2.4 GHz:** ETS 300 826; FCC Part 15 • **MMDS**: FCC Part 21 • **3.*x* GHz:** EN 300 385; EN 300 386-2; ETS 300 132-2 • **5.8 GHz:** FCC Part 15
Radio	• **700 MHz:** FCC Part 27 • **900 MHz:** FCC Part 15 • **2.4 GHz:** EN 300 328-1; FCC Part 15; RSS 139; Telec; AS/NZS 4771 • **MMDS:** FCC Part 21 • **3.*x* GHz:** EN 301 253; RSS 192 • **5.8 GHz:** FCC Part 15; RSS 210
Safety	UL 1950, EN 60950
Environmental	ETS 300 019

Notes:

- For a detailed Declaration of FCC Conformity, see Appendix G, "Declaration of FCC Conformity".
- For a list of standards compliance per ASWipLL device, see the "Technical Specifications" subsection of the relevant section describing each device.

2.5. RF Antennas

Depending on the model, ASWipLL radios either contain an integrated (built-in) flat-panel antenna, or a port(s) for connecting an off-the-shelf, third-party external antenna. The table below lists the ASWipLL radio antenna configuration per frequency band.

Table 2-4: ASWipLL radio antenna configuration per frequency band

Frequency band	ASWipLL radio antenna configuration (integral / external)			
	BSR	PPR	SPR	IDR
700 MHz	Int. / Ext.	Ext.	Int. / Ext.	Int. / Ext.
900 MHz	Int. / Ext.	Ext.	Int. / Ext.	Int. / Ext.
925 MHz	Ext.	Ext.	Ext.	--
1.5 GHz	Int. / Ext.	Ext.	Int. / Ext.	--
1.9 GHz	2 x Int. / Ext.	--	Int. / Ext.	--
2.3 GHz	2x Int. / 2 x Ext.	--	Int. / Ext.	--
2.4 GHz	2x Int. / 2 x Ext.	Int. / Ext.	Int. / Ext.	Int. / Ext.
2.5 GHz	2x Int. / 2 x Ext.	Int. / Ext.	Int. / Ext.	--
2.8 GHz	2x Int. / 2 x Ext.	Int. / Ext.	Int. / Ext.	--
3.x GHz	2x Int. / 2 x Ext.	Int. / Ext.	Int. / Ext.	Int. / Ext.
5.8 GHz	2x Int. / 2 x Ext.	Int. / Ext.	Int. / Ext.	--

Note:

Table 2-5 provides a general description of the ASWipLL RF antenna parameters.

Table 2-5: General description of ASWipLL RF antennas

Parameter	Description
Internal antenna types	Integral flat-panel antenna for ASWipLL radios (BSR, PPR, SPR, and IDR). No RF cable is involved in the outdoor radio unit-to-indoor switch/hub unit (ODU-to-IDU) connection. Instead, a CAT-5 cable is used. The integrated flat-panel antennas provide gains of between 6 and 16. However, for certain radios high-gain antennas (i.e. 18 dBi) are provided, e.g. BSR operating in the 3.5 GHz band, and SPR and PPR operating in the 3.5 GHz and 2.4 GHz bands.
Polarization	Vertical (horizontal polarization is optional for SPR at 3.5 GHz).
ETSI compliant	EN 302 085, Class CS1 for the BSR, and TS2 for the SPR.
Receive diversity	Supported in a single BSR through dual (two) integrated (2.3 GHz, 2.4 GHz, 2.5 GHz, 2.8 GHz, 3.GHz, 5.8 GHz) or third-party external (700 MHz, 900 MHz, and 925 MHz) antennas.
Optional third-party external antennas	Provides further flexibility for the ASWipLL operator to improve link budget and cost-effectiveness of the Base Station. For example, an omni-directional antenna for 360° coverage can be used by a BSR.

Parameter	Description
	External antennas connect to BSR, PPR, and SPR using an N-type connector, and to IDR using a TNC connector. For BSRs operating in the 700 MHz, 900 MHz, and 925 MHz bands, two N-type connectors are provided for attaching two external antennas for dual antenna diversity at the ASWipLL Base Station. Optional attachment of third-party external antennas are provided by ASWipLL radios depending on operating frequency (see Table 2-4).

Notes:
1) For ASWipLL radio FCC compliancy, see Appendix G, "Declaration of FCC Conformity".
2) Devices with ports for connecting external antennas do not contain built-in (internal) antennas.

2.5.1. Dual Antenna Receive Diversity

For BSRs operating in the 700 MHz, 900 MHz, and 925 MHz bands, two antennas are provided for antenna receive diversity at the ASWipLL Base Station. This allows the BSR to select the antenna providing the best RF reception to receive the signal.

For these BSR models without built-in, internal antennas, dual diversity is provided by the existence of two N-type connectors for attaching two external antennas. When operating in the 700 MHz band, the BSR is supplied with a panel-type antenna and the SPR model with a yagi-type antenna.

Notes:
1) The BSR with two antennas transmits using only one of the antennas (factory selected).
2) Antennas must be orientated to cover the same area/cell (i.e. subscriber sites), from only a slightly different location.

2.5.2. ASWipLL 700

Except for ASWipLL 700, the integrated flat-panel antenna of all ASWipLL products covers their entire respective frequency bands. However, ASWipLL 700's integral antenna covers only Band-C (i.e. 710 to 716 MHz, and 740 to 746 MHz) frequency band. Therefore, for ASWipLL 700, Airspan provides an external antenna, allowing coverage in the entire 700-MHz band (698 to 746 MHz), including the licensed A and B bands used in USA.

For most ASWipLL products a wide variety of external antennas can be used. However, ASWipLL 700 allows connection to a limited variation of external antennas (optionally supplied by Airspan), including, among others, the following:

- **BSR:** 90° panel or omni-directional antenna
- **SPR:** 14-element yagi antenna

2.5.3. RF Planning Considerations for Band-C in FCC Markets

Some operators (e.g. in the USA) have licenses for Band-C (710 – 716 MHz and 740 – 746 MHz). A maximum of four BSRs operating in Band-C are allowed at a Base Station (in accordance with FCC regulations). This regulation ensures minimum RF interference with other radio devices that may be operating in nearby frequencies.

In the 1 megasymbols per second (Msps) mode, the center frequencies are 711.5, 712.5, 713.5, 714.5, 741.5, 742.5, 743.5, and 744.5. Thus, the frequency allocation for four BSRs is **711.5**, **741.5**, **714.5**, and **744.5**.

In the 1.33 Msps mode, the center frequencies are 712, 713, 714, 742, 743, and 744. Thus, the frequency allocation for four BSRs is **712**, **742**, **714**, and **744**.

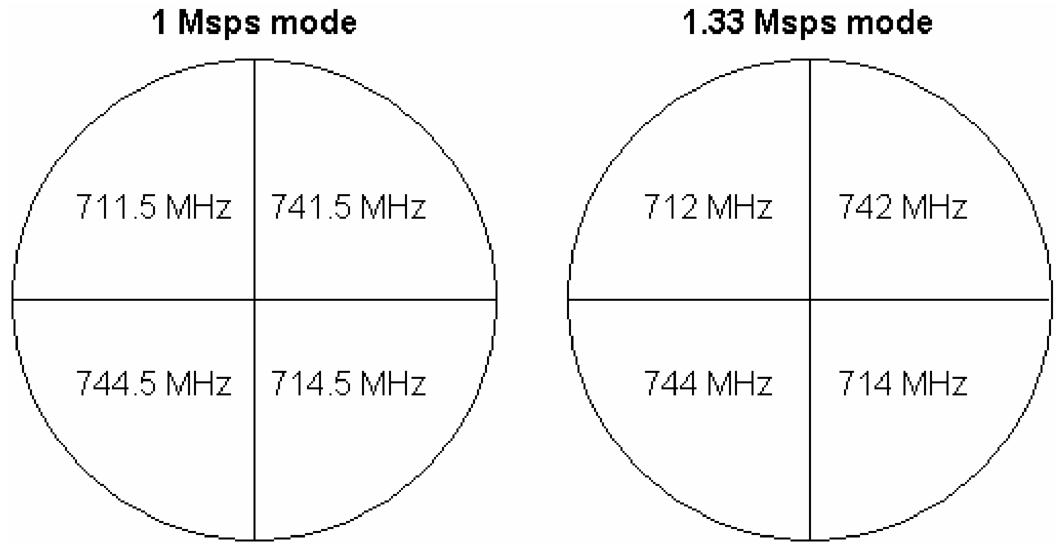


Figure 2-6: Frequency allocation in a four-sector Base Station

Radio interference may occur between the BSRs operating in the upper frequency range (i.e. 742 MHz and 744 MHz) and the lower frequency range (i.e. 712 MHz and 714 MHz). To overcome this interference, a **1-meter vertical separation** (in addition to the general 1-meter horizontal separation) is recommended between the BSRs operating in the upper frequency and the BSRs operating in the lower frequency.

2.6. Radio Planning

ASWipLL radio planning can be divided into the following areas:

- Main technical parameters
- Coverage analysis
- Interference analysis: FDD vs. TDD
- Frequency allocation: Synchronized vs. Unsynchronized operation
- Capacity considerations
- Selecting appropriate mode of operation
- Radio planning software tool

2.6.1. Main Technical Parameters

The table below summarizes main technical parameters required for RF planning in the ASWipLL system.

Table 2-6: ASWipLL parameters required for RF planning

Parameter	Value
Radio Technology	FH-CDMA
Multiple Access Method	Proprietary Adaptive TDMA protocol (PPMA)
Max. Power Output	27 dBm, except for models operating in the following frequencies: • 700 MHz: 31 dBm • 900 MHz, 925 MHz, and 1.5 GHz: 30 dBm **Note:** when operating in countries complying with FCC, the max. power for certain frequencies are different (see Appendix G, "Declaration of FCC Conformity)
Sub-Channel Spacing	1 MHz (1.75 MHz for devices in 3.5 GHz band)
Symbols per second (Msps)	• Two modes supported: 1 Msps or 1.33 Msps
Sub-Channel bandwidth (measured at 20 dB attenuation point)	1 MHz or 1.33 MHz (depending on selected mode)
Modulation	Multilevel 2-, 4-, or 8-level CPFSK[1]
Receiver Sensitivity (BER 1E-6 at 2/4/8 FSK)	-90/ -83/ -75 dBm
SNR Thresholds (BER 1E-6 at 2/4/8 FSK)	12/ 20/ 28 dB
Interference Rejection Factor for 1.33 Msps mode (1 Msps mode): • ± 1 MHz • ± 2 MHz • ± 3 MHz • ± 4 MHz • ± 5 MHz	 • 5 dB (7 dB) • 30 dB (40 dB) • 52 dB (53 dB) • 58 dB (60 dB) • 63 dB (64 dB)
Receiver Noise Figure	10 dB

[1] The intermediate 4-FSK modulation is not supported when 1.33 Msps mode is selected

2.6.2. System Coverage

System coverage includes the following:

- Line of sight
- Link budget

2.6.2.1. Line of Sight

Generally, ASWipLL requires the existence of a line of sight (LOS) between the Base Station transmitter and the subscriber's receiver (near line of sight [NLOS] may be possible to a limited extent for ranges of a few hundred meters). Therefore, the availability of LOS (clear first Fresnel Zone) should be estimated during CPE installation or preferably during network planning.

Recommended propagation models used in coverage analysis are based on free-space propagation with compensation for ground and irregular terrain reflections and diffraction. Specific propagation model names vary between different software tools. The model should also include a certain level of fade margin, as discussed in the next section.

2.6.2.2. Link Budget

The coverage analysis of ASWipLL includes the analysis of the power balance between the transmitter and the receiver, threshold considerations, margins, reserves, and certain system statistics. Therefore, the lead-in reception level is measured by the following equation:

Rx = Tx – LossTx + AntGainTx – PathLoss + AntGainRx – LossRx

Where,

Rx = reception level in dBm

Tx = transmitter power in dBm (27 dBm in the ASWipLL system)

LossTx = transmitter losses in dB (0 dB in the ASWipLL system)

LossRx = terminal receiver losses in dB (0 dB in the ASWipLL system)

AntGainTx = transmitter antenna gain

AntGainRx = receiver antenna gain in dBi (decibels referenced to isotropic radiator)

PathLoss = propagation loss in dB

Note: Both the Base Station and the subscriber site can serve as transmitter and receiver. For downlink budget, the transmitter is the Base Station and the receiver is the subscriber; and vice versa for the uplink budget.

2.6.2.2.1. Propagation loss

Propagation is the dispersal of the signal into space as it leaves the antenna. The loss of this propagation depends on the signal path between the transmitter and the receiver. Obstructions in the signal path such as trees and buildings can cause signal degradation. Several models simulate signal attenuation along this path.

Propagation loss should incorporate fading margins to compensate different phenomenon such as multipath shadowing and climatic behavior of the waves. Based on this, the parameter path loss can be calculated by the following equation:

$$PathLoss = L + Fade\ Margin$$

- **Free Space model:**

  Free space propagation loss is valid when the first Fresnel Zone is clear. In this case, free space propagation loss is given by the following equation:

  $$LFS = 32.44 + 20logd_{[km]} + 20logf_{[MHz]}$$

- **Fade Margin:**

  Fade margin further introduces fading factor to the propagation loss to cover the different signal fading and shadow effects, as well as the degradation caused by interferences. The fading factor depends on the time availability parameter defined by the operator, and should be calculated according to the ITU 530 model for 99.9% availability.

For simplicity purposes, the ITU model can be replaced by a 10 dB Flat fade margin as a rough estimation.

- **Rainfall:**

  Radio signals are attenuated by moisture in the atmosphere. The level of attenuation varies with carrier frequency, the quantity of rainfall, and the distance from the transmitter to the receiver. The variation of attenuation with frequency is particularly strong and highly non-linear. At 3 GHz, the highest attenuation is about 0.06 dB/km; for a typical WLL path of, for example, 6 km, the attenuation is only 0.36 dB. Therefore, for the purpose of link budget, we can assume that the impact of rainfall is negligible.

2.6.2.2.2. Link Budget Calculations and Fresnel Zone

Link budget calculations depend on whether the first Fresnel Zone is clear or not. When using the free space model to calculate path loss, it is assumed that line of sight (LOS) exists. Thus, if the first Fresnel Zone is not clear, it is inappropriate to use the free space model.

One method for clearing the Fresnel Zone (in order to use the free space model to calculate link budget) is by changing the antenna height to improve received signal strength (RSS) levels.

The first Fresenel Zone radius is calculated by

$$r = \sqrt{\frac{75 \cdot d}{f}}$$

where f is the frequency (in MHz) and d is the distance (in meters).

For example, using the formula above, a link of 4 km at 700 MHz produces a first Fresnel Zone radius clearance of about 20 meters. This implies that to ensure the ground does not enter into the first Fresnel Zone, both antennas (i.e. at Base Station and subscriber) must be mounted at least 20 meters above ground level (or clutter level).

Typically, at least 60% clearance of the first Fresnel Zone is considered as LOS. Therefore, in the above example, a height of at least 12 meters (i.e. 60% of 20 meters) above ground level is sufficient for LOS.

In scenarios where the Fresnel Zone can not be cleared, other standard propagation models (e.g. Hata model) can be used to calculate link budget. The appropriate model to use depends on the environment (e.g. open area, urban, and suburban) in which the ASWipLL system is operating. When using RF planning software and GIS databases, the software generally chooses the appropriate model automatically.

For example, when operating in open areas, it is possible to use the following Hata open formula:

$$F = \text{Frequency (MHz)} \qquad T = \text{Transmiter Height}$$
$$km = \text{Distance (km)} \qquad R = \text{Receiver Height}$$

$$\text{Small factor} = (1.1R - 1.56)\log_{10} F - 0.7R + 0.8$$
$$\begin{aligned} PathLoss = {} & 44.49\log_{10} F - 4.78\log_{10}^{2} F - 13.82\log_{10} T + 44.9\log_{10} km \\ & - 6.55\log_{10} T \log_{10} km + 28.61 - \text{Small factor} \end{aligned}$$

In this example, if the antenna height is increased sufficiently, the Hata open coincides with the free space propagation model. The difference between using the Hata formula and the free space formula may be substantial in scenarios where the Fresnel Zone is not clear.

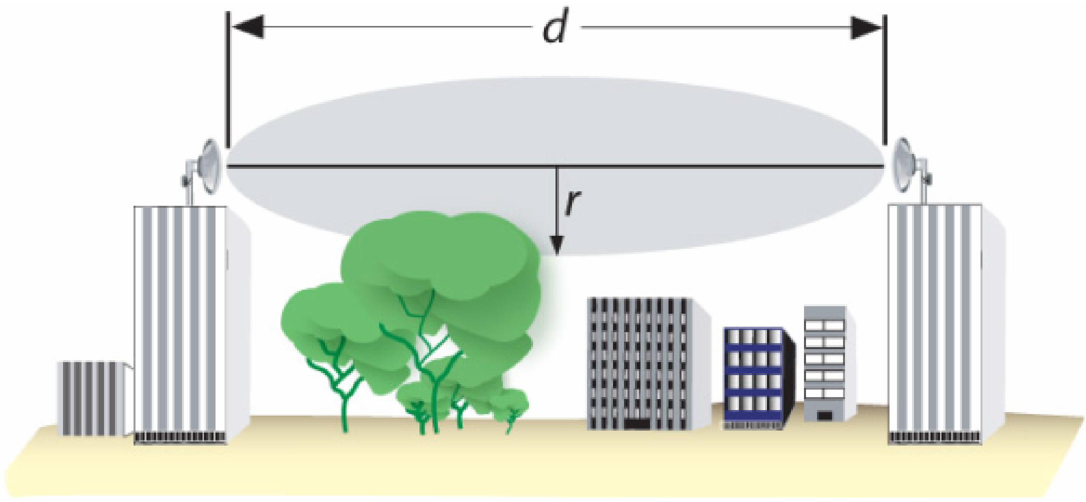


Figure 2-7: Fresnel Zone partially blocked

2.6.2.2.3. Link Budget Results

Based on the previous equations mentioned in the above sections, Table 2-7 shows the link budget results obtained for 99.9% availability.

Table 2-7: Link budget results

Modulation	Rate (Mbps)	Range (in km)					
		2.4 GHz[2]	MMDS (2.5 GHz)	3.5 GHz	5.8 GHz	900 MHz	700 MHz
8 FSK	3 or 4	8	8	7	6	8	15
4 FSK	2	11	11	10	8	11	22
2 FSK	1 or 1.33	14	14	13	11	15	28

Note: Link budget is calculated for the standard integrated, built-in ASWipLL antennas. Where required, the range can be increased to up to 38 km by implementing external antennas.

2.6.3. Interference Analysis: FDD vs. TDD

Interference analysis should be based on parameters defined in Section 2.6.1, "Main Technical Parameters" to determine the downlink and uplink carrier-to-interference ratio (C/I). The C/I is a key factor in determining the supported modulation for each link. Thresholds for C/I for the different modulations are mentioned in Section 2.6.1, "Main Technical Parameters".

Interference analysis depends on the duplex scheme implemented in the system. Since ASWipLL supports both FDD and TDD, different considerations should be applied.

[2] Although the transmitter is capable of transmitting 27 dBm, in most cases the EIRP in the ISM band is limited by local regulations. For example, ETSI limits the EIRP to 20 dBm, FCC to 36 dBm, and TELEC to 27 dBm. The link budget calculated here assumes no limit.

Frequency Division Duplex (FDD) interference analysis is relatively simple. The frequency separation between downlink and uplink (50 to 100 MHz) enables Airspan to conduct downlink and uplink interference analysis independently.

However, in Time Division Duplex (TDD), since Tx and Rx are not synchronized, cross-link interference may result, for example, between a transmitting BSR and an adjacent receiving BSR. It is expected that these interferences will be dominant in the TDD mode.

The major consequence of this is the different limitations imposed on frequency separation between adjacent BSRs:

- **FDD:** 2-MHz frequency separation
- **TDD:** 4-MHz frequency separation

The required separation is a function of the isolation between co-located antennas. The 4-MHz separation is based on 60 dB isolation. Based on this, a simple frequency allocation for a stand-alone cell is presented in Figure 2-8.

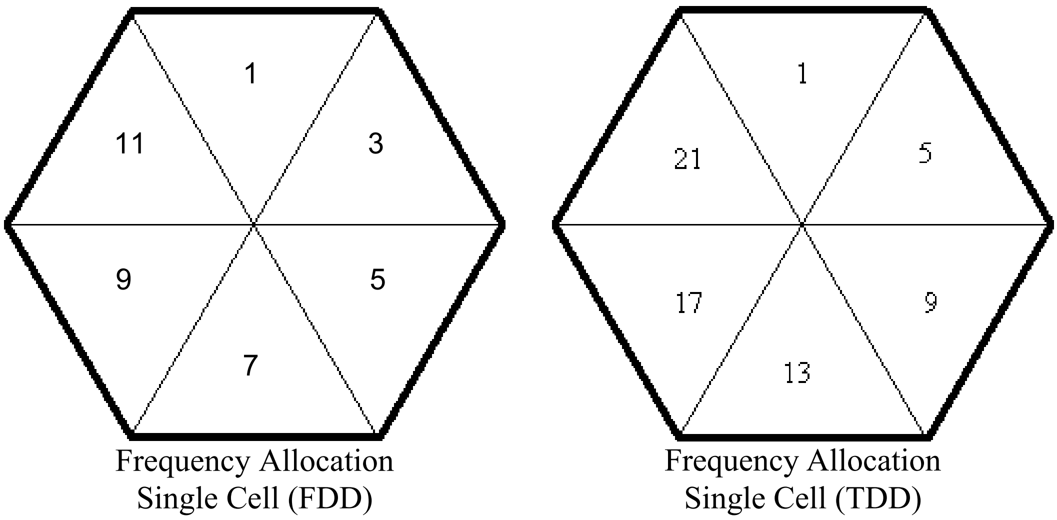


Figure 2-8: Frequency allocation for a stand-alone cell: FDD (left) vs. TDD (right)

2.6.4. Frequency Allocation

Frequency allocation includes the following issues:

- Synchronized vs. Unsynchronized operation
- Frequency Reuse
- Frequency Allocation template

2.6.4.1. Synchronized versus Unsynchronized Operation

The frequency allocation scheme in ASWipLL depends on the mode of operation. Three main options exist:

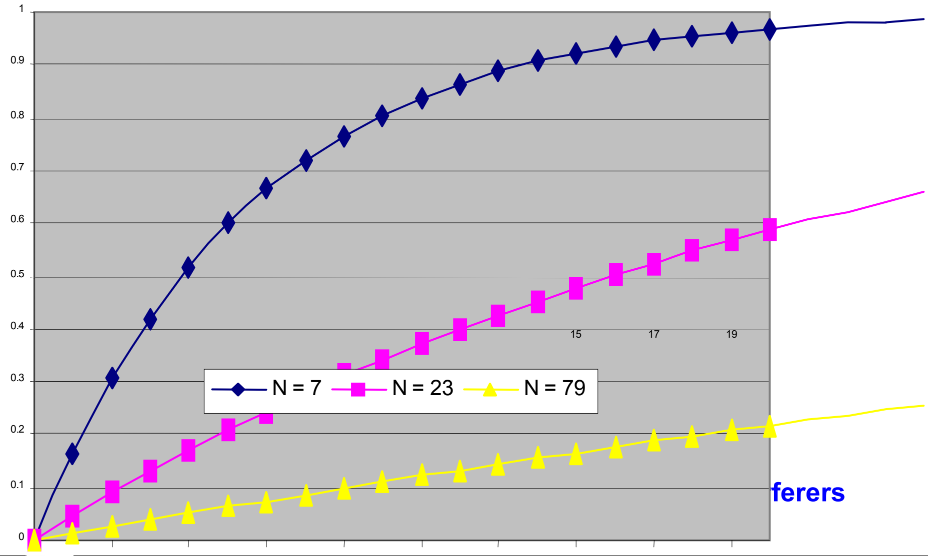
- Unsynchronized Frequency Hopping
- Synchronized Frequency Hopping
- Fix Sub-Channel Assignment

2.6.4.1.1. Unsynchronized Frequency Hopping

A scenario may exist whereby the operator does not want to synchronize Base Stations due to cost or regulatory issues. In such a scenario, the BSRs (and SPRs) are assigned pseudo-random frequency tables, and, therefore, collisions between transceivers are possible, resulting in some level of retransmissions. However, implementing orthogonal frequency tables (hopping sequences) reduces collisions.

In this mode of operation, the available set of sub-channels, which must include a prime number of sub-channels, is organized into several different hopping sequences that are orthogonal to each other. Each BSR in the coverage area is assigned a different sequence (until there is a need to start reusing the tables). The degradation level in performance due to collisions will be a random number, depending on the length of the frequency tables (the number of available sub-channels).

The figure below displays a graph depicting the hit or blocking probability as a function of number of interferers for different table lengths (7, 23, and 79).



Note: The probability of collisions with 20 interferers and 79 sub-channels is only 20%.

2.6.4.1.2. Synchronized Frequency Hopping

In most scenarios, the operator synchronizes between ASWipLL Base Stations located in the same coverage area. This option provides the best control over intra-system interferences.

In this mode of operation, the available set of sub-channels is arranged in a single hopping sequence, common to all transceivers (BSRs and SPRs) in the coverage area. Since the table ID is identical to all radios, the only parameter that needs to be assigned is the phase, that is, the starting point within the sequence.

By selecting the sequence appropriately, the relative frequency separation between the transceivers remains constant over time, so that interference analysis is quite similar to any Frequency Division Multiple Access (FDMA) system.

2.6.4.1.3. Fix Sub-Channel Assignment

In some scenarios—mainly licensed bands in which available spectrum is limited—it is possible to create a set of "hopping" tables, each based on a single sub-channel. Using this approach, the hopping nature of the system is actually disabled, so that synchronization is not required. The trade-off of this approach is loss of frequency diversity, discussed previously as a means to overcome frequency-selective fading.

Interference analysis in this mode is identical to any FDMA system.

2.6.4.2. Frequency Allocation

The figure below presents frequency allocation for three adjacent cells for the FDD and TDD schemes. This frequency allocation is relevant only for synchronized frequency hopping or fix sub-channel assignment options. For the unsynchronized frequency hopping option described previously, orthogonal frequency tables are assigned instead of specific sub-channels (or phases). As described in Section 2.6.3, "Interference Analysis", 60-dB isolation between co-located BSRs is assumed for the TDD allocation.

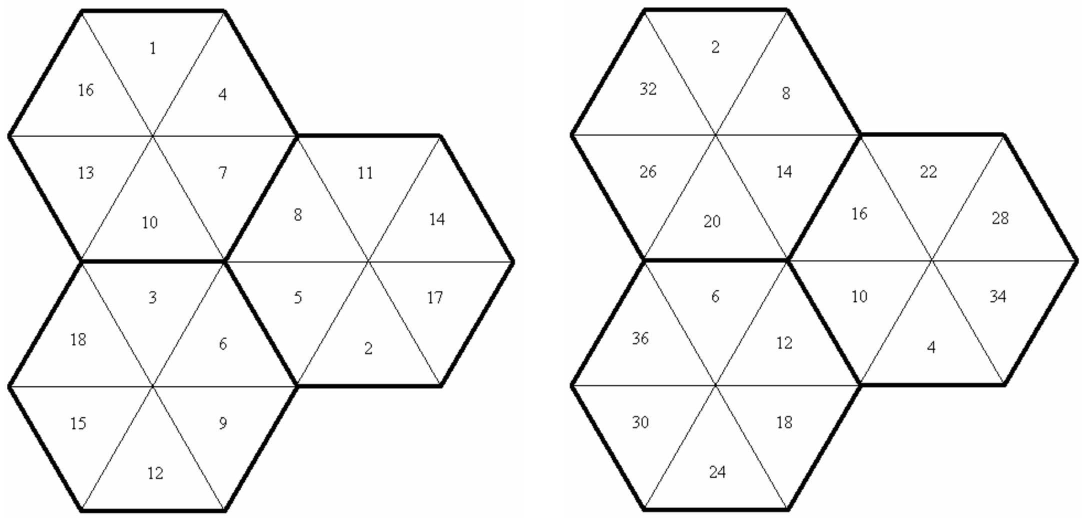


Figure 2-10: Frequency allocation (FDD - left and TDD - right)

2.6.5. Capacity Considerations

This section provides high-level guidelines for evaluating ASWipLL capacity. This capacity relates to the number of subscribers supported by a single BSR according to a certain service mix. The methodology presented here provides a simplified approach for evaluating ASWipLL capacity capabilities. It can be used as an initial estimation; however, it cannot replace a more accurate capacity analysis performed by an RF planning team.

2.6.5.1. General

The general concept for determining the number of subscribers per BSR is presented in the figure below.

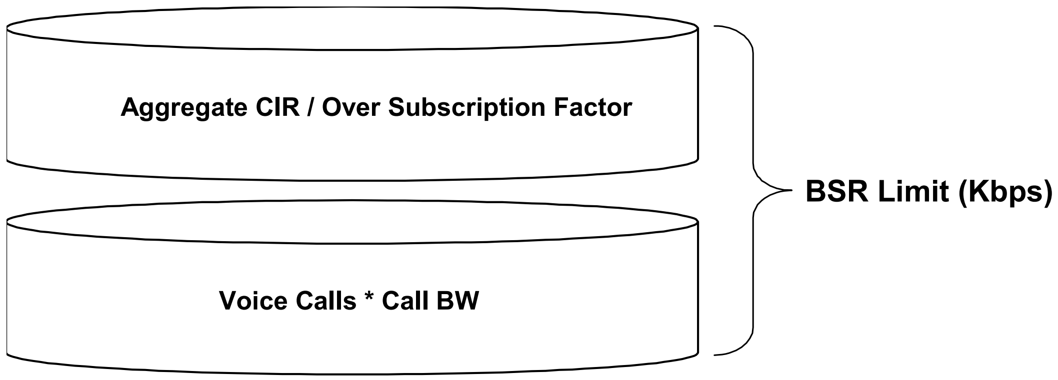


Figure 2-11: Determining number of subscribers per BSR

The BSR limit is 4 Mbps; therefore, the total voice and data bandwidth must be lower or equal to 4 Mbps.

The number of voice calls should be derived from Erlang B tables according to voice traffic per subscriber (in erlangs), and expected blocking probability (typically 1%) parameters. The VoIP bandwidth depends on the specific codec that will be used. Typical values are specified in the next section.

The data portion of the aggregated traffic is based on the sum of the committed information rate (CIR) for all subscribers assigned to the BSR, divided by the appropriate over subscription rate.

Since voice and data services differ by their packet size and their sensitivity to delay, their protocol efficiency can be substantially different. Therefore, when calculating bandwidth for different applications, the gross bandwidth, which takes into account the protocol efficiency, should be used.

2.6.5.2. VoIP Bandwidth and Simultaneous Calls

The VoIP bandwidth and the number of supported simultaneous calls are a function of the selected codec and the sample interval. Assuming a 4-Mbps gross rate, the following numbers can be used:

Table 2-8: VoIP simultaneous calls for 4 Mbps gross rate

Codec	Sample Interval (msec)	Simultaneous Calls
G.711 (64 Kbps)	20	10
	40	15
G.729 (8 Kbps)	20	14
	40	28
G.723.1 (5.3 Kbps)	30	22
	60	42

If silence suppression is used, a factor of 65% should be applied on the call bandwidth.

Note: The selection of the appropriate codec should be based on a balance between the occupied bandwidth and the voice quality.

2.6.5.3. Data Bandwidth

It is assumed that packet size for data applications is relatively large (about 1,500 bytes), resulting in a protocol efficiency of 80%. Taking this into account, the sum of all data bandwidth should be divided by 80% to obtain the bandwidth over the air.

2.6.5.4. Calculation Example

This example assumes that the required services are based on voice traffic of 100 merlangs per subscriber and a CIR of 256 Kbps. In addition, in this example, a 1% blocking is expected for voice calls, and 1:10 over subscription is expected for data. The number of subscribers that can be supported by a single BSR (N) is equal to

$$Calls(traffic, Gos) \cdot \frac{4{,}000Kbps}{Sim\_Calls(Codec)} + \frac{10\% \cdot N \cdot 256Kbps}{80\%} \leq 4{,}000Kbps$$

Assume that N = 40. Therefore, the aggregate voice traffic is equal to 4 erlangs. Using Erlang B tables with 1% blocking, 10 voice channels (calls) are required. For G.729 with 40 msec sample interval and silence suppression, the total capacity set for voice is obtained by *10*143 Kbps*65% = 930 Kbps*. The total capacity set for data is obtained by *40*256 Kbps*10%/80% = 1,280 Kbps*. This implies that more subscribers can be supported, since the aggregated capacity (*2,210 Kbps)* is lower than the 4 Mbps limit. If N (BSRs) increases, the limit of 4 Mbps will be reached for *N = 80*. (The process of finding N can be simplified by using an electronic spreadsheet).

2.6.6. Selecting an Appropriate Operation Mode

ASWipLL enables the operator the flexibility to choose between several modes of operation according to the operator's needs. One of the optional modes relates to the symbol rate of the modem. This section presents the main issues that should be considered when selecting an operation mode when deploying the ASWipLL system.

2.6.6.1. ASWipLL Multiple Modes

ASWipLL offers the capability to select between two operating modes in terms of symbol rate. The modem can operate in either 1 or 1.33 Msps. The operating mode is software selectable for each BSR. The differences between the modes of operation are related to the bit rate and the channel bandwidth.

2.6.6.1.1. Bit Rate

The 1-Msps mode supports three levels of modulation, as presented in Table 2-9.

Table 2-9: ASWipLL bit rate at 1 Msps

Modulation	Bit/Symbol	Bit rate (Mbps)
8-level FSK	3	3
4-level FSK	2	2
2-level FSK	1	1

The 1.33-Msps mode supports two levels of modulation according to Table 2-10.

Table 2-10: ASWipLL bit rate at 1.33 Msps

Modulation	Bit/Symbol	Bit rate (Mbps)
8-level FSK	3	4
2-level FSK	1	1.33

Note: The differences in sensitivity and SNR values between the two modes are negligible.

2.6.6.1.2. Channel Bandwidth

The 1.33 Msps is based on shorter symbols, with the trade-off of a wider channel bandwidth. The 20 dB attenuation point for the 1 Msps mode and the 1.33 Msps mode is 1 MHz and 1.33 MHz, respectively.

2.6.6.2. System Range Considerations

System range depends on the maximum output power of the system. Different approaches exist, depending on region and frequency band.

2.6.6.2.1. Unlicensed Bands

FCC part 15 (paragraph 247) differentiates between three types of systems: Digital modulated, Frequency Hopping, and Hybrid.

ASWipLL is a Hybrid system and, therefore, limitations on transmit (Tx) power and Effective Isotropic Radiated Power (EIRP) differ on this basis. Table 2-11 summarizes limitations for different ASWipLL products operating in FCC markets.

Table 2-11: ASWipLL radio Tx power and EIRP compliancy with FCC

Frequency	Mode	Max. Tx power	Max. EIRP	System mode
900 MHz	3 Mbps	17.5 dBm	36 dBm	**Hybrid**
	4 Mbps	23 dBm	36 dBm	**Hybrid**
2.4 GHz	3 Mbps/4 Mbps	23 dBm	36 dBm	**Hybrid**
5.8 GHz	4	21	36	**Hybrid**

For ASWipLL 900, the BSR's external antenna must have a minimum cable loss of 2.5 dB to comply with FCC's EIRP limit of 36 dBm. EIRP is calculated as:

`Max. Power Output + Antenna Gain - Cable Loss ≤ 36 dBm (EIRP)`

The table below lists examples of cable loss per cable for maximum antenna gains for ASWipLL 900, based on the formula above. Note that the EIRP is either equal to or less than 36 dBm.

Table 2-12: Example of cable loss per cable for maximum antenna gains

Cable type	Cable length (ft)	Tx power (dBm)	Cable loss (dB)	Max. Antenna gain (dBi)	Max. EIRP (dBm)
BELDEN - 9913	10	21.1	0.6	15.5	36
	30	22	1.5	15.5	36
	100	23	4.4	15.5	34.1
BELDEN - 89907	10	22.4	1.9	15.5	36
	30	23	5.2	15.5	33.3
	100	23	16.3	15.5	22.2

Table 2-13, Table 2-14, and Table 2-15 present system ranges (in kilometers) for the different frequency bands (900 MHz, 2.4 GHz, and 5.8 GHz, respectively) and modes of operation (i.e. 1 Msps and 1.33 Msps).

Table 2-13: ASWipLL range at FCC limits for 900 MHz

Mode	Modulation	Rate (Mbps)	Range (km)
1 Msps	8 FSK	3	4
	4 FSK	2	10
	2 FSK	1	24
1.33 Msps	8 FSK	4	6
	2 FSK	1.33	35

Table 2-14: ASWipLL range at FCC limits for 2.4 GHz

Mode	Modulation	Rate (Mbps)	Range (km)
1 Msps	8 FSK	3	4
	4 FSK	2	10
	2 FSK	1	22
1.33 Msps	8 FSK	4	1
	2 FSK	1.33	8

Table 2-15: ASWipLL range at FCC limits for 5.8 GHz

Mode	Modulation	Rate (Mbps)	Range (km)
1 Msps	8 FSK	3	2
	4 FSK	2	5
	2 FSK	1	10
1.33 Msps	8 FSK	4	1
	2 FSK	1.33	8

Note: Link budget is calculated for the uplink assuming free space propagation standard integrated antenna and 10-dB fade margin.

As shown in the tables, the system range for the 1 Msps mode is approximately three times higher than for the 1.33 Msps mode due to the 9 dB differences in Tx (transmit) power.

2.6.6.2.2. Licensed Bands (3.5 GHz)

No distinction exists between the two modes in terms of system range.

2.6.6.3. Interference Rejection

Two types of interference should be considered:

- **Intra-system interference:** caused by multiple ASWipLL transmitters
- **Inter-system interference:** caused by external transmitters, mainly in the unlicensed bands

2.6.6.3.1. Intra-system Interference

As mentioned previously, 1.33 Msps mode is achieved by using wider channel bandwidth. This results in a higher bit rate at the expense of increasing adjacent channel interference. This difference can become critical mainly for licensed bands in which the available spectrum might be very limited. It is beyond the scope of this document to provide specific rules regarding the preferred mode as a function of the available spectrum. This is due to the fact that such analysis depends on many parameters such as the cell layout and the topography of the coverage area. However, it should be evaluated during radio planning.

2.6.6.3.2. Inter-system Interference in ETSI Markets

The immunity of the ASWipLL system to external interference is due to its spread spectrum system. Exposure to external interference is highest when operating in the unlicensed band. The European Telecommunications Standards Institute (ETSI) sets limits on the spreading level that is required by a frequency hopping spread spectrum system (FHSS).

According to EN 300 328, FHSS modulation must use at least 20 well-defined, non-overlapping channels separated by the channel bandwidth as measured at 20 dB below peak power.

Since ASWipLL's carriers must be located at integer multiples of megahertz (MHz), the above statement limits the channel spacing to 1 MHz for the 1 Msps mode, and 2 MHz for the 1.33 Msps mode. This limits the number of possible hops in the ASWipLL system when operating under ETSI regulations to between 20 and 80 for the 1-Msps mode, and between 20 and 40 for the 1.33-Msps mode.

In general, since the number of different hops is substantially lower, the capability of ASWipLL to overcome interferences is reduced. In practice, ETSI allows the operator the flexibility not to use the entire spectrum, in case, for example, a constant interference is identified in a portion of the spectrum.

2.6.6.4. System Capacity Calculations Based on FSK Modulation

The modulation for each link in the ASWipLL system is adaptively determined according to the signal strength and the BER. When evaluating system capacity, it should be taken into account that the intermediate 4-FSK modulation is not supported when operating at 1.33 Msps.

Assume an ASWipLL deployment where subscribers are located at various distances from the Base Stations. In general, three coverage circles can be expected around each Base Station:

- **Inner circle:** supporting 8-level FSK
- **Intermediate circle:** supporting 4-level FSK
- **Outer circle:** supporting 2-level FSK

The data throughput of an ASWipLL sector and the throughput per CPE depends on many factors such as:

- RF conditions (that effect the modulation and ARQ)
- ASWipLL operation mode:

Mode (Mbps)	Net throughput (Mbps)
4 / 1.33	3.2
3 / 2 / 1	2.4

- CIR and MIR values (aggregated and asymmetric)
- VoIP or TDMoIP existence and the policy that the operator sets for allocations of bandwidth – whether it is included in CIR/MIR values or added on top of them (in higher priority)
- Application used by the different CPEs (e.g. TCP- and UDP-based)
- Demand (bandwidth divided only between active CPEs, i.e. generating load)

The table below shows the bit rate per FSK modulation.

Table 2-16: Bit rate per FSK modulation

Modulation	Bit per symbol	Mode (Msps)	Bit rate (Mbps)
8-level FSK	3	• 1 • 1.33	• 3 • 4
4-level FSK	2	1	2
2-level FSK	1	• 1 • 1.33	• 1 • 1.33

In other words, in a scenario where CPEs are using equal bandwidth demand, a CPE operating in 2-FSK modulation requires that the Base Station radio dedicate three times more bandwidth to it than to 8-FSK CPE since the 2-FSK has a rate three times slower than 8-FSK CPE .

The formula below can be used to calculate throughput based on FSK modulation and operation mode:

$$\frac{N1 + N2 + N3}{N1 + (N2*2) + (N3*3)} * (2.4 \text{ or } 3.2 \text{ Mbps})$$

Where,

N1 = number of CPEs in 4-Mbps mode

N2 = number of CPEs in 2-Mbps mode

N3 = number of CPEs in 1.33-Mbps mode

2.4 Mbps = for 1-, 2-, and 3-Mbps modes

3.2 Mbps = for 1.33- and 4-Mbps modes

The following table provides an example of system capacity calculations for two scenarios:

Scenario A (4-Mbps mode)	Scenario B (3-Mbps mode)
• 11 CPEs in 8-FSK modulation • 19 CPEs in 2-FSK modulation • All CPEs operating in 4-Mbps mode (i.e. 3.2 Mbps net throughput) • All CPEs are active and generate the same demand • All CPEs share identical CIR/MIR definitions	• 11 CPEs in 8-FSK modulation • 19 CPEs in 2-FSK modulation • All CPEs operating in 3-Mbps mode (i.e. 2.4 Mbps net throughput) • All CPEs are active and generate the same demand • All CPEs share identical CIR/MIR definitions
Calculation: $\frac{11 + 19}{11 + (19*3)} * 3.2 \text{ Mbps} = \frac{30*3.2}{68} = 1.41 \text{ Mbps}$	**Calculation:** $\frac{11 + 19}{11 + (19*3)} * 2.4 \text{ Mbps} = \frac{30*2.4}{68} = 1.05 \text{ Mbps}$
Conclusion: The maximum throughput of this cell is 1.41 Mbps when all CPEs are simultaneously active	**Conclusion:** The maximum throughput of this cell is 1.05 Mbps when all CPEs are simultaneously active

Note: As the number of CPEs operating in low modulations (i.e. 2 and 4 FSK) increases, a decrease in cell bandwidth efficiency is expected. Therefore, to enable the highest bandwidth efficiency, it's recommended to ensure (e.g. RF planning) that all CPEs operate in the highest modulation (i.e. 8 FSK).

2.6.6.5. Conclusion

The 1.33 Msps mode provides superior bit rate, but at the expense of a possible reduction in radio coverage (FCC), and/or increase in interference. A certain amount of radio planning is required to determine the preferable mode to maximize the overall capacity of the access network.

2.6.7. Radio Planning Software Tool

To design an optimal fixed wireless broadband network, the operator requires an RF design tool that includes features of a geographic information system (GIS) module, a propagation prediction module, and a fixed wireless module.

The GIS module should map data that contain or can be assigned geographic coordinates, for example, terrain elevation, land-use classification, site locations, design area boundaries, roads, and highways.

The propagation prediction module should provide RF propagation analysis and predictions. This module must support features that allow the propagation model to be calibrated using drive test measurements.

The fixed wireless module should support directional CPE antennas for coverage, capacity and interference analysis in LOS and NLOS conditions, and adaptive modulation.

In addition, to enable detailed and accurate propagation prediction, terrain information must be supplemented by a **Geographic Information Systems (GIS) database**. Clutter databases are typically based on Satellite or Aerial photography, depending on the resolution of the planning. Clutter databases should include Definition of Clutter Types and Clutter Height relative to the underlying DEM.

The resolution of data varies depending on the environment at which the planning is targeted. Airspan recommends the following:

- **Rural:** 10 to30 meters
- **Urban:** 5 to 20 meters

The specific format of the database depends on the planning tool. The planning software provider or user's manual should be consulted to obtain the appropriate format.

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3

ASWipLL's Air MAC Protocol

The ASWipLL system implements Airspan's proprietary Preemptive Polling Multiple Access (PPMA) technology for multiple access control between its wireless units. This technology specifies media access control (MAC) and physical layers for its units.

3.1. MAC Protocol Features

ASWipLL's MAC protocol, provided by PPMA, offers the following features:

- Supports up to 252 subscriber sites (SPRs/IDRs) per BSR, and up to 6,048 subscriber sites per Base Station
- High throughput efficiency - 80% of the bit rate
- Automatic rate control to maximize throughput under high bit error rate (BER)
- Re-transmission of lost packets - reliable operation in a high BER environment
- Centrally coordinated air protocol - designed for point-to-multipoint (PMP) environments
- No transmission collisions
- Real-time assessments on required and available bandwidth resources to control data flow
- Intelligent polling of customer premises equipment (SPRs and IDRs)

3.2. Preemptive Polling Multiple Access Protocol

The ASWipLL system implements Airspan's proprietary Preemptive Polling Multiple Access (PPMA) technology. PPMA is an "adaptive" Time Division Multiple Access (TDMA) protocol, i.e. the same RF channel is used for multiple subscribers, and the time interval for subscriber transmission is adaptive to the subscriber's resource requirements (based on QoS). PPMA is designed specifically for point-to-multipoint wireless local loop (WLL) applications to provide best effective throughput.

PPMA has many advantages over competing solutions such as the IEEE 802.11 Carrier Sense Multiple Access (CSMA) protocol. For a list of advantages over 802.11 CSMA, see Section 3.2.4, "PPMA vs. CSMA"

The PPMA technology is implemented at OSI's Layer 2 (Data Link layer). Layer 2 builds up Ethernet packets, sends them to the channel via the Physical layer, receives packets, checks if these packets are error free, and then delivers error-free packets to the Network layer.

Preemptive Polling Multiple Access is a centrally coordinated protocol that controls packet transmissions between the BSR and SPRs/IDRs. The BSR coordinates transmission over the air, constantly gathering information from SPRs/IDRs regarding resource requirements. Resource requirement is rated according to QoS, number of packets in the SPR's/IDR's queues, and the maximum delay allowed for the first packet in the queue (represented by a Time To Live [TTL] value).

Once the BSR has determined the SPRs'/IDRs' resource requirements, it polls the SPRs/IDRs for the next few milliseconds. The SPRs/IDRs with the higher resource requirement rates are polled first.

The following sub-sections describe the PPMA mechanism.

3.2.1. Slotted Aloha Process

The constant gathering of SPRs'/IDRs' required resources information is performed using the *Slotted Aloha* process. Slotted Aloha divides the channel into time slots, requiring the subscriber to send messages only at the beginning of a time slot.

At specific time intervals (not exceeding 100 msec), the BSR sends a "Channel Clear" message inviting SPRs/IDRs to send the score of their resource requirements. The BSR then waits a specific time and receives these requirements. This waiting time is called *Slotted Aloha.* The BSR waits for a time that is equivalent to 16 "Request to Send" (RTS) messages. The messages are synchronized so that an SPR/IDR transmits a message only after the previous message has ended. The timing of each RTS message is represented as a "slot".

SPRs/IDRs can choose which time slots to use for sending their requirements. Occasionally, a collision between SPRs\IDRs can occur in a slot, resulting in a lost RTS. Each SPR/IDR can use more than one slot to send its RTS. An SPR/IDR that is denied transmission can retry during the next Slotted Aloha process.

The Slotted Aloha process ensures that all SPRs/IDRs receive equal opportunities to transmit their RTS message.

3.2.2. Packet Transmission

Once the BSR has received the RTS messages from the SPRs\IDRs and determined their priorities, it sends a "Clear to Send" (CTS) message to the first SPR/IDR. The SPR/IDR then transmits its packet.

In the header of each packet, additional information regarding the status of the queues is included. This eliminates the need for the SPR/IDR to participate in the next Slotted Aloha process.

The data packet is divided into fragments. To each fragment is added a cyclic redundancy check (CRC). Once the packet has been received, the BSR sends an "Acknowledge" (ACK) message that includes information about all fragments that were reported as errors. The SPR/IDR can re-transmit these fragments several times until the entire message is successfully transmitted.

3.2.3. Polling Sequence

Polling of an SPR/IDR occurs each time the BSR sends a CTS message to an SPR/IDR. Polling of SPRs/IDRs can occur according to the information gathered during the Slotted Aloha process, or periodically—every few milliseconds—regardless of the Slotted Aloha process, depending on the application transmitting data at the time.

The polling sequence of data applications is controlled by the BSR based on the information gathered during the Slotted Aloha process. Data applications can sustain relatively long delays before expecting a response. Therefore, their packets can be delayed within the SPRs/IDRs before being sent to the BSR and on to the customer's backbone. Applications that require shorter packet delays are polled first.

Some applications are configured to transmit a burst of several packets in raw, before expecting any response from the other party. In such a case, the polling mechanism supports several pollings of an SPR/IDR, one after the other.

3.2.4. PPMA vs. CSMA

The PPMA technology, implemented in the ASWipLL system, outweighs the IEEE 802.11 CSMA protocol used by many BWA products.

The CSMA protocol "listens" to the transmission media before transmitting data. If "noise" is detected, then no data is transmitted. This mechanism is called "Collision Avoidance" (CA). However, if after a certain time, "noise" is still detected, the packet is transmitted regardless, with a chance of data collisions with concurrent users. Therefore, the more users the lower the network efficiency and performance due to a high BER.

In the 802.11 CSMA protocol, each network device performs CSMA locally. Therefore, there is no central control of granting bandwidth, controlling delays, and prioritizing different applications.

The graph in Figure 3-1 compares PPMA with CSMA in regard to network efficiency related to number of subscribers.

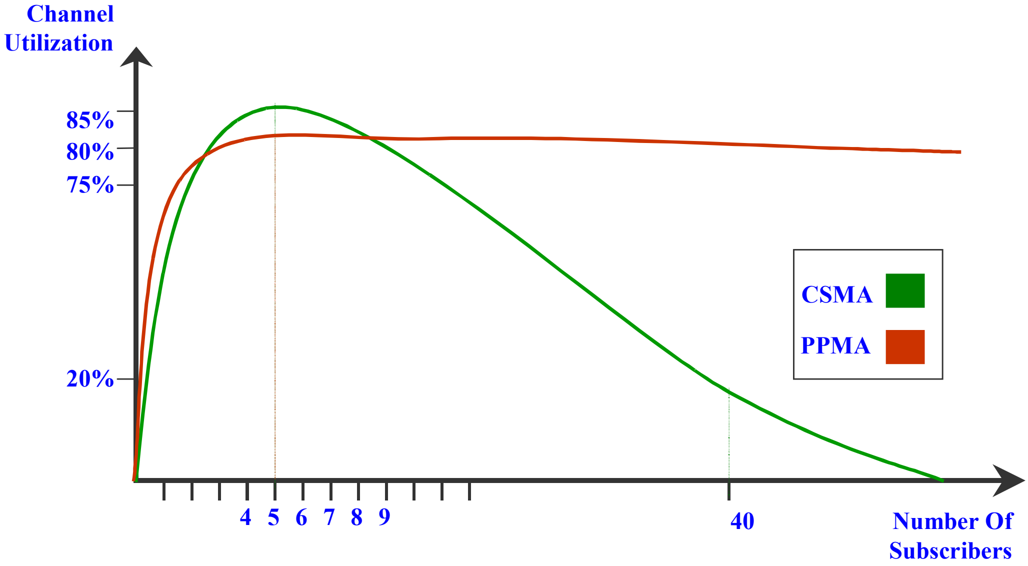


Figure 3-1: PPMA vs. 802.11 (CSMA) in network efficiency as the number of subscribers increase

As depicted in the figure, CSMA depends on the number of subscribers, while PPMA is not affected at all. In CSMA, as the number of subscribers increase, so the channel utilization decreases.

Table 3-1 lists the advantages of PPMA over 802.11.

Table 3-1: Advantages of Airspan's PPMA over 802.11 CSMA

	802.11 CSMA	PPMA
Access method	Carrier Sense	Centrally Coordinated
Maximum number of concurrent transmitting stations	4 to 7: More sessions degrade the performance of the network	50: The traffic is manageable by the base station
Modes of operation	Collision Avoidance	Preemptive Polling Multiple Access or adaptive Time Division Multiple Access (adaptive TDMA)
Support for Quality of Service	No	Embedded in the protocol
Operation under interference	Reduced performance due to delay added to packets, and the BER	None
Originally designed for	Wireless LAN systems, and indoor use.	Point-to-multipoint wireless local loop (WLL) systems
Near/far phenomenon	Yes. Subscribers near the base station receive better performance than subscribers far away.	No. Subscribers receive the same service quality regardless of their distance from the base station.
Re-transmission of packets	No	Yes

4

ASWipLL Networking

The ASWipLL system provides extensive networking capabilities, supporting the following main networking features:

- IP Routing
- PPPoE Bridging
- 802.1Q/p
- Transparent Bridging
- Quality of Service
- Bandwidth Management
- Security

4.1. IP Routing

ASWipLL can operate in one of the following two modes:

- IP routing and point-to-point over Ethernet (PPPoE)
- Transparent bridging

When ordering the ASWipLL system, the required mode must be specified. However, it is possible to later change modes by local configuration.

ASWipLL provides IP routing based on layer 3 of the Open System Interconnection (OSI) standard (see Table 4-1). ASWipLL's BSR, PPR, SPR, and IDR devices route IP traffic according to routing algorithms, routing tables, and routing considerations. IP routing allows for easy, logical network segmentation, since each LAN is assigned a different IP subnet address. Therefore, all users on a subscriber's LAN have IP addresses that belong to the same IP subnet. The subscriber's default router (often referred to as the default gateway) is the SPR/IDR.

Table 4-1: ASWipLL hardware - OSI model perspective

ASWipLL device	Description	OSI Layer
BSR, PPR	• IP router and PPPoE bridge, or • Transparent bridge	2 and 3
SPR, IDR	• IP router and PPPoE bridge, or • Transparent bridge	2 and 3
BSDU	Layer 2 switch	2
SDA-4S	Ethernet switch	2
SDA-4H, SDA-1, SDA-1 Type II	Ethernet hub	1

The BSR, PPR, SPR, and IDR devices implement static IP routing. The BSR's/PPR's routing table consists of up to 350 routing entries, supporting up to 350 IP networks or IP subnets in its routing table. The SPR's/IDR's routing table consists of up to 16 routing entries.

The following subsections discuss the features and advantages supported by ASWipLL's IP routing.

4.1.1. Multiple IP Subnets

ASWipLL's SPRs/IDRs can contain numerous IP addresses on each LAN port, allowing multiple IP subnets. This is useful for defining multiple groups of users on the same physical LAN, or when using a second layer LAN switch that supports Virtual LANs (VLANs). Each VLAN can be assigned its own IP subnet, and traffic among VLANs is enabled through the SPR/IDR. In such scenarios, the SPR/IDR provides "one-leg routing" on its LAN port. The SPR/IDR can also use IP filters as a security mechanism between IP hosts in the LAN.

4.1.2. Increased Network Efficiency - No Broadcast Packets

IP routing increases the network efficiency by eliminating the need to send broadcast packets over the wireless network. Therefore, ASWipLL's support for IP routing is a key differentiator over competing fixed broadband wireless systems that are based on bridging.

4.1.3. Support for DHCP Relay Agent

ASWipLL, as an IP router, also supports Dynamic Host Configuration Protocol (DHCP) relay agent functionality, by transferring DHCP packets over the network. DHCP protocol allows dynamic allocation of IP addresses and other IP host parameters to hosts such as Windows-based PCs.

4.1.4. Eliminates Need for External Routers

Since ASWipLL's SPR/IDR is also an IP router, an additional third-party IP router at the subscriber's site is not required. In contrast, competing fixed broadband wireless solutions based on bridging, either suffer from the typical disadvantages of bridges, or require an additional third-party dual-LAN IP router at the subscriber's site. This need for an additional IP router increases the cost of the solution, and makes network management more complex.

4.1.5. Interoperability with Third-Party IP Routers

The ASWipLL system, as an IP router, is interoperable with third-party IP routers. ASWipLL Base Station equipment provides easy connectivity to third-party IP routers to provide, for example, E1 connections to the backbone. This connection is via ASWipLL's 10BaseT or Fast Ethernet ports. ASWipLL provides quick-and-easy configuration for ASWipLL IP routing and third-party IP routing.

4.1.6. Efficient Air IP Subnet Addressing

An IP router has each of its ports assigned to a different IP network or subnet. The BSR, PPR, SPR, and IDR ports that interface on the wireless side (i.e. air) must be assigned IP subnet addresses. The ASWipLL operator can define these "air" ports in one of two ways:

- **Non-economical:** IP addresses of the Air subnet ports are fixed ranging from 192.168.0.0 to 192.168.255.255 (see RFC 1918). Therefore, this mode provides Class C subnetting for all BSRs. This means that 254 addresses are available to choose for one BSR. Thus, many addresses are "wasted" (not used).

- **Economical:** IP addresses of the Air subnet ports of BSRs and SPRs are user-defined. This mode increases the flexibility of ASWipLL. It permits more efficient use of IP addresses in the user's network and often avoids a need for changing IP addresses in a pre-existing network. A user with private IP addresses from the range of 192.168.0.0 does not have to change IP addresses in the network when installing ASWipLL.

The Economical mode provides the subnet address 255.255.255.252, thereby, providing a total of four IP addresses, where only two of the addresses can be used for ASWipLL devices: one for the BSR and one for the SPR.

The Economical addressing is as follows:

BSR side	SPR side
192.168.*x*.1	192.168.*x*.2

where *x* is the SPR index number associated with the BSR in the ASWipLL database.

In the example in Figure 4-1, the air subnet addresses are automatically defined as **192.168.x.1** at the BSR side, and **192.168.x.2** at the SPR/IDR side. The WAN router requires static entries in its routing table for the different remote networks (for **70.x.x.x** and **80.x.x.x**).

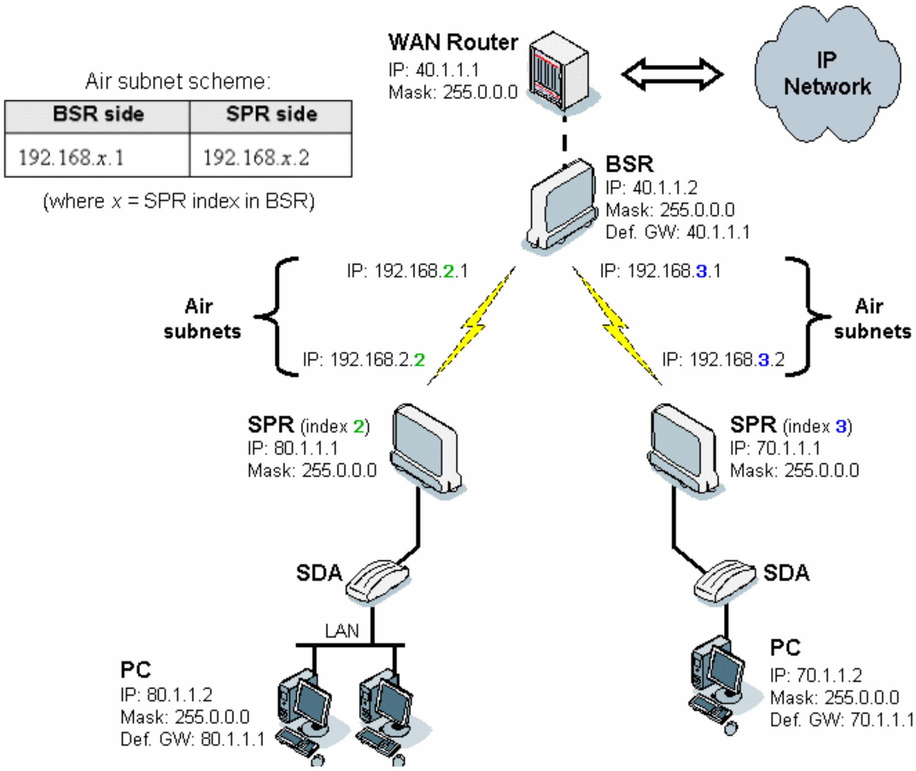


Figure 4-1: IP Air subnet addressing in a typical ASWipLL configuration

Figure 4-1 illustrates the following IP addressing configurations:

- Each subscriber's LAN contains a different IP network or subnet (in the example, **80.x.x.x** and **70.x.x.x** for SPR 1, and SPR 2, respectively).
- The SPR/IDR is the default gateway for the PCs on the SPR's/IDR's LAN. In the case of an RGW, the SPR/IDR is also the default gateway for the RGW.
- The SPR's/IDR's default gateway is the BSR/PPR.
- The BSR's default gateway is the WAN router
- Air addresses of BSR, PPR, SPR, and IDR are configured by the operator or defined automatically.

4.1.7. RFC 1918

Address allocation permits full network layer connectivity among all hosts inside an enterprise as well as among all public hosts of different enterprises. Using private Internet address space is costly due to the need to renumber hosts and networks between public and private.

The industry standard is that whenever possible, users of unregistered (or "dirty") networks use the reserved addresses in RFC 1918 on any networks inside the firewall.

The RFC 1918 addresses that can be used are:

- Class A: **10.x.x.x**
- Class B range: **172.16.0.0 to 172.31.255.255**
- Class C range: **192.168.x.y**

The advantages of using these addresses inside the firewall are twofold:

- Internal IP networks can "grow" without fear of running out of addresses
- There is no longer a risk of inadvertently using other networks' legitimate addresses

For example, if PCs use the Class C range of 192.31.7.0 for network addresses inside a firewall, the PCs will be unable to connect to other devices with a legitimate IP address such as 192.31.7.31. This is because the PC attempts to connect to a device inside your firewall that does not exist.

4.2. PPPoE Bridging

ASWipLL supports Point-to-Point Protocol over Ethernet (PPPoE) bridging. PPPoE is a standard specification for connecting subscribers on an Ethernet connection to the Internet through a common broadband medium (e.g. wireless).

ASWipLL's PPPoE solution assumes that the PPPoE clients are located behind the SPRs/IDRs—single or multiple clients—and that the PPPoE server—Broadband Remote Access Server (BRAS)—is located behind the BSR.

ASWipLL bridges PPPoE traffic as follows:

- SPR/IDR forwards upstream and downstream PPPoE unicast packets
- SPR/IDR forwards upstream broadcast PPPoE packets
- SPR/IDR contains a MAC table for PPPoE sessions:
    - The BSR tracks the PPPoE sessions. Once a PPPoE session ends successfully, the relevant entry is erased from the MAC table to permit new sessions.
    - When a PPPoE session terminates unsuccessfully, the MAC table invokes an aging mechanism. By default, aging is 60 minutes—but this is configurable.
- BSR is an OSI Layer 2, PPPoE aware, and learning bridge
- BSR forwards all upstream PPPoE packets, and forwards all downstream PPPoE unicast packets

Figure 4-2 displays ASWipLL's implementation of PPPoE for Internet access and VoIP.

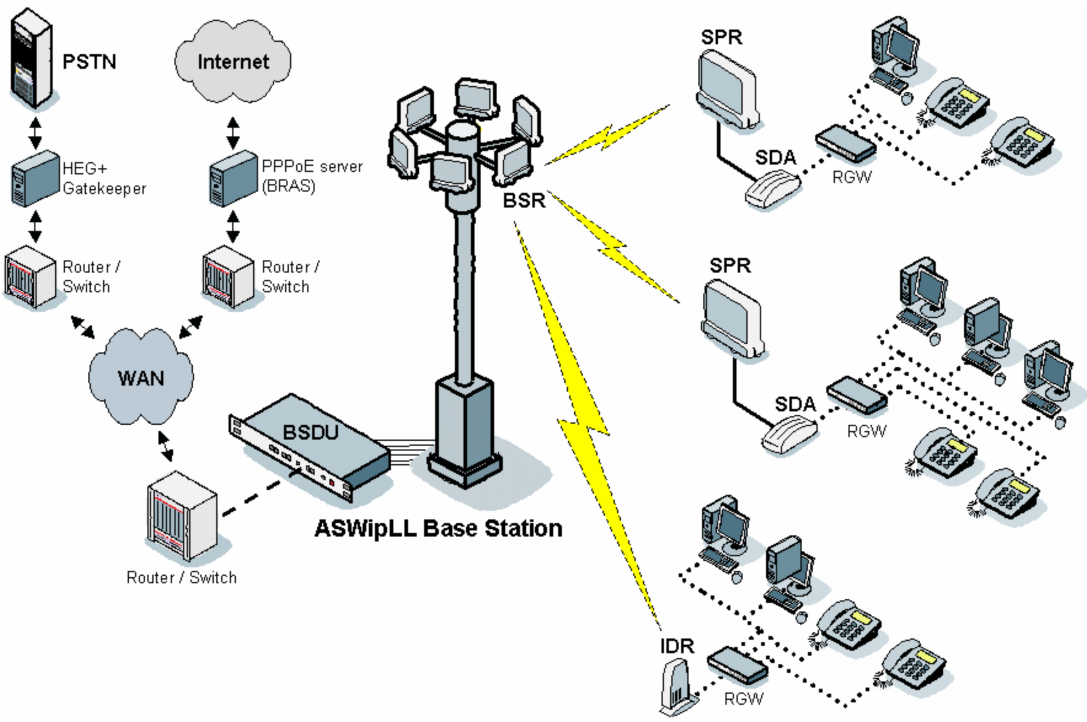


Figure 4-2: ASWipLL's PPPoE for Internet access and VoIP

4.2.1. PPPoE Limitations

The limitations of PPPoE in the ASWipLL system includes the following:

- PPPoE software runs only over ASWipLL 4M hardware
- BSR supports a maximum of 128 simultaneous PPPoE sessions
- IP filters and PPPoE are not supported simultaneously

4.2.2. PPPoE Bridging and IP Routing Support

ASWipLL can be configured to support PPPoE bridging, IP routing, or both PPPoE and IP routing. This configuration is performed using ASWipLL's management tool—WipManage. When ASWipLL is configured for both PPPoE and IP routing, ASWipLL operates as a router/bridge (or "brouter").

ASWipLL's Quality of Service (QoS) includes PPPoE as an application or protocol. This enables PPPoE to be prioritized in relation to other applications and protocols such as VoIP, TCP, UDP, FTP, and TFTP.

When ASWipLL is configured for both PPPoE and IP routing, ASWipLL performs the following:

- Bridges PPPoE
- Routes IP packets (for example, FTP, TFTP, Web, e-mail, and SNMP)

4.3. 802.1Q/p Support

ASWipLL is an IP routing system that also bridges PPPoE packets. As such, it employs mechanisms such as IP subnetting, IP routing, and IP filters to group subscribers. As an enhanced IP routing platform, ASWipLL provides all the necessary services without the need for 802.1Q/p. The 802.1Q standard creates a trunk between VLANs by adding tags; the 802.1p standard provides Quality of Service (QoS). ASWipLL provides enhanced QoS based on IP addresses, protocols (such as TCP, UDP, and ICMP), and applications (such as Web, Telnet, and SNMP).

However, ASWipLL also supports 802.1Q and 802.1p in an IP routing environment to support networks with the following configurations:

- Existing equipment in the customer's network that supports 802.1Q
- ATM and FR switches using 802.1Q for mapping VLANs to virtual circuits (VC)

- Multiprotocol Label Switching (MPLS) routers using 802.1Q tags
- Creating Virtual Private Networks (VPNs) using 802.1Q (although IPSec is the leading technology for secured VPNs in IP environments)

Figure 4-3 displays the ASWipLL system's 802.1Q VLAN support.

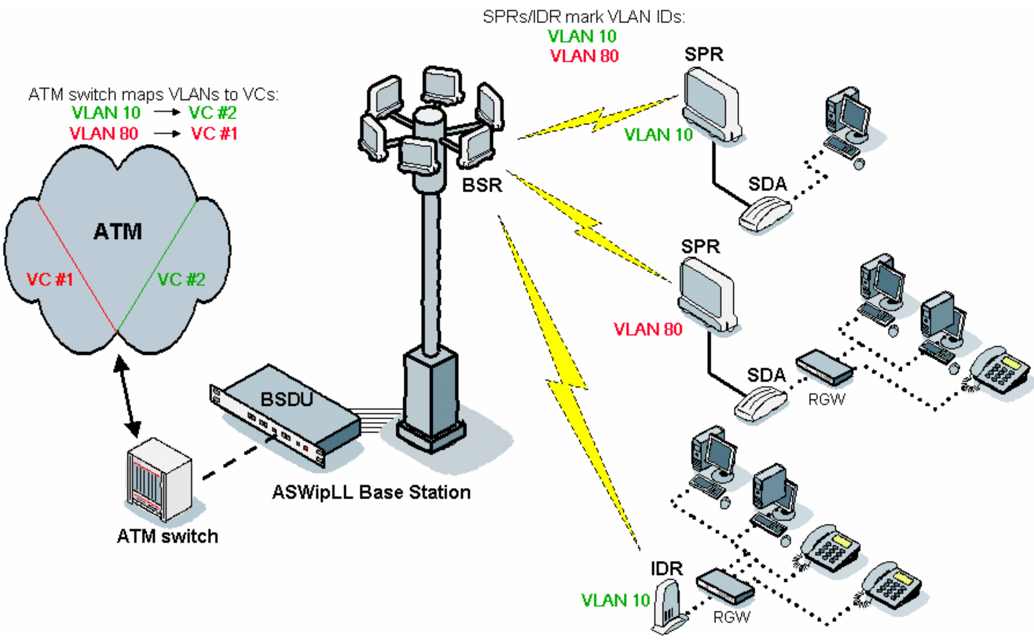


Figure 4-3: ATM switch using VLAN tag assignment for SPRs/IDRs

Table 4-2 compares ASWipLL's IP routing to 802.1Q/p.

Table 4-2: IP Routing vs. 802.1Q/p

Feature	IP routing	802.1Q/p
Creating groups of users	IP subnets	VLANs
Allowing connectivity between groups of users	IP routing	Using the same VLAN ID in the tag
Forbidding connectivity between groups of users	IP filters	Using different VLAN IDs in the tags
Quality of Service	IP-based QoS	802.1p
End-to-end QoS	DiffServ / TOS	802.1p

4.3.1. IP Routing

ASWipLL supports 802.1Q in an IP routing environment. Despite ASWipLL being an IP router, it also allows the routed IP packets to be tagged by 802.1Q tags. In addition, BSR and SPR/IDR prioritize packets based on 802.1p, and SPRs/IDRs can even tag and untag routed IP packets.

ASWipLL handles IEEE 802.1Q-based packets as they pass through the system, in one of the following ways:

- Transfers the IEEE 802.1Q tagged IP frames through the system—this is useful when different elements in the network (e.g. LAN switches in the CPE) tag and untag the packets permitted by ASWipLL.
- Adds/removes a single IEEE 802.1Q tag to the outgoing/incoming packets – this is useful when ASWipLL is requested to create tags, and untag them. SPR/IDR tags packets when they leave towards the BSR. When packets arrive at the SPR/IDR from the BSR, the SPR/IDR verifies that they have the correct tag, and if so, untags them and allows the packets entry.

ASWipLL also allows the user to configure rules to map 802.1p into ASWipLL's QoS feature, thereby allowing end-to-end QoS.

4.3.2. PPPoE

ASWipLL also supports 802.1Q in a PPPoE environment. Both the BSR and SPR/IDR can prioritize packets based on 802.1p. 802.1Q allows PPPoE packets to be tagged (and untagged) by the SPR/IDR. Each SPR/IDR can create two different tags: one for IP, the other for PPPoE. This is useful when using IP for voice (VoIP) and PPPoE for data. This allows the ATM, FR, or MPLS routers/switches to use the VLAN tags to easily distinguish voice from data traffic.

Notes:
1) 802.1Q/p for PPPoE is supported only over "4 Mbps hardware" BSRs and SPRs (similar to PPPoE bridging).
2) 802.1Q/p for PPPoE is supported only when IP filters are not used.

4.4. Transparent Bridging

ASWipLL supports transparent bridging, where all devices may share the same IP subnet address.

The ASWipLL system is a "learning" transparent bridge providing up to 1,024 MAC addresses per BSR/PPR (including MAC addresses of SPRs/IDRs), and up to 128 MAC addresses per SPR/IDR. The ASWipLL BSR/PPR devices need only to "learn" MAC addresses on its air port, and does not need to learn MAC addresses on its LAN port. This is made possible by the BSR's/PPR's connectivity to ASWipLL's Ethernet LAN switch (BSDU or SDA-4S) or a router, which "learns" the MAC addresses of ASWipLL radio devices.

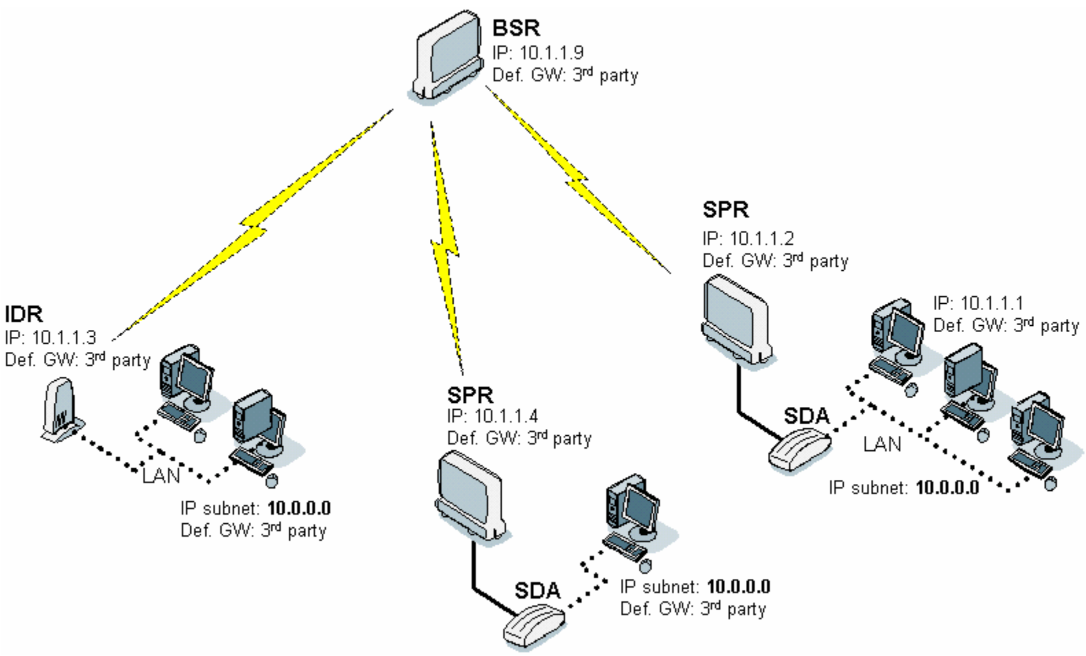


Figure 4-4: Simplistic example of ASWipLL's transparent bridging

In Figure 4-4, all the ASWipLL devices belong to the same subnet, a fundamental characteristics of transparent bridging. SPR/IDR in tag/untag mode, tags transmitted packets over-the-air with a VLAN ID, and untags received traffic from over-the-air, if the packets contain the correct VLAN ID.

ASWipLL's transparent bridging provides the following advantages:

- Fully transparent, connectionless network (one logical network)
- Self-learning mechanism of MAC addresses of all devices
- Simple and easy IP address schemes for ASWipLL's subscriber devices (i.e. SPRs/IDRs)
- Reduces complexity of IP addressing (as all devices are in the same subnet)
- Reduces traffic and improves network response time

Note: Transparent bridging does not support IP filtering.

4.5. Quality of Service

ASWipLL's Quality of Service (QoS) feature allows the operator to define priorities for each service type to ensure that each service is handled efficiently.

Quality of Service setup for the SPR/IDR and BSR/PPR is similar. The only difference is that BSR's QoS is pertinent to downlinks (traffic from the BSR to all SPRs associated with the BSR); SPR's QoS is pertinent to uplinks (traffic from the SPR to the BSR.

ASWipLL QoS are governed by the following:

- **Network type:**
  - **IP:** all IP packets
  - **PPPoE Discovery:** broadcast packets concerned with PPPoE
  - **PPPoE Session:** PPPoE data packets
  - **Others:** all packets except the above.

- **Transport protocols:**
  - TCP
  - UDP
  - ICMP
- **Applications:** based on transport protocol (e.g. TCP) and port number. For example, FTP (Transport = TCP; port = 21).
- **IP addresses**: packets originating from specific IP addresses

ASWipLL prioritizes this traffic based on the following two parameters:

- **Class (traffic priority):** Range 0 through 6. Class determines the relevant importance of a packet, the higher the value, the higher the importance. Highest class is typically assigned to VoIP and video packets.
- **Stamp:** Stamp refers to the Time-To-Live (TTL) assigned to the packet. The lower the TTL, the higher the priority. After expiration, the packet is discarded. When a packet arrives from the Ethernet network the system recognizes the type of packet and assigns it with an ASWipLL Time-To-Live (TTL) value. TTL determines which packets go first, where packets share the same priority. Higher priority packets always go first regardless of the TTL of lower priority packets. The stamp range is from 3 through 4,000 milliseconds.

In addition, ASWipLL allows you to cross-map (or customize) 802.1p and DiffServ/TOS prioritization levels. For example, you can define that for DiffServ/TOS priority level 1, ASWipLL will assign its own priority level of 2.

Figure 4-5 shows the concept of QoS, where certain applications require more network resources than others.

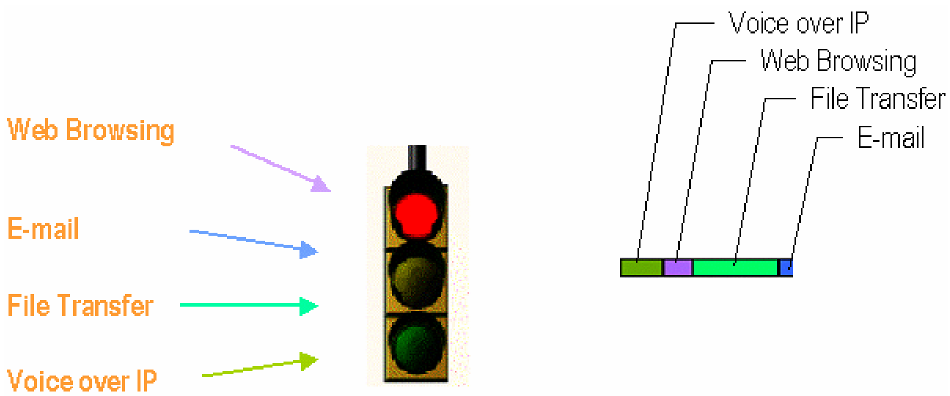


Figure 4-5: ASWipLL QoS Concept

When a packet arrives from the Ethernet network to an SPR/IDR, ASWipLL identifies the packet type and assigns it a TTL value. TTL determines which packets go first when packets have the same priority level. Each packet is marked whether critical or not, to determine if it should be sent or dropped when TTL expires. Higher priority packets are always sent first, regardless of the TTL of lower priority packets.

Note: When setting priority for a specific IP address, QoS for BSR is according to source; QoS for SPR is according to destination.

4.5.1. ASWipLL End-to-End QoS

In the world of IP, there are two conceptual methods for QoS:

- **Guaranteed QoS**
- **Differentiated QoS (DiffServ)**

In guaranteed QoS, parameters of each flow have explicit values to guarantee QoS parameters. IP Integrated Services (IntServ) and Recourse Reservation Protocol (RSVP) provide guaranteed QoS solutions, but they are not scalable. They waste bandwidth, require new hardware and software in routers, and require that applications be QoS aware.

A more practical approach is provided by DiffServ, where:

- Traffic is classified in "classes" (as opposed to specific, independent "flows")
- Relative priorities are defined

If all elements in the network support DiffServ/TOS, then end-to-end QoS is available. This is the reason for using DiffServ/TOS in IP phones, Residential Gateways (RGWs), routers, and head-end gateways. These network elements either mark DiffServ/TOS bits and prioritize packets based on them, or simply prioritize packets based on DiffServ/TOS.

MultiProtocol Label Switching (MPLS) provides an ideal solution for forwarding packets in the backbone, and providing QoS and VPN services. MPLS differs from standard routing in that it relates not only to IP addresses, but also to other criteria such as DiffServ/TOS marking. Thus, DiffServ/TOS is useful for both traffic engineering as well as criteria for MPLS rules.

4.5.1.1. DiffServ/TOS

ASWipLL provides a solution for voice and data with an enhanced QoS mechanism. ASWipLL's DiffServ/TOS provides end-to-end QoS. Elements in the network of different vendors mark DiffServ/TOS bits and use DiffServ/TOS bits as another criterion for QoS. The BSR/PPR and SPR/IDR can map specific DiffServ/TOS bits into ASWipLL's QoS priorities.

By using the ASWipLL management tool (i.e. WipManage), the operator can map DiffServ/TOS markings to ASWipLL's QoS. As shown in Figure 4-6, ASWipLL is linked to the IP/MPLS/ATM backbone via a router/switch. The backbone router, like ASWipLL, can use DiffServ/TOS bits for QoS. For MPLS, the backbone router can use DiffServ/TOS bits as the criteria for its rules.

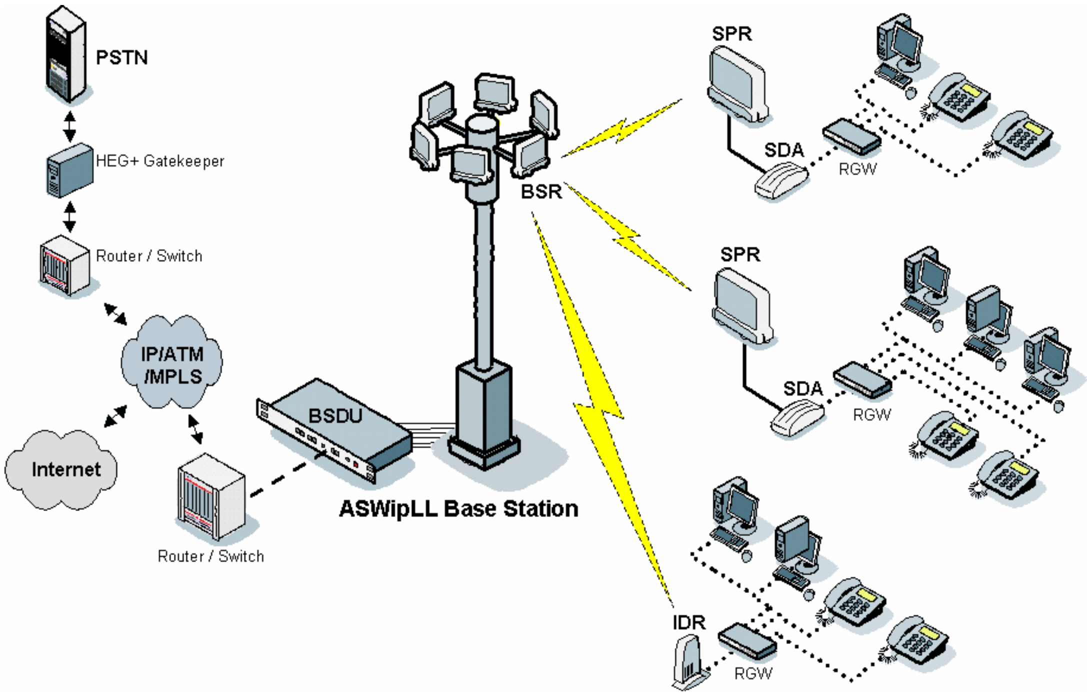


Figure 4-6: ASWipLL DiffServ/TOS links

4.5.1.2. 802.1p

ASWipLL handles the IEEE 802.1Q/p-based packets as they go through the system in one of two ways:

- Transfers the IEEE 802.1Q/p tagged IP frames through the system. This is useful when different elements in the network (for example, RGWs and LAN switches in the CPE) tag and untag the IP packets permitted by ASWipLL. It translates the priorities of 802.1p into ASWipLL's QoS so that ASWipLL can provide end-to-end QoS.

- Adds/removes a single IEEE 802.1Q/p tag to the outgoing/incoming packets. This is useful when ASWipLL is requested to create tags, and untag them. SPR/IDR tags packets when they leave towards the BSR. When packets arrive at the SPR/IDR from the BSR, the SPR/IDR verifies that they have the correct tag, and if so, untags them and allows the packets entry.

In IP routing mode, the SPR/IDR can tag/untag IP packets with one VLAN ID, and tag/untag PPPoE with another VLAN ID. In transparent bridging mode, the SPR/IDR can tag/untag all packets with one VLAN ID.

4.6. Bandwidth Management

ASWipLL provides enhanced bandwidth management mechanisms by implementing the following functionality:

- **Committed Information Rate** CIR)
- **Maximum Information Rate** (MIR)
- **VoIP bandwidth priority**
- **CIR proportional degradation**
- **Fairness**

4.6.1. MIR and CIR

The ASWipLL system allows operators to manage the bandwidth policy allocated to their subscribers, assuring optimal network performance. ASWipLL allows operators to provide a maximum amount of bandwidth to a subscriber, referred as *maximum information rate* (MIR). In addition, ASWipLL allows operators to provide a guaranteed bandwidth, referred as *committed information rate (*CIR), to a subscriber even when the network is loaded. Typically, subscribers pay different rates for the levels of desired bandwidth commitment. Different levels of CIR and MIR can be sold as different services (for example, Platinum, Gold, Silver, and Bronze) at different prices.

ASWipLL allows the operator to implement CIR and MIR in the following two modes:

- **Asymmetric CIR/MIR:** different CIR and MIR values for uplink (i.e. traffic from subscriber to Base Station) than for CIR and MIR downlink. This is useful in applications such as cable TV (CATV), where a higher downlink bandwidth is needed than in uplink.

- **Aggregated CIR/MIR:** values defined for the sum of the uplink and downlink traffic. This is useful when there exists varying bandwidth demands on the network, different applications, or different user types.

4.6.1.1. MIR

ASWipLL's MIR feature allows the operator to define a maximum bandwidth for the subscriber, which cannot be exceeded (see Figure 4-7).

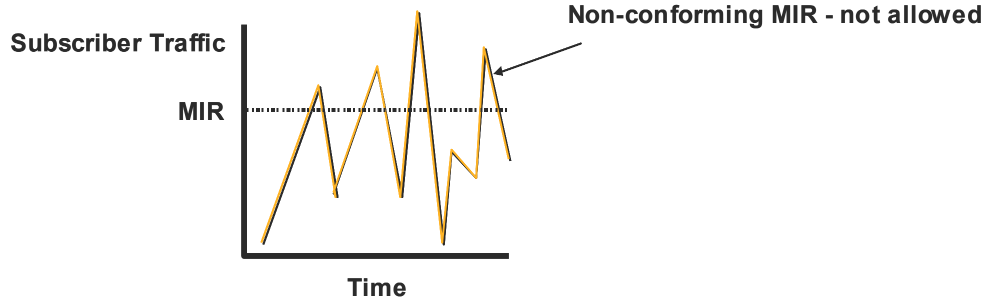


Figure 4-7: MIR for a subscriber

ASWipLL's MIR feature includes the following:

- Operators use MIR to limit the subscriber's bandwidth for the following reasons:
  - To sell different levels of service
  - To avoid unreasonable customer expectations in a network that is being gradually developed and populated—when the number of subscribers in a cell increases, bandwidth per subscriber decrease.
- BSR, as the cell coordinator, is responsible for the assignment of bandwidth for the SPRs/IDRs. Therefore, MIR definitions are part of BSR's configuration.
- BSR calculates and allocates the bandwidth to the SPRs/IDRs every eight milliseconds (however, a packet transmission is completed even if it takes longer). Bandwidth allocation every eight milliseconds compensates for the previous time period.
- MIR values are set as ***n****64 kbps, where ***n*** is an integer number (***n*** = 1, 2, 3,… and so on).

- MIR values are defined per SPR/IDR.
- Bandwidth cannot exceed the MIR.
- Bandwidth limitation is applied to the sum of the uplink and downlink or separate values for uplink and downlink.

4.6.1.2. CIR

ASWipLL's CIR feature allows the operator to define a guaranteed bandwidth to a subscriber, even when the network is loaded (see Figure 4-8).

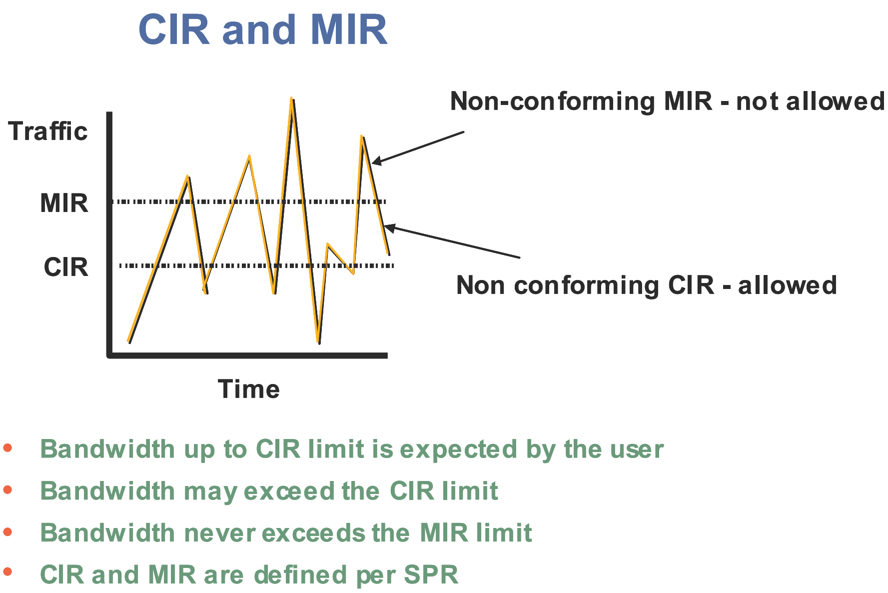


Figure 4-8: ASWipLL's Committed Information Rate (CIR)

The CIR features include the following:

- If the subscriber's bandwidth requirement is less than or equal to the CIR, then ASWipLL aspires to meet this bandwidth requirement.
- Bandwidth may exceed the CIR limit. If the subscriber's bandwidth requirement is greater than the CIR, and available bandwidth exists, the ASWipLL system can provide more bandwidth than the CIR level.

- Subscribers often understand CIR as being "guaranteed bandwidth", but sometimes the system cannot guarantee this bandwidth. Therefore, operators declare that CIR is guaranteed at an ***x*** percentage of the time.
- BSR, as the cell coordinator, is responsible for bandwidth assignment to the SPRs/IDRs. Therefore, CIR definitions are part of BSR's configuration.
- BSR calculates and allocates the bandwidth to the SPRs/IDRs every eight milliseconds (however, a packet transmission is completed even if it takes longer). Bandwidth allocation every eight milliseconds compensates for the previous time period.
- CIR values are set as ***n****64 kbps, where ***n*** is an integer number or zero (***n*** = 0, 1, 2, …and so on)
- CIR values are defined per SPR/IDR.

4.6.2. CIR Proportional Degradation

When the total CIR of active SPRs and IDRs is greater than the available bandwidth for data (CIR overbooking), ASWipLL implements its CIR Proportional Degradation feature.

CIR overbooking can derive from the following:

- Large number of active SPRs/IDRs (running data)
- Large number of VoIP calls
- Modem rate decreases to an unexpected value
- Poor RF conditions (this may be relevant even in a, for example, fixed modem rate)

In the event of CIR overbooking, the CIR decreases in proportion to the configured CIR of the SPRs/IDRs. In other words, each SPR/IDR receives bandwidth that equals to ***k*configured CIR***, where 0<**k**<1 (**k** is referred to as the proportion factor). Therefore, the proportion between CIR bandwidth values of all SPRs/IDRs is maintained.

Table 4-3 shows an example of CIR proportional degradation for three active subscribers (SPRs) where the modem rate is 3 Mbps and data packets are used.

Table 4-3: Example of CIR Proportional Degradation

	3.2 Mbps	2.4 Mbps due to 80% efficiency (80%*3 Mbps)
SPR	CIR (Mbps)	CIR Proportional Degradation (Mbps) k = 2.4/3.2
A	1.28	2.4/3.2 * 1.28 = 0.96
B	1.28	2.4/3.2 * 1.28 = 0.96
C	0.64	2.4/3.2 * 0.64 = 0.48

4.6.3. ASWipLL CIR/MIR and VoIP

ASWipLL supports voice and data. Voice is provided by Voice-over-IP (VoIP) gateways or residential gateways (RGW) located at subscribers and central locations in the network. VoIP sessions consume bandwidth that depends on the codec (e.g. G.711, G.723, G.729).

ASWipLL provides as much bandwidth as required for VoIP calls, regardless of MIR. For standard data, however, ASWipLL provides bandwidth based on the CIR/MIR definitions (see Section 4.6.1, "MIR and CIR"). Even if the subscriber utilizes maximum bandwidth for standard data applications, according to the defined MIR (e.g. 128 Kbps), the subscriber can still make VoIP calls (e.g. 128 Kbps for data, plus ***x*** Kbps for VoIP). Therefore, the bandwidth allocated for VoIP calls is not at the expense of the bandwidth for the standard data.

ASWipLL assigns a higher bandwidth priority for VoIP calls than bandwidth for data applications. In other words, allocating bandwidth for VoIP calls has higher priority than meeting the CIR/MIR settings. Therefore, in a cell that is loaded with VoIP calls, meeting the CIR/MIR requirements may be difficult. In such a scenario, CIR proportional degradation occurs (see Section 4.6.2, "CIR Proportional Degradation"). However, careful network and capacity planning minimizes the occurrences of such a scenario.

The ASWipLL operator may prefer a different approach by configuring ASWipLL to include VoIP bandwidth within the CIR/MIR definitions.

4.6.4. ASWipLL CIR/MIR and Modem Rate

The ASWipLL BSR may automatically decrease the modem rate for communicating with each of the SPRs/IDRs. The changes in modem rate are according to the following schemes:

- 4 Mbps / 1.33 Mbps
- 3 Mbps / 2 Mbps / 1 Mbps

Subscribers' MIR and CIR are maintained despite modem rate decreases. However, if CIR overbooking occurs, CIR proportional degradation occurs (see Section 4.6.2, "CIR Proportional Degradation").

4.6.5. Fairness

For certain IP applications such as FTP, a subscriber that demands high bandwidth (due to, for example, possessing many PCs) can cause bandwidth reduction to other subscribers who are less active.

Some operators or service providers prefer to divide available bandwidth equally among subscribers, irrespective of the subscribers' number of active PCs and applications. ASWipLL's Fairness feature achieves this bandwidth division, by allocating equal bandwidth to all active subscribers. Figure 4-9 shows a typical implementation of ASWipLL's Fairness feature. In the example, Subscriber #1, despite requiring more bandwidth, receives the same bandwidth (i.e. 1.2 Mbps) as Subscriber #2.

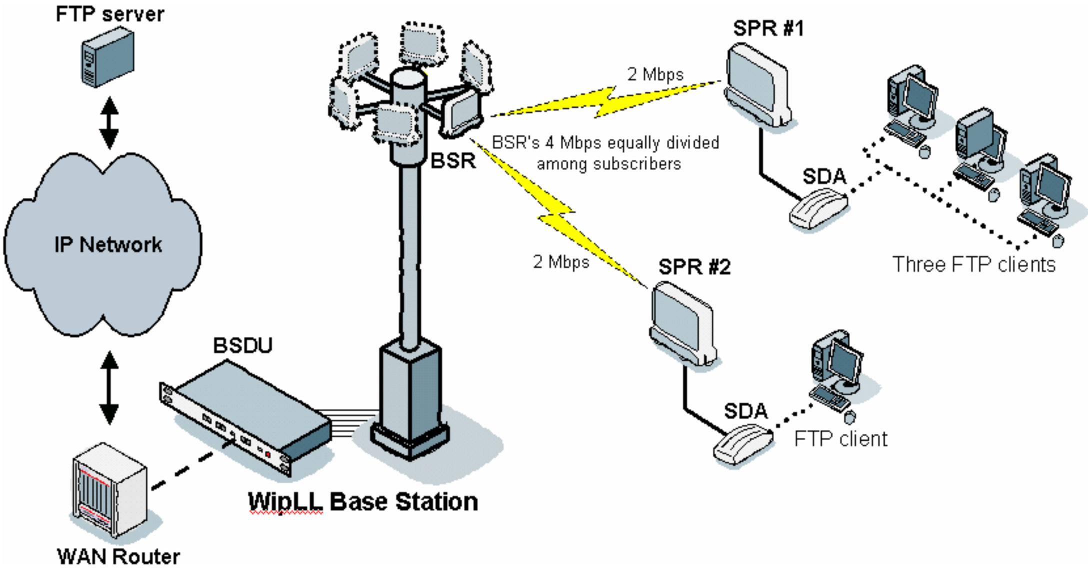


Figure 4-9: Example of ASWipLL's Fairness Feature

ASWipLL implements Fairness in the following way:

- The BSR divides the available effective throughput equally among the active SPRs/IDRs at a given time
- If there are ***n*** SPRs/IDRs, each device is allocated with 1/***n*** of the available bandwidth. For example, a 3 Mbps BSR with 3 subscribers is 3/3 = 1.
- The number of active users is calculated every four milliseconds.

4.7. Security

The ASWipLL system provides extensive security features to ensure security on all levels of the OSI Model. Figure 4-10 displays ASWipLL's security features for the various OSI layers.

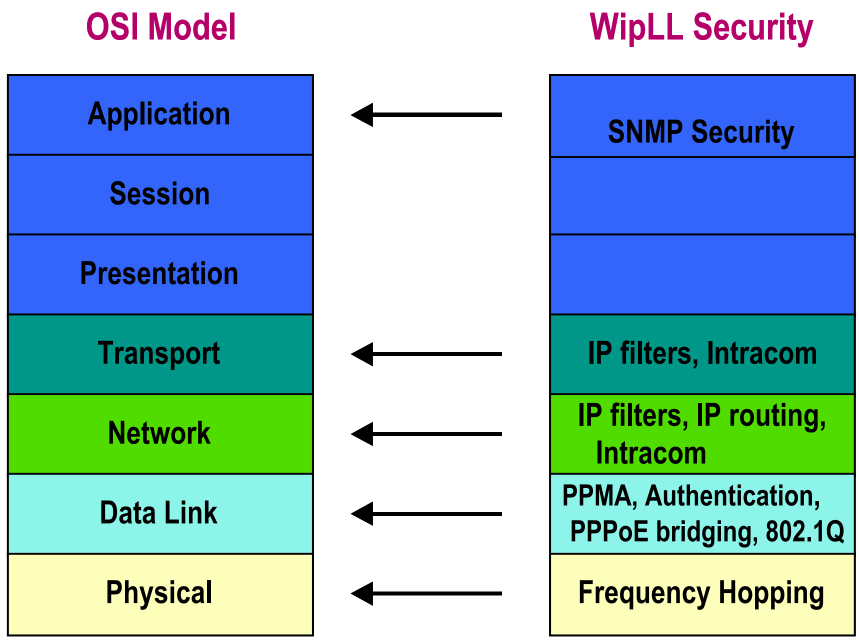


Figure 4-10: ASWipLL Security features for the OSI layers

4.7.1. Layer 1: Frequency Hopping

ASWipLL's implementation of the Frequency Hopping Spread Spectrum (FHSS) technology provides security at OSI's Layer 1. In FHSS, the carrier wave frequency at which the information signal is transmitted is continuously changing. Therefore, it is very difficult to detect the transmission frequency at any given time; and if detected, the frequency changes within a few milliseconds, rendering external interceptions almost impossible.

ASWipLL's BSR stores up to 64 frequency tables: each table storing up to 96 frequencies. The BSR centrally coordinates the entire cell.

Frequency Hopping Spread Spectrum provides the following security features:

- Multiple access capability
- Interference rejection (relevant in unlicensed band only)
- Protection against multipath interference
- Anti-jamming
- Low probability of interception (LPI)
- Privacy

4.7.2. Layer 2

The ASWipLL system provides OSI Layer 2 security, with regards to the following:

- Preemptive Polling Multiple Access (PPMA)
- Authentication
- Encryption
- PPPoE bridging (authentication)
- 802.1Q (VLAN security)

4.7.2.1. PPMA

ASWipLL implements a proprietary MAC protocol called Preemptive Polling Multiple Access (PPMA), which provides high-level security (see Chapter 3, "ASWipLL's Air MAC Protocol").

4.7.2.2. Authentication (PPMA)

To receive service from the BSR, the SPR/IDR must be registered with the BSR. This registration is based on the SPR's/IDR's **index number** and the BSR's **unique air MAC address**, configured by the ASWipLL management tool (WipManage).

ASWipLL’s authentication operates in the following manner:

1. When an SPR/IDR attempts to register with the BSR, the SPR/IDR sends a "Request to Send" message.
2. The BSR then checks if the SPR’s/IDR’s address is listed in the BSR’s "Allowed SPRs/IDRs" list. This list is maintained by ASWipLL’s network management system.
3. If the SPR/IDR is listed, then an "Association" message is sent to the SPR/IDR. If the SPR/IDR is not included in the "Allowed SPRs/IDRs" list, or the address it provides the BSR is incorrect, then no message is sent to the SPR/IDR, and the association process is terminated.
4. After the SPR/IDR receives the BSR's "Association" message, the SPR/IDR then sends its own information to the BSR, and is now considered "associated" and can start sending and receiving messages.

4.7.2.3. Encryption

ASWipLL’s PPMA supports key-encrypted authentication based on a public key (defined in each BSR) and a private key (defined in each SPR/IDR).

4.7.2.4. PPPoE Bridging

The PPPoE standard allows authentication and billing for data applications. It is exported to broadband technologies from dial-up networks (that use PPP for authentication).

The PPPoE clients communicate with a PPPoE server (BRAS) that is connected to the Internet. The PPPoE server typically terminates the PPPoE sessions. The PPPoE server performs authentication. ASWipLL bridges PPPoE traffic (running on ASWipLL 4M only, and without IP filters), thereby providing the ASWipLL operator with a powerful security tool.

ASWipLL also provides 802.1Q support for the bridged PPPoE traffic.

4.7.2.5. 802.1Q

ASWipLL implements the 802.1Q standard for VLAN security. ASWipLL allows the creation of VLANs and trunks between VLANs. Subscribers belonging to a specific VLAN are not allowed to communicate with subscribers in a different VLAN.

ASWipLL handles the IEEE 802.1Q-based packets in one of the following ways:

- Transfers the IEEE 802.1Q tagged frames through the system. This is useful when different elements in the network (e.g. LAN switches in the CPE) tag and untag the packets permitted by ASWipLL.
- Adds and removes an IEEE 802.1Q tag to and from the outgoing and incoming packets, respectively. This is useful when ASWipLL is requested to tag and untag the packets. SPR/IDR tags the packets when they leave toward the BSR/PPR. When packets arrive at the SPR/IDR from the BSR/PPR, the SPR/IDR verifies that they contain the correct tags. If they contain the correct tags, the SPR/IDR untags them, and then allows them to pass through.

In the IP routing mode, each SPR/IDR can support a VLAN tag for routed IP traffic, and a VLAN tag for bridged PPPoE traffic. ASWipLL is always an IP router for tagged and untagged packets, and a PPPoE bridge for tagged and untagged packets.

In transparent bridging mode, SPR/IDR tag/untag all packets with only one VLAN ID. When combined with SDA-4S/VLtag it can tag/untag packets with four VLAN IDs.

4.7.3. Layers 3 to 7

ASWipLL's BSR and SPR/IDR devices are IP routers, and also provide network security by supporting IP filtering and Intracom features. In addition, ASWipLL provides 802.1Q support for routed IP traffic or any bridged traffic (layer 2).

4.7.3.1. IP Filtering

Using IP filtering[3], the ASWipLL operator can specify traffic based on IP addresses, protocols, and applications to permit or deny through ASWipLL. IP filtering relates to downlink and uplink traffic. This provides efficient use of bandwidth as well as security.

IP filters are based on a combination of the following criteria:

- Destination IP address
- Source IP address
- Destination IP subnet
- Source IP subnet
- Protocol type (TCP, UDP, and ICMP)
- Port number: defines the application (For example, Telnet, e-mail, and Web)

ASWipLL's IP filtering reduces the need for an external firewall, or firewall capabilities in a central router.

IP filters are defined using ASWipLL's user-friendly SNMP-based NMS (WipManage). For a detailed description on defining IP filters, please refer to the *WipManage User's Guide.*

Note: The IP filters feature is applicable only when the ASWipLL system operates in the IP routing mode.

[3] **Note**: IP Filtering is supported only by BSRs and SPRs with 4 Mbps hardware, and where PPPoE is not implemented.

4.7.3.2. Intracom

Intracom provides ASWipLL security for layers 3 to 7. Typically, traffic among ASWipLL subscribers (SPR/IDR to SPR/IDR) is sent via the BSR.

The Intracom feature allows two routing modes:

- **Regular**: traffic among SPRs/IDRs is routed through the BSR.
- **Centralized**: traffic among SPRs/IDRs is routed through the BSR to a central router or firewall that is connected to the BSR (or BSDU) via Ethernet (or Fast Ethernet). The central router or firewall includes security definitions based on, for example, IP addresses, IP subnets, UDP, TCP, and ICMP ports. If traffic is allowed according to these definitions, it is routed back to the BSR, which then routes it to the relevant SPR/IDR.

By using ASWipLL's WipManage management tool, the operator can define Intracom.

Note: The Intracom feature is applicable only when the ASWipLL system operates in the IP routing mode.

4.7.3.3. Management (SNMP)

ASWipLL's WipManage NMS can be used to *Get* and *Set* ASWipLL's configuration parameters, traps, and statistics. To avoid unauthorized use of WipManage, the following security measurements are provided:

- Management of ASWipLL can be restricted to NMS stations with specific IP addresses (up to five) that are configured for the ASWipLL devices.
- Password login ensures only authorized operators. Access rights include Read and/or Write login passwords.
- If an incorrect password is entered, an authentication trap is sent to WipManage.

5

ASWipLL Voice-over-IP Solution

The ASWipLL system enables customers the flexibility of migration from a data-only network to an integrated Voice-over-IP and data network. The ASWipLL system's VoIP feature provides interoperability with almost any vendor or platform.

5.1. Main Features

The ASWipLL VoIP feature supports the following:

- Interoperability with third-party products such as residential gateways (RGW), access gateways, gatekeepers, and softswitches.
- Supports standard VoIP protocols such as H.323, SIP, MGCP, and MEGACO.
- Supports various speech codecs and capabilities such as G.711, G.723.1, G.729a/b, silence suppression, and T.38 (for fax).
- Supports different network interfaces such as SS7, GR-303, and V5.2 over E1, allowing deployment in multi-national markets.
- Enhanced Quality of Service (QoS) mechanism to ensure voice is prioritized over data. The SPR/IDR prioritizes the transmission of voice packets over data packets. In addition, the BSR, which centrally co-ordinates the SPRs/IDRs, provides higher priority to SPRs/IDRs with voice packets than SPRs/IDRs with data packets.

5.2. Interconnection with PSTN

The ASWipLL voice solution provides interoperability with any third-party IP-to-PSTN network gateway. The use of the IP-to-PSTN gateway allows ASWipLL operators seamless PSTN connectivity such as SS7, GR-303, and V5.2 over E1, allowing deployment in multi-national markets.

5.3. Number of Supported VoIP Calls

The number of VoIP calls supported by a BSR depends on the following:

- Type of VoIP equipment
- Speech codec (e.g. G.711, G.723, or G.729)
- Use (or lack) of silence suppression
- Sampling interval configured in the VoIP products (e.g. 20 msec, 30 msec, 40 msec, other)
- RF conditions

Table 5-1 shows the number of simultaneous calls supported by a BSR, dependant on various parameters.

Table 5-1: Number of simultaneous calls supported by a BSR

Codec	Rate	Sampling interval	Simultaneous calls supported	
			Silence suppression disabled	Silence suppression enabled
G.711	64 Kbps	20 msec	10	15
		30 msec	13	19
		40 msec	15	22
G.729B	8 Kbps	20 msec	14	21
		30 msec	21	30
		40 msec	28	40

Codec	Rate	Sampling interval	Simultaneous calls supported	
			Silence suppression disabled	Silence suppression enabled
G.723.1	5.3 Kbps	30 msec	22	31
		60 msec	42	60

Notes:

- All numbers refer to a 4-Mbps modem and are based on mathematical analysis.
- Silence suppression figures are based on a conservative assumption of 30% efficiency of the silence suppression implementation.

5.4. VoIP Related Capabilities

The ASWipLL system provides different VoIP related capabilities:

- **ASWipLL can be configured to support QoS based on DiffServ/TOS, 802.1Q/p, UDP/TCP port numbers, or IP addresses:**
  - If the residential gateway (RGW) supports Type Of Service (TOS), then ASWipLL's QoS can be based on TOS.
  - If the RGW supports 802.1p, then ASWipLL's QoS can be based on 802.1p.
  - If the RGW does not support TOS and 802.1p, then UDP/TCP port numbers or IP addresses can be used for QoS to prioritize VoIP over data, and ensure reasonable delay and jitter.
- **Bandwidth Management (CIR and MIR) providing highest priority of bandwidth for VoIP:**

  If more VoIP calls occur than is expected, CIR proportional degradation occurs—every subscriber receives less of its CIR, but CIR proportions between subscribers are maintained. For example, subscriber A has a CIR of 128 Kbps, and subscriber B has a CIR of 64 Kbps. However, due to too many VoIP calls, insufficient bandwidth occurs to meet the CIR requirements. Subsequently, proportional degradation in CIR occurs: subscriber A receives k*128 Kbps, and subscriber B receives k*64 Kbps, where k is the degradation factor.

- **Different VLAN tagging for VoIP and data:**

  In the IP routing mode, SPRs/IDRs at the subscriber sites use separate VLAN tags for VoIP and for data (PPPoE network). The VoIP tag is later mapped by an ATM switch, MPLS switch, or FR access device to a certain VC/path dedicated for voice. The data (PPPoE) tag is later mapped by ATM/MPLS switch, or FRAD to another VC.

- **Uninterruptible Power Supply** (UPS)-based solutions for the subscriber site can be provided (voice and data subscriber often require battery backup).

- **Base Station Power System** (BSPS) provides N+1 or N+2 power charger redundancy and connectivity for Backup Batteries.

6

ASWipLL TDMoP Solution

The ASWipLL system supports TDM-over-packet (TDMoP) solutions, including the following E1/T1 and leased lines applications:

- Full E1/T1 PTP
- Fractional E1/T1 point-to-point (PTP)
- V.35 point-to-point

In these applications, ASWipLL sends the E1/T1 timeslots or V.35 traffic over a wireless Ethernet path between the ASWipLL radios. E1/T1 over Ethernet (TDMoP) is accomplished using the ASWipLL SDA-E1 device, which is an E1/T1-Ethernet converter. V.35 over Ethernet is accomplished using a third-party V.35-Ethernet converter (manufactured by Resolute). These devices are located behind the ASWipLL radios. Thus, ASWipLL provides transparent E1/T1-over-Ethernet and V.35-over-Ethernet traffic conversion.

E1 is the European format for digital transmission. E1 carries signals at 2 Mbps (32 channels at 64 Kbps, with 2 channels reserved for signaling and controlling). T1 is the North American format for digital transmission. T1 carries signals at 1.544 Mbps (24 channels at 64 Kbps). E1 and T1 lines may be interconnected for international use.

6.1. TDMoP Applications

The subsections below describe the following supported TDMoP applications:

- Full E1/T1 Point-to-Point
- Fractional E1 Point-to-Point

- Point-to-Point V.35

6.1.1. Full E1/T1 Point-to-Point

ASWipLL provides full E1/T1 over an Ethernet wireless infrastructure. ASWipLL, when used in an Ethernet environment, typically provides a maximum link (uplink and downlink combined) of up to 3.3 Mbps. Therefore, to support speeds greater than 1.5 Mbps full duplex (i.e. full E1 is 2 Mbps full duplex – 30 timeslots), a double ASWipLL PTP link is required. This link consists of two PPRs and two SPRs.

In this application, an E1/T1-to-Ethernet converter (ETC) at each end converts E1 to Ethernet, and vice versa. In this configuration PPRs and SPRs require a 4-MHz separation for TDD or a 2-MHz separation for FDD. In addition, ASWipLL acts as an IP router to differentiate between uplink and downlink and, thereby, providing the required higher throughput.

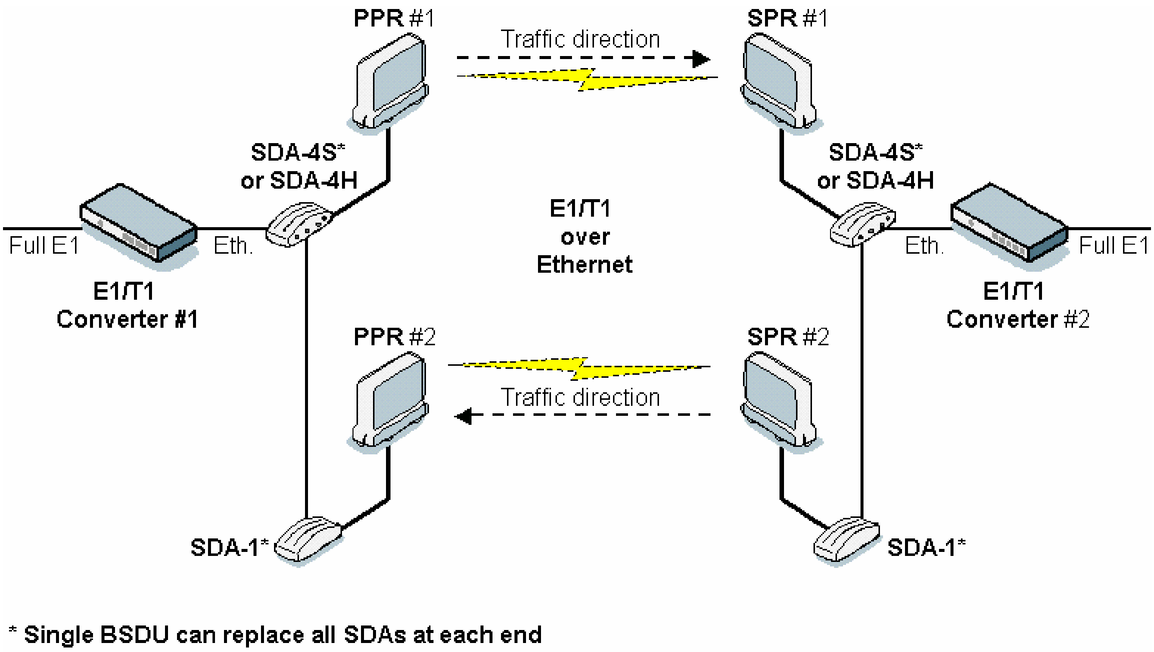


Figure 6-1: Full E1/T1 over Ethernet

The configuration and flow of traffic depicted in the above figure is as follows:

- PPR #1 is defined as default gateway for E1/T1 Converter #1. Therefore, traffic from this converter passes to PPR #1, then to SPR #1, and then to E1/T1 Converter #2.
- SPR #2 is defined as default gateway for E1/T1 Converter #2. Therefore, traffic from this converter passes to SPR #2, then to PPR #2, and then to E1/T1 Converter #1.

6.1.2. Fractional E1 Point-to-Point

ASWipLL supports fractional E1/T1 over Ethernet in a point-to-point setup. In this configuration only a single link is required and the ASWipLL SDA-E1 device is implemented at both ends.

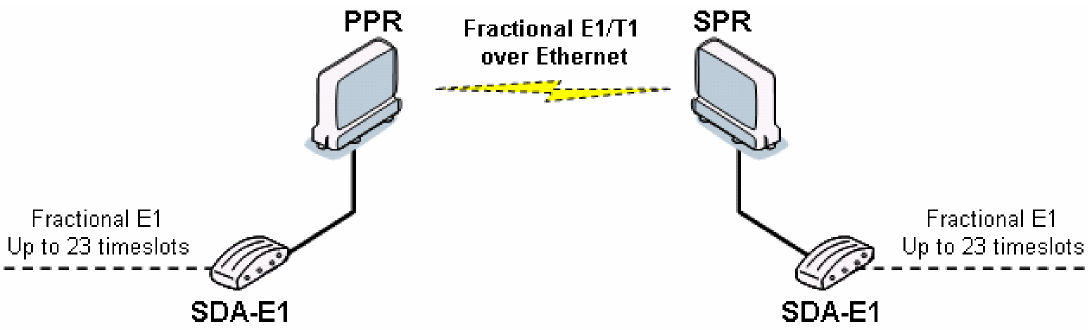


Figure 6-2: Fractional E1/T1 over Ethernet

6.1.3. Point-to-Point V.35

ASWipLL supports V.35 over Ethernet in a point-to-point setup, as displayed in the figure below.

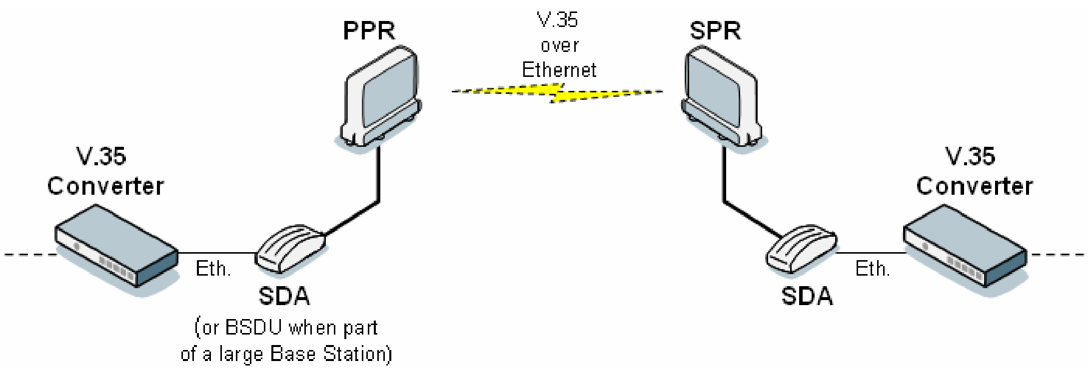


Figure 6-3: V.35 over Ethernet

6.2. SDA-E1 Device

The SDA-E1 (shown in the figure below) is an indoor, fully integrated TDM over Packet (TDMoP) device that multiplexes one fractional E1/T1 (fE1) circuit and Ethernet/IP data over a standard ASWipLL link. The SDA-E1 is thus, an E1/T1-Ethernet converter with standard SDA features.

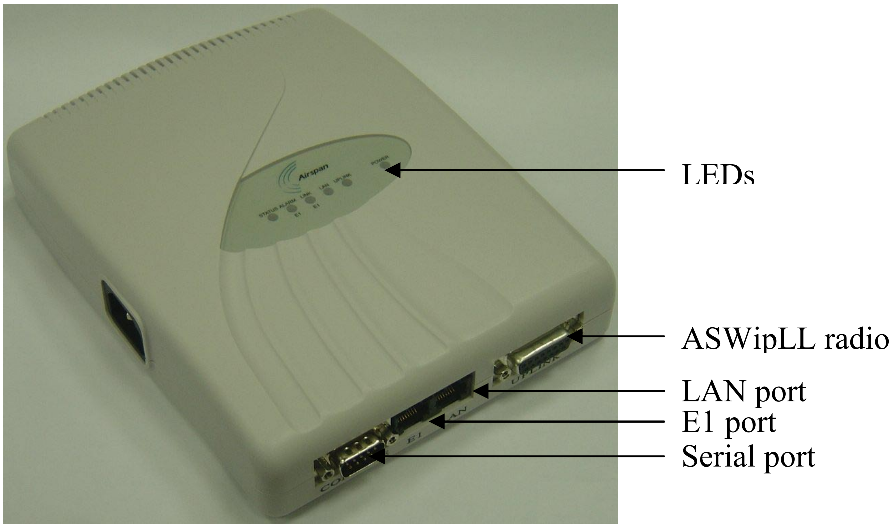


Figure 6-4: SDA-E1

An SDA-E1, at the near-end, converts TDM bitstream into packets and transmits them over ASWipLL's packet network. An SDA-E1 at the far-end, receives the packets and converts the payload back into a TDM bitstream. The TDM packets can be multiplexed with Ethernet data packets.

6.2.1. Hardware Interfaces

The SDA-E1 provides various hardware interfaces, as listed in the following table.

Table 6-1: SDA-E1 hardware interfaces

Port	Label	Interface
15-pin D-type female	**UPLINK**	Provides 10BaseT and power interfaces with radio (i.e. BSR, PPR, SPR)
8-pin RJ-45	**LAN**	10/100BaseT auto-negotiation with subscriber's PC or network (typically used for management)
8-pin RJ-45	**E1**	E1/T1 interface
9-pin D-type male	**CONSOLE**	Local serial configuration (Telnet, CLI, third-party Arranto console)
AC power	--	Power supplied by external AC/DC power adapter connected to mains

6.2.2. Connector Pinouts

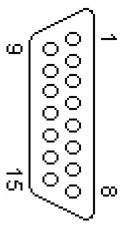
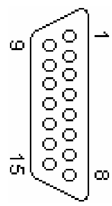
This section describes the pinouts for the following connectors:

- 15-pin D-type
- 8-pin RJ-45 (E1)
- 8-pin RJ-45 (LAN)
- 9-pin D-type

6.2.2.1. 15-Pin D-Type

The table below describes the SDA-E1's 15-pin D-type connector pinouts.

Table 6-2: SDA-E1 connector pinouts for 15-pin D-type

Straight-through CAT-5 UTP PVC 4 Pair 24 AWG cables							
15-pin D-type male	ASWipLL radio		Wire color	Wire pair	SDA-E1		15-pin D-type male
	Pin	Function			Pin	Function	
	1	+48 VDC	Blue / White	1	1	+48 VDC	
	2	48 RTN	Blue		2	48 RTN	
	3	Tx+	Orange / White	2	3	Rx+	
	4	Tx-	Orange		4	Rx-	
	5	Rx+	Green / White	3	5	Tx+	
	6	Rx-	Green		6	Tx-	

Note: Pins not mentioned are not used.

6.2.2.2. 8-Pin RJ-45 (E1)

The table below describes the SDA-E1's connector pinouts for the RJ-45 connector for E1 connectivity.

Table 6-3: SDA-E1 connector pinouts for RJ-45 connector for E1 interface

RJ-45 (straight-through cable)	
Pin	Function
1	-Rx
2	+Rx
4	-Tx
5	+Tx

Note: Pins not mentioned are not used.

6.2.2.3. 8-Pin RJ-45 (LAN)

The table below describes the SDA-E1's connector pinouts for the RJ-45 connector for LAN connectivity.

Table 6-4: SDA-E1 connector pinouts for RJ-45 connector for LAN interface

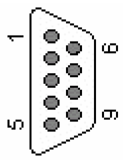
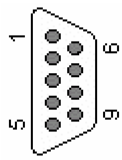
RJ-45 (straight-through cable)	
Pin	**Function**
1	+Rx
2	-Rx
3	+Tx
6	-Tx

Note: Pins not mentioned are not used.

6.2.2.4. 9-pin D-type

The table below describes the 9-pin D-type connector for the SDA-E1's **CONSOLE** port.

Table 6-5: 9-pin D-type connector pinouts for SDA-E1 serial port

Crossover cable					
SDA-E1			**PC**		
9-pin D-type female	**Pin**	**Function**	**Pin**	**Function**	**9-pin D-type female**
	2	RS232 Rx	3	Tx	
	3	RS232 Tx	2	Rx	
	5	GND	5	GND	

6.2.3. LED Indicators

The SDA-E1 provides LEDs for indicating traffic and power. The LED lights are located on the top panel.

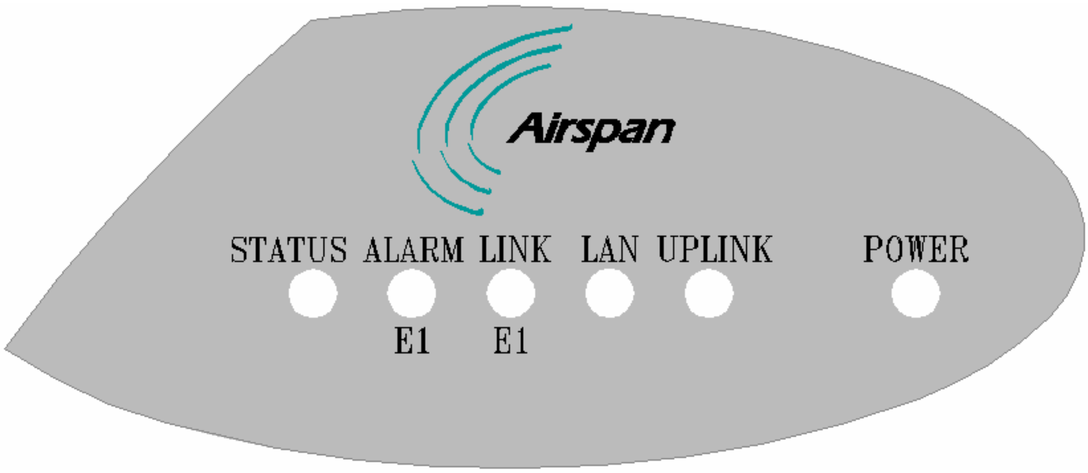


Figure 6-5: SDA-E1 LEDs located on the top panel

The tables below describe the SDA-E1 LED indicators.

Table 6-6: Description of E1 LEDs

E1 LEDs		Meaning
Link E1	Alarm E1	
Off	Off	Port not configured or administratively down
Green	Off	Normal
Green	Red	Red alarm due to framing error
Off	Red	Red alarm due to loss of carrier
Off	Yellow	Yellow alarm
Green	Flashing yellow	Blue alarm
Flashing green	yellow	Port in loopback

Table 6-7: Description of STATUS, LAN, UPLINK, AND POWER LEDs

LED	Color	Status	Meaning
Status	--	Off	Not a normal state after SDA-E1 is initiated
	Red	On	Failure during power-on self-test
	Flashing Red	On	Failure during functional test
	Green	On	System is operating correctly: both TDM receive and transmit data paths are working with peer module and E1/T1 port.
	Flashing Green	On	One of the data paths is not operating correctly
	Alternating **Red** / **Green**	On	Functional test in progress with no failures
LAN	**Green**	On	Network link (i.e. SDA-E1 with LAN) active
	Yellow	On	Link connected
	--	Off	Not connected
Uplink	**Green**	On	Radio link (e.g. BSR with SDA-E1) active
	Yellow	On	Link connected
	--	Off	Not connected
POWER	**Green**	On	Power received
		Off	No power received

6.2.4. Network Management

The SDA-E1 can be managed and configured by one of the following methods:

- Third-party Management Console: a PC-based application that can configure the SDA-E1 via serial or network connection. The Management Console can also monitor performance and define default parameters used to initialize a standalone unit.

- Command Line Interface (CLI): provides access to all of the user modifiable parameters. The CLI can be run from a serial terminal (HyperTerminal) or a PC via a serial interface or via a network connection (e.g. Telnet).

6.2.5. Specifications

The following table lists the specifications of the SDA-E1:

Table 6-8: SDA-E1 specifications

Parameter	Description
Interfaces	• 10BaseT with radio • E1/T1 • LAN (10/100BaseT) • Serial • Power
Ports	• 15-pin D-type: connects to ASWipLL radio (i.e. BSR, PPR, SPR) • Two 8-pin RJ-45: connection to subscriber's LAN network and E1 network • 9-pin D-type: serial interface (Telnet, CLI, third-party Arranto E1/T1 converter) • AC/DC Power connector
Environmental conditions	Temperature: 0ºC to +55ºC (32ºF to 131ºF)
Power supply	• 110-240 VAC • 50/60 Hz • 0.3 to 0.7A
Output voltage	48 VDC
Weight	0.53 kg
Dimensions (H x W x D)	200 mm (7.87 inches) x 150 mm (5.9 inches) x 40 mm (1.57 inches)

7

ASWipLL Base Station Devices

The ASWipLL Base Station is comprised of several devices (some optional) that provide the following functionalities:

- Radio communication with subscriber sites
- Interface with provider's Internet backbone
- Internal traffic switching
- Synchronization
- Power supply and power redundancy

The above functionalities are provided by the following devices (some optional and third-party devices):

- **Base Station Radio (BSR):** ASWipLL outdoor radio transceiver that provides radio communication with the subscriber sites. The BSR interfaces with the service provider's backbone through the Base Station Distribution Unit (BSDU) or Subscriber Data Adapter (SDA), depending on the number of BSRs at the Base Station.
- **Point-to-Point Radio (PPR):** ASWipLL outdoor radio transceiver similar to the BSR, but implemented in a point-to-point radio configuration, providing wireless communication with a single remote ASWipLL radio device (i.e. Subscriber Premises Radio - SPR).

- **Base Station Distribution Unit (BSDU):** ASWipLL device that interfaces between BSRs and the service provider's backbone. The BSDU also provides local switching, frequency hopping-based synchronization for BSRs, BSDUs, and Base Stations, and power to BSRs. One BSDU can serve up to six BSRs, and up to four BSDUs can be daisy-chained at a Base Station to support up to 24 BSRs.
- **GPS:** optional third-party Global Positioning System antenna that provides a satellite clock signal for synchronizing BSDUs, BSRs, and Base Stations.
- **Base Station Power System (BSPS):** optional third-party device that provides multiple BSDUs with –48 VDC power supply and power redundancy.

The area covered by a Base Station is divided into sectors. Each sector is covered by a BSR, the central coordinator of the sector. Each Base Station provides a wireless link to all subscribers in the Base Station's sector. For full coverage, several Base Stations can be set up over an extended area.

ASWipLL operates in accordance with the service provider's backbone. ASWipLL uses the provider's backbone to connect between Base Stations, and to connect to the ASWipLL management station and other resources on the network.

7.1. Base Station Radio (BSR)

The BSR is an outdoor radio transceiver providing the last-mile wireless link between the service provider's backbone and subscribers (i.e. SPRs/IDRs).

The BSR has several roles in the following OSI layers:

- MAC layer: responsible for synchronizing SPRs/IDRs regarding timing, frequency hopping sequence, authentication, and control—allowing (or refusing) data transmission in the sector.
- Network layer: performs routing between the Base Station's Ethernet network (i.e. service provider's backbone) and the SPRs. The BSR contains a routing table that can support up to 251 subscribers. BSR supports two modes of operation: IP routing and PPPoE bridging, and transparent bridging.
- Transport layer: determines how to support an application regarding bandwidth, delays, and modes of operation.

The BSRs are typically connected to the service provider's wired backbone through the BSDU's Fast Ethernet port. However, a Base Station comprised of a single BSR can be connected to the backbone through ASWipLL's SDA device. The BSRs connect to the BSDU (or SDA) through a standard 100-meter CAT-5 cable, thereby, eliminating the need for expensive RF/IF cables.

Note: The indoor unit to outdoor unit (IDU/ODU) connectivity can be extended to 200 meters by using a 100-meter CAT 5 cable joined by an Ethernet hub, or to 300 meters using three 100-meter CAT 7 cables joined by Ethernet hubs.

A typical ASWipLL Base Station contains multiple BSRs. With internal antennas, each BSR can cover a sector with an azimuth angle (yaw) of 60 degrees. Therefore, six BSRs can provide 360-degree coverage of the entire sector, as shown below.

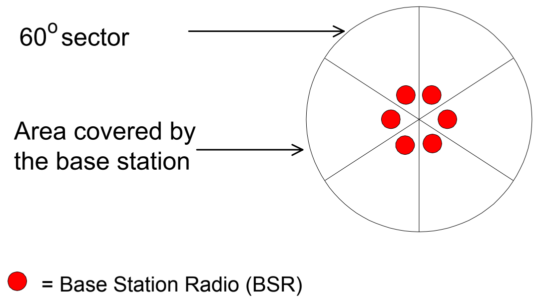


Figure 7-1: Base Station with six BSRs covering 360 degrees

Not all six sectors need be covered by BSRs. For example, at a housing development that faces open farmland, one could configure a Base Station to cover only 180 degrees to provide facilities only to a housing development.

The maximum number of BSRs that can be connected depends mainly on the radio bandwidth allocated to the system. Each BSR delivers up to 4 Mbps (net throughput of 3.2 Mbps) to be shared among a maximum of 252 subscribers located in its sector. As capacity demand grows, more BSRs can be added to service over 6,000 discrete subscriber sites, provided that the spectrum can accommodate this amount of subscribers.

The BSR is typically pole mounted (see figure below), but can be wall mounted as well, allowing optimal positioning for best reception with the subscriber sites.

Figure 7-2: Pole-mounted BSR

7.1.1. BSR Models

The BSR is available in various models, differing mainly in antenna configuration (i.e. integrated flat-panel antenna or N-type port for attaching a third-party external antenna). In addition, some BSR models with integral antennas support either horizontal or vertical polarization. The usage of these polarization options depends on the environment in which the BSR is operating. Horizontal polarized (H-pol) waves reflect better from horizontal surfaces (e.g. ground), while vertical polarized (V-pol) waves reflect better from vertical surfaces (e.g. building walls).

This explains why broadcast television uses H-pol waves while cellular technologies use V-pol waves. Therefore, it is expected that in rural areas H-pol will propagate better than V-pol, and vice versa in urban areas.

Furthermore, in an area saturated with interference generated from V-pol transmitters, the use of H-pol antenna may substantially improve the C/I (Carrier to Interference) ratio, thus improving system performance.

7.1.1.1. BSR with Integrated, Flat-Panel Antenna

This BSR model type contains an integrated (internal) flat-plate antenna(s). The number of integrated antennas depends on the operating frequency band see Chapter 2, Section 2.5, "RF Antennas".

The presence of two internal antennas provides antenna diversity, whereby the incoming signals are received by the antenna measuring the strongest received signal strength (i.e. RSSI) to overcome multi-path effects.

The front panel of the BSR model is displayed below.

Figure 7-3: BSR model with internal antennas (front panel)

The BSR model with an integrated antenna(s) is available in the following variations:

- **Standard BSR:** provides 8- through 12-dBi antenna gain, depending on operating frequency.
- **BSR with Narrow-Beam Antenna:** provides an 18-dBi antenna gain. This model is only applicable for the ASWipLL 3.*x* (3.5 GHz band) system.

7.1.1.2. BSR with N-Type Connector for Third-Party External Antenna

Airspan provides BSR models that provide an N-type connector(s) for attaching a third-party external antenna(s). The number of N-type connectors (one or two) depends on the operating frequency band.

- **BSR with one N-type connector:** for ASWipLL 5.8 (i.e. 5.8 GHz), ASWipLL 3.*x* (i.e. 3 GHz), ASWipLL 2.8 (i.e. 2.8 GHz), ASWipLL MMDS (i.e. 2.5 GHz), ASWipLL 2.4 (i.e. 2.4 GHz), ASWipLL 2.3 (i.e. 2.3 GHz), and ASWipLL 1.9.

Figure 7-4: BSR model with one N-type connector

- **BSR with two N-type connectors:** provides an option for attaching two third-party external antennas for dual antenna diversity. This model is applicable for BSRs operating in the 925-MHz (ASWipLL 925), 900-MHz (ASWipLL 900), and 700-MHz (ASWipLL 700) bands. The N-type connectors are labeled **Primary** (transmit and receive) and **Secondary** (receive only). (For the 700-MHz band, Airspan supplies either a 90° (14 dBi) or omni-directional (7 dBi) antenna.)

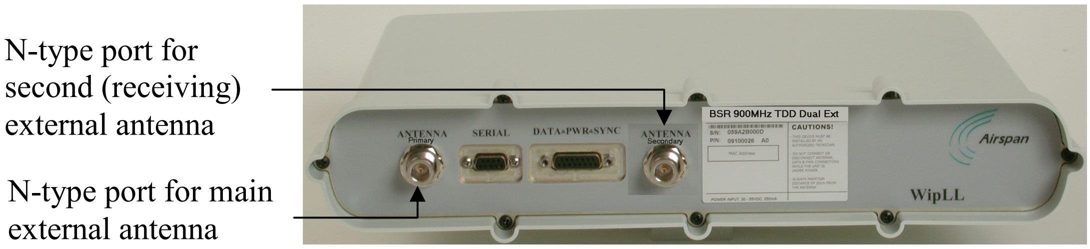


Figure 7-5: BSR model with two N-type connectors

Notes:
1) It is recommended that third-party external antennas provide 50-ohm impedance and a VSWR of less than 1:1.5.
2) BSR models with a connector(s) to attach an external antenna(s) do not contain integrated antennas.
3) An external antenna may provide a gain of 5 to 15 dBi. Compliance is the responsibility of the customer.

7.1.2. Standard Accessories

The following accessories are provided with each BSR kit:

- **Mounting kit** for pole mounting with tilting options
- **15-pin D-type** data connector for Ethernet interface
- **N-type** connector for attaching a third-party external antenna (for BSR model without an integrated antenna)

7.1.3. Hardware Interfaces

The BSR's hardware interfaces are described in the table below.

Table 7-1: BSR hardware interfaces

Port	Interface
15-pin D-type	• Ethernet (10BaseT) with the BSDU (or SDA) • Synchronization (controlled by BSDU) • Power (supplied by BSDU or SDA)
9-pin D-type	Serial (RS-232) local initial configuration (using WipConfig tool) during installation
N type (applicable only for BSR models without integrated antenna)	For attaching third-party external antennas. BSR models for the 700, 900, and 925 MHz bands provide two N-type ports.

7.1.4. Connector Pinouts

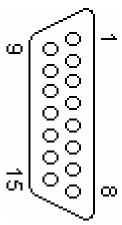
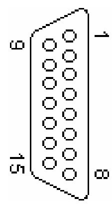
This section describes the connector pinouts for the following connectors:

- 15-pin D-type (Ethernet, synchronization, power interface)
- 9-pin D-type (serial interface)

7.1.4.1. 15-pin D-type Connector (Ethernet)

The BSR's 15-pin D-type port interfaces with the BSDU's/SDA's 15-pin D-type port through a CAT 5 cable with 15-pin D-type connectors on either side. Table 7-2 describes these connector pinouts.

Table 7-2: 15-pin D-type connector pinouts for BSR-to-BSDU cabling

Straight-through CAT-5 UTP PVC 4 Pair 24 AWG cables							
15-pin D-type male	BSR		Wire color	Wire pair	BSDU		15-pin D-type male
	Pin	Function			Pin	Function	
	1	+48 VDC	Blue / White	1	1	+48 VDC	
	2	48 RTN	Blue		2	48 RTN	
	3	Tx+	Orange / White	2	3	Rx+	
	4	Tx-	Orange		4	Rx-	
	5	Rx+	Green / White	3	5	Tx+	
	6	Rx-	Green		6	Tx-	
	7	Sync.+	Brown / White	4	7	Sync.+	
	8	Sync.-	Brown		8	Sync.-	

Notes:

- A CAT 5 cable connects to the 15-pin D-type port, therefore, only eight pins are used (i.e. pins 9 through 15 are not used).
- The wire color-coding described in the table (and shown in the figure below) is ASWipLL's standard for wire color-coding. However, if you implement your company's wire color-coding scheme, ensure wires are paired and twisted according to pin functions (e.g. Rx+ with Rx-).
- When the BSR is connected to an SDA, pins 7 and 8 are not used (i.e. no synchronization).

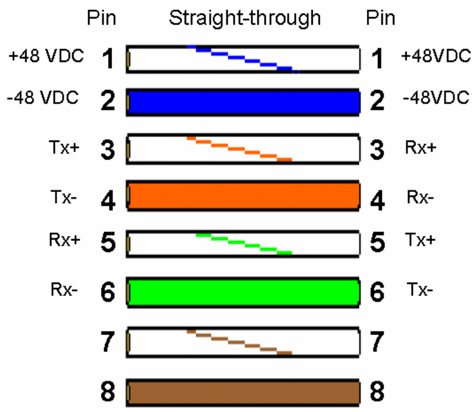


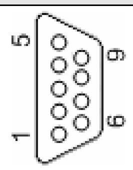
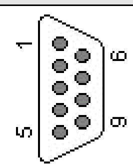
Figure 7-6: ASWipLL wire color-coding for 15-pin D-type connectors

> **Note:** The wires are twisted together in pairs, for example, blue/white with blue, and orange/white with orange. This prevents electrical interference between the transmitter pins. For example, pin 3 (Tx+; orange / white) is paired and twisted with pin 4 (Tx-; orange).

7.1.4.2. 9-pin D-type Connector (Serial)

For BSR serial configuration, the BSR's 9-pin D-type port (labeled **SERIAL**) interfaces with a PC's serial COM port. The following table describes the 9-pin D-type connector pinouts for BSR serial cabling.

Table 7-3: 9-pin D-type connector pinouts for BSR-to-PC serial connection

Crossover cable					
BSR			PC		
9-pin D-type male	Pin	Function	Pin	Function	9-pin D-type female
	2	RS232 Rx	3	Tx	
	3	RS232 Tx	2	Rx	
	5	GND	5	GND	

Note: For BSR serial configuration, the BSR must remain connected to the BSDU/SDA (i.e. the BSR's 15-pin D-type port remains connected to the BSDU's/SDA's 15-pin D-type port).

7.1.5. Network Management

The BSR is managed remotely by ASWipLL's NMS program (i.e. WipManage) from anywhere that provides IP connectivity to the BSR. ASWipLL's SNMP-based WipManage program uses standard proprietary MIBs for configuring and managing the BSR. WipManage provides the BSR with fault, configuration, performance, and security management. For a detailed description on WipManage, see Chapter 12, "Management System".

7.1.6. Technical Specifications

The tables below describe the BSR technical specifications.

Table 7-4: BSR and MAC specifications

Parameter	Value	Comment
Operating frequency range	5.8 GHz; 3.x GHz; 2.8 GHz; MMDS; 2.4 GHz; 2.3 GHz; 1.5 GHz; 1.9 GHz; 925 MHz; 900 MHz; 700 MHz	Other ranges available for trial
Spectrum spreading method	Frequency hopping	Per ETSI EN301 253
Duplex method	• Time Division Duplexing (TDD): 5.8 GHz, 3.*x* GHz, 2.8 GHz, MMDS, 2.4 GHz, 2.3 GHz, 925 MHz, 900 MHz, 700 MHz • Frequency Division Duplexing (FDD): 3.*x* GHz, 1.9 GHz; 1.5 GHz	
Transmit bit rates	Up to 4 Mbps	BER and distance dependent
Channel spacing	1 MHz	For 3.5 GHz the channel spacing can be 1 MHz or 1.75 MHz
Output power from the BSR	• 31 dBm: 700 MHz • 30 dBm: 1.9 GHz, 1.5 GHz, 925 MHz, 900 MHz • 27 dBm: 5.8 GHz, 3.*x* GHz, 2.8 GHz, MMDS, 2.4 GHz, 2.3 GHz	Depending on local regulations (e.g. FCC—see Appendix G, "Declaration of FCC Conformity"), maximum output power can be configured at the factory

Parameter	Value	Comment
Modulation method	8-level CPFSK	
Channel access method	PPMA / Adaptive TDMA	
Protocol efficiency	Up to 80%	For large data packets
Number of SPR/IDR per BSR	Up to 251	

Table 7-5: BSR EMC and radio standards compliance

Parameter	Value
Radio Standards Compliance	• ETSI EN 300 328-1 • ETSI EN 301 253 • FCC part 15 • RSS139 • Telec
EMC	• ETSI ETS 300 826 • ETSI EN 300 385 • ETSI EN 300 386-2 • ETSI ETS 300 132-2 • FCC part 15

Table 7-6: BSR agency certification

Parameter	Value
Emissions / Immunity	EN 300 339 EN 300 386-2 ETS 300 328
Safety	EN / IEC 60950
Environmental	ETS 300 019-2-x; IP66 (protected against dust and low pressure jets of water)

Table 7-7: BSR network specifications

Parameter	Value	Comment
Filtering Rate	10,500 frames/sec	At 64 byte packets
Forwarding Rate	1,300 frames/sec	At 64 byte packets
Routing table length	350 networks, including subnets	

Table 7-8: BSR power requirements

Parameter	Value	Comment
Voltage • Minimum: • Maximum:	48 VDC nominal • 30 VDC • 55 VDC	Voltage is received from the BSDU or SDA, depending on Base Station setup
Maximum Amperes:	500 mA	
Max power consumption:	15W	

Table 7-9: BSR environmental conditions

Parameter	Value	Comment
Operating temperature of outdoor units (BSR and SPR)	-30ºC to +60ºC (-22ºF to 140ºF)	Optional range of -40ºC to +70ºC
Storage temperature	-40ºC to +80ºC (-40ºF to 176ºF)	

Table 7-10: BSR network interface

Parameter	Value	Comment
Ethernet Network	UTP EIA/TIA	Category 5
Standards Compliance	ANSI/IEEE 802.3 and ISO/IEC 8802-3 10Base-T compliant	
Serial Port	RS-232	

Table 7-11: BSR physical dimensions

Parameter	Value	Comment
Height	400 mm (15.74 inches)	Excluding mounting kit
Width	317 mm (12.48 inches)	
Depth	65.5 mm (2.58 inches)	
Weight	4.7 kg	

7.2. Base Station Distribution Unit (BSDU)

The ASWipLL Base Station Distribution Unit (BSDU) provides an interface between multiple BSRs and the service provider's backbone (Wide Area Network - WAN). The BSDU provides the following functionalities:

- **Data switching:** between up to six BSRs and two 100BaseT Ethernet ports (i.e. backbone)
- **Frequency Hopping Synchronization:** between daisy-chained BSDUs and between BSRs
- **Power distribution:** provides DC power from a single –48 VDC source to six BSRs

The BSDU is designed to be installed in a standard 19-inch cabinet, and provides built-in mounting bracket flanges for mounting the BSDU into the cabinet. Figure 7-7 and Figure 7-8 display the front and rear panels of the BSDU respectively.

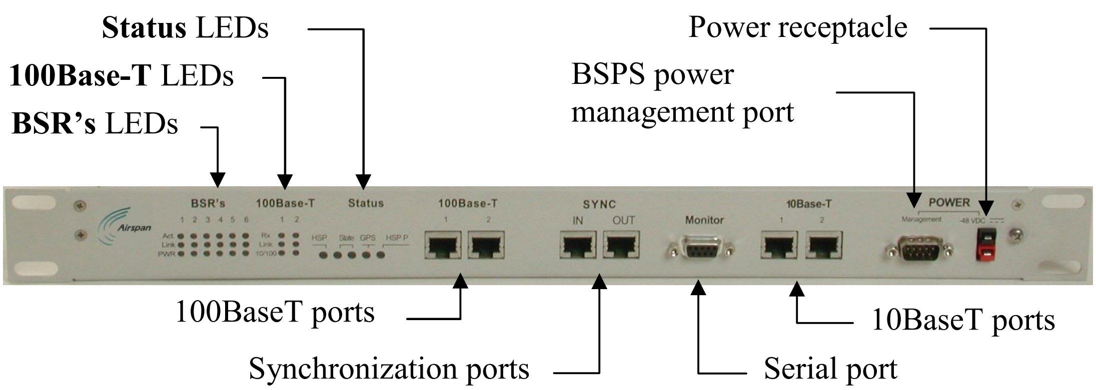


Figure 7-7: BSDU front panel

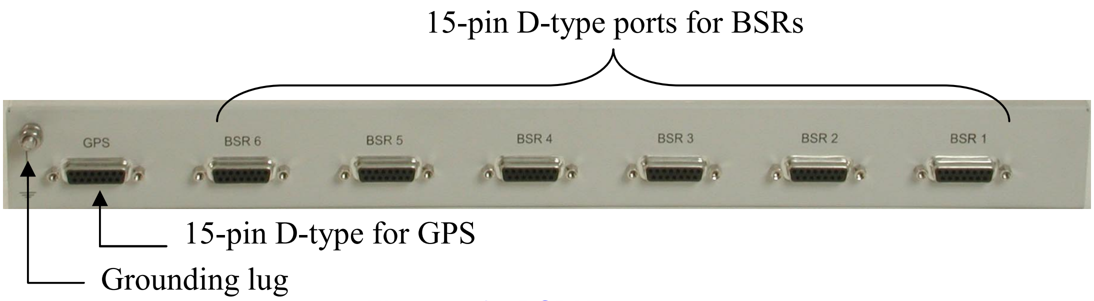


Figure 7-8: BSDU rear panel

7.2.1. Hardware Interfaces

Table 7-12 describes the BSDU ports and interfaces.

Table 7-12: BSDU hardware interfaces

Panel side	Port / connector	Label	Interface	Description
Front	8-pin RJ-45 (two)	**100Base-T**	100Base-T	Interface with provider's backbone; local IP management for daisy-chained BSDUs and BSRs if **10Base-T 1** and **10Base-T 2** ports looped
	8-pin RJ-45 (two)	**SYNC**	10Base-T	Hopping synchronization between daisy-chained BSDUs
	9-pin D-type female	**Monitor**	RS-232	BSDU serial initial configuration
	8-pin RJ-45	**10Base-T 1**	10Base-T	Local IP network management (by WipManage) of all BSRs connected to BSDU
	8-pin RJ-45	**10Base-T 2**	10Base-T	Local IP network management (by WipManage) of the BSDU
	9-pin D-type male	**Management**	RS-232	BSPS IP network management
	DC power input	**-48 VDC**	Power	–48 VDC supply from BSPS
Rear	15-pin D-type (six)	**BSR**	10Base-T	Ethernet, synchronization, and power interface with BSR
	15-pin D-type	**GPS**	GPS sync.	Interface with GPS for ASWipLL clock synchronization

7.2.2. LED Indicators

The BSDU provides LED indicators located on the BSDU's front panel (see Figure 7-7). These LEDs are grouped under the following labels:

- **BSR's**
- **100Base-T**
- **Status**

7.2.2.1. BSR's LEDs

The BSDU's **BSR's** LED indicators include three LEDs for each of the six BSR ports. These LEDs are described in Table 7-13.

Table 7-13: Description of BSR's LEDs

LED	Color	Status	Meaning
Act	Yellow	On	Ethernet activity detected on BSR port
		Off	No Ethernet activity detected on BSR port
Link	Yellow	On	Physical link exists between BSDU and BSR
		Off	No physical link exists between BSDU and BSR
PWR	Yellow	On	Power supplied to BSDU's **BSR** port
		Off	BSDU's **BSR** port is disabled by software, or port failure has occurred

7.2.2.2. 100Base-T LEDs

The BSDU's **100Base-T** LED indicators include three LEDs for each of the two 100Base-T ports. These LEDs are described in Table 7-14.

Table 7-14: Description of 100Base-T LEDs

LED	Color	Status	Meaning
Rx	Yellow	On	Data is received through the 100Base-T port
		Off	No data is received through the 100Base-T port
Link	Yellow	On	Viable physical link between the 100Base-T port and the external device to which this port connects
		Off	No physical link between 100Base-T port and external device to which this port connects
10/100	Yellow	On	Power is supplied to the 100Base-T port
		Off	No power at the 100Base-T port

7.2.2.3. Status LEDs

The BSDU's **Status** LED indicators display the status of various synchronization signals. These LEDs are described in Table 7-15.

Table 7-15: Description of Status LEDs

LED	Color	Status	Meaning
HSP (Hop Synchronization Process)	Green	On	BSDU synchronization process is active
State (two LEDs)	Green	Only right LED is on	Synchronization process is starting
		Both LEDs are on	BSDU is the master (i.e. controller) in the synchronization ring
		Only left LED is on	BSDU is a slave device
		Both LEDs are off	BSDU sync pulse lost
GPS (Global Positioning Satellite)	Green	On	GPS is connected to the BSDU
		Blinking	Receiving a satellite signal
HSP P	Green	On	Change state for the Hop Synchronization Process Pulse

7.2.3. Network Management

The BSDU can be managed remotely by ASWipLL's NMS program (i.e. WipManage) from anywhere that provides IP connectivity to the BSDU. ASWipLL's SNMP-based WipManage program uses standard proprietary MIBs and ASWipLL proprietary MIBS for managing the hop synchronization and other specific parameters. For a detailed description of WipManage, see Chapter 12, "Management System".

7.2.4. Technical Specifications

The tables below describe the BSDU technical specifications.

Table 7-16: BSDU network specifications

Parameter	Value
Filtering rate	105,000 frames/sec
Forwarding rate	62,500 frames/sec

Table 7-17: BSDU power requirements

Parameter	Value	Comment
Voltage	-48 VDC nominal	
Power consumption	Maximum 200W	Including feeding of six BSRs

Table 7-18: BSDU environmental conditions

Parameter	Value
Operating temperature	0ºC to +50ºC (32ºF to 122ºF)
Storage temperature	-40ºC to +80ºC (-40ºF to 176ºF)
Humidity	90% at 30ºC (86ºF)

Table 7-19: BSDU network interface

Parameter	Value	Comment
Ethernet Network – RJ-45	UTP EIA/TIA	Category 5
Standards Compliance	ANSI/IEEE 802.3, ISO/IEC 8802-3, 10/100BaseT compliant	
Serial port	RS-232	

Table 7-20: BSDU physical dimensions

Parameter	Value
Height	4.32 cm (1.7 inches)
Width	48.26 cm (19 inches)
Depth	22.86 cm (9 inches)
Weight	2.9 kg

7.3. Global Positioning Satellite Antenna

To synchronize between Base Stations implementing **frequency hopping**, and avoid radio frequency ghosting effects, it is crucial that the entire ASWipLL network operates with the same clock. To achieve this, each ASWipLL Base Station can be equipped with a GPS antenna that receives a universal Global Positioning System (GPS) satellite clock signal.

The GPS is a rugged, self-contained GPS receiver and antenna that connects to the BSDU's 15-pin D-type port. This completely sealed unit is designed to meet and exceed MIL-STD 810E standards.

Figure 7-9: Global Positioning System (GPS) antenna

7.3.1. Configurations and Optional Hardware

The GPS is available in a variety of configurations to suit the integration requirements: RS-232 for use with cables up to 15 meters, DGPS input, 1 pulse-per-second output, 7- or 12-pin connectors, direct or cable mount, and 1-14 UNS thread or 3 screw 10-32 UNF mounting.

The ASWipLL GPS feature provides the following optional GPS hardware:

- Magnet mount
- 5/8-inch adaptor
- 5, 15, or 50-meter mating cable

The optional ASWipLL GPS features include:

- WAAS DGPS accuracy
- RTCM-104 DGPS corrections output derived from the WAAS DGPS system
- T-RAIM for timing applications
- Carrier phase measurements at 1 Hz

7.3.2. Connector Pinouts

The GPS connects to the BSDU's 15-pin D-type port labeled **GPS**, located on the rear BSDU panel. The cable uses a single 12-pin cable connector. Connector pinouts are shown in Figure 7-10 and described in Table 7-21.

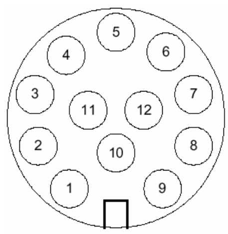


Figure 7-10: GPS connector – underside view

Table 7-21: GPS connector pinouts

12-pin female (GPS)			15-pin D-type male (BSDU)	
Pin	**Pin name**	**Cable color**	**Pin**	**Lead**
1	POWER	**Red**	9	
2	RX_DATA_1-	**Blue**	5	TD+ (after R5)
3	RX_DATA_1+	**Black**	6	TD-
4	TX_DATA_1-	**Yellow**	4	RD-
5	TX_DATA_1+	**Black**	3	RD+ (after R3)
6	RX_DATA_2-	**Brown**	x	
7	RX_DATA_2+	**Black**	x	
9	GND	**Black**	10	
11	1PPS+	**Green**	8	1PPS-
12	1PPS-	**Black**	7	1PPS+ (After R7)

7.3.3. Technical Specifications

The following table describes the GPS technical specifications.

Table 7-22: GPS specifications

Parameter	Description
Environmental conditions	Operating temperature: -30ºC to +75ºC (-22ºF to 167ºF)
Power requirements	• 36 VDC from BSDU (Note: AC/DC adapter is available for previous BSDU models) • 1.8 Watts
Dimensions	• Diameter: 4.5" (115 mm) • Height: 3.6" (90 mm)
Weight	0.454 kg (2 lb)

7.4. Base Station Power System (BSPS)

The Base Station Power System (BSPS) is a third-party full-redundancy 48 VDC power system that provides the following:

- 48 VDC power to an ASWipLL Base Station (i.e. BSDUs and BSRs).
- Backup power during a mains failure by providing a battery bank, which it charges. Thus, the BSPS is essentially a DC-UPS with a battery connected to it. The size of the battery determines the backup and charging time. Since the system is current limited, the maximum battery size is based on this limit.
- Full (remote) management by ASWipLL's WipManage NMS application.

The BSPS is supplied in a standard 19" x 11U rack, providing available space for additional equipment (i.e. BSDUs, which require 1U each). The total weight of the rack including the BSPS is 100 kg (220 lb).

The BSPS power requirements without load (i.e. not connected to BSDUs) or batteries are less than 0.5A.

7.4.1. Features

The BSPS offers the following main features:

- Two to four parallel rectifiers
- Universal input voltage (90 VAC to 270 VAC continuous, no selectors or switches)
- A built-in dual low voltage battery disconnect (LVD) protects the battery (two branches are protected) by disconnecting the battery from the load
- Remote BSPS power management (WipManage) using an RJ-45 terminal connected to the ASWipLL BSDU device
- Dual battery management (two branches) including battery test
- Boost or float charge, managed by the BSPS System Controller
- Battery terminals are protected by a dedicated thermal-magnetic circuit breaker

- Load terminals are protected by a dedicated thermal-magnetic circuit breaker
- Fine system voltage adjustment on the front panel of the BSPS Main unit
- Active current sharing among all rectifiers in the system for optimal performance
- An output diode on each rectifier averts a system breakdown when a rectifier short circuits
- Provides measurement of AC, DC, battery, temperature, and other parameters

7.4.2. System Description

Figure 7-11 provides a block diagram of the general system description of the BSPS.

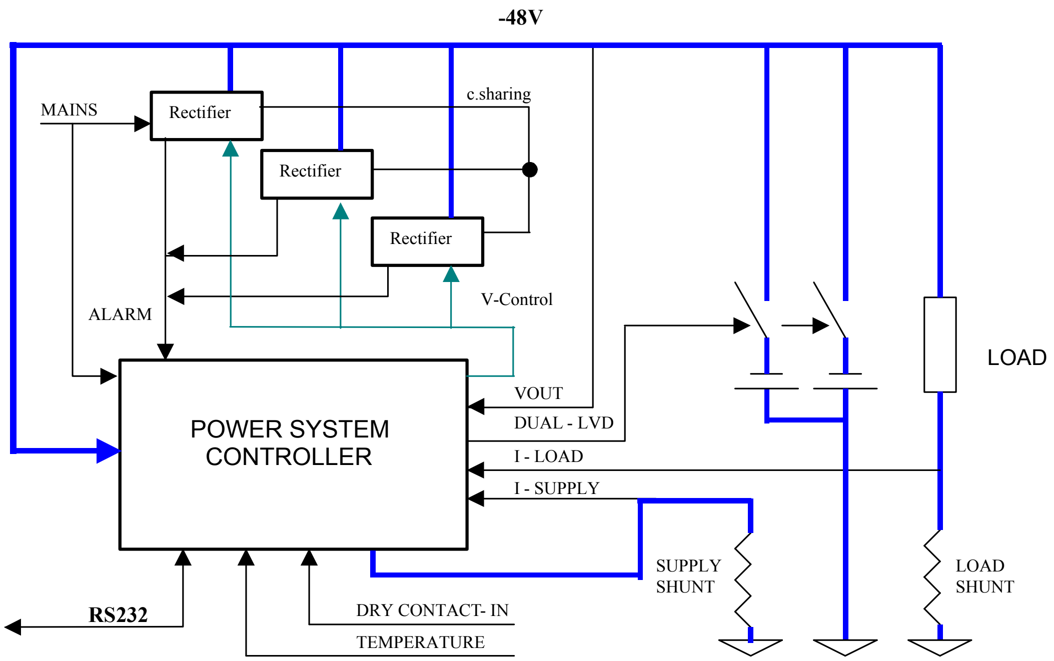


Figure 7-11: BSPS block diagram

As shown in Figure 7-11, three BSPS rectifiers (up to four) are chained in parallel to provide the required current capacity. The output voltage of the rectifiers feeds the load and charges the batteries through the dual LVD.

A dedicated bus that connects the BSPS rectifiers performs current sharing autonomously.

The rectifiers share a voltage control bus (V-CONTROL) controlled by the BSPS System Controller, which allows the changing of the output DC voltage of the system.

Another bus (ALARM) sends the information of a faulty rectifier to the System Controller.

Two accurate shunt-resistors monitor the load and the total current. The battery current is then calculated by the System Controller to be the difference between the two.

Two temperature sensors are connected to measure the battery temperature.

The status of the various circuit breakers (CB's) is monitored constantly by using their auxiliary switches. The opening of a CB will result in an audio/visual alarm. When the cause of the alarm is resolved, the alarm clears and stops.

The BSPS is composed of the following units:

- **Main**
- **DC Distribution**
- **Battery**

7.4.3. Main Unit

The BSPS Main unit is the core of the Full-Redundancy 48 VDC-power system. The Main unit consists of the following components (see Figure 7-12):

- **Rectifiers**: two to four rectifiers can be housed in the Main unit
- **System Controller:** manages the BSPS
- **Low Voltage Detector** (LVD)
- Load and battery circuit breakers for DC protection and distribution

Figure 7-12 illustrates the front panel of the BSPS Main unit.

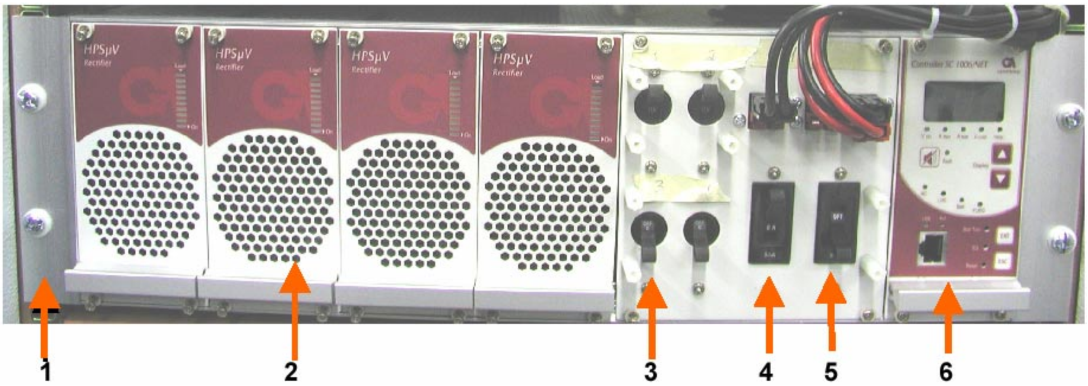


Figure 7-12: BSPS main unit - front panel

Legend:

1 = Adjustable 19-inch mounting flange

2 = Rectifier module (four rectifiers shown)

3 = Load breaker

4 = Battery breaker

5 = Line breaker

6 = System Controller

Figure 7-13 illustrates the rear panel of the BSPS Main unit:

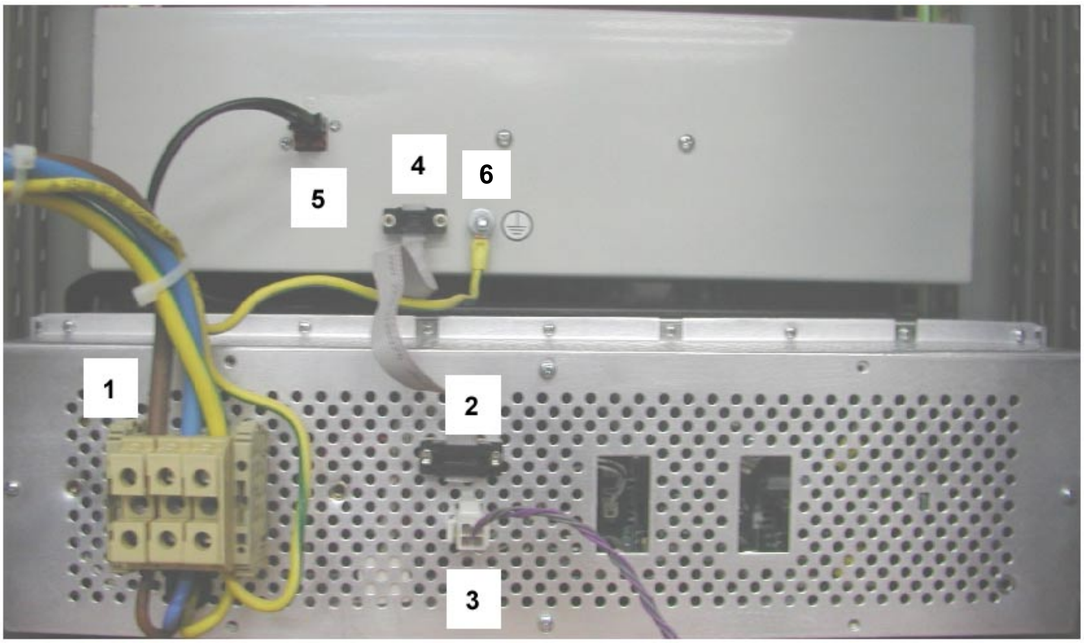


Figure 7-13: BSPS main rack - rear view

Legend:

1 = AC connection

2 = Comm-to-DC Distribution

3 = Temperature Sensor

4 = Comm to power system

5 = LVD connection

6 = Ground

7.4.3.1. Rectifier Module

The BSPS Rectifier module is the heart of the Full-Redundancy 48 VDC power system. It is a plugged-in module designed specifically for modular systems. Up to four rectifiers can be housed in the Main unit. The rectifiers can be "hot plugged". This enables the user to define an N+1 or N+2 redundancy system.

The power factor correction (PFC) device at the input enables clean, stable, sinusoidal current consumption from the mains. This converter produces a 382 VDC output, which is then converted to the 50 VDC output. The rectifier can be calibrated to adjust the output voltage.

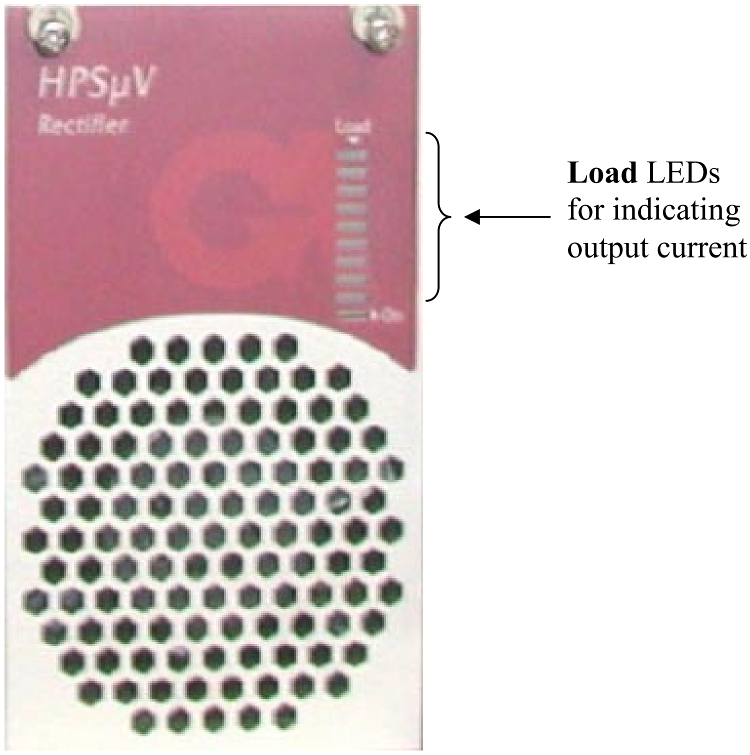


Figure 7-14: BSPS Rectifier module (front panel)

A current sharing circuit is responsible for current sharing among the rectifiers. This enables each one of the rectifiers to slightly increase its output voltage. The rectifiers follow the highest output voltage of the rectifiers that are used. For example, assume a BSPS has two rectifiers, and one of the rectifiers has an output voltage that is greater than the other rectifier. The rectifier with the higher output voltage becomes the master and dictates the output voltage of the BSPS system. The second rectifier raises its voltage slightly until its output current equals the output current of the master rectifier. Thus, one rectifier in the system is the master and the other rectifiers are slaves.

When the master rectifier fails to operate, the rectifier with the next highest initial output automatically becomes the new master of the system.

The output current indication is indicated by the LED bar graph shown on the front panel (see Figure 7-14). This bar graph is used to verify current sharing operation, and to indicate the percentage of the full load.

An RFI input filter built into the input stage suppresses the generated noise traveling to the line.

Note: The sharing mechanism tends to raise the BSPS's output voltage. A limit of approximately one-volt of correction is applied to the system.

Figure 7-15 displays a block diagram of the BSPS Rectifier.

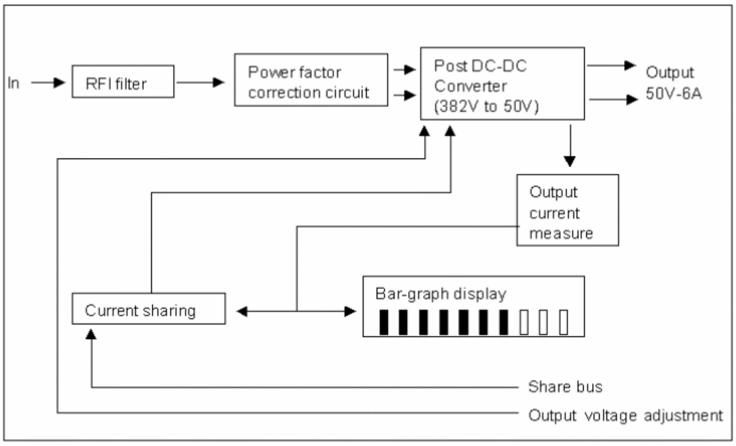


Figure 7-15: BSPS Rectifier - simplified block diagram

7.4.3.1.1. Specifications

The following table lists the BSPS Rectifier specifications:

Table 7-23: BSPS Rectifier specifications

	Parameter	Value
Input	Voltage	90VAC to 270VAC
	Current (nominal)	3.2A @ 230V / 4.3A @ 115V
	Frequency	47Hz to 63Hz
	Power factor (nominal line/load)	Greater or equal to 0.993
Output	Voltage (default)	53.5VDC
	Regulation (line & load)	±0.4%
	Adjustable range	47 to 58 VDC
	Current	12A @ 54V
	Ripple & noise	50mVp-p
	Efficiency (nominal load)	85% @ 230V / 82% @ 115V
	Overload current	<12A
	Over-voltage protection	60 VDC
	Over-temperature protection (measured on case, upper panel corner)	• 80±5°C rectifier stops • 72±5°C rectifier recovers
	Walk-in time	< 0.5 sec
	Hold-up time	40 ms
General	Withstand voltage (1 min)	• 4230VDC INPUT/OUTPUT • 2120VDC INPUT/GND • 1700VDC OUTPUT/GND
	Working temperature	-10 to 45°C
	Storage temperature	-50 to 80°C
	Dimensions (mm)	235 x 150 x 50 (L x W x H)
	Weight	1100g
	EMC	Refer to system specifications
	Safety	According to: IEC950

7.4.3.2. System Controller

The System Controller is a hot-swappable unit that manages the BSPS. The Figure 7-16 displays the front panel of the BSPS System Controller module.

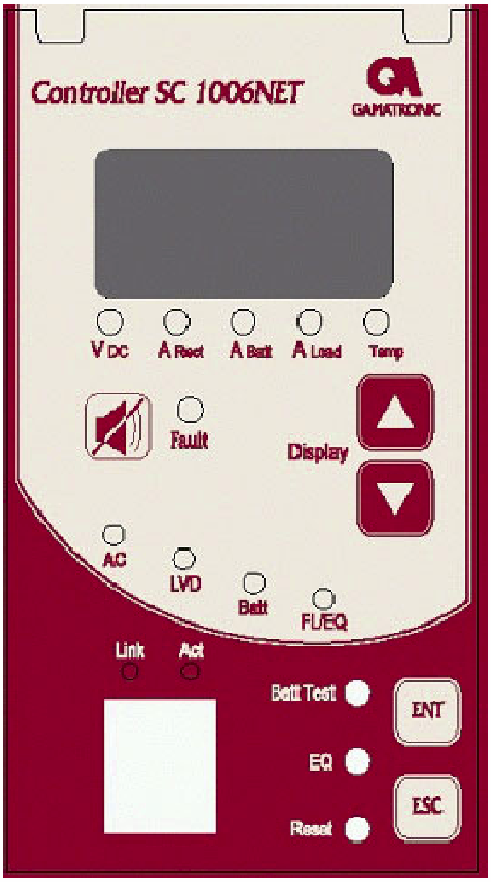


Figure 7-16: System controller front panel

The System Controller front panel provides the following:

- **AC:** input AC voltage is normal (green)
- **DC:** output DC voltage is normal (green)

- **LVD:** Low Voltage Disconnect circuit is open (battery is disconnected = red)
- **BATT:** battery test passed (green)
- **FAULT:** general alarm fault (red-continuous), faulty rectifier (red-blinks)
- **BATT TEST:** manual battery test (use a pencil tip to initiate)
- **ALARM OFF:** silences the internal buzzer (use a pencil tip)
- **RESET:** resets the controller (use a pencil tip)
- **RS232:** connector to the BSDU for BSPS power management

7.4.3.2.1. Main Functions

The BSPS System Controller provides the following main functions:

- RS232 communication with a host (i.e. through the BSDU to the ASWipLL NMS - WipManage)
- Controlling dual-LVD for managing two branches of batteries. LVD voltages are settable and nonvolatile
- Boost/Float charging, voltages are settable and nonvolatile
- Battery test for two branches
- Three dry-contacts for alarm, user-defined
- Audio-visual alarm
- LED indicators for AC, DC, LVD, battery, and general fault
- Optional: 2 x 3 digits display for system voltage/current metering
- Faulty rectifier detection
- Open breakers detection (any of them)
- LVD bypass activation alarm
- Abnormal condition detection (AC, DC, battery, over-temperature etc.)

7.4.3.2.2. Power Management through the BSDU

Connecting the BSPS's System Controller module to the ASWipLL BSDU provides the user with the ability to control the BSPS power system operating parameters, and retrieve system data and status information.

The BSPS System Controller connects to the BSDU(s) via an RJ-45 port located on the front panel of the System Controller. This is connected to the BSDU's 9-pin D-type port, labeled **POWER Management**.

The BSPS to BSDU connection cable is shown in Figure 7-17.

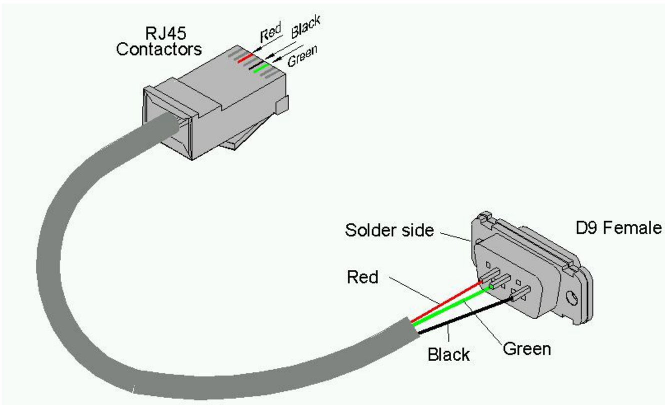
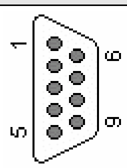
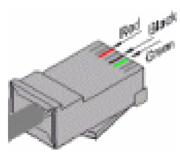


Figure 7-17: BSDU-to-BSPS management connectors

The table below shows the connector pinouts for the 9-pin D-type connector.

Table 7-24: BSPS-to-BSDU connector pinouts for BSPS management

Straight-through cable					
BSDU			BSPS		
9-pin D-type female	Pin	Function	Pin	Function	8-pin RJ-45
	2	Rx	3	Rx	
	3	Tx	6	Tx	
	5	GND	5	GND	

7.4.4. DC Distribution Unit

The BSPS DC Distribution unit is an optional unit that provides more circuit breakers (CB's) for distributing the output current to multiple BSDUs.

The DC Distribution contains a bypass switch to bypass the LVD. When this switch is activated, the battery is no longer protected against deep discharge and the System Controller alarm is activated.

The DC Distribution also provides terminations for connecting to other units of the BSPS (namely, to the Main unit and extension racks).

Figure 7-18 displays the front panel of the BSPS DC Distribution unit.

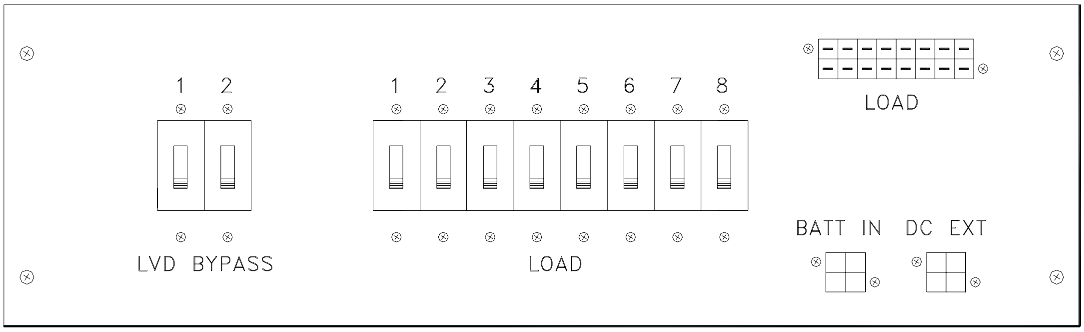


Figure 7-18: BSPS DC Distribution unit - front panel

Legend:

- **LOAD:** DC connection to BSDUs
- **DC EXT:** extension rack DC power input connection
- **BATT IN:** battery input connection
- **LVD BYPASS:** bypass circuit breakers
- **LOAD:** load circuit breakers

Figure 7-19 displays the rear panel of the BSPS DC Distribution unit.

Figure 7-19: BSPS DC Distribution Unit - Rear Panel

Legend:

- **LVD BYPASS:** LVD bypass input connection from the BSPS Main unit
- **COMM:** Main/Extension unit communication port

7.4.4.1. Specifications

The following table lists the BSPS DC Distribution specifications:

Table 7-25: BSPS DC Distribution Specifications

Group	Parameter	Value
Input	Voltage	90VAC to 270VAC
	Current (at full load) N =Number of rectifier modules	• N*3.2A @ 230V • N*4.3A @ 115V
	Frequency	47Hz to 63Hz
	Power factor (at full load)	Greater or equal to 0.993
	Voltage (programmable)	42 to 60VDC ± 0.5VDC
Output	Default float and boost voltage	54 and 57VDC respectively
	Regulation (line, load, sharing)	±1%
	Current	N*12A (48A max.)

Group	Parameter	Value
	Psophometric noise	-52 dBm (over 600 Ω)
	Ripple & noise	50mVp-p
	Efficiency (nominal load)	85% @ 230V / 82% @ 115V
	Overload current	< N*12A
	Over-voltage protection	60VDC
	Walk-in time	< 1 sec
	Hold-up time	40 ms
	Output current indication	10 LED's bar-graph
	Active current sharing	±10% accuracy at full load
	Withstand voltage (1 min)	2120VDC INPUT/GND
General	Working temperature	-10 to 45°C
	Storage temperature	-50 to 80°C
	Dimensions (19" X 3U)	Depth is 320 mm W/O terminals, 360 mm with terminals
	Weight	13 kg (main unit + 3 rectifiers)
	RS232 Communication	9600 bps, no-parity, 1 stop-bit
	EMC	According to: • EN300-386-2 SUB 7.2.3 • EN55022 class B • IEC1000-4-2 • IEC1000-4-3 • IEC1000-4-4 • IEC1000-4-5 • IEC1000-4-6 • IEC1000-4-11 • IEC1000-3-2 • IEC1000-3-3
	Safety	According to: IEC950
	Maximum current withstand	2x70A
LVLD (optional)	Trip voltage level	Disconnect default: 43± 0.5 VDC, user programmable Re-connect: with AC recovery

7.4.5. Battery Unit

To provide ASWipLL system back-up power during a mains failure, two battery circuits can be connected to the BSPS. The BSPS supports **up to two sets** of 4x38Ah 12 VDC batteries. The BSPS provides power redundancy by charging the battery bank. Thus, the BSPS is essentially a DC-UPS with a battery connected to it. The size of the battery determines the backup and charging time. Since the system is current limited, the maximum battery size is based on this limit.

Batteries are located on two shelves fitted in the lower sections of the Airspan cabinet. These batteries are connected to the BSPS DC Distribution unit.

Note: Airspan does not supply batteries.

7.5. Typical Base Station Configurations

The following subsections describe typical ASWipLL Base Station configurations.

7.5.1. Base Station with Single BSR

The ASWipLL Base Station can consist of a single BSR. In such a scenario, the BSR connects to the provider's backbone via an SDA. The SDA provides the BSR with an interface to the customer's backbone, as well as with power supply.

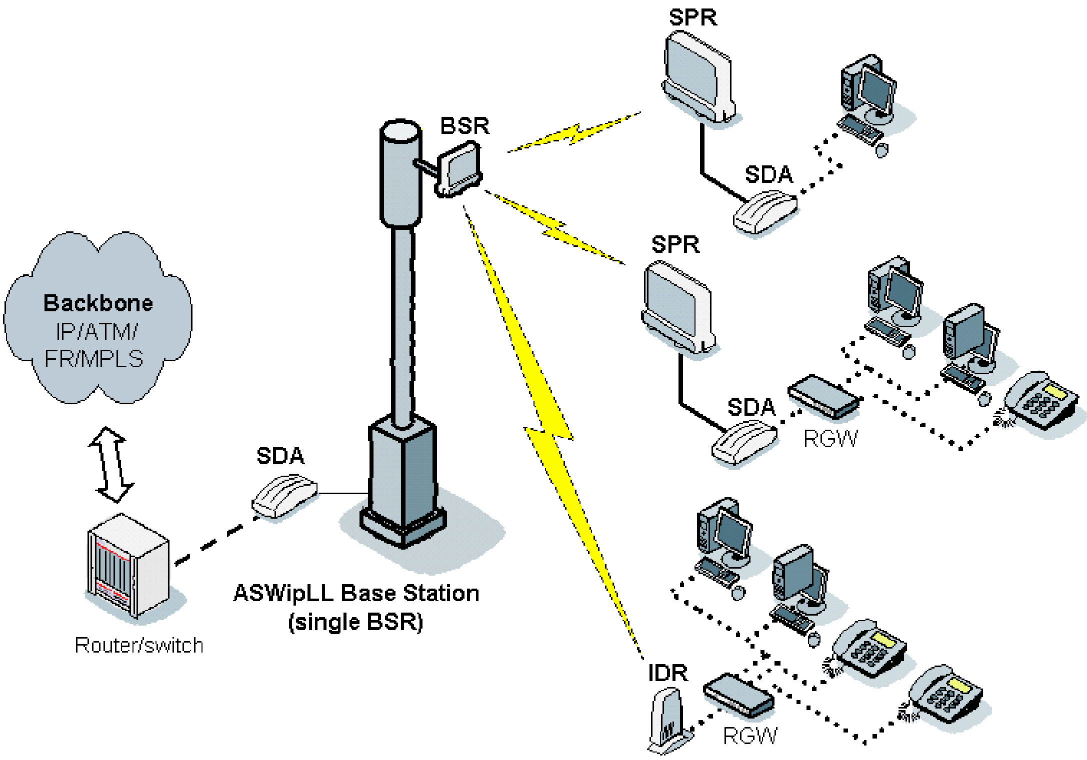


Figure 7-20: Base station with a single BSR

7.5.2. Multi-Layer Base Station

To support a large number of subscriber sites, multiple BSRs can be installed at a Base Station (see Figure 7-21). In such a scenario, the BSRs connect to the customer's backbone via the ASWipLL BSDU.

The BSDU can support up to six BSRs. In addition, up to four BSDUs can be daisy-chained to support a maximum of 24 BSRs at one Base Station. The BSDU not only interfaces between the BSR and the customer's backbone, but also provides power and frequency hop synchronization between BSRs.

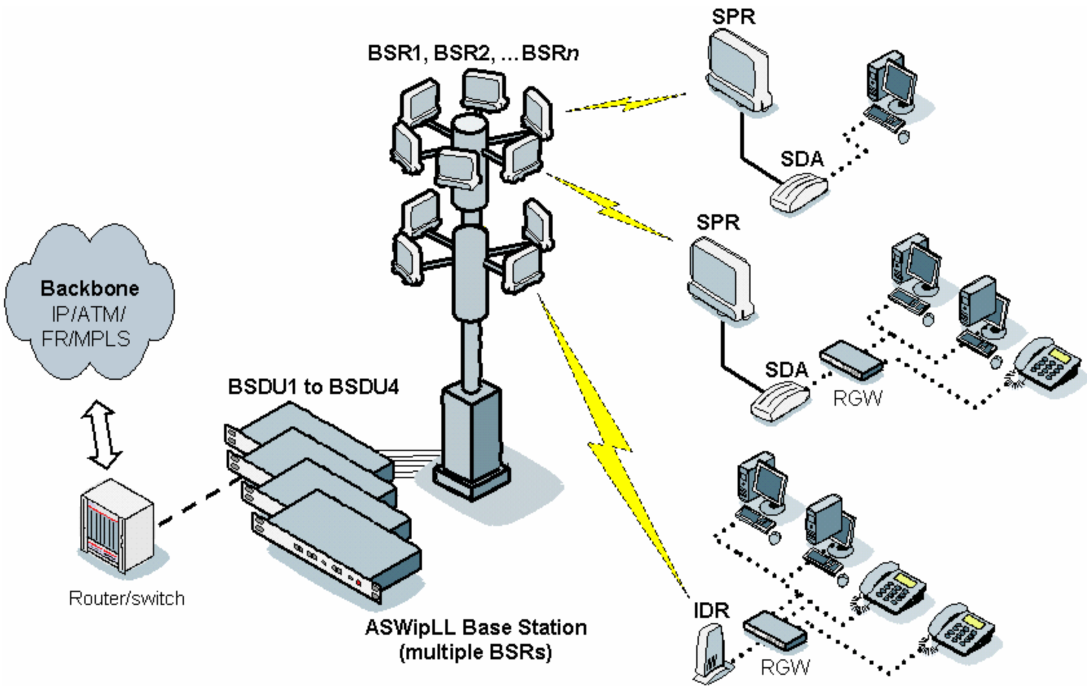


Figure 7-21: Base Station with multiple BSRs

8

ASWipLL CPE Devices

The subscriber site includes the following ASWipLL customer premises equipment (CPE), depending on configuration:

- **Subscriber Premises Radio (SPR):** outdoor radio transceiver that receives and transmits data from and to the ASWipLL Base Station (i.e. BSR) respectively
- **Subscriber Data Adapter (SDA):** Ethernet hub or switch connected to SPR[4]
- **Indoor Data Radio (IDR)[5]:** indoor radio that combines functionality of a radio transceiver and Ethernet hub (i.e. replaces the SPR and SDA)

ASWipLL's CPE devices perform traffic routing between the subscriber sites and the Base Station. The devices also provide local Quality of Service (QoS) such as re-ordering of packets and assigning Time-to-Live (TTL) values.

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4 The IDR does not require an SDA. However, the IDR may be connected to the SDA-4S model for specific configuration setups.

5 Functionally identical to the SPR, but typical antenna gain is less than the SPR, and therefore, the IDR is used for shorter ranges.

Figure 8-1 and Figure 8-2 show typical ASWipLL subscriber site configurations.

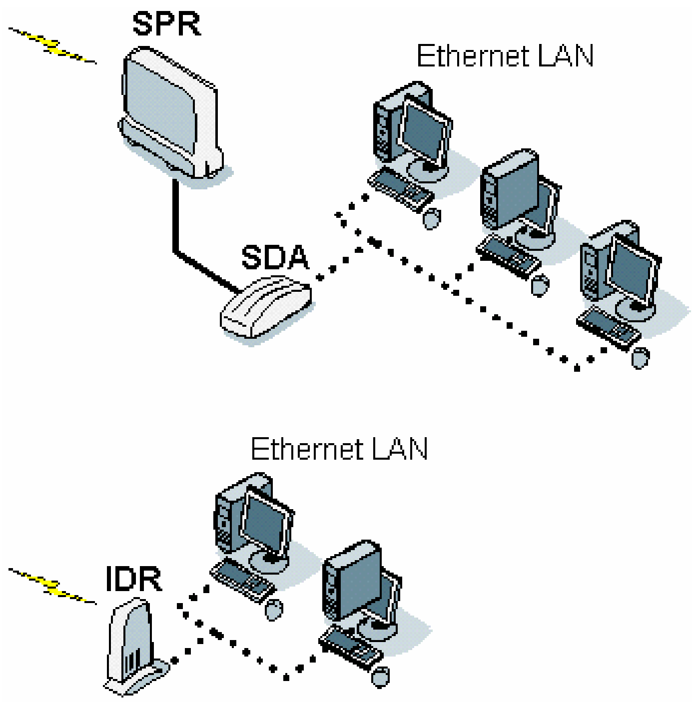


Figure 8-1: Typical data subscriber configurations (SPR and SDA, and IDR)

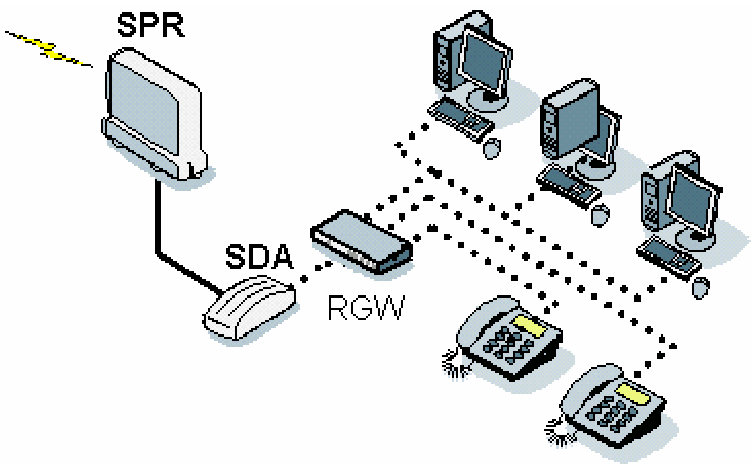


Figure 8-2: Typical voice and data subscriber configuration (SPR, SDA, and RGW)

8.1. Subscriber Premises Radio (SPR)

The ASWipLL Subscriber Premises Radio (SPR) is an outdoor radio that transmits and receives traffic to and from the Base Station (i.e. BSR), respectively. The SPR provides subscribers with "always-on" Internet, high-speed data-only, or data and voice (VoIP) services. Each SPR provides an access capacity of up to 4 Mbps.

The SPR interfaces with the subscriber's network (LAN) through the SDA Ethernet hub or switch. The SPR connects to the SDA's 10BaseT interface port by a standard 100-meter CAT-5 cable (i.e. no RF cable required).

Each SPR is configured with a unique BSR reference number, preventing unauthorized relocation of the SPR to another subscriber premises.

For VoIP, the subscriber site includes a third-party residential gateway (RGW) that connects to the SDA.

The SPR can be pole or wall mounted, allowing optimal positioning for best reception with the Base Station. The figure below shows an SPR mounted outdoors on a pole at the subscriber's premises.

Figure 8-3: Typical SPR mounted outdoors on a pole

Note: The indoor unit to outdoor unit (IDU/ODU) connectivity can be extended to 200 meters by using two 100-meter CAT 5 cables joined by an Ethernet hub, or to 300 meters using three 100-meter CAT 7 cables joined by Ethernet hubs.

8.1.1. SPR Models

The SPR is available in various models, differing mainly in antenna configuration.

The table below provides a brief description of the SPR models and the frequencies in which they can operate.

Table 8-1: Operating frequency bands per SPR model

SPR general model	Operating frequency (MHz)	Antenna configuration
SPR 700	698 to 746	Internal or external
SPR 900	902 to 928	Internal or external
SPR 925	910 to 940	External
SPR 1.5	1,427 to 1,525	Internal or external
SPR 1.9	1,930 to 1,990 for Rx; 1,850 to 1,910 for Tx	Internal or external
SPR 2.3	2,300 to 2,400	Internal or external
SPR 2.4	2,400 to 2,500	Internal or external
SPR MMDS	2,500 to 2,686	Internal or external
SPR 2.8	2,700 to 2,900	Internal or external
SPR 3.*x*	3,300 to 3,810	Internal or external
SPR 5.8	5,725 to 5,875	Internal or external

8.1.1.1. SPR with Integrated, Flat-Panel Antenna

This SPR model type contains an integrated (internal) flat-plate antenna. These models are available when operating in the 700 MHz, 900 MHz, 1.5 GHz, 1.9 GHz, 2.3 GHz, 2.4 GHz, MMDS, 2.8 GHz, 3.*x* GHz, and 5.8 GHz bands.

The front panel of this model is displayed below.

Figure 8-4: SPR with built-in antenna - front panel

Note: Previous SPR models provide a 9-pin D-type serial port in addition to the standard 15-pin D-type port. The latest SPR models provide only a 15-pin D-type port, supporting both Ethernet and serial interfaces.

The SPR with built-in antenna models are available in the following variations:

- **Standard SPR:** typically provides an internal antenna with a 15-dBi antenna gain, covering an area of 23 degrees. These models are generally used for 700 MHz (8 dBi), MMDS, 2.4 GHz, 2.8 GHz, 3.5 GHz, and 5.8 GHz frequency bands. For 5.8 GHz, the antenna gain is 16 dBi, for 1.9 GHz the gain is 12 dBi.

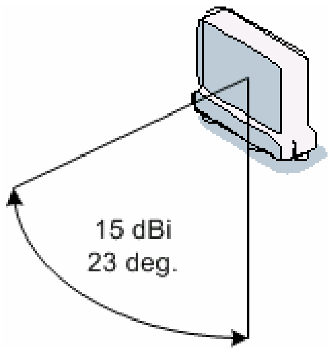


Figure 8-5: SPR with standard antenna gain

- **Large SPR (SPR-L):** larger dimensions (same dimensions as the BSR) than the standard SPR, allowing the use of a high-gain internal antenna.

  For the 2.4 GHz and 3.5 GHz frequency bands, this model provides an 18-dBi antenna gain covering 15 degrees. For the 900 MHz and 700 MHz frequency bands, this model provides an 8-dBi antenna gain and a 60-degree coverage. For the 1.5 GHz band, this model provides a 13-dBi antenna gain.

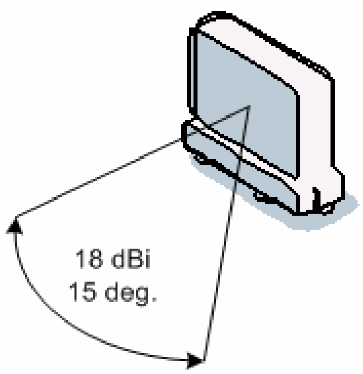


Figure 8-6: SPR with high-gain antenna

Notes:
1) The SPR 700 MHz and SPR 900 MHz models have larger dimensions than the standard SPR models. Their dimensions are the same as that of the BSR.
2) The SPR 3.5 GHz and SPR 2.4 GHz models are available in large and standard (smaller) dimensions. The dimensions affect the antenna gain (i.e. the greater the dimension, the higher the gain).
3) The 700 MHz internal antenna covers only 710 to 716 MHz, and 740 to 746 MHz (i.e. Band-C). To cover the entire band of 698 to 746 MHz, an external antenna is used (see Section 2.5.3, "RF Planning Considerations for Band-C in FCC Markets").

8.1.1.2. SPR with N-Type Connector for Third-Party External Antenna

Airspan provides SPR models that provide an N-type connector for attaching a third-party external antenna (see Figure 8-7). These models are available for all ASWipLL operating frequency bands (i.e. 700 MHz, 900 MHz, 925 MHz, 1.5 GHz, 1.9 GHz, 2.3 GHz, 2.4 GHz, MMDS, 2.8 GHz, 3.*x* GHz, and 5.8 GHz). When operating in the 700-MHz band, a Yagi-type antenna (15-dBi antenna gain) is supplied.

N-type port for external antenna

Figure 8-7: SPR model with N-type port for third-party external antenna

Notes:
1) It is recommended that third-party external antennas provide 50-ohm impedance and a VSWR of less than 1:1.5.
2) SPR models with a port to attach an external antenna do not have built-in antennas.

8.1.2. Standard Accessories

The following accessories are provided with each SPR kit:

- **Mounting kit** for wall mounting the SPR
- **15-pin D-type** waterproof connector for IDU/ODU connectivity (data and power interface)
- **N-type** connector for attaching a third-party external antenna (for SPR model without a built-in antenna)

8.1.3. Hardware Interfaces

The SPR's hardware interfaces are described in the table below.

Table 8-2: SPR hardware interfaces

Port	Interface
15-pin D-type	• Ethernet (10BaseT) with SDA • Power supplied by SDA • Serial (RS-232) local initial configuration (using WipConfig tool) during installation using a Y-cable (see Note 1)
N-type	For attaching third-party external antenna (see Note 2)

Notes:

1. For previous SPR models that provide a 9-pin D-type serial port, serial interface is provided by using a crossover cable between this port and the computer's serial port.
2. SPR models with built-in antennas do not provide an N-type port.

8.1.4. Connector Pinouts

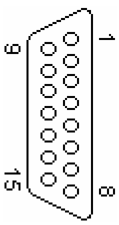
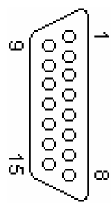
This section describes the 15-pin D-type port connector pinouts for the following interfaces:

- Ethernet
- Serial

8.1.4.1. 15-Pin D-Type Connector (Ethernet)

The table below describes the 15-pin D-type connector pinouts for the SPR-to-SDA interface, which provides Ethernet and power interfaces.

Table 8-3: 15-pin D-type connector pinouts for interfacing with SDA

Straight-through cable							
15-pin D-type male	SPR		Wire color	Wire pair	SDA		15-pin D-type male
	Pin	Function			Pin	Function	
	1	+48 VDC	Blue / White	1	1	+48 VDC	
	2	48 RTN	Blue		2	48 RTN	
	3	Tx+	Orange / White	2	3	Rx+	
	4	Tx-	Orange		4	Rx-	
	5	Rx+	Green / White	3	5	Tx+	
	6	Rx-	Green		6	Tx-	

Notes:

- Only pins 1 to 6 are used in the 15-pin D-type port.
- The wire color-coding described in the table (and shown in the figure below) is ASWipLL's standard for wire color-coding. However, if you implement your company's wire color-coding scheme, ensure that the wires are paired and twisted according to the pin functions listed in the table above (e.g. Rx+ with Rx-).

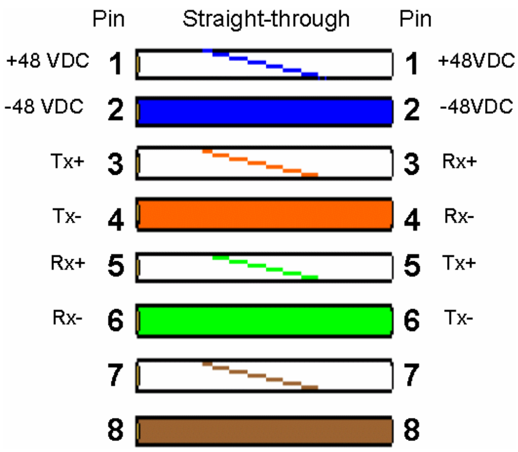


Figure 8-8: ASWipLL wire color-coding for 15-pin D-type connectors

Note: The wires are twisted together in pairs, for example, blue/white with blue, and orange/white with orange. This prevents electrical interference between the transmitter pins. For example, pin 3 (Tx+; orange / white) is paired and twisted with pin 4 (Tx-; orange).

8.1.4.2. 15-Pin D-Type Connector (Serial)

For SPR serial configuration, a Y-cable (splitter cable) is used for connecting SPR's 15-pin D-type port to the management station (i.e. PC running WipConfig) and to the SDA, as displayed below. This ensures that the SPR receives power from the SDA.

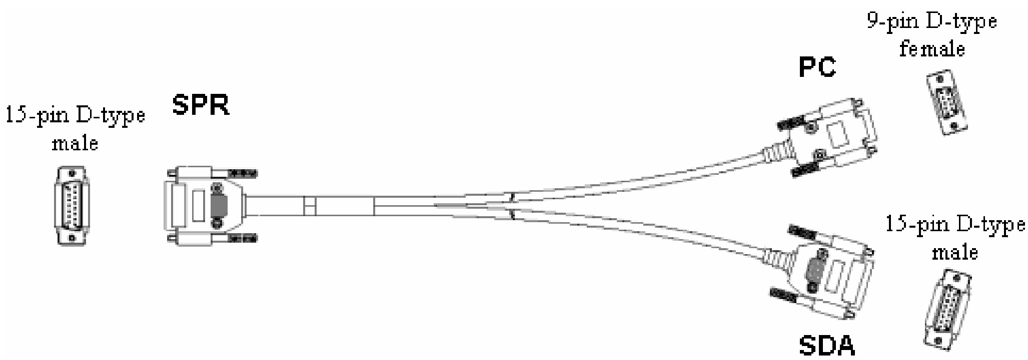
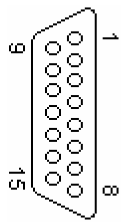
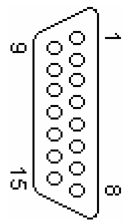
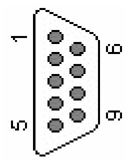


Figure 8-9: Y-cable for SPR serial configuration

Table 8-4 describes the 15-pin D-type connector pinouts for SPR serial configuration using a Y-cable.

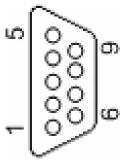
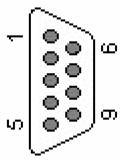
Table 8-4: Y-cable connector pinouts for SPR-to-SDA side

<table>
<tr><th colspan="6">Straight-through Y-cable</th></tr>
<tr><th colspan="3">SPR</th><th colspan="3">SDA</th></tr>
<tr><th>15-pin D-type male</th><th>Pin</th><th>Function</th><th>Pin</th><th>Function</th><th>15-pin D-type male</th></tr>
<tr><td rowspan="11"></td><td>1</td><td>+48 VDC</td><td>1</td><td>+48 VDC</td><td rowspan="6"></td></tr>
<tr><td>2</td><td>48 RTN</td><td>2</td><td>48 RTN</td></tr>
<tr><td>3</td><td>Ethernet Tx+</td><td>3</td><td>Rx+</td></tr>
<tr><td>4</td><td>Ethernet Tx-</td><td>4</td><td>Rx-</td></tr>
<tr><td>5</td><td>Ethernet Rx+</td><td>5</td><td>Tx+</td></tr>
<tr><td>6</td><td>Ethernet Rx-</td><td>6</td><td>Tx-</td></tr>
<tr><th colspan="2">SPR</th><th colspan="3">PC</th></tr>
<tr><th>Pin</th><th>Function</th><th>Pin</th><th>Function</th><th>9-pin D-type female</th></tr>
<tr><td>12</td><td>GND</td><td>5</td><td>GND</td><td rowspan="3"></td></tr>
<tr><td>14</td><td>RS232 Rx</td><td>3</td><td>Rx</td></tr>
<tr><td>15</td><td>RS232 Tx</td><td>2</td><td>Tx</td></tr>
</table>

8.1.4.3. 9-pin D-type Connector (for Previous SPR Models)

Previous SPR models provide (in addition to the 15-pin D-type port) a 9-pin D-type port for serial interface. The following table describes the 9-pin D-type connector pinouts for SPR-to-PC serial cabling.

Table 8-5: SPR connector pinouts for SPR-to-PC serial interface

Crossover cable					
SPR			PC		
9-pin D-type male	Pin	Function	Pin	Function	9-pin D-type female
	2	RS232 Rx	3	Tx	
	3	RS232 Tx	2	Rx	
	5	GND	5	GND	

Note: For SPR serial configuration, the SPR must remain connected to the SDA (i.e. the SPR's 15-pin D-type port remains connected to the SDA's 15-pin D-type port).

8.1.5. Network Management

The SPR is managed remotely by ASWipLL's NMS program (i.e. WipManage) from anywhere that provides IP connectivity to the SPR. ASWipLL's SNMP-based WipManage program uses standard and ASWipLL proprietary Management Information Bases (MIB) for configuring and managing the SPR. WipManage provides the SPR with fault, configuration, performance, and security management. For a detailed description on WipManage, see Chapter 12, "Management System".

8.1.6. Technical Specifications

The tables below describe the SPR technical specifications.

Table 8-6: SPR and MAC specifications

Parameter	Value	Comment
Operating frequency	5.8 GHz; 3.x GHz; 2.8 GHz; MMDS; 2.4 GHz; 2.3 GHz; 1.5 GHz; 1.9 GHz; 925 MHz; 900 MHz; 700 MHz	
Spectrum spreading method	Frequency hopping	Per ETSI EN 301 253
Duplexing Method	• Time Division Duplexing (TDD): 5.8 GHz, 3.*x* GHz, 2.8 GHz, MMDS, 2.4 GHz, 2.3 GHz, 925 MHz, 900 MHz, 700 MHz • Frequency Division Duplexing (FDD): 3.*x* GHz, 1.9 GHz; 1.5 GHz	
Transmit Bit Rates	Up to 4 Mbps	BER and distance dependent
Channel spacing	1 MHz (except when operating in the 3.5 GHz band: 1 MHz or 1.75 MHz)	
Output power from the radio	• 31 dBm: 700 MHz • 30 dBm: 1.5 GHz, 925 MHz, 900 MHz • 27 dBm: 5.8 GHz, 3.*x* GHz, 2.8 GHz, MMDS, 2.4 GHz, 2.3 GHz	Depending on local regulations (e.g. FCC—see Appendix G, "Declaration of FCC Conformity"), maximum output power can be configured at the factory
Modulation method	8-level CPFSK	
Channel access method	PPMA / Adaptive TDMA	
Protocol efficiency	Up to 80%	For large data packets

Table 8-7: SPR EMC and radio standards compliance

Parameter	Value
Radio Standards Compliance	• ETSI EN 300 328-1 • ETSI EN 301 253 • FCC part 15 • RSS139 • Telec
EMC	• ETSI ETS 300 826 • ETSI EN 300 385 • ETSI EN 300 386-2 • ETSI ETS 300 132-2 • FCC part 15

Table 8-8: SPR agency certification

Parameter	Value
Emissions / Immunity	EN 300 339, EN 300 386-2, ETS 300 328
Safety	EN/IEC 60950
Environmental	ETS 300 019-2-x; IP66 (protected against dust and low pressure jets of water)

Table 8-9: SPR network specifications

Parameter	Value	Comment
Filtering rate	10,500 frames / sec	At 64 bytes
Forwarding rate	1,300 frames / sec	At 64 bytes
Routing table length	16	

Table 8-10: SPR power requirements

Parameter	Value	Comment
• Voltage • Minimum • Maximum	• 48VDC nominal • 30VDC • 55VDC	Power supplied by SDA
Consumption	Maximum	500 mA

Table 8-11: Environmental considerations

Parameter	Value
Operating temperature	-30ºC to +60ºC (-22ºF to 140ºF)
Storage temperature	-40ºC to +80ºC (-40ºF to 176ºF)

Table 8-12: Network interface

Parameter	Value	Comment
Ethernet Network	UTP EIA / TIA	Category 5
Standards Compliance	ANSI/IEEE 802.3 and ISO/IEC 8802-3; 10BaseT compliant	
Serial Port	RS-232	

Table 8-13: SPR physical dimensions (without high-gain antenna)

Parameter	Value	Comment
Height	311 mm (12.24 inches)	Excluding mounting kit
Width	244 mm (9.6 inches)	
Depth	65.5 mm (2.57 inches)	
Weight	2.5 kg	

Table 8-14: SPR physical dimensions (with high-gain antenna)

Parameter	Value	Comment
Height	400 mm (15.74 inches)	Excluding mounting kit
Width	317 mm (12.48 inches)	
Depth	65.5 mm (2.57 inches)	
Weight	4.7 kg	

8.2. Subscriber Data Adapter (SDA)

The ASWipLL Subscriber Data Adapter (SDA) is an indoor Ethernet hub or switch (depending on SDA model). The SDA interfaces between the SPR and the subscriber's peripheral devices (i.e. subscriber's network). The SDA can support 10BaseT or 100BaseT networks, depending on SDA model.

The SDA is typically installed at the subscriber's site. However, it can be installed at a Base Station that consists of a single BSR/PPR. In such a scenario, the SDA provides Ethernet interface between the BSR/PPR and the service provider's backbone.

The SDA supplies -48 VDC power to the SPR over a CAT 5 cable. In addition, the SDA provides lightning protection to the SPR and subscriber's local network. The SDA is either powered by an external power adapter (110-240 VAC), or by a 10 to 52 VDC power source, depending on SDA model.

The SDA is installed indoors, typically mounted on a wall or placed on a shelf or desktop. The location of the mounted SDA must ensure that the CAT-5 cable connecting the SDA to SPR is less than 100 meters.

A third-party residential gateway (RGW) can be connected to the SDA to provide VoIP services to the subscriber.

Note: The indoor unit to outdoor unit (IDU/ODU) connectivity can be extended to 200 meters by using two 100-meter CAT 5 cables joined by an Ethernet hub, or to 300 meters using three 100-meter CAT 7 cables joined by Ethernet hubs.