



Leader in Converged IP Testing

WLAN Site Assessment – Best Practices for Pre- and Post-Deployment Verification





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With the tremendous growth of Wireless LANs (WLANs) in corporate environments and the migration of mission critical applications to these networks, a WLAN is “nice to have” no more. Contemporary WLANs must deliver 100% reliable service while maintaining end-user Quality of Experience (QoE).

The proliferation of client devices in WLANs is a constant challenge to the IT administrator. Each client device, be it a laptop, smart-phone, netbook, scanner, or patient monitor, has its own unique networking behavior. Clients used in proximity of each other actually have impact on each other’s performance. Client devices have also been observed to give varying levels of performance based on where they were first turned on in the environment, and what physical path the user has followed to get to a specific location. When and how the client chooses to roam, how the client chooses an AP in a noisy environment, what driver settings are chosen, and even the physical orientation of a client device are all variables that have impact on the delivered Quality of Experience.

This document introduces best-practices for WLAN network qualification before a network is turned on, while the network is operational, or when a network upgrade is planned. As end-user QoE is the ultimate goal of the network administrator, Site Assessments need to be conducted from the perspective of the end-user and with a tool that can provide data which isolates the network aspects of performance from the client contribution.

No longer can the Network Engineer consider their task completed once an RF site survey is done. Site Assessments involving actual client devices, with meaningful, measureable and repeatable loads – is the requirement for delivering a known good wireless network. The best practices described provides the guidance for using WaveDeploy to accomplish delivery of excellence in wireless networks.

Methodology – Measure performance not coverage

Site Assessment is not “site survey”. Site survey tools measure the RF power level and co-channel interference that is present at every location in the surveyed facility. Using this information, the tool then guesstimates phy rates, effective download speeds, voice quality and end-user experience. While these signal power measurements may provide basic insight into Access Point (AP) placement, it is not possible to accurately predict end-user QoE. RF-based site survey gives an indication of the relationship a client device may be able to enjoy with an Access Point, but the only means of ensuring end-user QoE is to include the operating network behind the AP in addition to the AP itself. RF-based measurements are a necessary ingredient of predicting performance, but not sufficient to do so alone. Site Assessment involving actual traffic is required.

Site Assessment needs to meet three objectives: 1) measure real end-user QoE with authentic traffic, 2) verify end-user QoE with every type of client found on the network, and 3) obtain results in ideal network conditions as well as in loaded network conditions. WaveDeploy, the industry’s first strategic site performance test solution, achieves these objectives.

WaveDeploy measures actual end-user QoE through creation of application traffic, such as web download, Voice over IP (VoIP) calls, and streaming video, and measures the applicable metrics for each type of application. For example, voice quality can only be

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Since actual client devices are a significant contributor to end-user QoE, Site Assessment needs to be conducted with the actual end-user devices.

conclusively assessed by measuring the Mean Opinion Score (MOS) while web surfing quality can be assessed by measuring effective web download speeds.

Since actual client devices are a significant contributor to end-user QoE, Site Assessment needs to be conducted with the actual end-user devices. WaveDeploy tests are conducted using the actual devices, without the need to install proprietary or special-purpose WLAN adapters in them. IxVeriWave has created the WaveAgent, a software agent installed on the client devices, for the purpose of extending proprietary and reliable test methodology to the end-user client device. Actual user devices include laptops, netbooks, smart-phones, scanners, and a variety of other WLAN enabled clients. WaveDeploy tests offer the unique Single Pass Site Survey allowing the tester to conduct a single pass through the assessed facility with all client types being tested. Only then does the network engineer have a confirmation of performance with given client devices, their operating system and the combination of wireless network interface card and driver.

Conducting a Site Assessment in ideal network conditions with little, or low, load provides a baseline of the network and indicates fundamental differences between various client types and the expected end-user experience. Since real networks are rarely lightly loaded, WaveDeploy adds the ability to measure end-user QoE in the presence of pre-defined, vertical market-specific loads.

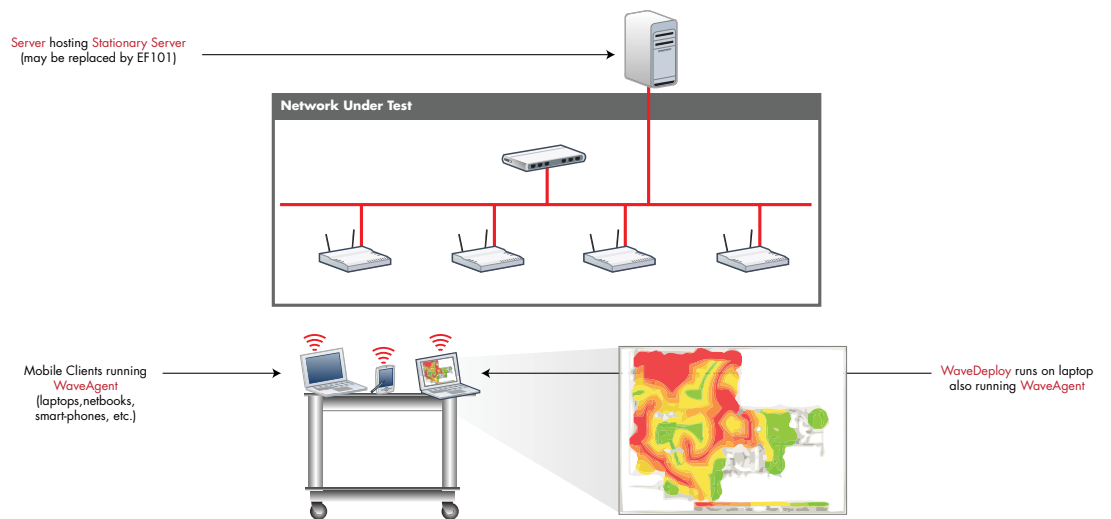


Figure 1. Conducting Site Assessment in ideal or lightly loaded network conditions

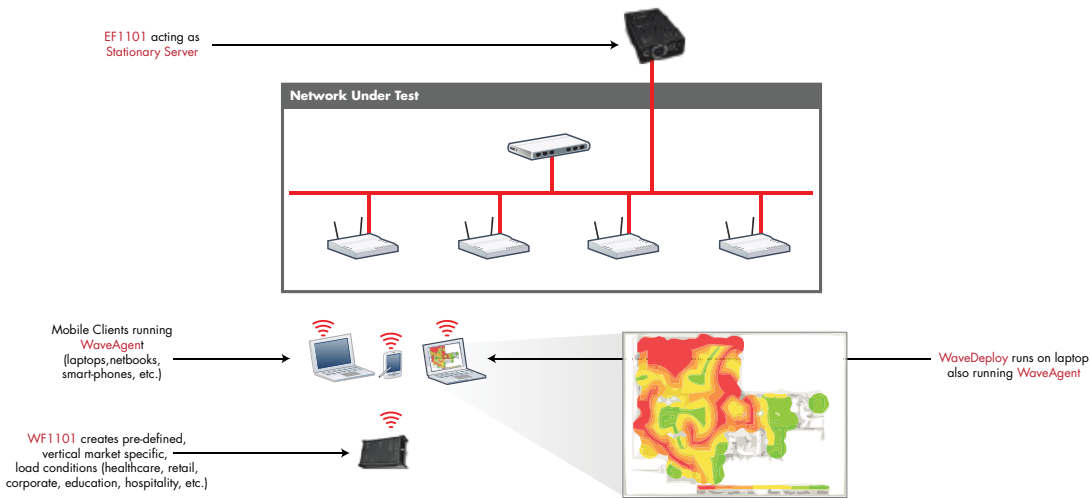


Figure 2. Conducting Site Assessment in planned, realistic, loaded, network conditions

Prior to Wave Deploy, Site Assessment in realistic network conditions was very difficult. For example, when a WLAN was deployed and users had not yet moved into the facility, attempting to coordinate and achieve meaningful and repeatable load tests was impractical and time consuming using “carts of laptops”. However, by utilizing the WF1101 Wi-Fi Traffic Generator, the network can be loaded with traffic from scores of “golden clients” that provide the traffic loads users will place on the network. Not only does this expedite testing, it allows the tester to detect any deficiencies in the network or in mobile-client interaction before actual users move in and suffer from these deficiencies. The ability to test at scale is an industry- unique aspect of WaveDeploy when used with the WF1101 and EF1101 Traffic Generators, as is the ability to include the actual client devices with the scaled traffic.

Prior to Wave Deploy, Site Assessment in realistic network conditions was very difficult.

Defining Target Rates and Service Level Agreements (SLA)

Conducting a Site Assessment using WaveDeploy allows the user to set the Target Rate for each traffic type run to a mobile-client device as well as the Service Level Agreement (SLA), or target performance, each mobile-client will be measured against. To determine the Target Rate and SLA, a number of factors need to be considered:

- Mobile-client and Network technology
- Number and types of mobile-clients participating the site assessment
- Ecosystem loading with the WF1101
- Background loading of the network under test

Mobile-Client and Network Capability

Mobile-client capability varies significantly between client types. While laptops may be equipped with 802.11n 3x3 MIMO Network Interface Cards (NICs), and smart-phones with 802.11n 1x1 or 2x2 MIMO NICs, patient monitors in healthcare environments and scanners in retail and warehouse environments may be equipped with legacy 802.11b

or 802.11g wireless capabilities. These differences must be observed to allow for realistic loading of the site being assessed.

Network capabilities also vary widely based on when the network was deployed and what services it needs to support.

In Site Assessments conducted using WaveDeploy, individual mobile-client performance is measured against pre-set SLAs that are applicable to the type of client, the application(s) supported by the mobile-client, and the capabilities of the network being tested.

Mobile-client technology, applications and SLAs

The following are examples of best practices for measuring mobile-clients based on their capabilities and the applications they serve:

- Laptops should support web download speeds better than 15Mbps in lightly loaded 802.11g networks, and better than 80Mbps in lightly loaded 802.11n networks, while offering VoIP over WLAN with MOS values better than 3.80 and streaming video with Media Delivery Index (MDI) Media Loss Rates (MLR) better than 1% and Delay Factors (DF) better than 150mSec.
- Smart-phones should support web download speeds better than 5Mbps in lightly loaded 802.11g networks, and better than 10Mbps in lightly loaded 802.11n networks, while offering VoIP over WLAN with MOS values better than 4.00.
- Patient Monitors, scanners, and other low data-rate monitoring devices: should support effective TCP downstream and upstream data rates of at least 20kbps.

Network Technology

Traffic loads and modulation rates will be different in legacy (802.11a/b/g) networks versus 802.11n high-throughput (HT) networks, and may be different even between 2.4 GHz and 5 GHz HT networks. The 2.4 GHz band of an 802.11n network will typically be configured for 20 MHz operation, while a 5 GHz band will be configured for 40 MHz operation. The traffic loads and SLAs appropriate to each of these three network type choices (legacy, 802.11n-20 MHz and 802.11n-40 MHz) scales by the theoretical capacity under the three network definitions.

Legacy networks support up to 54 Mbps. 802.11n-20 MHz networks support modulation rates of 130 Mbps with 2x2 MIMO and frame aggregation, and 195 Mbps in 3x3 MIMO networks. 802.11n-40 MHz networks advance those transport figures to 300 Mbps for 2x2 MIMO and 450 Mbps for 3x3 MIMO.

And while choice of representative clients is crucial to assessing the networks ability to handle the actual planned or currently used applications, a more aggressive approach needs to be used when the goal is to assess the maximum capabilities of the network or its ability to grow in the future. In these cases the best practice is to always conduct the site assessment with mobile-client devices which equal or exceed the capability of the network under test. This ensures network performance is being assessed, not client capability.

For dual band networks, the preferred approach is to conduct separate surveys of the 2.4 GHz and 5 GHz bands, configuring the mobile-client to match the band being tested. It is important to certify the ability of the network to deliver service on each band individually.

Traffic loads and modulation rates will be different in legacy (802.11a/b/g) networks versus 802.11n high-throughput (HT) networks, and may be different even between 2.4 GHz and 5 GHz HT networks.

Some networks can be configured to balance loads between the bands, but during the site assessment process it is important to document what each band is capable of supporting. If a survey was being conducted on the 2.4 GHz band, configured for 20 MHz operation, the client could choose to connect to an AP advertising the same network on the 5 GHz band, and the resulting measurements would be of the 40 MHz environment, resulting in incorrectly optimistic results.

Number and Type of Mobile-Clients participating in Site Assessment

Since multiple mobile-clients will typically be used in a Site Assessment, two testing modes should be employed: 1) assessing end-user QoE when multiple mobile-clients are present in the environment, as would be the case in many real-world conditions, to assess the ability of the various mobile-clients to coexist while maintaining end-user expectations, and 2) assessing end-user QoE for each individual mobile-client when it is the only user of the network resources to obtain a “best-case” measurement. WaveDeploy has been designed to deliver both of these results at each measurement point.

At each measurement location on a map, WaveDeploy first runs a traffic load test that involves all selected traffic to all mobile-client devices simultaneously. This provides an accurate measurement of QoE delivered while the client devices are in proximity of each other and running traffic. This is called the “coexistence test”, and lasts for a few seconds. In the Notification section of the user interface, the traffic types that are applied are displayed.

Immediately following the coexistence test, WaveDeploy then applies the selected traffic to one mobile-client at a time, one traffic type at a time. This is called the “speed test” and provides the verification of selected traffic performance to/from a mobile-client without traffic to other mobile-clients, or other traffic to the selected mobile-client.

The advantage of this style of testing is two-fold: 1) if the client devices are interacting with each other, this will be evident in the results of the coexistence test. One mobile-client monopolizing the media will achieve acceptable SLA figures while other mobile-clients will not, and 2) this approach gives verification at each physical location of the performance the mobile-client is capable of, if not affected by other client-devices. Client-devices getting poor coexistence figures but getting good speed test figures are being affected by other client-devices. Those getting poor speed test figures are being affected by their relationship with the network, or other interference sources.

The best practice Load and SLA values defined in this document were calculated for the case where one mobile-client of each type (laptop, smart-phone, scanner, patient monitor, etc) is being used to apply the wireless load, and is therefore expected to provide all traffic for that client type. When two or more identical type mobile-clients are used, the Upstream Web HTTP and Downstream Web HTTP loads used in the coexistence test are applied to all mobile-clients of that type simultaneously. Care should be taken that the sum of all coexistence traffic does not create an overload condition for the network. The rule to be applied is to divide the Upstream Web HTTP and Downstream Web HTTP loads and SLA by the number of like mobile-clients configured in the test.

At each measurement location on a map, WaveDeploy first runs a traffic load test that involves all selected traffic to all mobile-client devices simultaneously.

Ecosystem Loading with the WF1101

In addition to the actual mobile-clients in the test, the WF1101 Wi-Fi traffic generator can be used in conjunction with an EF1101 Ethernet traffic generator to subject the network to additional traffic, referred to as “ecosystem traffic.” On each WF1101, up to 64 Stationary Clients can be created, and the traffic streams associated with those clients will be tied to an EF1101 as Stationary Server. Under this use model, both the coexistence tests and the speed tests described above will be conducted in the presence of a constant, but user-configurable, background load.

In the case where Stationary Clients are included in the site assessment, care should be taken to decrease the Target Rate and SLA values for the mobile-clients accordingly, so the sum of the stationary ecosystem traffic plus mobile-client traffic does not exceed the capacity of the network. The rule to be applied in this case is to subtract the total amount of stationary ecosystem traffic from the both the Upstream and Downstream Web HTTP target loads and the Speed test figures, then divide the Upstream and Downstream Web HTTP target rates by the number of mobile-clients configured in the test.

In addition to the actual mobile-clients in the test, the WF1101 Wi-Fi traffic generator can be used in conjunction with an EF1101 Ethernet traffic generator to subject the network to additional traffic, referred to as “ecosystem traffic.”

Summary of Loading Considerations

To summarize:

- WaveDeploy runs two measurement cases at each assessment point on a map:
 - Coexistence Traffic
 - Speed Test
- The type, direction, Target Rate and SLA values for both Coexistence Traffic and Speed Test Traffic can be adjusted on the “Advanced” section of the WaveDeploy user interface. For faster test times, select fewer traffic types to be included in the speed test.
- In addition to the two measurement cases listed above, the WF1101 and EF1101 can be used to add Ecosystem Traffic, which is equivalent to adding up to 64 stationary wireless clients per WF1101 employed and the traffic as configured on the “Advanced” page under “Ecosystem Laptop” and “Ecosystem Smartphone” Host Types.
- The total load that WaveDeploy will apply to the network under test at any one time will be:
 - During Coexistence Testing- the sum of Coexistence Traffic types selected per Host Type, times the number of that Host Type included in the test, plus the sum of all Ecosystem Traffic defined and connected.
 - During Speed Testing – the traffic load of each selected Traffic type, one at a time, plus the sum of all Ecosystem Traffic defined and connected.
- It is up to the user to ensure that the total load does not exceed the capability of the network.

Background Loading of the Network Under Test

When a site assessment is conducted, the network will be in one of two conditions:

- Unloaded, as in the case of a newly deployed network prior to arrival of building occupants, or during testing in off- hours
- Loaded, as in the case of an existing production network being tested during working hours

The best practice Load and SLA values defined in this document contain settings for “Unloaded” network conditions and provide levels of load and expected performance commensurate with certifying a network installation. Using these on an unloaded network will provide sufficient traffic stress to prove the network equipment and the network configuration. However, if used on a network that is already carrying a production load of user traffic, this could result in an overload condition and disrupt the production use of the network. If the network is already loaded with production traffic, more modest levels of traffic should be used.

Performing Baseline Measurements

It is good practice to conduct baseline measurements before commencing a site assessment. Two types of baseline measurements are recommended:

- Qualify the capability of the wired LAN (Stationary Server) test element: since the site assessment involves passing traffic upstream and downstream to/from the wired LAN part of the network, WaveDeploy utilizes a Stationary Server to act as a source and sink of test traffic on the Ethernet side of the network. This server can either be a computer with a WaveAgent installed and running, or an EF1101 Ethernet traffic generator. It is crucial that the Stationary Server has sufficient capacity so as not to influence test results. A method for qualifying the a computer used as a Stationary Server is described in Appendix A.
- Verify the Target Rate and SLA settings: prior to conducting the site assessment, it is prudent to perform a short spot-check to ensure the target traffic rates and SLA settings are correct and do not create a total load that is beyond the capacity of the network, and that SLA settings are adjusted so that acceptable performance results are displayed correctly on the coloring of the maps. This is best done by placing the selected mobile-clients to be used in the survey in a favorable location with respect to an AP, and performing a set of four measurements. If the testing results in poor performance, the cause should be addressed before proceeding to a Site Assessment. A method for verifying load and SLA settings is described in Appendix B.

It is good practice to conduct baseline measurements before commencing a site assessment.

Consequence of Overloading the Network Under Test

Some words of caution are in order with regards to Target Rate settings. The proprietary core traffic generation technology of WaveAgent and in the EF1101 and WF1101 traffic generators is designed specifically to apply the traffic loads as configured by the user. This means that WaveDeploy can easily be configured to subject the network under test to more traffic than it can successfully transport. All client devices and WaveDeploy products involved in a test must communicate over the network being tested. If that network is loaded to the point where significant frame loss occurs, communication between the elements of WaveDeploy can be disrupted.

Unlike other utilities which stop stressing the network when communication between the ends is interrupted, WaveDeploy allows true measurements under known load conditions to be made.

WaveDeploy is unique in its ability to deliver stressful and predictable traffic loads to the network, but requires reliable communication to exist between the WaveDeploy console and all WaveAgents, EF1101 and WF1101 appliances participating in a given test. Unlike other utilities which stop stressing the network when communication between the ends is interrupted, WaveDeploy allows true measurements under known load conditions to be made. While this is a great advantage for deriving measurements that directly correspond to the end user's quality of experience, it does require the user to configure the intended loads such that total loading of the network under test does not exceed the actual capacity of the network to the point where WaveDeploy control packets between devices suffer extremely high loss.

The WaveDeploy default Target Rate settings are deliberately set lower than what the tables below recommend. A properly configured and functioning network will support the figures below, however it is advisable to confirm operation at the lower load settings before proceeding to tests with recommended loads. If WaveDeploy testing is producing missing results, or error messages are displayed which indicate responses from fixed or mobile agents are missing, it is likely that the Target Rates being requested from the individual WaveAgents and WaveDeploy hardware units is exceeding the current capacity of the network.

Load and Service Level Agreement Values for Healthcare Networks

This section contains best-practice traffic load and SLA values for healthcare networks. The types of mobile-clients typically found in these networks are:

- Laptops, tablet-PCs, and netbooks
- Bed-side patient monitors
- Scanners
- Infusion pumps
- Handheld VoFi phones

The traffic loads and SLAs should be set to fit the type of network being tested and the type of mobile-clients being used. All values assume no other traffic load exists on the tested network. If the network is loaded with medium to heavy traffic loads, adjustments will have to be considered. Contact IxVeriWave for additional information.

Legacy Network - Applications SLAs

Traffic Type	Minimum Acceptable Rate (Mbps)	Target Rate (Mbps)	Maximum Acceptable Video MLR (packets/s)	Target Video MLR (packets/s)	Maximum Acceptable Video DF (sec)	Target Video DF (sec)	Maximum Acceptable Loss (%)	Target Loss (%)	Maximum Acceptable Jitter (sec.)	Target Jitter (sec.)	Minimum Acceptable MOS	Target MOS	Notes
<i>Laptop</i>													
Upstream Web HTTP	4	8											1
Down-stream Web HTTP	4	8											1
Upstream TCP Speed Test	8	15											2
Down-stream TCP Speed Test	8	15											2
Upstream UDP Speed Test	10	20											2
Down-stream UDP Speed Test	10	20											2
Voice UDP							1	0			3.80	4.20	
Down-stream Video RTP			1	0	0.15	0							
<i>Smart-phone</i>													
Upstream Web HTTP	1	2											1
Down-stream Web HTTP	1	2											1
Upstream TCP Speed Test	2	4											2
Down-stream TCP Speed Test	2	4											2
Upstream UDP Speed Test	3	8											2
Down-stream UDP Speed Test	3	8											2
Voice UDP							1	0			4.00	4.20	
<i>Patient Monitor</i>													
Upstream TCP	0.01	0.02											
Down-stream TCP	0.01	0.02											
<i>Scanner</i>													
Upstream UDP	0.01	0.02					10	0	0.50	0			
Down-stream UDP	0.01	0.02					10	0	0.50	0			
<i>VoFi</i>													
Voice UDP							1	0			4.00	4.20	

Notes:

1. SLAs assume one mobile-client of each type in a testing session and no ecosystem traffic on WF1101. For multiple mobile-clients of a given type, divide the Target Rate and Minimum Acceptable Rate by the number of clients, after accounting for ecosystem traffic.
2. Speed Test measurements are made one traffic type and client at a time. It is not necessary to alter these settings for the case of multiple mobile-clients, however ecosystem traffic must be accounted for.

Legacy Network - RF Signal SLAs

Host Type	Mimum Acceptable Signal Strength (dBm)	Target Signal Strength (dBm)	Minimum Acceptable Signal Difference (dB)	Target Signal Difference (dB)	Minimum Acceptable PHY Rate (Mbps)	Target PHY Rate (Mbps)
Signal Strength	-65	-45				
Co-Channel Interference			15	25		
PHY Rate					11	54

802.11n, 20 MHz, Network - Applications SLAs

Traffic Type	Minimum Acceptable Rate (Mbps)	Target Rate (Mbps)	Maximum Acceptable Video MLR (packets/s)	Target Video MLR (packets/s)	Maximum Acceptable Video DF (sec)	Target Video DF (sec)	Maximum Acceptable Loss (%)	Target Loss (%)	Maximum Acceptable Jitter (sec.)	Target Jitter (sec.)	Minimum Acceptable MOS	Target MOS	Notes
Laptop													
Upstream Web HTTP	10	20											1
Down-stream Web HTTP	10	20											1
Upstream TCP Speed Test	15	30											2
Down-stream TCP Speed Test	15	30											2
Upstream UDP Speed Test	20	40											2
Down-stream UDP Speed Test	20	40											2
Voice UDP							1	0			3.80	4.20	
Down-stream Video RTP			1	0	0.15	0							
Smart-phone													
Upstream Web HTTP	1	2											1
Down-stream Web HTTP	1	2											1
Upstream TCP Speed Test	2	4											2
Down-stream TCP Speed Test	2	4											2
Upstream UDP Speed Test	3	8											2
Down-stream UDP Speed Test	3	8											2
Voice UDP							1	0			4.00	4.20	
Patient Monitor													
Upstream TCP	0.01	0.02											
Down-stream TCP	0.01	0.02											
Scanner													

Upstream UDP	0.01	0.02					10	0	0.50	0			
Down-stream UDP	0.01	0.02					10	0	0.50	0			
VoFi													
Voice UDP							1	0				4.00	4.20

Notes:

1. SLAs assume one mobile-client of each type in a testing session and no ecosystem traffic on WF1101. For multiple mobile-clients of a given type, divide the Target Rate and Minimum Acceptable Rate by the number of clients, after accounting for ecosystem traffic.
2. Speed Test measurements are made one traffic type and client at a time. It is not necessary to alter these settings for the case of multiple mobile-clients, however ecosystem traffic must be accounted for.

802.11n, 20 MHz, Network – RF Signal SLAs

Host Type	Mimum Acceptable Signal Strength (dBm)	Target Signal Strength (dBm)	Minimum Acceptable Signal Difference (dB)	Target Signal Difference (dB)	Minimum Acceptable PHY Rate (Mbps)	Target PHY Rate (Mbps)
Signal Strength	-65	-45				
Co-Channel Interference			15	25		
PHY Rate					26	78

802.11n, 40 MHz, Network - Application SLAs

Traffic Type	Minimum Acceptable Rate (Mbps)	Target Rate (Mbps)	Maximum Acceptable Video MLR (packets/s)	Target Video MLR (packets/s)	Maximum Acceptable Video DF (sec)	Target Video DF (sec)	Maximum Acceptable Loss (%)	Target Loss (%)	Maximum Acceptable Jitter (sec.)	Target Jitter (sec.)	Minimum Acceptable MOS	Target MOS	Notes
Laptop													
Upstream Web HTTP	15	30											1
Down-stream Web HTTP	15	30											1
Upstream TCP Speed Test	25	50											2
Down-stream TCP Speed Test	25	50											2
Upstream UDP Speed Test	40	80											2
Down-stream UDP Speed Test	40	80											2
Voice UDP							1	0			3.80	4.20	
Down-stream Video RTP			1	0	0.15	0							
Smart-phone													
Upstream Web HTTP	1	2											1
Down-stream Web HTTP	1	2											1

Upstream TCP Speed Test	2	4											2
Downstream TCP Speed Test	2	4											2
Upstream UDP Speed Test	3	8											2
Downstream UDP Speed Test	3	8											2
Voice UDP						1	0				4.00	4.20	
Patient Monitor													
Upstream TCP	0.01	0.02											
Downstream TCP	0.01	0.02											
Scanner													
Upstream UDP	0.01	0.02				10	0	0.50	0				
Downstream UDP	0.01	0.02				10	0	0.50	0				
VoFi													
Voice UDP						1	0				4.00	4.20	

Notes:

1. SLAs assume one mobile-client of each type in a testing session and no ecosystem traffic on WF1101. For multiple mobile-clients of a given type, divide the Target Rate and Minimum Acceptable Rate by the number of clients, after accounting for ecosystem traffic.
2. Speed Test measurements are made one traffic type and client at a time. It is not necessary to alter these settings for the case of multiple mobile-clients, however ecosystem traffic must be accounted for.

802.11n, 40 MHz, Network – RF Signal SLAs

Host Type	Mimum Acceptable Signal Strength (dBm)	Target Signal Strength (dBm)	Minimum Acceptable Signal Difference (dB)	Target Signal Difference (dB)	Minimum Acceptable PHY Rate (Mbps)	Target PHY Rate (Mbps)
Signal Strength	-65	-45				
Co-Channel Interference			15	25		
PHY Rate					90	180

Load and Service Level Agreement Values for Corporate Networks

This section contains best-practice traffic load and SLA values for corporate networks, sometimes referred to as “carpeted enterprise networks”. The types of mobile-clients typically found in these networks are:

- Laptops and netbooks
- Smart-Phones
- Handheld VoFi phones

The Target Rates and SLAs should be set to fit the type of network being tested and the type of mobile-clients being used. All values assume no other traffic load exists on the tested network. If the network is loaded with medium to heavy traffic loads, adjustments will have to be considered.

Legacy Network - Applications SLAs

Traffic Type	Minimum Acceptable Rate (Mbps)	Target Rate (Mbps)	Maximum Acceptable Video MLR (packets/s)	Target Video MLR (packets/s)	Maximum Acceptable Video DF (sec)	Target Video DF (sec)	Maximum Acceptable Loss (%)	Target Loss (%)	Maximum Acceptable Jitter (sec.)	Target Jitter (sec.)	Minimum Acceptable MOS	Target MOS	Notes
Laptop													
Upstream Web HTTP	4	8											1
Down-stream Web HTTP	4	8											1
Upstream TCP Speed Test	8	15											2
Down-stream TCP Speed Test	8	15											2
Upstream UDP Speed Test	10	20											2
Down-stream UDP Speed Test	10	20											2
Voice UDP							1	0			3.80	4.20	
Down-stream Video RTP			1	0	0.15	0							
Smart-phone													
Upstream Web HTTP	1	2											1
Down-stream Web HTTP	1	2											1
Upstream TCP Speed Test	2	4											2
Down-stream TCP Speed Test	2	4											2
Upstream UDP Speed Test	3	8											2
Down-stream UDP Speed Test	3	8											2
Voice UDP							1	0			4.00	4.20	
VoFi													
Voice UDP							1	0			4.00	4.20	

Notes:

1. SLAs assume one mobile-client of each type in a testing session and no ecosystem traffic on WF1101. For multiple mobile-clients of a given type, divide the Target Rate and Minimum Acceptable Rate by the number of clients, after accounting for ecosystem traffic.
2. Speed Test measurements are made one traffic type and client at a time. It is not necessary to alter these settings for the case of multiple mobile-clients, however ecosystem traffic must be accounted for.

Legacy Network - RF Signal SLAs

Host Type	Mimum Acceptable Signal Strength (dBm)	Target Signal Strength (dBm)	Minimum Acceptable Signal Difference (dB)	Target Signal Difference (dB)	Minimum Acceptable PHY Rate (Mbps)	Target PHY Rate (Mbps)
Signal Strength	-65	-45				
Co-Channel Interference			15	25		
PHY Rate					11	54

802.11n, 20 MHz, Network - Application SLAs

Traffic Type	Minimum Acceptable Rate (Mbps)	Target Rate (Mbps)	Maximum Acceptable Video MLR (packets/s)	Target Video MLR (packets/s)	Maximum Acceptable Video DF (sec)	Target Video DF (sec)	Maximum Acceptable Loss (%)	Target Loss (%)	Maximum Acceptable Jitter (sec.)	Target Jitter (sec.)	Minimum Acceptable MOS	Target MOS	Notes
Laptop													
Upstream Web HTTP	10	20											1
Down-stream Web HTTP	10	20											1
Upstream TCP Speed Test	15	30											2
Down-stream TCP Speed Test	15	30											2
Upstream UDP Speed Test	20	40											2
Down-stream UDP Speed Test	20	40											2
Voice UDP							1	0			3.80	4.20	
Down-stream Video RTP			1	0	0.15	0							
Smart-phone													
Upstream Web HTTP	1	2											1
Down-stream Web HTTP	1	2											1
Upstream TCP Speed Test	2	4											2
Down-stream TCP Speed Test	2	4											2
Upstream UDP Speed Test	3	8											2
Down-stream UDP Speed Test	3	8											2
Voice UDP							1	0			4.00	4.20	
VoFi													
Voice UDP							1	0			4.00	4.20	

Notes:

1. SLAs assume one mobile-client of each type in a testing session and no ecosystem traffic on WF1101. For multiple mobile-clients of a given type, divide the Target Rate and Minimum Acceptable Rate by the number of clients, after accounting for ecosystem traffic.
2. Speed Test measurements are made one traffic type and client at a time. It is not necessary to alter these settings for the case of multiple mobile-clients, however ecosystem traffic must be accounted for.

802.11n, 20 MHz, Network – RF Signal SLAs

Host Type	Mimum Acceptable Signal Strength (dBm)	Target Signal Strength (dBm)	Minimum Acceptable Signal Difference (dB)	Target Signal Difference (dB)	Minimum Acceptable PHY Rate (Mbps)	Target PHY Rate (Mbps)
Signal Strength	-65	-45				
Co-Channel Interference			15	25		
PHY Rate					26	78

802.11n, 40 MHz, Network - Application SLAs

Traffic Type	Minimum Acceptable Rate (Mbps)	Target Rate (Mbps)	Maximum Acceptable Video MLR (packets/s)	Target Video MLR (packets/s)	Maximum Acceptable Video DF (sec)	Target Video DF (sec)	Maximum Acceptable Loss (%)	Target Loss (%)	Maximum Acceptable Jitter (sec.)	Target Jitter (sec.)	Minimum Acceptable MOS	Target MOS	Notes
Laptop													
Upstream Web HTTP	15	30											1
Down-stream Web HTTP	15	30											1
Upstream TCP Speed Test	25	50											2
Down-stream TCP Speed Test	25	50											2
Upstream UDP Speed Test	40	80											2
Down-stream UDP Speed Test	40	80											2
Voice UDP							1	0			3.80	4.20	
Down-stream Video RTP			1	0	0.15	0							
Smart-phone													
Upstream Web HTTP	1	2											1
Down-stream Web HTTP	1	2											1
Upstream TCP Speed Test	2	4											2
Down-stream TCP Speed Test	2	4											2
Upstream UDP Speed Test	3	8											2
Down-stream UDP Speed Test	3	8											2

Voice UDP						1	0			4.00	4.20	
VoFi												
Voice UDP						1	0			4.00	4.20	

Notes:

1. SLAs assume one mobile-client of each type in a testing session and no ecosystem traffic on WF1101. For multiple mobile-clients of a given type, divide the Target Rate and Minimum Acceptable Rate by the number of clients, after accounting for ecosystem traffic.
2. Speed Test measurements are made one traffic type and client at a time. It is not necessary to alter these settings for the case of multiple mobile-clients, however ecosystem traffic must be accounted for.

802.11n, 40 MHz, Network – RF Signal SLAs

Host Type	Mimum Acceptable Signal Strength (dBm)	Target Signal Strength (dBm)	Minimum Acceptable Signal Difference (dB)	Target Signal Difference (dB)	Minimum Acceptable PHY Rate (Mbps)	Target PHY Rate (Mbps)
Signal Strength	-65	-45				
Co-Channel Interference			15	25		
PHY Rate					90	180

Load and Service Level Agreement Values for Higher-education, Service-provider and Hospitality Networks

This section contains best-practice traffic load and SLA values for Higher-Education (college and university), Service-Provider and Hospitality networks. The types of mobile-clients typically found in these networks are:

- Laptops and netbooks
- Smart-Phones

The traffic loads and SLAs should be set to fit the type of network being tested and the type of mobile-clients being used. All values assume no other traffic load exists on the tested network. If the network is loaded with medium to heavy traffic loads, adjustments will have to be considered. Contact IxVeriWave for additional information.

Legacy Network - Application SLAs

Traffic Type	Minimum Acceptable Rate (Mbps)	Target Rate (Mbps)	Maximum Acceptable Video MLR (packets/s)	Target Video MLR (packets/s)	Maximum Acceptable Video DF (sec)	Target Video DF (sec)	Maximum Acceptable Loss (%)	Target Loss (%)	Maximum Acceptable Jitter (sec.)	Target Jitter (sec.)	Minimum Acceptable MOS	Target MOS	Notes
Laptop													
Upstream Web HTTP	4	8											1
Down-stream Web HTTP	4	8											1
Upstream TCP Speed Test	8	15											2
Down-stream TCP Speed Test	8	15											2
Upstream UDP Speed Test	10	20											2

Down-stream UDP Speed Test	10	20											2
Voice UDP							1	0			3.80	4.20	
Down-stream Video RTP			1	0	0.15	0							
Smart-phone													
Upstream Web HTTP	1	2											1
Down-stream Web HTTP	1	2											1
Upstream TCP Speed Test	2	4											2
Down-stream TCP Speed Test	2	4											2
Upstream UDP Speed Test	3	8											2
Down-stream UDP Speed Test	3	8											2
Voice UDP							1	0			4.00	4.20	

Notes:

1. SLAs assume one mobile-client of each type in a testing session and no ecosystem traffic on WF1101. For multiple mobile-clients of a given type, divide the Target Rate and Minimum Acceptable Rate by the number of clients, after accounting for ecosystem traffic.
2. Speed Test measurements are made one traffic type and client at a time. It is not necessary to alter these settings for the case of multiple mobile-clients, however ecosystem traffic must be accounted for.

Legacy Network – RF Signal SLAs

Host Type	Mimum Acceptable Signal Strength (dBm)	Target Signal Strength (dBm)	Minimum Acceptable Signal Difference (dB)	Target Signal Difference (dB)	Minimum Acceptable PHY Rate (Mbps)	Target PHY Rate (Mbps)
Signal Strength	-65	-45				
Co-Channel Interference			15	25		
PHY Rate					11	54

802.11n, 20 MHz, Network – Application SLAs

Traffic Type	Minimum Acceptable Rate (Mbps)	Target Rate (Mbps)	Maximum Acceptable Video MLR (packets/s)	Target Video MLR (packets/s)	Maximum Acceptable Video DF (sec)	Target Video DF (sec)	Maximum Acceptable Loss (%)	Target Loss (%)	Maximum Acceptable Jitter (sec.)	Target Jitter (sec.)	Minimum Acceptable MOS	Target MOS	Notes
Laptop													
Upstream Web HTTP	10	20											1
Downstream Web HTTP	10	20											1
Upstream TCP Speed Test	15	30											2
Downstream TCP Speed Test	15	30											2
Upstream UDP Speed Test	20	40											2
Downstream UDP Speed Test	20	40											2
Voice UDP							1	0			3.80	4.20	
Downstream Video RTP			1	0	0.15	0							
Smart-phone													
Upstream Web HTTP	1	2											1
Downstream Web HTTP	1	2											1
Upstream TCP Speed Test	2	4											2
Downstream TCP Speed Test	2	4											2
Upstream UDP Speed Test	3	8											2
Downstream UDP Speed Test	3	8											2
Voice UDP							1	0			4.00	4.20	

Notes:

1. SLAs assume one mobile-client of each type in a testing session and no ecosystem traffic on WF1101. For multiple mobile-clients of a given type, divide the Target Rate and Minimum Acceptable Rate by the number of clients, after accounting for ecosystem traffic.
2. Speed Test measurements are made one traffic type and client at a time. It is not necessary to alter these settings for the case of multiple mobile-clients, however ecosystem traffic must be accounted for.

802.11n, 20 MHz, Network – RF Signal SLAs

Host Type	Minimum Acceptable Signal Strength (dBm)	Target Signal Strength (dBm)	Minimum Acceptable Signal Difference (dB)	Target Signal Difference (dB)	Minimum Acceptable PHY Rate (Mbps)	Target PHY Rate (Mbps)
Signal Strength	-65	-45				
Co-Channel Interference			15	25		

Co-Channel Interference			15	25		
PHY Rate					26	78

802.11n, 40 MHz, Network – Application SLAs

Traffic Type	Minimum Acceptable Rate (Mbps)	Target Rate (Mbps)	Maximum Acceptable Video MLR (packets/s)	Target Video MLR (packets/s)	Maximum Acceptable Video DF (sec)	Target Video DF (sec)	Maximum Acceptable Loss (%)	Target Loss (%)	Maximum Acceptable Jitter (sec.)	Target Jitter (sec.)	Minimum Acceptable MOS	Target MOS	Notes
Laptop													
Upstream Web HTTP	15	30											1
Down-stream Web HTTP	15	30											1
Upstream TCP Speed Test	25	50											2
Down-stream TCP Speed Test	25	50											2
Upstream UDP Speed Test	40	80											2
Down-stream UDP Speed Test	40	80											2
Voice UDP							1	0			3.80	4.20	
Down-stream Video RTP			1	0	0.15	0							
Smart-phone													
Upstream Web HTTP	1	2											1
Down-stream Web HTTP	1	2											1
Upstream TCP Speed Test	2	4											2
Down-stream TCP Speed Test	2	4											2
Upstream UDP Speed Test	3	8											2
Down-stream UDP Speed Test	3	8											2
Voice UDP							1	0			4.00	4.20	

Notes:

1. SLAs assume one mobile-client of each type in a testing session and no ecosystem traffic on WF1101. For multiple mobile-clients of a given type, divide the Target Rate and Minimum Acceptable Rate by the number of clients, after accounting for ecosystem traffic.
2. Speed Test measurements are made one traffic type and client at a time. It is not necessary to alter these settings for the case of multiple mobile-clients, however ecosystem traffic must be accounted for.

802.11n, 40 MHz, Network – RF Signal SLAs

Host Type	Minimum Acceptable Signal Strength (dBm)	Target Signal Strength (dBm)	Minimum Acceptable Signal Difference (dB)	Target Signal Difference (dB)	Minimum Acceptable PHY Rate (Mbps)	Target PHY Rate (Mbps)
Signal Strength	-65	-45				
Co-Channel Interference			15	25		
PHY Rate					90	180

Load and Service Level Agreement Values for Retail and Warehouse Networks

This section contains best-practice traffic load and SLA values for Retail and Warehousing networks. The types of mobile-clients typically found in these networks are:

- Laptops and netbooks
- Inventory and Point Of Sales (POS) scanners
- Handheld VoFi phones

The traffic loads and SLAs should be set to fit the type of network being tested and the type of mobile-clients being used. All values assume no other traffic load exists on the tested network. If the network is loaded with medium to heavy traffic loads, adjustments will have to be considered. Contact IxVeriWave for additional information.

Legacy Network - Application SLAs

Traffic Type	Minimum Acceptable Rate (Mbps)	Target Rate (Mbps)	Maximum Acceptable Video MLR (packets/s)	Target Video MLR (packets/s)	Maximum Acceptable Video DF (sec)	Target Video DF (sec)	Maximum Acceptable Loss (%)	Target Loss (%)	Maximum Acceptable Jitter (sec.)	Target Jitter (sec.)	Minimum Acceptable MOS	Target MOS	Notes
Laptop													
Upstream Web HTTP	4	8											1
Down-stream Web HTTP	4	8											1
Upstream TCP Speed Test	8	15											2
Down-stream TCP Speed Test	8	15											2
Upstream UDP Speed Test	10	20											2
Down-stream UDP Speed Test	10	20											2
Voice UDP							1	0			3.80	4.20	
Down-stream Video RTP			1	0	0.15	0							
Smart-phone													
Upstream Web HTTP	1	2											1
Down-stream Web HTTP	1	2											1

Upstream TCP Speed Test	2	4											2
Downstream TCP Speed Test	2	4											2
Upstream UDP Speed Test	3	8											2
Downstream UDP Speed Test	3	8											2
Voice UDP							7	0			4.00	4.20	
Scanner													
Upstream UDP	0.01	0.02					10	0	0.50	0			
Downstream UDP	0.01	0.02					10	0	0.50	0			
VoFi													
Voice UDP							7	0			4.00	4.20	

Notes:

1. SLAs assume one mobile-client of each type in a testing session and no ecosystem traffic on WF1101. For multiple mobile-clients of a given type, divide the Target Rate and Minimum Acceptable Rate by the number of clients, after accounting for ecosystem traffic.
2. Speed Test measurements are made one traffic type and client at a time. It is not necessary to alter these settings for the case of multiple mobile-clients, however ecosystem traffic must be accounted for.

Legacy Network – RF Signal SLAs

Host Type	Mimum Acceptable Signal Strength (dBm)	Target Signal Strength (dBm)	Minimum Acceptable Signal Difference (dB)	Target Signal Difference (dB)	Minimum Acceptable PHY Rate (Mbps)	Target PHY Rate (Mbps)
Signal Strength	-65	-45				
Co-Channel Interference			15	25		
PHY Rate					11	54

802.11n, 20 MHz, Network - Application SLAs

Traffic Type	Minimum Acceptable Rate (Mbps)	Target Rate (Mbps)	Maximum Acceptable Video MLR (packets/s)	Target Video MLR (packets/s)	Maximum Acceptable Video DF (sec)	Target Video DF (sec)	Maximum Acceptable Loss (%)	Target Loss (%)	Maximum Acceptable Jitter (sec.)	Target Jitter (sec.)	Minimum Acceptable MOS	Target MOS	Notes
Laptop													
Upstream Web HTTP	10	20											1
Downstream Web HTTP	10	20											1
Upstream TCP Speed Test	15	30											2
Downstream TCP Speed Test	15	30											2
Upstream UDP Speed Test	20	40											2

Down-stream UDP Speed Test	20	40											2
Voice UDP							1	0			3.80	4.20	
Down-stream Video RTP			1	0	0.15	0							
Smart-phone													
Upstream Web HTTP	1	2											1
Down-stream Web HTTP	1	2											1
Upstream TCP Speed Test	2	4											2
Down-stream TCP Speed Test	2	4											2
Upstream UDP Speed Test	3	8											2
Down-stream UDP Speed Test	3	8											2
Voice UDP							1	0			4.00	4.20	
Scanner													
Upstream UDP	0.01	0.02					10	0	0.50	0			
Down-stream UDP	0.01	0.02					10	0	0.50	0			
VoFi													
Voice UDP							1	0			4.00	4.20	

Notes:

- SLAs assume one mobile-client of each type in a testing session and no ecosystem traffic on WF1101 . For multiple mobile-clients of a given type, divide the Target Rate and Minimum Acceptable Rate by the number of clients, after accounting for ecosystem traffic.
- Speed Test measurements are made one traffic type and client at a time. It is not necessary to alter these settings for the case of multiple mobile-clients, however ecosystem traffic must be accounted for.

802.11n, 20 MHz, Network – RF Signal SLAs

Host Type	Mimum Acceptable Signal Strength (dBm)	Target Signal Strength (dBm)	Minimum Acceptable Signal Difference (dB)	Target Signal Difference (dB)	Minimum Acceptable PHY Rate (Mbps)	Target PHY Rate (Mbps)
Signal Strength	-65	-45				
Co-Channel Interference			15	25		
PHY Rate					25	78

802.11n, 40 MHz, Network - Application SLAs

Traffic Type	Minimum Acceptable Rate (Mbps)	Target Rate (Mbps)	Maximum Acceptable Video MLR (packets/s)	Target Video MLR (packets/s)	Maximum Acceptable Video DF (sec)	Target Video DF (sec)	Maximum Acceptable Loss (%)	Target Loss (%)	Maximum Acceptable Jitter (sec.)	Target Jitter (sec.)	Minimum Acceptable MOS	Target MOS	Notes
<i>Laptop</i>													
Upstream Web HTTP	15	30											1
Down-stream Web HTTP	15	30											1
Upstream TCP Speed Test	25	50											2
Down-stream TCP Speed Test	25	50											2
Upstream UDP Speed Test	40	80											2
Down-stream UDP Speed Test	40	80											2
Voice UDP							1	0			3.80	4.20	
Down-stream Video RTP			1	0	0.15	0							
<i>Smart-phone</i>													
Upstream Web HTTP	1	2											1
Down-stream Web HTTP	1	2											1
Upstream TCP Speed Test	2	4											2
Down-stream TCP Speed Test	2	4											2
Upstream UDP Speed Test	3	8											2
Down-stream UDP Speed Test	3	8											2
Voice UDP							1	0			4.00	4.20	
<i>Scanner</i>													
Upstream UDP	0.01	0.02					10	0	0.50	0			
Down-stream UDP	0.01	0.02					10	0	0.50	0			
<i>VoFi</i>													
Voice UDP							1	0			4.00	4.20	

Notes:

1. SLAs assume one mobile-client of each type in a testing session and no ecosystem traffic on WF1101. For multiple mobile-clients of a given type, divide the Target Rate and Minimum Acceptable Rate by the number of clients, after accounting for ecosystem traffic.
2. Speed Test measurements are made one traffic type and client at a time. It is not necessary to alter these settings for the case of multiple mobile-clients, however ecosystem traffic must be accounted for.

802.11n, 40 MHz, Network – RF Signal SLAs

Host Type	Minimum Acceptable Signal Strength (dBm)	Target Signal Strength (dBm)	Minimum Acceptable Signal Difference (dB)	Target Signal Difference (dB)	Minimum Acceptable PHY Rate (Mbps)	Target PHY Rate (Mbps)
Signal Strength	-65	-45				
Co-Channel Interference			15	25		
PHY Rate					90	180

Load and Service Level Agreement Values for Utility and Industrial Networks

This section contains best-practice traffic load and SLA values for Utility and Industrial networks. The types of mobile-clients typically found in these networks are:

- Laptops, tablet-PCs and netbooks
- Handheld VoFi phones

The traffic loads and SLAs should be set to fit the type of network being tested and the type of mobile-clients being used. All values assume no other traffic load exists on the tested network. If the network is loaded with medium to heavy traffic loads, adjustments will have to be considered. Contact IxVeriWave for additional information.

Legacy Network - Application SLAs

Traffic Type	Minimum Acceptable Rate (Mbps)	Target Rate (Mbps)	Maximum Acceptable Video MLR (packets/s)	Target Video MLR (packets/s)	Maximum Acceptable Video DF (sec)	Target Video DF (sec)	Maximum Acceptable Loss (%)	Target Loss (%)	Maximum Acceptable Jitter (sec.)	Target Jitter (sec.)	Minimum Acceptable MOS	Target MOS	Notes
Laptop													
Upstream Web HTTP	4	8											1
Down-stream Web HTTP	4	8											1
Upstream TCP Speed Test	8	15											2
Down-stream TCP Speed Test	8	15											2
Upstream UDP Speed Test	10	20											2
Down-stream UDP Speed Test	10	20											2
Voice UDP							1	0			3.80	4.20	
Down-stream Video RTP			1	0	0.15	0							
Smart-phone													
Upstream Web HTTP	1	2											1
Down-stream Web HTTP	1	2											1
Upstream TCP Speed Test	2	4											2

Down-stream TCP Speed Test	2	4											2
Upstream UDP Speed Test	3	8											2
Down-stream UDP Speed Test	3	8											2
Voice UDP							1	0			4.00	4.20	
VoFi													
Voice UDP							1	0			4.00	4.20	

Notes:

1. SLAs assume one mobile-client of each type in a testing session and no ecosystem traffic on WF1101. For multiple mobile-clients of a given type, divide the Target Rate and Minimum Acceptable Rate by the number of clients, after accounting for ecosystem traffic.
2. Speed Test measurements are made one traffic type and client at a time. It is not necessary to alter these settings for the case of multiple mobile-clients, however ecosystem traffic must be accounted for.

Legacy Network - RF SLAs

Host Type	Mimum Acceptable Signal Strength (dBm)	Target Signal Strength (dBm)	Minimum Acceptable Signal Difference (dB)	Target Signal Difference (dB)	Minimum Acceptable PHY Rate (Mbps)	Target PHY Rate (Mbps)
Signal Strength	-65	-45				
Co-Channel Interference			15	25		
PHY Rate					11	54

802.11n, 20 MHz, Network - Application SLAs

Traffic Type	Minimum Acceptable Rate (Mbps)	Target Rate (Mbps)	Maximum Acceptable Video MLR (packets/s)	Target Video MLR (packets/s)	Maximum Acceptable Video DF (sec)	Target Video DF (sec)	Maximum Acceptable Loss (%)	Target Loss (%)	Maximum Acceptable Jitter (sec.)	Target Jitter (sec.)	Minimum Acceptable MOS	Target MOS	Notes
Laptop													
Upstream Web HTTP	10	20											1
Down-stream Web HTTP	10	20											1
Upstream TCP Speed Test	15	30											2
Down-stream TCP Speed Test	15	30											2
Upstream UDP Speed Test	20	40											2
Down-stream UDP Speed Test	20	40											2
Voice UDP							1	0			3.80	4.20	
Down-stream Video RTP			1	0	0.15	0							
Smart-phone													
Upstream Web HTTP	1	2											1

Upstream Web HTTP	1	2											1
Down-stream Web HTTP	1	2											1
Upstream TCP Speed Test	2	4											2
Down-stream TCP Speed Test	2	4											2
Upstream UDP Speed Test	3	8											2
Down-stream UDP Speed Test	3	8											2
Voice UDP							1	0				4.00	4.20
VoFi													
Voice UDP							1	0				4.00	4.20

Notes:

- SLAs assume one mobile-client of each type in a testing session and no ecosystem traffic on WF1101. For multiple mobile-clients of a given type, divide the Target Rate and Minimum Acceptable Rate by the number of clients, after accounting for ecosystem traffic.
- Speed Test measurements are made one traffic type and client at a time. It is not necessary to alter these settings for the case of multiple mobile-clients, however ecosystem traffic must be accounted for.

802.11n, 20 MHz, Network – RF Signal SLAs

Host Type	Minimum Acceptable Signal Strength (dBm)	Target Signal Strength (dBm)	Minimum Acceptable Signal Difference (dB)	Target Signal Difference (dB)	Minimum Acceptable PHY Rate (Mbps)	Target PHY Rate (Mbps)
Signal Strength	-65	-45				
Co-Channel Interference			15	25		
PHY Rate					26	78

802.11n, 40 MHz, Network - Application SLAs

Traffic Type	Minimum Acceptable Rate (Mbps)	Target Rate (Mbps)	Maximum Acceptable Video MLR (packets/s)	Target Video MLR (packets/s)	Maximum Acceptable Video DF (sec)	Target Video DF (sec)	Maximum Acceptable Loss (%)	Target Loss (%)	Maximum Acceptable Jitter (sec.)	Target Jitter (sec.)	Minimum Acceptable MOS	Target MOS	Notes
Laptop													
Upstream Web HTTP	15	30											1
Down-stream Web HTTP	15	30											1
Upstream TCP Speed Test	25	50											2
Down-stream TCP Speed Test	25	50											2
Upstream UDP Speed Test	40	80											2
Down-stream UDP Speed Test	40	80											2

Down-stream UDP Speed Test	40	80											2
Voice UDP							1	0			3.80	4.20	
Down-stream Video RTP			1	0	0.15	0							
Smart-phone													
Upstream Web HTTP	1	2											1
Down-stream Web HTTP	1	2											1
Upstream TCP Speed Test	2	4											2
Down-stream TCP Speed Test	2	4											2
Upstream UDP Speed Test	3	8											2
Down-stream UDP Speed Test	3	8											2
Voice UDP							1	0			4.00	4.20	
VoFi													
Voice UDP							1	0			4.00	4.20	

Notes:

- SLAs assume one mobile-client of each type in a testing session and no ecosystem traffic on WF1101. For multiple mobile-clients of a given type, divide the Target Rate and Minimum Acceptable Rate by the number of clients, after accounting for ecosystem traffic.
- Speed Test measurements are made one traffic type and client at a time. It is not necessary to alter these settings for the case of multiple mobile-clients, however ecosystem traffic must be accounted for.

802.11n, 40MHz, Network - RF Signal SLAs

Host Type	Mimum Acceptable Signal Strength (dBm)	Target Signal Strength (dBm)	Minimum Acceptable Signal Difference (dB)	Target Signal Difference (dB)	Minimum Acceptable PHY Rate (Mbps)	Target PHY Rate (Mbps)
Signal Strength	-65	-45				
Co-Channel Interference			15	25		
PHY Rate					90	180

Load and Service Level Agreement Values for K-12 Education Networks

This section contains best-practice traffic load and SLA values for K-12 Education networks. These networks typically see only laptop and netbook traffic on them.

The traffic loads and SLAs should be set to fit the type of network being tested and the type of mobile-clients being used. All values assume no other traffic load exists on the tested network. If the network is loaded with medium to heavy traffic loads, adjustments will have to be considered. Contact IxVeriWave for additional information.

Traffic Type	Minimum Acceptable Rate (Mbps)	Target Rate (Mbps)	Maximum Acceptable Video MLR (packets/s)	Target Video MLR (packets/s)	Maximum Acceptable Video DF (sec)	Target Video DF (sec)	Maximum Acceptable Loss (%)	Target Loss (%)	Maximum Acceptable Jitter (sec.)	Target Jitter (sec.)	Minimum Acceptable MOS	Target MOS	Notes
Laptop													
Upstream Web HTTP	4	8											1
Downstream Web HTTP	4	8											1
Upstream TCP Speed Test	8	15											2
Downstream TCP Speed Test	8	15											2
Upstream UDP Speed Test	10	20											2
Downstream UDP Speed Test	10	20											2
Voice UDP							1	0			3.80	4.20	
Downstream Video RTP			1	0	0.15	0							
Smart-phone													
Upstream Web HTTP	1	2											1
Downstream Web HTTP	1	2											1
Upstream TCP Speed Test	2	4											2
Downstream TCP Speed Test	2	4											2
Upstream UDP Speed Test	3	8											2
Downstream UDP Speed Test	3	8											2
Voice UDP							1	0			4.00	4.20	

Notes:

- SLAs assume one mobile-client of each type in a testing session and no ecosystem traffic on WF1101. For multiple mobile-clients of a given type, divide the Target Rate and Minimum Acceptable Rate by the number of clients, after accounting for ecosystem traffic.
- Speed Test measurements are made one traffic type and client at a time. It is not necessary to alter these settings for the case of multiple mobile-clients, however ecosystem traffic must be accounted for.

Legacy Network - RF Signal SLAs

Host Type	Minimum Acceptable Signal Strength (dBm)	Target Signal Strength (dBm)	Minimum Acceptable Signal Difference (dB)	Target Signal Difference (dB)	Minimum Acceptable PHY Rate (Mbps)	Target PHY Rate (Mbps)
Signal Strength	-65	-45				
Co-Channel Interference			15	25		
PHY Rate					26	78

PHY Rate					11	54
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802.11n, 20 MHz, Network - Application SLAs

Traffic Type	Minimum Acceptable Rate (Mbps)	Target Rate (Mbps)	Maximum Acceptable Video MLR (packets/s)	Target Video MLR (packets/s)	Maximum Acceptable Video DF (sec)	Target Video DF (sec)	Maximum Acceptable Loss (%)	Target Loss (%)	Maximum Acceptable Jitter (sec.)	Target Jitter (sec.)	Minimum Acceptable MOS	Target MOS	Notes
Laptop													
Upstream Web HTTP	10	20											1
Downstream Web HTTP	10	20											1
Upstream TCP Speed Test	15	30											2
Downstream TCP Speed Test	15	30											2
Upstream UDP Speed Test	20	40											2
Downstream UDP Speed Test	20	40											2
Voice UDP							1	0			3.80	4.20	
Downstream Video RTP			1	0	0.15	0							
Smart-phone													
Upstream Web HTTP	1	2											1
Downstream Web HTTP	1	2											1
Upstream TCP Speed Test	2	4											2
Downstream TCP Speed Test	2	4											2
Upstream UDP Speed Test	3	8											2
Downstream UDP Speed Test	3	8											2
Voice UDP							1	0			4.00	4.20	

Notes:

- SLAs assume one mobile-client of each type in a testing session and no ecosystem traffic on WF1101. For multiple mobile-clients of a given type, divide the Target Rate and Minimum Acceptable Rate by the number of clients, after accounting for ecosystem traffic.
- Speed Test measurements are made one traffic type and client at a time. It is not necessary to alter these settings for the case of multiple mobile-clients, however ecosystem traffic must be accounted for.

802.11n, 20MHz, Network - RF Signal SLAs

Host Type	Minimum Acceptable Signal Strength (dBm)	Target Signal Strength (dBm)	Minimum Acceptable Signal Difference (dB)	Target Signal Difference (dB)	Minimum Acceptable PHY Rate (Mbps)	Target PHY Rate (Mbps)
Signal Strength	-65	-45				

Signal Strength	-65	-45				
Co-Channel Interference			15	25		
PHY Rate					26	78

802.11n, 40 MHz, Network - Application SLAs

Traffic Type	Minimum Acceptable Rate (Mbps)	Target Rate (Mbps)	Maximum Acceptable Video MLR (packets/s)	Target Video MLR (packets/s)	Maximum Acceptable Video DF (sec)	Target Video DF (sec)	Maximum Acceptable Loss (%)	Target Loss (%)	Maximum Acceptable Jitter (sec.)	Target Jitter (sec.)	Minimum Acceptable MOS	Target MOS	Notes
Laptop													
Upstream Web HTTP	15	30											1
Downstream Web HTTP	15	30											1
Upstream TCP Speed Test	25	50											2
Downstream TCP Speed Test	25	50											2
Upstream UDP Speed Test	40	80											2
Downstream UDP Speed Test	40	80											2
Voice UDP							1	0			3.80	4.20	
Downstream Video RTP			1	0	0.15	0							
Smart-phone													
Upstream Web HTTP	1	2											1
Downstream Web HTTP	1	2											1
Upstream TCP Speed Test	2	4											2
Downstream TCP Speed Test	2	4											2
Upstream UDP Speed Test	3	8											2
Downstream UDP Speed Test	3	8											2
Voice UDP							1	0			4.00	4.20	

Notes:

- SLAs assume one mobile-client of each type in a testing session and no ecosystem traffic on WF1101. For multiple mobile-clients of a given type, divide the Target Rate and Minimum Acceptable Rate by the number of clients, after accounting for ecosystem traffic.
- Speed Test measurements are made one traffic type and client at a time. It is not necessary to alter these settings for the case of multiple mobile-clients, however ecosystem traffic must be accounted for.

802.11n, 40 MHz, Network - RF Signal SLAs

<i>Host Type</i>	<i>Mimum Acceptable Signal Strength (dBm)</i>	<i>Target Signal Strength (dBm)</i>	<i>Minimum Acceptable Signal Difference (dB)</i>	<i>Target Signal Difference (dB)</i>	<i>Minimum Acceptable PHY Rate (Mbps)</i>	<i>Target PHY Rate (Mbps)</i>
<i>Signal Strength</i>	-65	-45				
<i>Co-Channel Interference</i>			15	25		
<i>PHY Rate</i>					90	180

Appendix A

A Method for Qualifying a Computer as a Wired Stationary Server

Since a Stationary Server used in any WaveDeploy site assessment acts as a centralized traffic source and traffic sink for WLAN traffic, the server hosting it must be equipped with a good quality Gigabit Ethernet port, be properly configured for continuous operation, and not be used for other purposes during testing. For example, a Windows machine that is set to perform automatic updates and restart itself, will take itself off-line at unpredictable times. Any machine that is used for other processor-intensive activities at unpredictable times will result in measurement results that are not accurate or repeatable.

Even in the case of a capable Windows machine hosting a Stationary Server, care must be taken whenever PC's are used to ensure that the traffic load levels required by the Mobile Agents does not exceed the capability of the Stationary Server. If such a condition is allowed to exist, WaveDeploy reports will reflect traffic measurements that are limited not by the performance of the network, but by the limitations of the computer acting as Stationary Server.

The most effective solution is to use the EF1101 Traffic Generator as the Stationary Server, as it delivers uninterrupted line-rate Gigabit Ethernet performance without the complexity of dealing with operating system variables. When a EF1101 is used, the method described here for qualifying the computer as Stationary Server need not be performed.

However, if a PC or laptop is used as a Stationary Server, it is important to ensure that the sum of all simultaneous traffic configured in WaveDeploy across the all mobile-clients and WF1101's does not exceed the capacity of the Stationary Server. The qualification being done here is a measure of the PC's ability to generate and receive traffic at the required rate, and is typically not a measure of the Ethernet port on the PC itself.

If a standard server, PC, or laptop is used to host the Stationary Server, follow the steps described here:

1. After disabling the wireless adapter in the console laptop, install and start the WaveDeploy WaveAgent on the server, PC, or laptop, per instructions found in the WaveDeploy User's Guide.
2. Connect the server, PC, or laptop to a wired Ethernet network with link speeds of at least 100Mbps if a legacy 802.11 network will be tested, and at least 1Gbps if an 802.11n network will be tested.
3. In the settings of the server, PC, or laptop, disable any applications or settings that would allow the Ethernet port to go to sleep, or would allow the machine to go into a power-save or hibernate mode. Also disable any automatic processes, such as updates, that may make machine become unavailable throughout the duration of the test.
4. Using WaveDeploy, make a measurement using loads and SLA described in the table titled "Baseline Load and SLA" below, with the Mobile Client residing on another Ethernet-capable machine. For example, if the server, PC, or laptop running the WaveDeploy application has a Gigabit Ethernet network interface card, simply disable the wireless adapter in the "network connections" window on that machine (it is not enough to just turn off the hardware switch controlling the wireless adapter) and make the measurement between the "localhost" address and the Stationary Server address, after connecting the WaveDeploy application machine to the wired Ethernet network. As previously noted, the figures in the "Baseline Load and SLA" tables apply for the case where 4 or less Mobile-Client laptops will be used.
5. Inspect the results and verify that all SLAs were met. While it is normal that the achieved loads could be slightly lower than the target rates, the achieved loads should not be more than 2% lower than the target rates.
6. It is recommended that a minimum of 4 consecutive measurements are then made in the same session, and inspected for variation. All results should meet the 2% criteria above.
7. If the demonstrated performance Ethernet-to-Ethernet is found to be outside the 2% criteria, the source of deviation must be found and eliminated before proceeding to wireless tests. Failure to establish a solid baseline for fixed client performance will result in site survey results where the variation in performance cannot be pinpointed.

The steps for qualifying a Stationary Server must be repeated for each new PC-based Stationary Server introduced into the testing process, and should be performed on wired portion of any new network. Only after the wired network infrastructure and Stationary Server performance are quantified can the user trust the wireless results.

Baseline Load and SLA for Stationary Server Qualification – Legacy Network

Traffic Type	Minimum Acceptable Rate (Mbps)	Target Rate (Mbps)
<i>Laptop</i>		
Upstream Web HTTP	35	40
Downstream Web HTTP	35	40
Upstream TCP Speed Test	70	80
Downstream TCP Speed Test	70	80
Upstream UDP Speed Test	70	80
Downstream UDP Speed Test	70	80

Notes:

- Measurements are assumed to be Ethernet-to-Ethernet across a network capable of 100 Mbps.
- Stationary Server is assumed to be a PC or laptop.

Baseline Load and SLA for Stationary Server Qualification - 802.11n Network

Traffic Type	Minimum Acceptable	Target Rate
<i>Laptop</i>		
Upstream Web HTTP	140	150
Downstream Web HTTP	140	150
Upstream TCP Speed Test	70	75
Downstream TCP Speed Test	70	75
Upstream UDP Speed Test	95	100
Downstream UDP Speed Test	95	100

Notes:

- Measurements are assumed to be Ethernet-to-Ethernet across a network capable of 1Gbps.
- Stationary Servers are assumed to be hosted on a server, PC, or laptop.
- The settings for this table apply to configurations where 4 or less 802.11n-capable mobile-clients are used. For configurations of 5 or more 802.11n laptops, the upstream and downstream web HTTP settings must be increased to match the loads applied by all the laptops together, or multiple Stationary Servers must be used, or a single WaveDeploy Ethernet can be used.

Appendix B

Verifying Target Rate and SLA Settings

A spot-check to verify target rate for traffic and SLA settings is recommended to ensure all selections are appropriate to the actual conditions in the site being tested. The recommended procedure is:

1. Load and run WaveAgent on all mobile-clients participating in the survey.
2. Position the mobile-clients in close proximity to an AP and confirm, using WaveDeploy, that they are all connected to that AP. Confirm through their respective wireless utilities that they reporting expected connection characteristics, such as signal strength and phy rate. The goal is to have all mobile-client devices connected to the same AP, and all devices positioned such that a high-quality connection is being made between them and the AP.
3. Set the target rate and SLA values in accordance with the values specified in this document, based on the type of network (legacy, 20 MHz 802.11n, or 40 MHz 802.11n), and technology of mobile-client devices. Remember to divide the coexistence traffic target rates by the number of like mobile-client devices. Also remember to leave bandwidth for ecosystem traffic, if used.
4. Using WaveDeploy make a set of four consecutive measurements, without ecosystem traffic, in a single survey, and confirm that all results meet the expected SLAs. If adjustments in the loads or SLA settings are needed, make those changes and repeat the set of four tests until satisfactory results are obtained.
5. If ecosystem traffic is to be used, configure the target rates for the ecosystem client types, and connect the stationary clients. When the application has reported that all ecosystem traffic is running, repeat step 4 above and confirm that the expected SLA's are achieved in the presence of ecosystem traffic. Adjust target rates as necessary, if the total load on the network has been exceeded.
6. If satisfactory results cannot be obtained with all mobile-clients and WF1101 positioned close to an AP, the source of performance limitation must be found and eliminated before proceeding with the Site Assessment. Some things to keep in mind while troubleshooting performance issues:
 - If the WaveDeploy application is reporting "no response" from one of the agents, this means that communication between the console where the application is running, and one or more of the devices involved in the test (WF1101, EF1101, Stationary Server, or mobile-client) is being interrupted.
 - The typical reason for interruption of communication is overloading of the network under test, or overloading the wireless media where the test is being done. For example, say the AP being used in the Verification step is on channel 1, and other AP's and traffic in the vicinity are also on channel 1. The bandwidth available to the test will be reduced by the amount of bandwidth being consumed by other traffic within range of the test setup. If other traffic within range happens to be on the air at a low phy rate, the impact on available bandwidth can be significant. Performing a packet capture to check for other traffic is recommended.
 - Another common situation that results in interruption of communication is action taken by a client device which makes it unavailable to the network for periods of time. If the client device chooses to search for another network frequently, or is set up to hibernate or drop in to long periods of power save behavior, or is set to prefer a network other than the test network, the in-band communication within WaveDeploy will be disrupted. The indication will be that the application reports that it does not receive a response from a particular client device during the course of the test.
 - A simple network overload situation can present itself either as poor results, or in the more extreme case, as lack of response from one or more of the agent devices (mobile-client or stationary server). If the sum of target rates do not exceed the media capacity and there is not interfering traffic, looking at network configurations and any rate-limiting settings is recommended.
 - If the speed test results are all satisfactory but the coexistence results show performance less than expected, inspecting the results of each mobile-client individually is recommended. If one client device is taking an unfair portion of the media, the results for that mobile-client will be good while all other devices will be lower. Remove the offending mobile-client from the test and repeat the test to verify and isolate the offending client device.



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