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Wireless LANs

Test Methodology Proposal for Measuring Fast BSS/BSS Transition Time

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Abstract

This document constitutes the draft text proposal for a test methodology for measuring metrics that characterize the time it takes an 802.11 client STA to transition, or "roam," between two APs.

1 Introduction

This document describes metrics and associated test methodologies for characterizing the BSS transition, or “roaming”, time of a STA (single client) that moves from one 802.11 AP to another.

Repeated measurement of the observed BSS transition time does not necessarily produce the same result, due to random factors in the operation of the protocol. Furthermore, measurement of the minimum possible transition time performance may not be appropriate when the STA is expected to experience only constant rate traffic. For this reason, repeated measurements are made using a fixed rate of traffic, such as typical of packet voice. These results could be used to produce an estimated cumulative distribution function (CDF) of the transition time. Presenting the results in this form is expected to be useful to, for example, planners of voice over IP over wireless networks. Even though presented in the context of a packet voice usage case, the metric is expected to be useful for any streaming application where service must be maintained as mobile 802.11 STAs roam between APs.

Add the following text at a suitable place in the 802.11.2 draft:

2 BSS Transition

2.1 Introduction and Purpose

This methodology explains how to characterize the time it takes for an 802.11 client station to change its network connectivity from one 802.11 AP to another. The process is formally called BSS transition, or simply "roaming"(at Layer2). BSS transition is inherently a time-varying activity, due to various underlying protocol mechanisms that must operate in concert to achieve the transition.

By making repeated measurements, the methodology can provide a statistical characterization of the observed BSS transition time in the form of a cumulative distribution function. Presenting the results in this form is useful to system designers and planners.

The system under test consists of a single 802.11 client station (STA) and two 802.11 APs in a conductive and isolated environment. The environment provides variable attenuators to control the signal levels reaching the station and AP. By changing the imposed attenuation in a controlled and repeatable manner, the STA is forced to roam from one AP to another and vice versa. The associated BSS transition time is measured and the experiment is repeated to produce a data set of transition times.

These results may be used produce an estimated cumulative distribution function (CDF) of the transition time. This metric is expected to be useful to, for example, planners of packet voice over wireless networks or for any other usage case where interruption of network service during to roaming potentially degrades user experience.

2.2 Definitions and Metrics

2.2.1 BSS Transition Time

The BSS transition time is the time that starts after the transmission of the last acknowledged data frame sent within an originating BSS and ends after the transmission of the first acknowledged data frame sent within the destination BSS. This time includes the BSS transition activities such as authentication, (re)association and QoS negotiation. The two BSSs should be in the same ESS. This definition encompasses both uplink and downlink data frames. This metric characterizes the link layer portion of the transition only, since some of these frames during transition may be part of a higher layer protocol.

2.3 Test Configuration

2.3.1 Resource Requirements

The following items are the minimum required to perform the BSS transition time test employing the baseline configuration according to Section 2.4.1.1:

- Two Access Points (APs)
- STA that is capable of associating with the APs
- Wired traffic analyzer/monitor to analyze the traffic over the DS
- Wireless (802.11) monitor/analyzer to monitor traffic over the airlink or RF cables
- Traffic generator, a device in the DS that is capable of receiving uplink traffic from the STA and capable of sending downlink traffic to the STA (on top of layer 2)
- Shielded enclosures for the APs, the STA, and the wireless monitors;

- Four Variable attenuators;
  These are devices used to control the received signal strengths of the wireless devices while the test is running. The level of the imposed attenuation shall be reproducible at any given time during the test.
- Three Calibrated combiners/splitters

Additionally, the following equipment might be required to conduct tests modifiying the baseline configuration according to Section 2.4.1.2:

- Authentication Server to perform first contact between the STA and AP using 802.1X as part of RSN security establishment (where applicable).
- Policy Server as part of the DS for setting the QoS (where applicable)

Any one of the devices in the test-bed can be considered a DUT. If more than one device is considered a DUT , then it becomes a SUT.

2.3.2 Test Environment

The environment required for this test is a conductive and isolated environment in which cables are connected to the antenna ports of the 802.11 devices. It is of prime importance that the STA receive signals only through the desired path, otherwise the STA may remain associated with an AP throughout the entire range of the variable attenuators, rather than switching to the more favorable AP. For this reason, all 802.11 devices (AP, STA, wireless monitor) should be operated from within separate shielded enclosures. Also, care should be taken to avoid the possibility of RF signals bypassing the variable attenuators, for similar reasons. It is also possible to use a radiative means, such as a near-field probe to connect the APs and STA into the test system instead of a conducted connection. However, this introduces additional insertion loss which must be accounted for to achieve a specific range of path loss. Also, using a near-field probe definitely requires that the 802.11 devices be operated from within shielded chambers.

The diagram in fig. 2.1 depicts the typical test set-up. The set up consists of two RF paths, each with path loss controlled by the variable attenuators.

There are several components connected to the Distribution System (DS). The Access points with which the STA associates with are AP1 and AP2. The traffic generator is a device connected to the wired network (DS) to provide an appropriate source or termination for traffic destined or originating from the wireless client (STA).

The DS monitor or wired analyzer is used to record all frames transmitted over the DS (wired network) on top of layer 2.

Each of the 802.11 monitor devices is connected through a splitter/combiner such that it receives all 802.11 frames transmitted by the AP and STA devices all the time during the experiment. These devices should be synchronized in some fashion so that the relative timing of airlink events can be established. The wireless monitors operate as passive devices and must not transmit any 802.11 frames.

Two variable attenuators shall be provided in each branch of the setup. The arrangement shown makes it possible for the wireless monitor devices to always hear both the AP and STA, regardless of whether the attenuators are set to prevent the AP and STA from hearing each other.

The attenuators vary over the course of a trial to produce a path loss for each STA-AP path according to a sweep function.

The sweep function and inter-roam period are test conditions and are discussed further in this section.

It has to be noted that the authentication server and the policy server are part of the modifiers and not required for the baseline configuration.

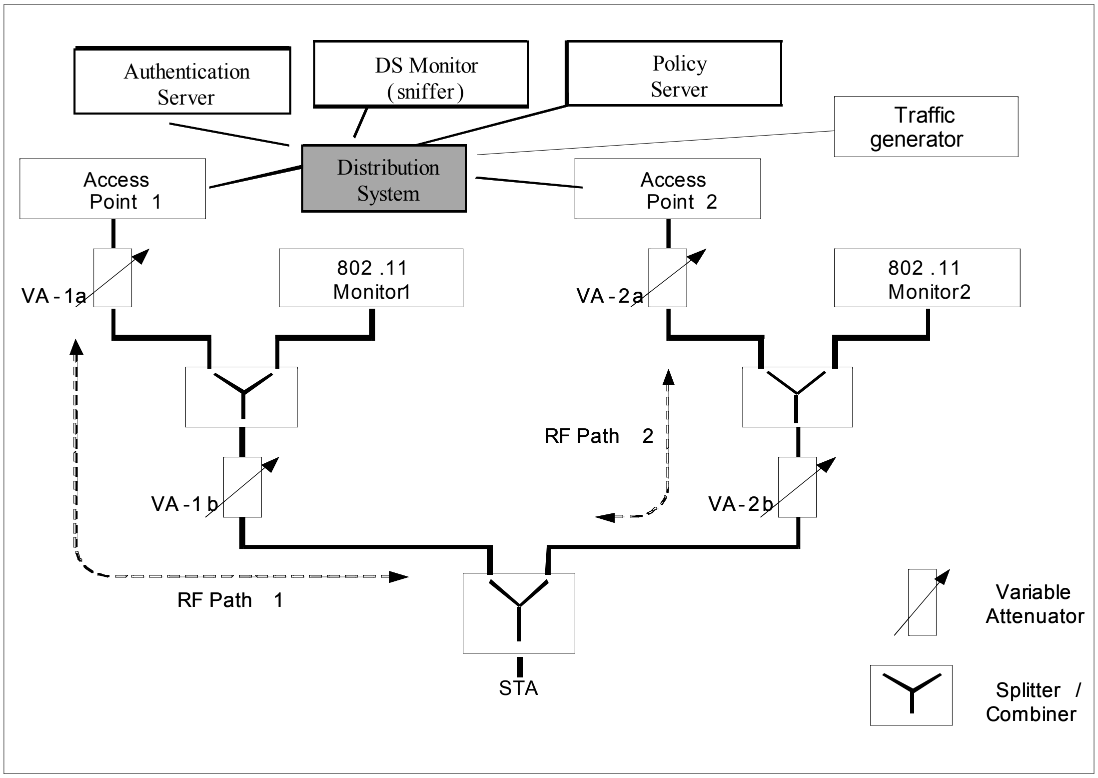

Fig. 2.1 BSS Transition measurement Test Set-up

2.3.2.1 Attenuation Function

For the baseline configuration, the attenuation imposed on the communication test signal shall be according to a sweep function. This sweep function is linear in dB. It is characterized by the min. and max. imposed attenuation and the sweep time (Δt) over which the attenuation is changed. The minimum path loss shall be high enough such that the signal received at any device does not result in more than 10% frame error rate. The maximum path loss should be sufficient to prevent the client STA from associating with the current AP.

The sweep function should reflect the expected range of velocities experienced by the system under test.

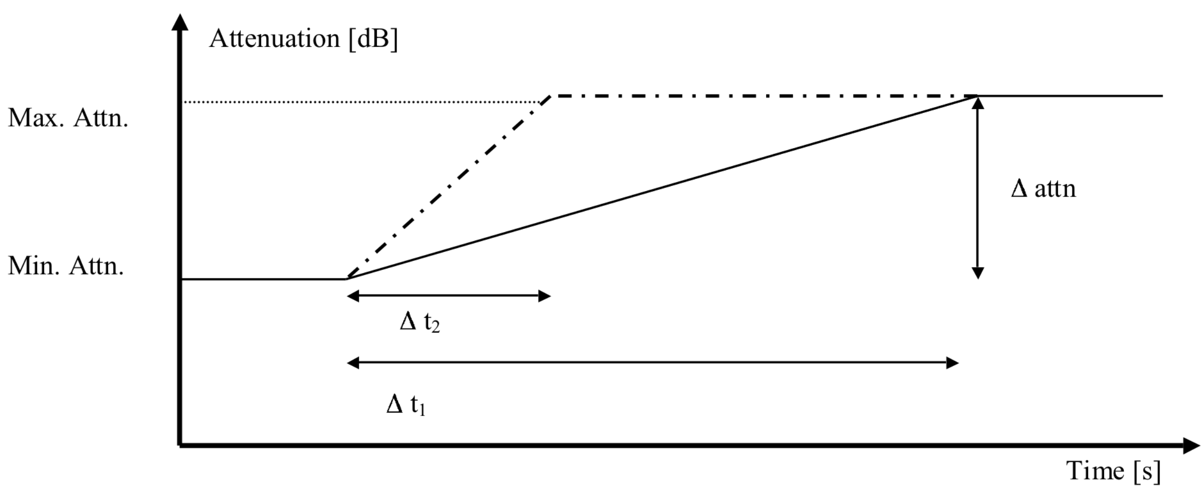

Fig. 2.2: Linear attenuation change (sweep function linear in dB) through one path

It is permissible to approximate an attenuation change strictly linear in dB by a stepwise change of the imposed attenuation (see Fig. 2.3). The interval over which the attenuation is kept constant ($\Delta t_{increase}$) shall be as short as possible according to the limits of the used equipment. The attenuation step size shall be kept constant. Both, $\Delta t_{increase}$ and the attenuation step size shall be reported.

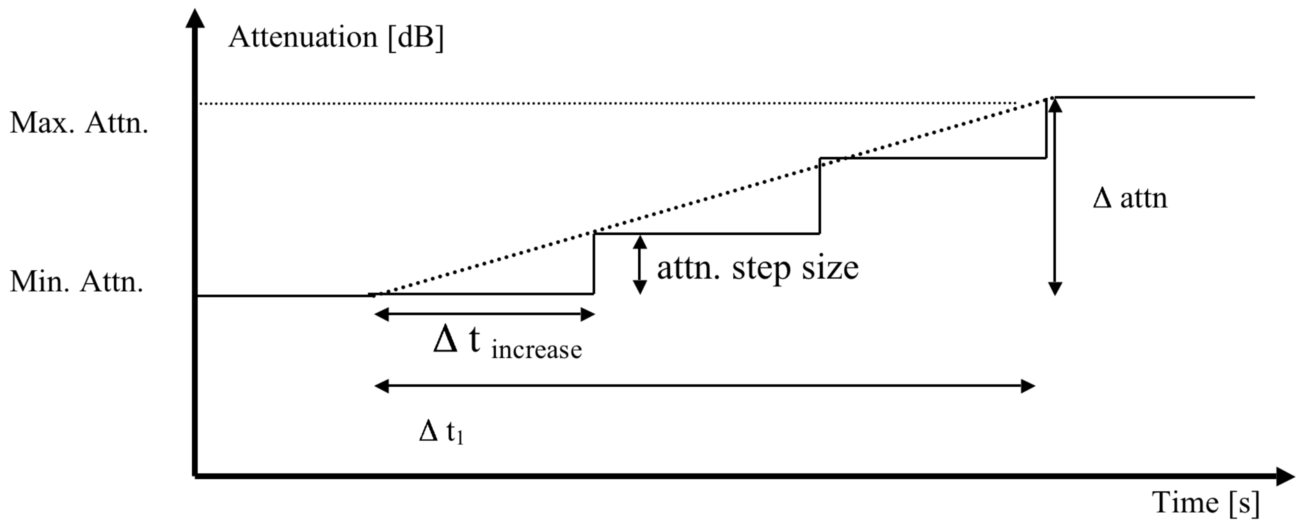

Fig. 2.3: Stepwise increase of imposed attenuation

For either case, i.e., a change strictly linear in dB or stepwise approximation, if an RF discontinuity is introduced during the switching of the attenuators, the discontinuity shall impact no more than one 802.11 frame.

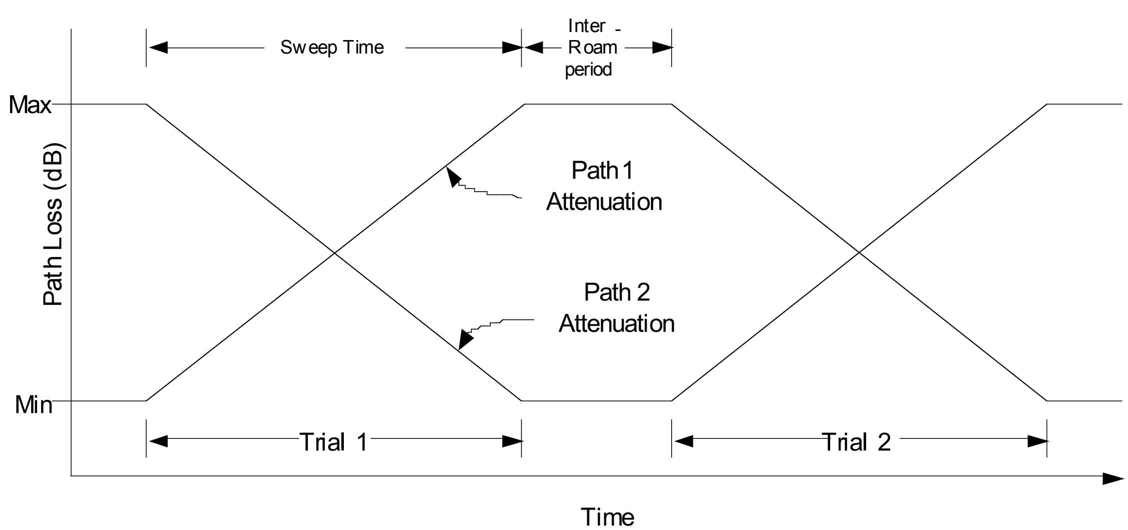

Fig. 2.4 Path loss profiles to be produced by the variable attenuators shown in Fig. 2.1

Fig. 2.4 is an example of path loss profiles. The point at which the two attenuation paths cross determines the amount of overlap between the BSSs. The overlap could range from significant gap between BSSs to 100% overlap between BSSs. BSS transition time can vary as a function of the degree of overlap.

2.3.3 Permissable Error Margins/Reliability of Test

Prior to beginning the test, the test equipment described above shall be calibrated, and all test software verified. The test setup may be monitored during the test to ensure that the test conditions do not change. The expected error margins for the measurement calibrations should be within +/-10 % for a specific set-up. The paths from one endpoint to another should be measured/characterized/calibrated. At any time assure that the wireless monitor should be able to listen to the test traffic during test run. The error margins for these metrics pertain to the timing of airlink events. For consistency and repeatability, timing of airlink events should be 10 to 20 times more accurate than the shortest measured BSS transition time

2.4 Test Approach

2.4.1 Configuration Parameters

This sub-clause provides a list of SUT setup parameters applicable to this test.

2.4.1.1 Baseline Configuration

The baseline SUT setup that should be configured, measured and reported whenever this test is performed is as follows:

Table 2.1 Baseline set-up parameters for BSS Transition time measurements

Parameter	Description
Channel A, Channel B	Access points should be set to use any two non-overlapping channels available within the same frequency band (to mitigate impact of co-channel interference).
AP transmit power	Maximum supported by the AP.
STA transmit power	Maximum supported by the STA.
Minimum path loss	High enough such that the signal received at any device does not result in more than 10% frame error rate.
Maximum path loss	The maximum path loss should be sufficient to prevent the client STA from associating with the AP.
Dot11RTSThreshold	2312 bytes (Maximum MAC frame size)
Dot11FragmentationThreshold	2312 bytes (Maximum MAC frame size)
Power save mode	Off
QoS access category (AC)	QoS frames not used (no 802.11e QoS control field)/Disabled
Security mode	Open System Authentication
Wireless data traffic direction	Uplink
Sweep function	Linear in dB according to fig. 2.2
Inter-roam period	Long enough to cause a steady state in the system for a roam to occur, sec
Sweep time	To achieve an attenuation slope of 1 dB per 1 sec

2.4.1.2 Modifiers:

The baseline SUT setup parameters may be modified as follows to enable additional iterations to be performed for this test. Only one variation should be tested at a time.

- Wireless data traffic direction (downlink, bi-directional)
- Sweep function: Sweep functions other than linear in dB may be employed
- Sweep time: Sweep times other than listed in the baseline may be employed
- 802.11e QoS support with access category for test traffic specified. EDCA parameters used in the test shoud be reported.
- Security: Authentication and Encryption Method (Shared WEP, WPA(802.1X/EAP, PSK), WPA2(802.1X/EAP, PSK))
  - Refer section 2.4.2 for details

Any deviations from the baseline not discussed in this section should be reported.

2.4.1.3 Test Conditions

The test parameters used while performing this test are as follows:

Table 2.2 Test configuration parameters for BSS transition time measurement.

Parameter	Description
Frame formats	Per RFC 2544 Appendix C with LLC/SNAP encoding per RFC 1042
Intended uplink traffic load	10, 20, 30 msec frame interval *(The resolution of the measurements is directly proportional to the frame interval chosen)*
Intended downlink traffic load	10, 20, 30 msec frame interval
Bidirectional traffic load	10, 20, 30 msec frame interval
PHY data rate	Auto
Number of iterations	At least 100
Measurement Duration	60, 300 sec (short, long)

The intended traffic loads are selected to achieve either uplink only, downlink only, or symmetric bidirectional traffic. If the traffic is bidirectional, the frame rates for the uplink and the downlink should be the same.

The baseline attenuator sweep function is linear in decibels. That is, the attenuator sweeps from one extreme to another at a constant rate as measured in decibels. Other sweep functions are possible, but are not the baseline.

The values specified in table 2.2 for different test parameters are representative examples.

2.4.2 Measurement Procedure

The STA is set-up using the baseline configuration and an initial set of test parameters. The STA is initially associated with AP1 on a particular channel.

- Traffic is generated between STA and traffic endpoint through AP1, according to the desired offered load and direction. After the traffic flows are established, the wired and wireless monitoring devices begin capturing all traffic passing between the AP and the STA.

- Attenuation is varied according to the sweep function and sweep time defined in section 2.4.1.
- The inter-roam period starts at the point when the attenuators sweep to their respective limits. By this time the STA should have performed a BSS transition from one AP to the other. This constitutes a single trial. The next trial starts after the inter-roam period within the same iteration.
- The wired monitor and 802.11 wireless monitor are used to record the transition procedure. For each trial, processing is carried out on the packets captured by the monitoring devices to determine the BSS transition time and the required time components.
- The processing of the captured data determines the time of occurrence of two events:
    - The time at which the last data frame was transmitted and acknowledged within the originating BSS (through the current AP1), and
    - The time at which the first data frame was transmitted and acknowledged within the destination BSS (through the new AP2).
- The BSS transition time is measured as the time between the above events, as indicated in the diagrams below as 'T_{total}'.
- Additionally the following time components as available can be captured as part of the measurement report for different modifiers (where applicable):
    - Open System Authentication: T_{probe} ,T_{open} , $T_{(re)assoc}$
    - Shared WEP: T_{probe} ,T_{shared} , $T_{(re)assoc}$
    - WPA:
        - PSK: T_{probe} ,T_{open} ,$T_{(re)assoc}$,T_{psk}
        - 802.1x: T_{probe} ,T_{open} , $T_{(re)assoc}$,$T_{802.1x}$, T_{key}
    - WPA2 or 802.11i:
        - PSK: T_{probe} ,T_{open} , $T_{(re)assoc}$,T_{psk}
        - 802.1x: T_{probe} ,T_{open} , $T_{(re)assoc}$, $T_{802.1x}$, T_{key}

    where T_{probe} = Probe request/response exchange with the target AP after the last data packet send within the old BSS, T_{open} = Open System Authentication, T_{shared} = Shared WEP authentication exchange, $T_{(re)assoc}$ = (Re)Association time, T_{psk} = 4-way handshake for PSK and GTK derivation, $T_{802.1x}$ = 802.1x EAP authentication method, T_{key} = 4-way handshake EAPOL Key exchange and GTK derivation.
    If QoS exchange is part of the Re-association process, then the time taken to exchange the QoS messages should be included as part of this report as well.
    - QoS or 802.11e exchange time:
        - $T_{802.11e}$
- The diagrams are representative of a downlink transfer, but as per the modifiers the transmission could be uplink, downlink or bi-directional.
- The processing activity should determine the time of these events for both uplink and downlink frames. For bidirectional traffic, an uplink or downlink data frame should be considered as the last data frame or the first data frame.

If the two APs are not identical models and firmware revisions, roaming time from AP2 to AP1 may be different from AP1 to AP2 and these different times have to be distinguished while collating the results.

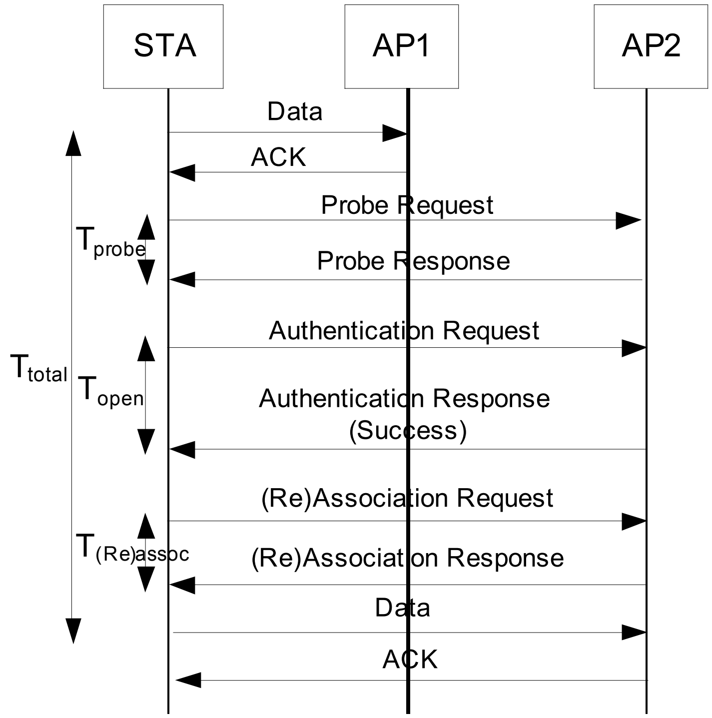

Figure 2.3 Open System Authentication

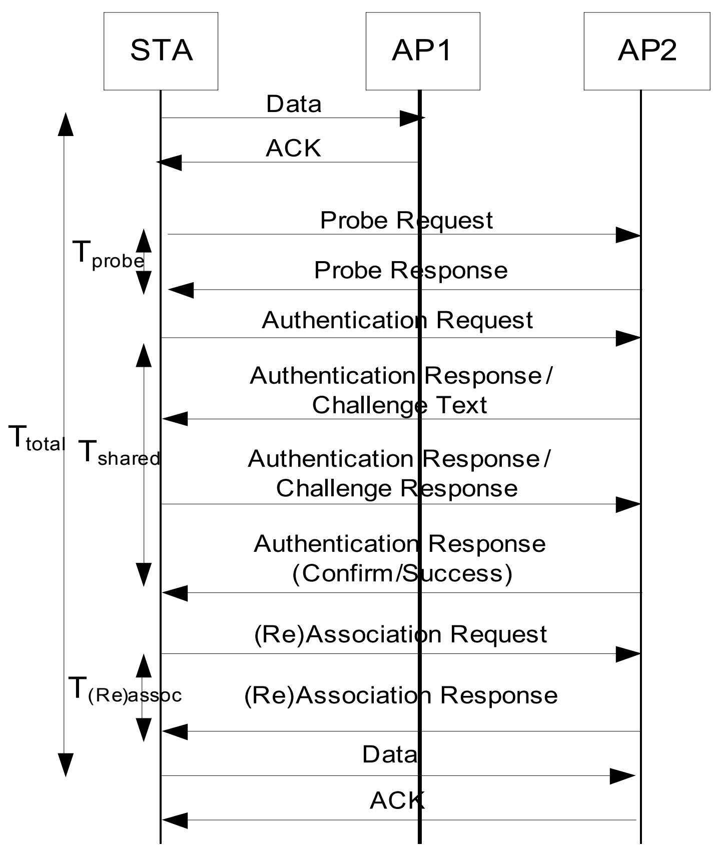

Figure 2.4 Shared WEP Authentication

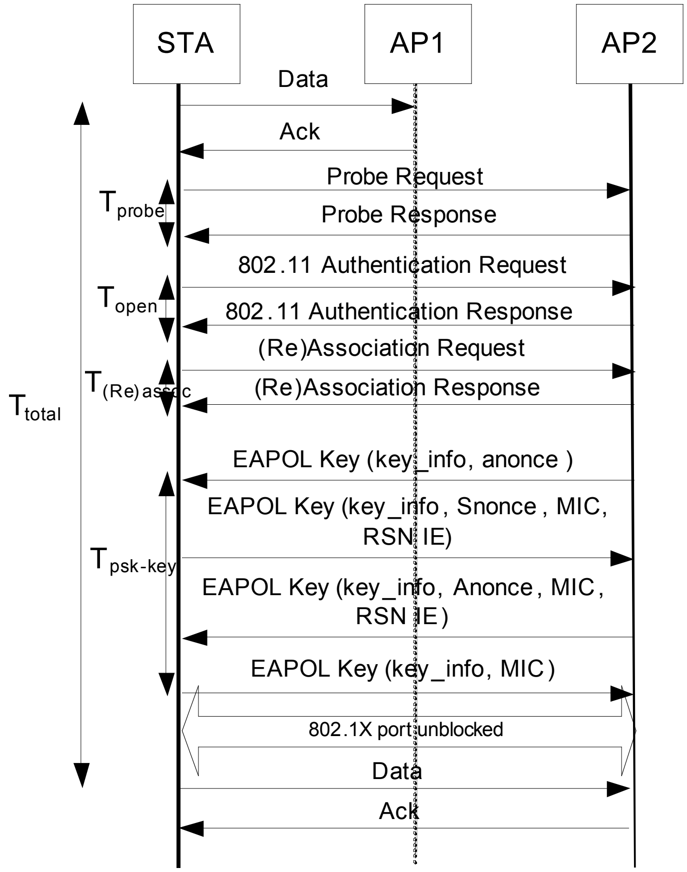

Figure 2.5 WPA with Pre-shared key authentication (PSK)

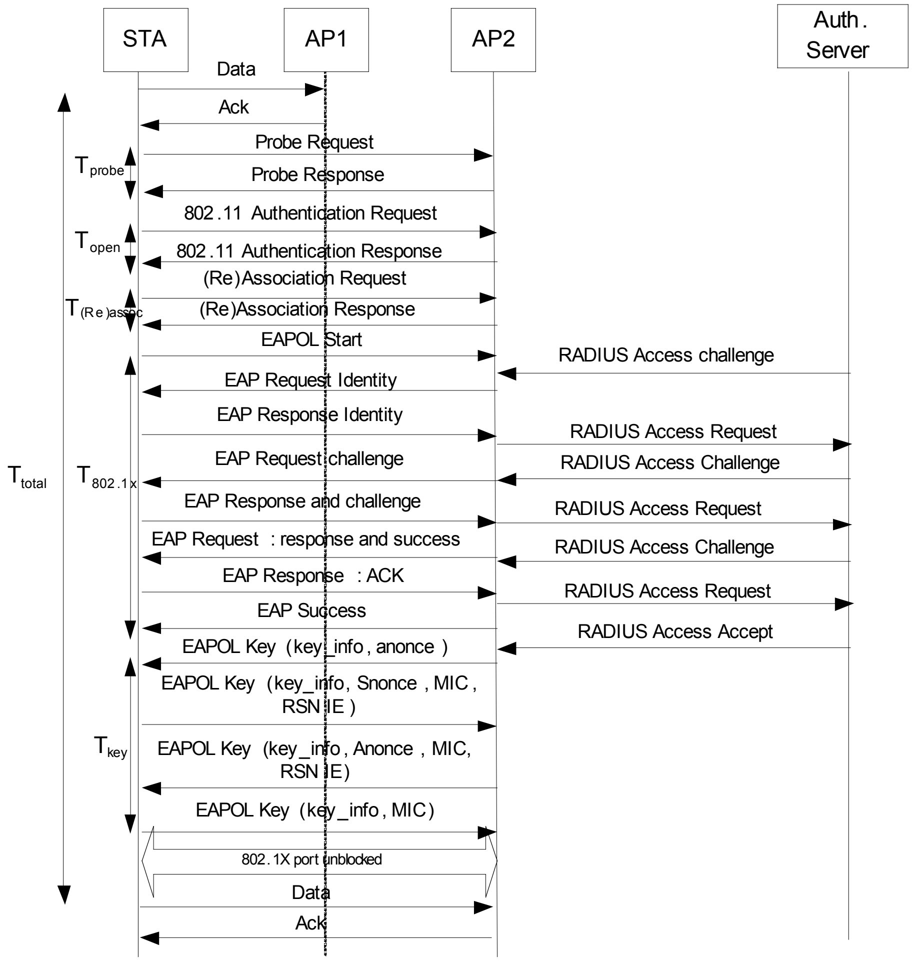

Figure 2.6 EAP Authentication (WPA/RSN Enterprise)

2.4.3 Reported Results

The results to be reported after performing the test procedure described above are the observed BSS transition times, as measured by the procedure and the number of iterations conducted. These results may be presented in the form of a cumulative distribution function. For example, the x-axis represents time, while the y-axis represents the probability that the BSS transition time is less than the corresponding time on the x-axis.

2.4.4 Specific Reporting Requirements

Additional information to be reported is as follows:

- System configuration
- All modifiers and test conditions in section 2.4,
- Retry limit for STA and APs
- Min. and max. imposed attenuation

If attenuation is approximated by a stepwise change of the imposed attenuation, the following parameters shall be included as well:

- Attenuation step size
- Time interval over which the imposed attenuation is kept constant

3 Fast BSS Transition

3.1 Introduction and Purpose

The purpose of this test is to propose a method for characterizing the actual fast BSS transition time it takes an 802.11 STA (DUT) to roam (or transition) from one 802.11 AP(Wireless Counterpart or WLCP) to another using 802.11r. BSS transition services based on the new standard, 802.11r, provide a mechanism by which the transition gap between the STA and AP in a Robust Security Network (RSN) can be considerably reduced.

The Fast BSS transition through 802.11r aims at minimizing the duration of lost connectivity when a STA moves across BSSs. This is especially applicable to real-time applications such as Voice over WLAN wherein loss of packets during transitions can result in poor voice quality. The Fast BSS transition time metric is the time spent by the STA in performing the secure reassociation with the target AP from the current AP.

The aim of this test method is to describe the conditions and procedure to measure this parameter. This test is applicable to Clients/STA (in BSS mode) only. This definition encompasses both uplink and downlink data frames.

The results may be used produce an estimated cumulative distribution function (CDF) of the fast BSS transition time. This metric is expected to be useful to, for example, planners of packet voice over wireless networks or for any other usage case where interruption of network service during to roaming potentially degrades user experience.

3.2 Definitions and Metrics

3.2.1 Fast BSS Transition Time

The Fast BSS transition time is the total transition time that starts after the transmission of the last acknowledged data frame sent within an originating BSS by the STA and ends after the transmission of the first acknowledged data frame sent within the destination BSS, while the station roams from one AP to another using fast roaming or 802.11r. The two BSSs should be in the same security and mobility domain. This transition time includes the BSS transition activities such as authentication, (re)association and QoS message exchanges during roaming. This definition encompasses both uplink and downlink data frames. The metric characterizes the link layer portion of the transition only.

3.3 Test Configuration

3.3.1 Resource Requirements

The following items are the minimum required to perform the BSS transition time test:

- Two Access Points (APs)
  STA that is capable of associating with the APs
- Wired traffic analyzer/monitor to analyze the traffic over the DS
- Wireless (802.11) monitor/analyzer to monitor traffic over the airlink or RF cables
- Traffic generator, a device in the DS that is capable of receiving uplink traffic from the STA and capable of sending downlink traffic to the STA (on top of layer 2)
- Shielded enclosures for the APs, the STA, and the wireless monitors
  Four Variable attenuators
  These are devices used to control the received signal strengths of the wireless devices while the test is running. The level of the imposed attenuation shall be reproducible at any given time during the test.

- Three Calibrated combiners/splitters
- Authentication Server to perform first contact between the STA and AP using 802.1X as part of RSN security establishment.

Additionally, the following equipment might be required to conduct tests modifiying the baseline configuration according to Section 3.4.1.2:

- Policy Server as part of the DS for setting the QoS (where applicable)

3.3.2 Test Environment

The environment required for this test is a conductive and isolated environment in which cables are connected to the antenna ports of the 802.11 devices. It is of prime importance that the STA receive signals only through the desired path, otherwise the STA may remain associated with an AP throughout the entire range of the variable attenuators, rather than switching to the more favorable AP. For this reason, all 802.11 devices (AP, STA, wireless monitor) should be operated from within separate shielded enclosures. Also, care should be taken to avoid the possibility of RF signals bypassing the variable attenuators, for similar reasons. It is also possible to use a radiative means, such as a near-field probe to connect the APs and STA into the test system instead of a conducted connection. However, this introduces additional insertion loss which must be accounted for to achieve a specific range of path loss. Also, using a near-field probe definitely requires that the 802.11 devices be operated from within shielded chambers.

The diagram in fig. 3.1 depicts the typical test set-up. The set up consists of two RF paths, each with path loss controlled by the variable attenuators.

There are several components connected to the Distribution System (DS). The Access points with which the STA associates with are AP1 and AP2. The traffic generator is a device connected to the wired network (DS) to provide an appropriate source or termination for traffic destined or originating from the wireless client (STA).

Each of the 802.11 monitor devices is connected through a set of splitter/combiner such that it receives all 802.11 frames transmitted by the AP and STA devices. These devices should be synchronized in some fashion so that the relative timing of airlink events can be established. The wireless monitors operate as passive devices and must not transmit any 802.11 frames.

The power splitters through which the wireless monitors are connected should such that it enables the 802.11 monitor to receive signals equally well from an AP and the STA.

The DS monitor or wired analyzer is used to record all frames transmitted data over the DS (wired network) on top of layer 2.

Two variable attenuators should be provided in each branch of the setup. The arrangement shown makes it possible for the wireless monitor devices to always hear both the AP and STA, regardless of whether the attenuators are set to prevent the AP and STA from hearing each other.

The attenuators vary over the course of trial to produce a path loss for each STA-AP path according to a sweep function.

The sweep function and inter-roam period are test conditions. The attenuation function is described in section 2.3.2.1

It has to be noted that the policy server is part of the modifiers and not required for the baseline configuration.

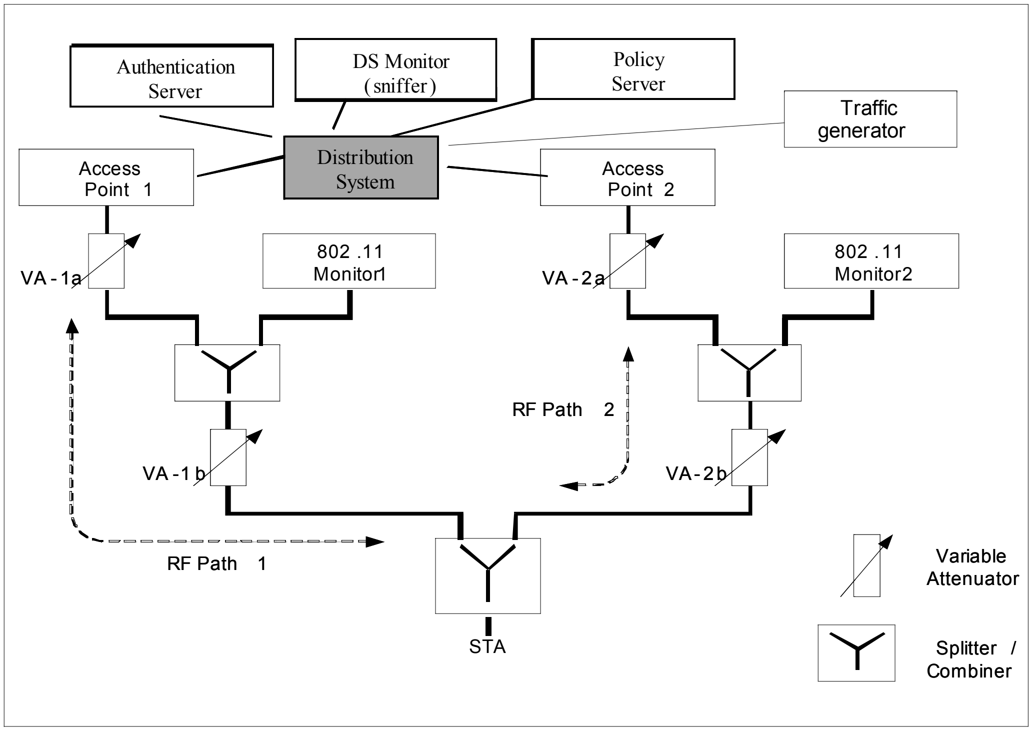

Fig. 3.1 Fast BSS Transition Test Set-up

3.3.3 Permissable Error Margins/Reliability of Test

Prior to beginning the test, the test equipment described above shall be calibrated, and all test software verified. The test setup may be monitored during the test to ensure that the test conditions do not change. The expected error margins for the measurement calibrations are +/-5 % for a specific set-up. The paths from one endpoint to another should be characterized. At any time assure that the wireless monitor should be able to listen to the test traffic during test run. The error margins for these metrics pertain to the timing of airlink events. For consistency and repeatability, timing of airlink events should be 10 to 20 times more accurate than the shortest measured Fast BSS transition time

Parameter	Description
Channel A, Channel B	Access points should be set to use any two non-overlapping channels available within the same frequency band (to mitigate impact of co-channel interference).
AP transmit power	Maximum supported by the AP.
STA transmit power	Maximum supported by the STA.
Minimum path loss	High enough such that the signal received at any device does not result in more than 10% frame error rate.
Maximum path loss	The maximum path loss should be sufficient to prevent the client STA from associating with the AP.
Dot11RTSThreshold	2312 bytes (Maximum MAC frame size)
Dot11FragmentationThreshold	2312 bytes (Maximum MAC frame size)
Power save mode	Off

Parameter	Description
QoS access category (AC)	QoS frames not used (no 802.11e QoS control field)/Disabled
Security mode	WPA-PSK
802.11k	Off
Wireless data traffic direction	Uplink
Sweep function	Linear in dB according to fig. 2.2
Inter-roam period	Long enough to cause a steady state in the system for a roam to occur, sec
Sweep time	To achieve an attenuation slope of 1 dB per 1 sec

3.3.3.1 Modifiers:

The baseline SUT setup parameters may be modified as follows to enable additional iterations to be performed for this test. Only one variation should be tested at a time.

- Wireless data traffic direction (downlink, bi-directional)
- Sweep time: Sweep times other than listed in the baseline may be employed
- Sweep function: Sweep functions other than linear in dB may be employed
- 802.11e QoS support with access category for test traffic specified. EDCA parameters used in the test shoud be reported.
- Security: Authentication and Encryption Method: WPA(802.1X/EAP), WPA2(802.1X/EAP, PSK)
    - Refer section 3.3.4 for details
- 802.11k

Any deviations from the baseline not discussed in this section should be reported.

3.3.3.2 Test Conditions

The test parameters used while performing this test are as follows:

Table 2.2 Test configuration parameters for BSS transition time measurement.

Parameter	Description
Frame formats	Per RFC 2544 Appendix C with LLC/SNAP encoding per RFC 1042
Intended uplink traffic load	10, 20, 30 msec frame interval *(The resolution of the measurements is directly proportional to the frame interval chosen)*
Intended downlink traffic load	10, 20, 30 msec frame interval
Bidirectional traffic load	10, 20, 30 msec frame interval
PHY data rate	Auto
Number of iterations	At least 100
Measurement Duration	60, 300 sec (short, long)

The intended traffic loads are selected to achieve either uplink only, downlink only, or symmetric bidirectional traffic. If the traffic is bidirectional, the frame rates for the uplink and the downlink should be the same.

The baseline attenuator sweep function is linear in decibels. That is, the attenuator sweeps from one extreme to another at a constant rate as measured in decibels. Other sweep functions are possible, but are not the baseline.

The values specified in table 2.2 for different test parameters are representative examples.

3.3.4 Measurement Procedure

The STA is set-up using the baseline configuration and an initial set of test parameters. The STA is initially associated with AP1 on a particular channel.

- Traffic is generated between STA and traffic endpoint through AP1, according to the desired offered load and direction.
- After the traffic flows are established, the wired and wireless monitoring devices begin capturing all traffic passing between the AP and the STA.
- Attenuation is varied according to the sweep function and sweep time defined in section 2.4.1.
- The inter-roam period starts at the point when the attenuators sweep to their respective limits. By this time the STA should have performed a BSS transition from one AP to the other. This constitutes a single trial. The next trial starts after the inter-roam period within the same iteration.
- The wired monitor and 802.11 wireless monitor record the transition procedure. For each trial, processing is carried out on the packets captured by the monitoring devices to determine the Fast BSS transition time.
- The Fast BSS transition time is shown in the diagrams denoted by 'T_{total}'. It is measured after the processing of the captured data that determines the time of occurrence of two events:
  - The time at which the last data frame was transmitted and acknowledged within the originating BSS (through the current AP1), and
  - The time at which the first data frame was transmitted and acknowledged within the destination BSS (through the new AP2).
- The processing activity should determine the time of these events for both uplink and downlink frames. For bidirectional traffic, an uplink or downlink data frame should be considered as the last data frame or the first data frame.
- The total fast BSS transition time is calculated as the time between the above events (T_{total}) as shown in the figures below for different scenarios. In addition, the following time components as available as part of the roaming process can be captured as part of the measurement procedure:
  - Fast BSS Transition Time (Baseline over the Air): T_{probe} , T_{FTauth} , $T_{(Re)assoc}$
  - Fast BSS Transition Time (Baseline over the DS): T_{probe} , $T_{(Re)assoc}$
  - Fast BSS Transition Time (Pre-reservation over the Air): T_{probe} , T_{FTauth} , $T_{(Re)assoc}$
  - Fast BSS Transition Time (Pre-reservation over the DS): T_{probe} , $T_{(Re)assoc}$

  where T_{probe} = Probe request/response exchange with the target AP after the last data packet send within the old BSS, T_{FTauth} = Fast BSS Transition initiation exchange, $T_{(re)assoc}$ = (Re)Association time.
- The diagrams are representative of a downlink transfer, but as per the modifiers the transmission could be uplink, downlink or bi-directional..

If the two APs are not identical models and firmware revisions, roaming time from AP2 to AP1 may be different from AP1 to AP2 and these different times have to be distinguished while collating the results.

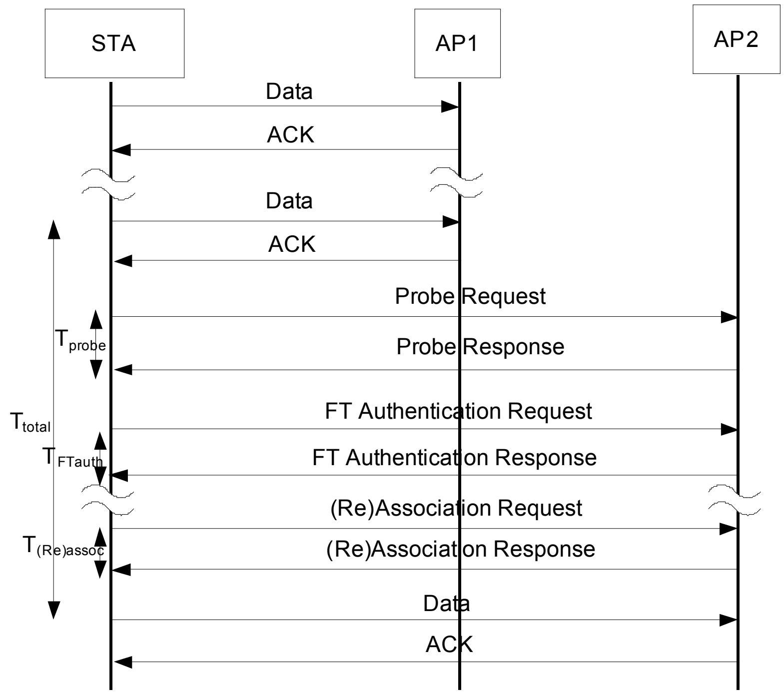

Fig. 3.2 Fast BSS Transition with Authentication Exchange over the air

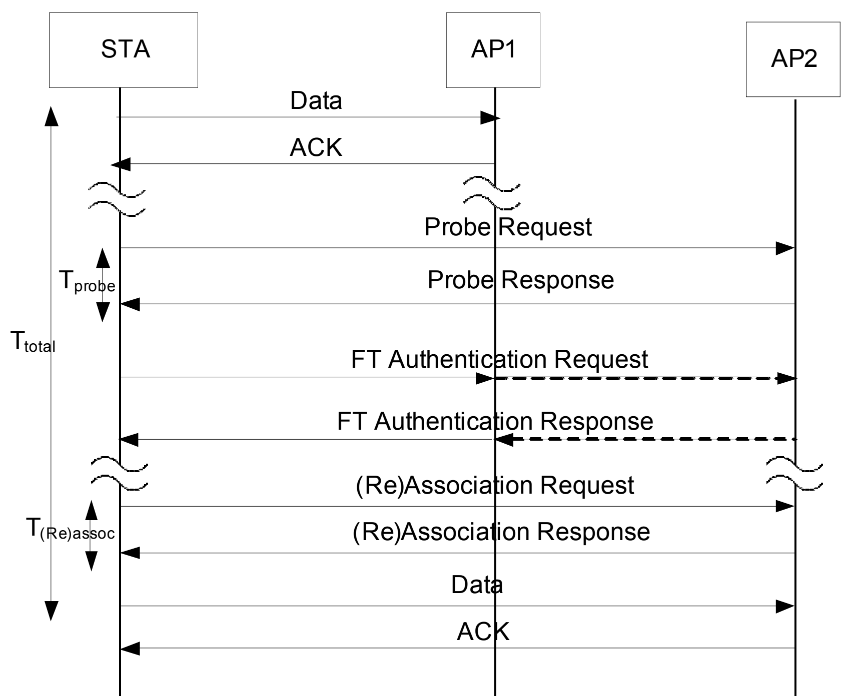

Fig. 3.3 Fast BSS Transition with Authentication Exchange over the DS

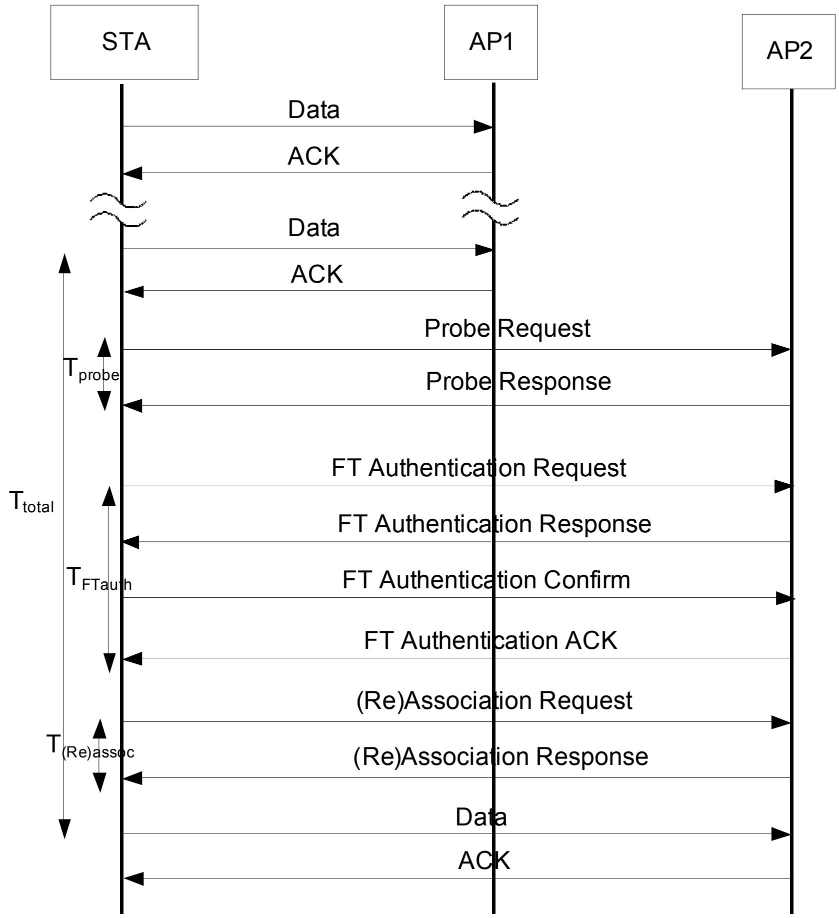

Fig. 3.4 Fast BSS Transition with Pre-Reservation Over the Air (And Auth Exchange over the Air)

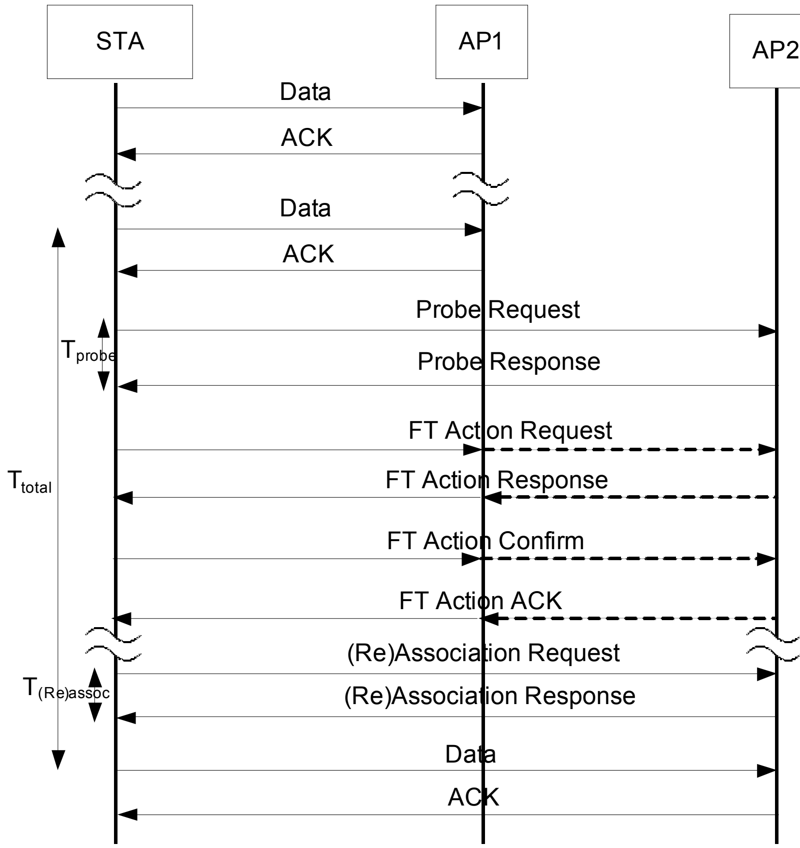

Fig. 3.5 Fast BSS Transition with Pre-Reservation Over the DS (And Auth Exchange over the DS)

3.3.5 Reported Results

The various Fast BSS transition times that could be measured are reported in the table below.

Metric	RSN	QoS and RSN
Fast BSS Transition Time (Auth Exchange over the DS, no pre-reservation)		
Fast BSS Transition Time (Auth Exchange over the Air, no pre-reservation)		
Fast BSS Transition Time (Auth Exchange and Pre-Reservation Over the DS)		
Fast BSS Transition Time (Auth Exchange and Pre-Reservation over the Air)		

The results to be reported after performing the test procedure described above are the observed BSS transition times, as measured by the procedure and the number of iterations conducted. These results may be presented in the form of a cumulative distribution function. The x-axis represents time, while the y-axis represents the probability that the BSS transition time is less than the corresponding time on the x-axis.

3.3.6 Specific Reporting Requirements

Additional information to be reported is as follows:

- System configuration
- All modifiers and test conditions in section 2.4,
- Retry limit for STA and APs
- Min. and max. imposed attenuation

If attenuation is approximated by a stepwise change of the imposed attenuation, the following parameters shall be included as well:

- Attenuation step size
- Time interval over which the imposed attenuation is kept constant

4 References:

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5 Assumptions and Risks

This document is subject to change based on the references. 802.11r is an emerging standard at the time of this document and this document will reflect those changes.