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Wireless LANs

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| TGai Evaluation Methodology |
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Abstract

This document contains evaluation scenarios and instructions in order to verify the fulfillment of TGai’s functional requirements. Additional evaluations showing the performance of proposed technical solutions are also described herein.

1 Introduction 3

2 Definitions, acronyms, and abbreviahations 3

3 Metrics & Parameters 3

4 System evaluation 3

4.1 Compliance to system requirements 3

4.1.1 Link set-up (Functional Req. 2.1.1.1) 3

4.1.2 Robustness against large number of users (Functional Req. 2.1.2.1) 4

4.1.3 Concurrency in information exchange (Functional Req. 2.1.3.1) 4

4.1.4 Link set-up time performance in an artificial environment 4

4.1.5 Performance for a minimum medium load in an artificial environment (Req. 2.2.2.1) 5

4.1.6 Performance in the presense of high medium loads in an artificial environment (Req. 2.2.2.2) 6

4.1.7 Evaluation of security level (Functional Req. 2.5.1.1) 7

4.1.8 Evaluation of backward compatibility (Functional Req. 2.5.1.2) 7

4.2 Use-case-based performance evaluation 8

5 Annex 8

5.1 Channel models 8

5.1.1 LOS free-space path loss 8

5.2 Traffic models 8

5.2.1 UDP-based medium load traffic profile 8

5.3 Parameters used for performance evaluations 8

5.4 Evaluation scenarios / set-up 8

5.4.1 Artificial scenario 1 8

# Introduction

The evaluation methodology defines conditions for functional requirements compliance and a limited set of simulation scenarios and comparison criteria for evaluating proposals.

# Definitions, acronyms, and abbreviahations

**Link Setup**: the process of gaining the ability to send IP traffic with a valid IP address through the AP. Link Setup may involve more than one AP in an ESS. This includes AP/Network discovery and (secure) Association and Authentication. [1]

# Metrics & Parameters

The terms used in this document are taken from the 11ai Use Case Reference List document [1]. The traits which differentiate the use cases are “Link-Attempt Rate”, “Media Load”, and “Link Setup Time”. The terms “link”, “association”, and “authentication” are as defined per 802.11.

**Link-Attempt Rate** is the number of STAs attempting to establish a link for the first time to an AP within an ESS as measured over a one second time interval.

**Media Load** is the “busyness” of the wireless medium of the ESS. It is measured as the percentage of time the medium is in use.

**Link Setup Time** is defined as the process of gaining the ability to send IP traffic with a valid IP address through the AP. Link Setup may involve more than one AP in an ESS. This includes AP/Network discovery and (secure) Association and Authentication. Link Setup Time is the amount time required in the use case to establish link setup. Timing starts when the STA elects to perform Link Setup.

# System evaluation

## Compliance to system requirements

### Link set-up (Functional Req. 2.1.1.1)

Each proposal shall show if it includes mechanisms for:

* AP detection,
* Network discovery,
* Association & authentication, and
* IP-address assignment

An abstract analysis or presentation of the features showing their existence is sufficient. For “IP-address assignment”, the analysis shall show if the assignment starts concurrently to the establishment of the MAC link or afterwards.

A full proposal shall demonstrate support of all features while partial proposals are characterized by focusing on subsets of the link set-up.

### Robustness against large number of users (Functional Req. 2.1.2.1)

Sufficient information shall be given to demonstrate the behavior of the system under extreme situations, e.g. high medium loads. The information shall provide compelling evidence that the system does not more likely break as compared to a legacy (non-TGai) 802.11-bases system.

Note: One approach to provide such compelling evidence may to compare the performance of a ledacy system against the performance of a TGai system / proposal using the method outlined below showing compliance to the system’s performance requirements.

### Concurrency in information exchange (Functional Req. 2.1.3.1)

Each proposal shall show if it includes mechanisms for providing concurrency in information exchange (e.g. to carry higher layer protocols possibly used to to obtain IP-address assignment during the link set-up phase).

An abstract analysis or presentation of the features showing the existence of “concurrency in information exchange” is sufficient.

A full proposal shall demonstrate support of this feature.

### Link set-up time performance in an artificial environment

An experiment as described by Scenario 5.4.1 shall be conducted.

Parameters:

* Channel model: Line Of Sight (LOS) free-space (channel model 5.1.1)
* Singe AP operating on a randomly selected channel.

Factors:

* Available (external) knowledge used to reduce the link set-up time (e.g. knowledge on specific channels used by APs in the current area).
	+ - One evaluation shall be conducted for having “no additional / external knowledge”
		- If external knowledge is available and used for decreasing the link set-up time, a detailed specification of that knowledge and how it is obtained / made available to the 802.11 MAC shall be given.
* Data rate
	+ - One evaluation shall be conducted for all STAs having a fixed data rate of 6 Mbps (ERP-OFDM PPDU frame format)
		- Additional data rates that should be considered are:
			* ERP PPDU short frame format: 1, 2, 5.5, 11 Mbps
			* ERP-OFDM PPDU frame format: 6, 12, 24, 54 Mbps

Note: Except for 54 Mbps, those are the “mandatory” data rates of ERP.

Note: ACK-Frames are not necessarily transmitted at the same rate as the preceding frame but at the next lower or equal mandatory frame rate (c.f. [IEEE 802.1-2007, Cls. 9.6])

* + - The data rate shall be fixed and the same for all STAs.
* Link attempt rate: The link attempt rate shall be varied from 1 to 100 non-AP STAs trying to establish a link with the AP. The factor shall be varied in steps of 10 Medium load:
	+ - Additional STAs imposing medium load shall cause a traffic flow according to 5.2.1.
		- The number of STAs causing medium load shall be varied from 0 (none) to 100 in steps of 10 (i.e.: 0, 10, 20, …, 90, 100). The medium load shall be reported in percent of channel occupancy[[1]](#footnote-1).

Metric:

* Link set-up time

The following reports shall be given for the link set-up time as a function of the factors:

* Percentile of STAs experiencing a link set-up time < 100ms
* Percentile of STAs experiencing a link set-up time < 5ms, 10ms, 20ms, 50ms
* Average link set-up time (including the 95% confidence interval)

The average link set-up time as a function of the medium load shall be reported. The 95% confidence intervals shall be given.

In order to fulfill the system requirements, a link set-up time of less than 100ms shall be achieved for the following factors: link attempt rate = 1; medium load = none, data rate = 6 Mbps (ERP-OFDM PPDU frame format)

### Performance for a minimum medium load in an artificial environment (Req. 2.2.2.1)

An experiment as described by Scenario 5.4.1 shall be conducted.

Parameters:

* Channel model: LOS free-space (channel model 5.1.1)
* Singe AP operating on a randomly selected channel.
* Link attempt rate: 100

Factors:

* Available (external) knowledge used to reduce the link set-up time (e.g. knowledge on specific channels used by APs in the current area).
	+ - One evaluation shall be conducted for having “no additional / external knowledge”
		- If external knowledge is available and used for decreasing the link set-up time, a detailed specification of that knowledge and how it is obtained / made available to the 802.11 MAC shall be given.
* Data rate
	+ - One evaluation shall be conducted for all STAs having a fixed data rate of 6 Mbps (ERP-OFDM PPDU frame format)
		- Additional data rates that should be considered are:
			* ERP PPDU short frame format: 1, 2, 5.5, 11 Mbps
			* ERP-OFDM PPDU frame format: 6, 12, 24, 54 Mbps

Note: Except for 54 Mbps, those are the “mandatory” data rates of ERP.

Note: ACK-Frames are not necessarily transmitted at the same rate as the preceding frame but at the next lower or equal mandatory frame rate (c.f. [IEEE 802.1-2007, Cls. 9.6])

* + - The data rate shall be the same for all STAs.
* Medium load:
	+ - Additional STAs imposing medium load shall cause a traffic flow according to 5.2.1.
		- The number of STAs causing medium load shall be varied from 0 (none) to 50 in steps of 100 (i.e.: 0, 10, 20, …, 90, 100).

Metric:

* Link set-up time

The 100% percentile of the link set-up time shall be given as a function of the factors.[[2]](#footnote-2)

In order to fulfill the system requirements, the 100% percentile of the link set-up time shall be a finite value (i.e. all STAs shall be capable to establish a link) for the following factors: medium load = none, data rate = 6 Mbps (ERP-OFDM PPDU frame format)[[3]](#footnote-3).

### Performance in the presense of high medium loads in an artificial environment (Req. 2.2.2.2)

An experiment as described by Scenario 5.4.1 shall be conducted.

Parameters:

* Channel model: LOS free-space (channel model 5.1.1)
* Singe AP operating on a randomly selected channel.
* Link attempt rate: 1 (only one non-AP STA trying to establish a link)

Factors:

* Available (external) knowledge used to reduce the link set-up time (e.g. knowledge on specific channels used by APs in the current area).
	+ - One evaluation shall be conducted for having “no additional / external knowledge”
		- If external knowledge is available and used for decreasing the link set-up time, a detailed specification of that knowledge and how it is obtained / made available to the 802.11 MAC shall be given.
* Data rate
	+ - One evaluation shall be conducted for all STAs having a fixed data rate of 6 Mbps (ERP-OFDM PPDU frame format)
		- Additional data rates that should be considered are:
			* ERP PPDU short frame format: 1, 2, 5.5, 11 Mbps
			* ERP-OFDM PPDU frame format: 6, 12, 24, 54 Mbps

Note: Except for 54 Mbps, those are the “mandatory” data rates of ERP.

Note: ACK-Frames are not necessarily transmitted at the same rate as the preceding frame but at the next lower or equal mandatory frame rate (c.f. [IEEE 802.1-2007, Cls. 9.6])

* + - The data rate shall be the same for all STAs.
* Medium load:
	+ - Additional STAs imposing medium load shall cause a traffic flow according to 5.2.1 (one STA imposing one traffic flow)
		- The number of STAs causing medium load shall be varied from 0 (none) to 100 in steps of 10 (i.e.: 0, 10, 20, …, 90, 100).

Metric:

* Link set-up time

The 100% percentile of the link set-up time shall be given as a function of the factors.[[4]](#footnote-4)

In order to fulfill the system requirements, the 100% percentile of the link set-up time shall be a finite value (i.e. all STAs shall be capable to establish a link) for the following factors: medium load = 50%, data rate = 6 Mbps (ERP-OFDM PPDU frame format)

### Evaluation of security level (Functional Req. 2.5.1.1)

Each proposal shall demonstrate that it maintains RSNA’s security level. Solutions shall demonstrate that they do not degrade the security offered by Robust Security Network Association (RSNA) already defined in 802.11. Solutions employing security schemes other than RSNA shall demonstrate that they are at least as secure as RSNA

All proposals effecting exisiting or introducing new security schemes shall submit an evaluation regarding the robustness of their security. The evaluation should at least include a description of the security properties; a description of the authentication of servers and clients; and a description of how encryption of traffic is done.

Any proposal effecting existing or introducing new security schemes shall requests comments from the entire WG via the TGai and 802.11-WG e-mail reflector at least two business days before being voted for inclusion in the TGai Draft.

### Evaluation of backward compatibility (Functional Req. 2.5.1.2)

Each proposal shall show that it maintains backward compatibility with existing 802.11 devices not supporting FLS.

An abstract analysis or presentation is sufficient if it shows how backward compatibility is assured.

## Use-case-based performance evaluation

Additional evaluations may be conducted to show the performance of the system for use-case specific parameter combinations. Though additional evaluations are not mandated to show compliance to the system requirements, TGai may asked presenters of proposals to come forward with such additional evaluations in order to allow TGai to better understand the behavior / performance of a particular proposal.

# Annex

## Channel models

### LOS free-space path loss

P\_r = P\_t \* (lambda / 4\*pi\*d)^2

## Traffic models

### UDP-based medium load traffic profile

Protocol: UDP

MSDU size: 8 kBytes

Offered load: 512 kBytes / s eaqually shared between up- and down-link (Packet generation rate: 64 packets / s 🡪 32 packets/s from the STA to the AP and 32 packets/s from the AP to the STA)

## Parameters used for performance evaluations

The following list of parameters shall be applied for all performance evaluations:

* Target beacon transmission time (TBTT): 100 ms
* Round trip times: The round trip time between any network elements shall be assumed to be 10ms.
* Processing times: All processing times shall be assumed to be zero. (Optimal, infinite processing power)

In addition to using those mandatory values, presenters may choose to employ different settings which should be explicitly called out in their evaluation.

## Evaluation scenarios / set-up

### Artificial scenario 1

Set-up: The AP shall be located at position (0,0) operating on a randomly selected channel number. Non-AP STAs are trying to establish a link with the AP. The non-AP STAs’ distance to the AP shall be 5m. The start of the link-set up shall be delayed by a random number that is uniformely distributed over a [1s, 1.1s] inverall. The goal therein is to put the system in steady state before starting the link-set-up The delay shall not be accredited to the link set-up time.[[5]](#footnote-5)

Additional non-AP STAs may be located at 5m-distance from the AP. Those STAs may impose a medium load on the system and shall have an established link with the AP.

Parameter for this scenario:

* Medium load: number of non-AP STAs imposing the load and traffic profile of the load per STA
* Link Attempt Rate: number of non-AP STAs trying to establish a link with the AP

**References:**

[1] 11-10/0238: TGai Use Cases

[2] 11-11/0811: TGai Evaluation Methodology

[3] 11-11/0745: TGai Functionl Requirements

1. Note: The imposed background load shall be reported as channel occupancy. Let *idle* be the time the media is (sensed) idle and let *busy* be the time the meda is indicated as busy. Then the channel occupancy is *busy / (busy + idle)* [↑](#footnote-ref-1)
2. Note: if not all STAs can establish a link, a value of “infinite” shall be reported. [↑](#footnote-ref-2)
3. Note: this does not mean, that all STAs have to experience a link set-up time of less than 100ms. [↑](#footnote-ref-3)
4. Note: if not all STAs can establish a link, a value of “infinite” shall be reported. [↑](#footnote-ref-4)
5. Drawing from this distribution allows additional STAs imposing a background load to reach a steady state. [↑](#footnote-ref-5)