IEEE P802.19
Wireless Coexistence

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| Discovery of Interfering TVBDs |
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| Author(s): |
| Name | Company | Address | Phone | email |
| Jari Junell | Nokia Research Center | Itämerenkatu 11-13, 00180 Helsinki, Finland | +358-718036575 | jari.junell@nokia.com |
| Mika Kasslin | Nokia Research Center | Itämerenkatu 11-13, 00180 Helsinki, Finland | +358-718036294 | mika.kasslin@nokia.com |

Abstract

This document is a submission to IEEE 802.19 TG1 about interferer discovery. This is a follow-up submission to the submission 19-11/0051r0 in which we used term neighbor discovery but now term interferer discovery is used instead because of the feedback received during the May 2011 interim.

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# Introduction

This document discusses potential ways to determine which TVBDs interfere with each other. Now on in this document the process of determining interfering TVBDs is called interferer discovery. Previously this topic has been discussed in document IEEE 802.19-11/0005r1 by AmeriSys and InterDigital and in IEEE 802.19-11/0051r0 from us. In the previous submission on this same topic we used terms neighbor TVBDs and neighbor discovery but based on the feedback received during the May 2001 interim meeting in Indian Wells, CA, USA, we have started talking about interferers instead. That’s also partly why we created a new submission instead of submitting a revision of the previous proposal.

First we need to define what we mean with interfering TVBDs. Two TVBDs are interferers if they both can interfere with each other or even if only one can interfere the other. We don’t always know locations of TVBDs but only the Mode II and Fixed device locations are known; Mode I device locations are not known. Similarly we can’t expect many Mode I devices to use the coexistence system services but for the IEEE 802.19.1 coexistence system the TVBDs that are using the services of the coexistence system via CEs are Mode II or Fixed devices. Despite all that we need to have means to take into account in interference estimations also the Mode I TVBDs even if they are not connected to the coexistence system and their location is not necessarily known.

In the case the TVBD that uses the coexistence system services serves Mode I TVBDs the system design needs to be such that it estimates locations of those Mode I TVBDs and especially those locations in which they would cause most interference to other TVBDs. For those registered TVBDs that serve only other registered TVBDs for which the location is known in the coexistence system there is no need to estimate TVBD location and potential related interference.

In this document we assume that the interferer discovery is performed by a coexistence discovery and information server (CDIS). It may, however, happen in any other entity as well as long as the performing entity has all the required information.

# Input parameters from a CE to the interferer discovery

Following information needs to be considered as input for interferer discovery calculations:

1. Geo-location of the Mode II or Fixed device
2. Environment type
	* Indoor/outdoor, urban/suburban/rural, (office, home, mall, floor number …)
3. HAAT (hT and hR)
4. Supported frequencies
5. Reference bandwidth (BW)
6. Receiver characteristics (two alternatives)
	* Minimum SINR for the network to operate (SINRmin) and noise figure (NF)
	* Minimum receiver sensitivity
		+ Is only noise assumed or should some interference also be assumed?
7. Transmitter characteristics
	* Maximum transmission power Ptxmax with antenna properties (see point 7)
	* EIRP
8. Antenna directivity D(θ, ϕ)
	* θ is an azimuth angle and ϕ is an elevation angle (implicitly included in later equation) and antenna loss La (Combination of directivity and antenna loss is antenna gain)

# Formulas for path loss evaluation

Propagation model has an essential role when estimating path loss between a transmitter and a receiver under study. Figure 1 illustrates a model to estimate interference between TVBDs of two networks, A and B. Locations of TVBDs a1 and b1 are known and those are the locations of Fixed or Mode II devices that are using the services of a coexistence system. TVBDs a2 and b2 represent the worst case locations from interference perspective in the two networks respectively. Locations of these two TVBDs are not known but they are estimated and in the estimation one looks for the location in which they are estimated to interfere each other or a TVBD with known location most. Depending on the relative positions of the devices either all the four TVBDs are needed in the calculations or the a2 can be merged to the a1 or the b2 can be merged to the b1.

Following aspects needs to be taken into account when evaluating whether TVBDs are interferers or not:

* Propagation model (L(r, x))
	+ L is attenuation over a certain link between a transmitter and a receiver. The r is the distance between the transmitter and the receiver and x represents all the other parameters that are needed to define the attenuation.
	+ The following formula can be used to evaluate the attenuation between a transmitter and a receiver

L (…) = 10log (4πr/λ)α – 20log(hT\*hR),

in which λ is a wavelength and α is an environment related attenuation exponential (free space = 2, otherwise higher). Operating environment and maximum transmission power should be used to define the value of the attenuation exponential.

* Communication area of a network
	+ Communication area is the coverage area that the a1, or b1, provides to their networks.
* Interference area of a network
	+ Interference area is the area within which the signal level from any device of the network within the communication area of the network is equal to or larger than N+Im
		1. Im is interference margin that defines how much interference a device tolerates above the noise level from another device at a receiver input before the other device is deemed as an interferer.
		2. If the specification defines a commonly used Im value for all the networks and users, one can determine the interference area for each network separately without knowledge about the other network and its devices parameters. If each network/device can determine their own interference margin, one needs to determine interference areas for network pairs rather than for individual networks.
* What is the highest potential interference level from a device in the network A to a device in the network B and vice versa?
	+ This may be estimated from communication and interference areas of both networks and their intersection:

Prx\_bx = Ptxmax\_ax + Gt\_ax(θ\_B) + Gr\_bx(θ\_A) – L(r\_ax\_bx, x),

where Prx\_bx is for either the b1 or b2, Ptxmax\_ax is for either the a1 or a2. The L(r\_ax\_bx, x) represents the path loss between the two devices of two networks that are estimated to interfere most each other.

With these parameters the CDIS estimates whether a TVBD and potential Mode I devices it may serve can interfere with TVBDs in another network operated by another TVBD connected to a coexistence system. Additionally, the CDIS estimates the interference type (mutual, source, victim) in case there is potential interference between the TVBDs.

Here we haven’t considered the frequency that is used in the calculations. We shouldn’t leave this entirely up to the implementations since if the range of the supported frequencies is large compared to the center frequency, the outcome of the analysis may vary a lot. We wonder if the specification should give clear rules in which frequencies of the commonly supported frequencies the analysis should be done.



Figure : An illustration of interference calculation between two TVBDs representing two networks

# Interferer discovery procedure

A CDIS performs interferer discovery calculations for each TVBD that has been registered to it. Calculations are done in TVBD pairs and if the TVBDs under consideration serve Mode I TVBDs, the CDIS needs to estimate the worst case location of the Mode I TVBDs and use those estimates in the calculations. Only those TVBDs that have overlap in operating frequency capabilities are taken into account in the calculations. Their current operating frequency is not considered in the calculations but the TVBDs are considered interferers only if they have potential to operate in a same frequency and interfere.

The procedure is roughly as follows for each TVBD pair:

1. Calculate communication and interference areas for both TVBDs
2. Evaluate the possible interference to both directions
	1. Prx\_ax to represent interference experienced by a device in the network A from a device in the network B
	2. Prx\_bx to represent interference experienced by a device in the network B from a device in the network A
3. Decision of interference status between the two networks and devices in them
	* Prx\_ax and Prx\_bx > Im+N (N=No+NF): Both are interferers to each other (mutual)
	* Prx\_ax and Prx\_bx < Im+N (N=No+NF): No interference
	* Prx\_ax > Im+N and Prx\_bx < Im+N (N=No+NF): Network A device is an interference victim
	* Prx\_ax < Im+N and Prx\_bx > Im+N (N=No+NF): Network A device is an interference source
	* If the communication areas overlap, following short cuts in the decision making can be done
		+ If the both networks are serving Mode I devices with unknown location, the networks’ devices are deemed interferers.
		+ If only one of the networks is service Mode I devices with unknown location, the communication area of that network has to contain a location of a Mode II or Fixed device of the other network and the communication area of the Mode II of Fixed device of the other network has to overlap with the communication area of the first network

Prx above would be actually 10\*lg (10^(Prx,calculated/10)+10^(N/10)) when measured in e.g. RSSI.

It is also worth to note that in real environments the highest interference between Mode I TVBDs is not always caused by the devices at a maximum distance from the informed location of the registered device in CDIS.

# The outcome of the discovery

The outcome of the interferer discovery is as follows:

1. Interference direction
	* Mutual, Source, Victim
2. Prx\_ax and Prx\_bx