WG1&3 INTERACTions on realistic pathloss and fading for emulations and simulations: how to do it?

Haute école d'ingénierie et d'architecture Fribourg
Hochschule für Technik und Architektur Freiburg

Fred Wagen, Yann Maret,

continued from COST IRACON TD(20)13063-(21)14038-(21)15033
COST INTERACT TD(22)01093

ARAMIS-No. 041-23

COST INTERACT **TD(22)02084**
13-15.6.2022

Abstract & plan

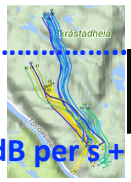
In **WG3, accurate multiusers system simulations or emulations** appears to be increasingly important to demonstrate the benefits or limitations of new schemes in all advanced communications systems. In **WG1, accurate modelling of the radio propagation** and of the radios Tx/Rx characteristics are of major interest. As ideal as impractical: WG1 would measure single links and WG3 would use measurement replays. With current computing power channel models using building, terrain and usage maps is only slightly less impratical. Statistical channel models are then derived but usually only for single links and usually not for mobile to mobile links. **Multiusers systems simulations use**

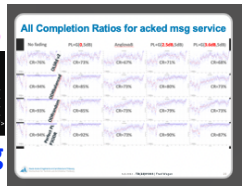
(1) a Probability Of Reception (POR = 1-**Packet Error Rate**)**-vs-SINR fitted to the radio system and the environment, including short term fading**, and

(2) a simple, or complex, **path loss model** in dB with or without an additional Gaussian random variable to simulate the effect "slow" fading.

Some results from past TDs and new **results** from the realistic Anglova.net MANET scenario will be discussed.

PL per s + ... AnglovaB





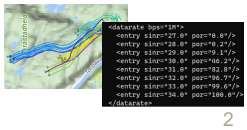
PL+G(3.6,5)dB per s + No fading

	No fading Pathloss PL	AnglovaB PER-vs-SNR	PL+G(3.6,5dB) Every second
OLSRd v2	76%	67%	68% Expected 67% ☺
ODR balanced	94%	73%	73% Expected 73% ☺
Perfect PL Predic. P3ODR	94%	73% Expected 73% ☺	87% Expected 94%

PL+ PER-SINR_AnglovaB ≈ PL+G(3.6,5)dB per s +PER-SINR_No fading

Providing our "fading datasets" might be of interest: to be discussed too.

PL adjacency matrix(t) & PER-SINR



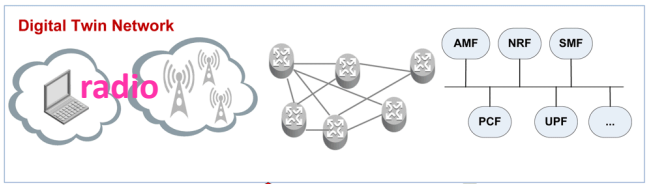
Recall TD(22)01093: same but less results

In the **context of beyond 5G, V2V, D2D, WiFi Mesh, etc.,** wireless system simulations are often use to compare new proposals to enhance the performances. When the performance metric is the link goodput or Packet Error Ratio versus SINR, bit level simulations of the radio system, e.g., 802.11, and of **fading** via standard radio propagation models, e.g., 802.11 TG, COST IRACON Geometry-based Stochastic Channel Model or Winner, are usually favored. When multi-user system performance metrics are considered, e.g., message completion ratio, the detailed radio propagation simulation approach is computationally expensive.

Another approach is to pre-compute the **Packet Error Ratio (PER)-vs-SINR** for a given Tx-Rx standard including the modulation and coding scheme used, a specific radio channel model including fading and a given packet size. Previous COST IRACON TDs contributed to show the benefit of the so-called "LOS+G" approach: using link level simulation, for 802.11n, the PER-vs-SINR curves in fading conditions, e.g., for 802.11 TGn B, can be reproduced by keeping the PER-vs-SINR for the non-fading Line-Of-Sight (LOS) case but adding, to each packet, a log-normal fading, i.e., a Gaussian random variable to the pathloss (PL) in dB: **PL+G(m=3.6, s=5)**. This contribution shows some results **comparing the "no fading", "PL+G every second" and "PER-VS-SINR" approaches** on the performance, here the message completion ratio, for a 24 nodes MANET using real time emulations playing the realistic anglova.net pathloss scenario. The fading effects on three routing algorithms for MANET are presented. The three routing algorithms are:

1. the **OLSRd2** from olsr.org,
2. so-called **Omniscient Dijkstra Routing (ODR) provided with non-faded pathloss values**, and
3. a Perfect Pathloss Prediction **P3ODR** provided with the "LOS+G every second" values.

Digital twin network: xG D2D, V2V, MANET

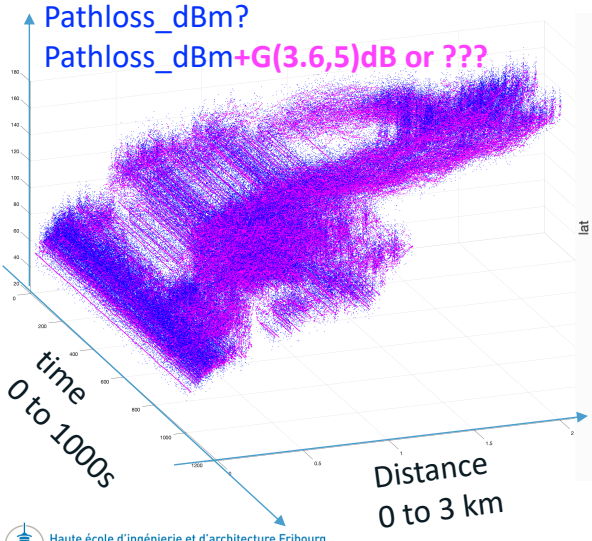


https://digitaltwin1.org/articles/1-5

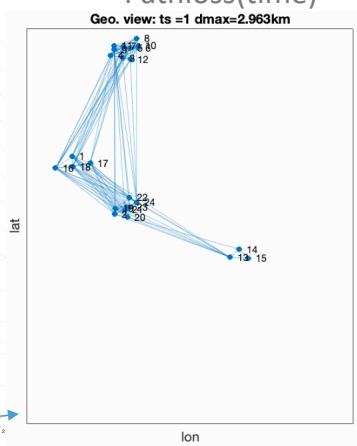
How to account for fading ?

How to be simple but not wrong ?

too emulate in real time the radio impairments ?



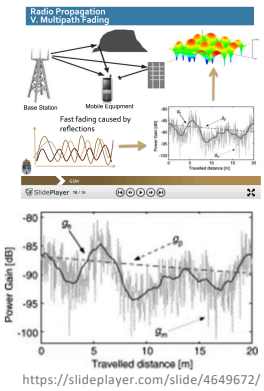
Pathloss(time)



RTTD=0.0016, RTTM=1.4432, RTTRR=2.3808[s]
RTT=2((0.0384+0.001)*1.6341+0.01*(0.63406)

(1) POR-vs-SINR (**enviro**)

S_dBm=PTx_dBm-Pathloss_dBm



https://slideplayer.com/slide/4649672/

Or (2) POR-vs-SINR (LOS)

S_dBm=PTx_dBm-Pathloss_dBm-**G(3.6,5)dB**

System simulations : abstract PHY+MAC
System emulation: +IP+UDP+User traffic

- At transmitter and receiver, modeling full MAC processing involves complete MAC frame generation at the MAC layer. Similarly, modeling full PHY processing involves complete operations related to waveform transmission and reception through a fading channel. When simulating large networks, full MAC and PHY processing is computationally expensive.

MathWorks®

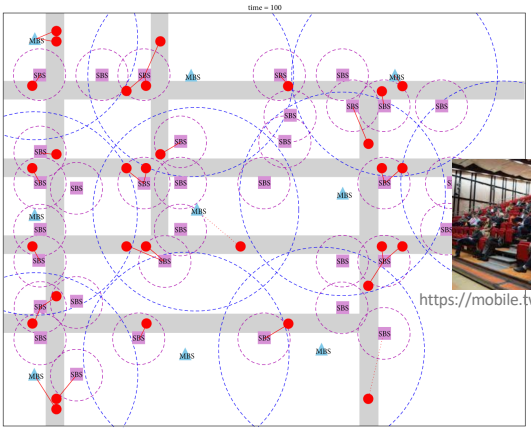
Help Center

ns-3

EMANE

COST INTERACTion WG1 and WG3

How realistic (path loss, fading, PER, scheduler, routing, transport, applications) models needs to be for system performance evaluations ?
How to make it as simple as possible …
… while keeping meaningful outcome ?

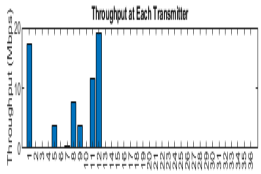


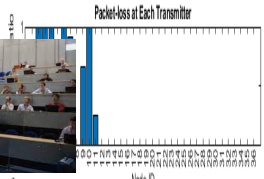
https://www.hindawi.com/journals/wcmc/2022/5006770/fig3/

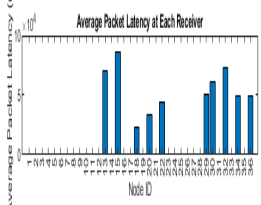
https://mobile.twitter.com/iraconaction

Com. System

https://mobile.twitter.com/iraconaction





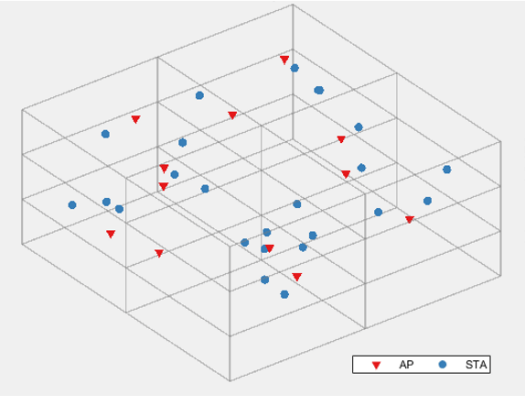


System simulation : 8021.11 or Matlab as exple

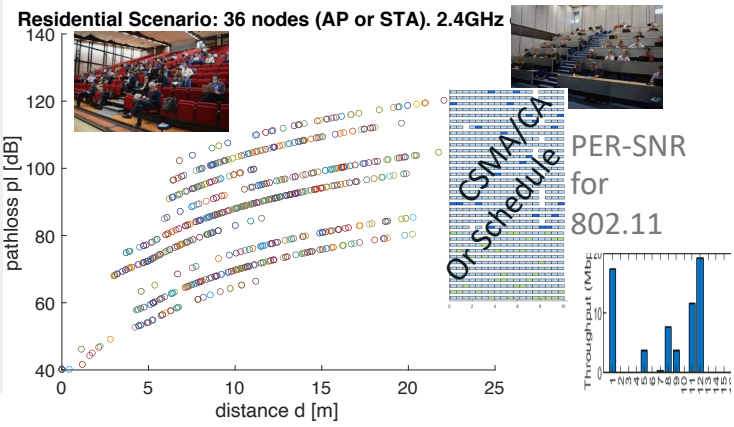
https://ch.mathworks.com/help/wlan/ug/802-11ax-multinode-system-level-simulation-of-residential-scenario-using-matlab.html

https://mentor.ieee.org/802.11/dcn/14/11-14-0571-12-00ax-evaluation-methodology.docx

A drop is defined as a specific set of AP and STA locations



Residential Scenario



(too) simple power law ? : **Pathloss (no fading ?)**

~~simple power law + "slow fading" :~~ **~~Pathloss+G(0,5dB)~~**

WG1 (PHY) and WG3 (MAC)

Yes this is might be an oversimplification

Images from MathWorks® Help Center

WG1 (PHY) and WG3 (MAC)

Share
Pathloss data
PER-SNR data
&
codes to read data

MathWorks Help Center | ns-3 | EMANE

Physical Layer Abstraction for System-Level Simulation

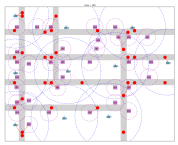
PER -vs- SINR(PL based) to simplify … but ?? for fading

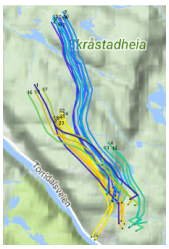
https://ch.mathworks.com/help/wlan/ug/physical-layer-abstraction-for-system-level-simulation.html

System sim.

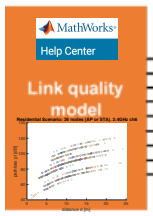
PHY abstraction: pathloss -> SINR -> Success or failure

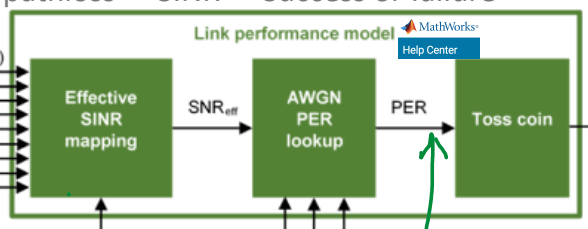
topology





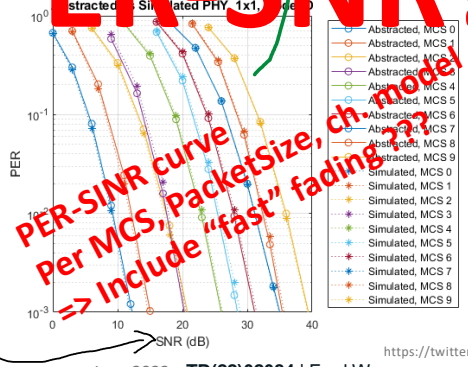
(lat, long, t)
+ Bldg +
Open Street Map
+ …





Path loss =
+
…
…
G(m,σ)
to include
slow fading
(every second
Or
every packet ?)

PL? PER-SNR?



PER-SNR curve
Per MCS, PacketSize, ch. model
=> Include "fast" fading ??

Cm. System

Not the focus of this TD but see TD(22)02083

Throughput
Packet Loss
Latency

https://twitter.com/phdcomics/status/1493308206830919683

Ref: COST IRACON TD(21)15033 summarized in this slide

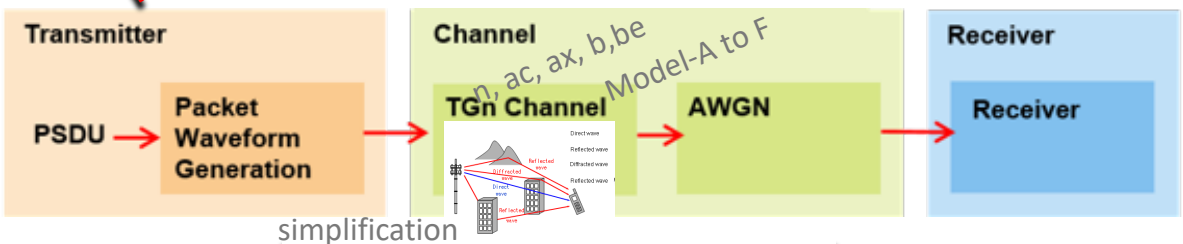
Conclusions from *TD(21)15033*: Use PL+G(m,σ)

2nd simplification: G(m=2.5 and σ=5) fixed

3rd simplification: Packet Size=300B fixed

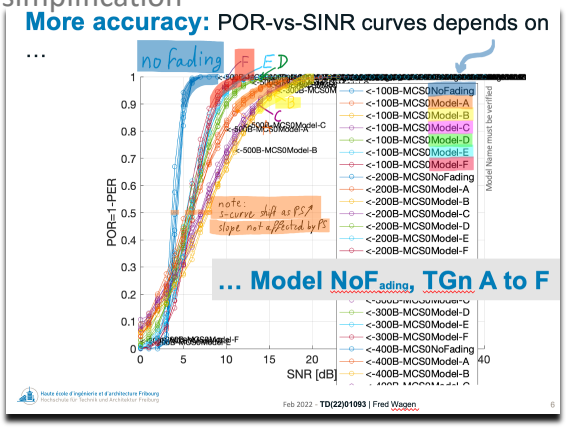
PER-SNR!

looks "wrong" to use the usual $(1\text{-PER})^{PS/100B}$



simplification

Link simulations:
For example
MCS0
took 5 days
to compute !!!



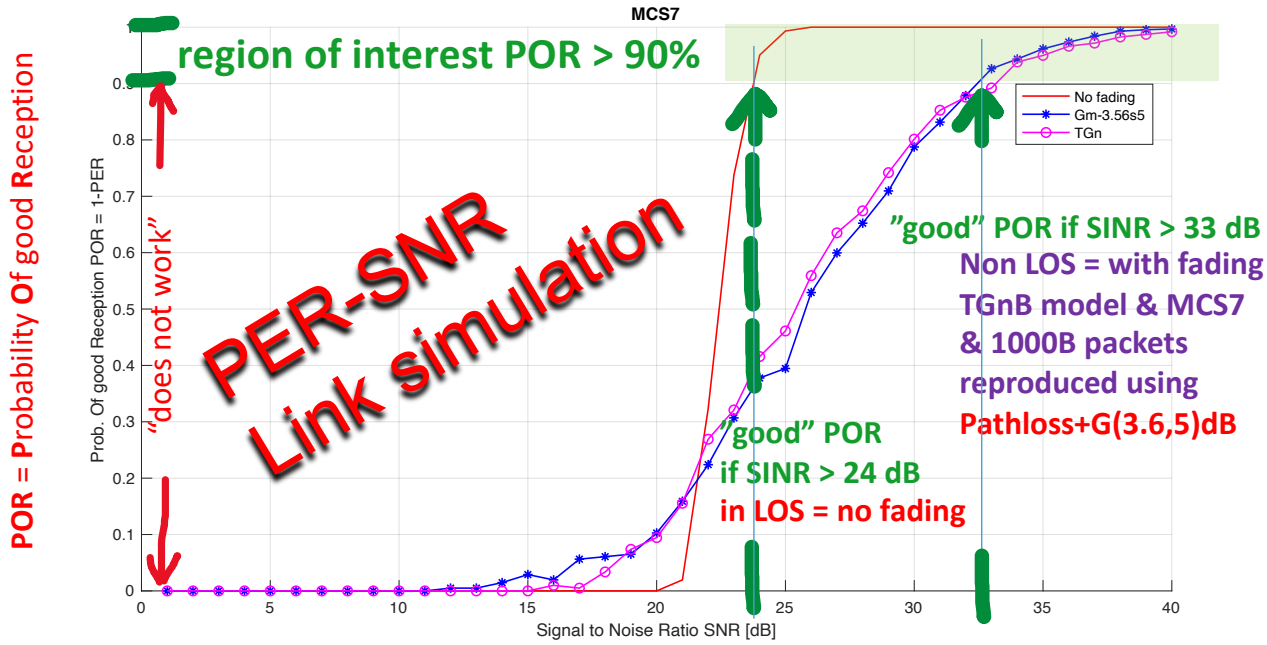
Model	Usage Model	
A	Gaussian Channel-like	Middle
B	Intra Room, Room to Room	Worst
C	Enclosed Offices Meeting, Conference or Class rooms	
D	Offices – cubes farms, open areas and large classrooms	
E	Indoor Hotspots with large rooms	
F	Large Indoor Hotspot – Airport	~LOS

https://mentor.ieee.org/802.11/dcn/19/11-19-0359-00-0eht-tgbe-channel-model-document.docx

Ref: COST IRACON TD(21)15033 summarized in the next slide

PER = fct(SINR,enviro TGnB, MCS7, 1000B)

≈ fct(SINR,enviro Pathloss+G(m3.6,σ5)dB)

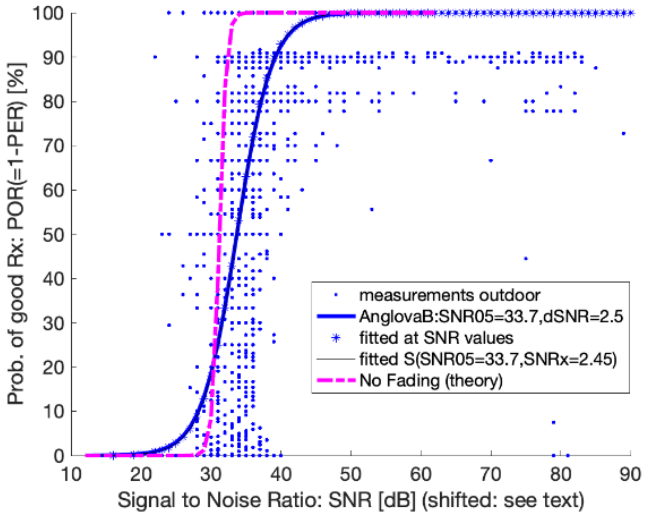


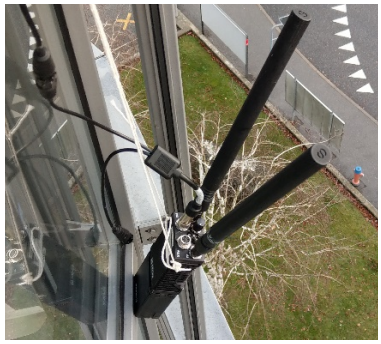
Measured PER-SNR?

Probability Of Reception (POR=1-PER)-vs-SNR : .

POR-vs-SNR with fading is obtained from real outdoor measurements.

$$\mathrm{POR} = 100 \cdot \left(\frac{1}{1 + e^{\frac{-(SINR - SINR05)}{deltaSINR}}} \right)$$ — AnglovaB:SNR05=33.7,dSNR=2.5





Silvius tactical radio

[Maret et al, ICMCIS2022]

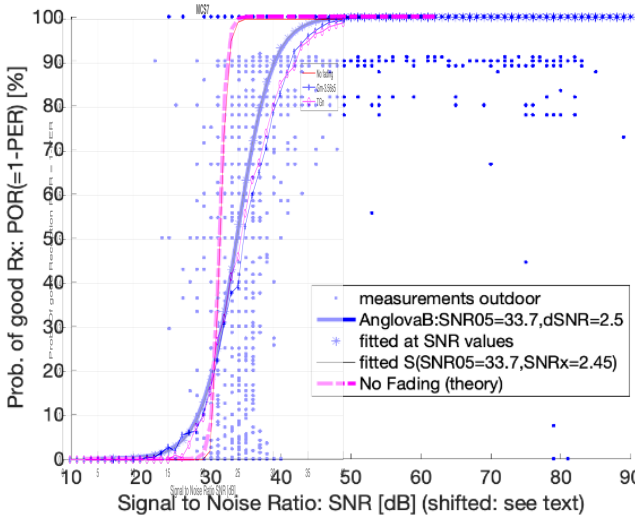
Measured "AnglovaB" ≈ "802.11TGnB"

Probability Of Reception (POR=1-PER)-vs-SNR : .

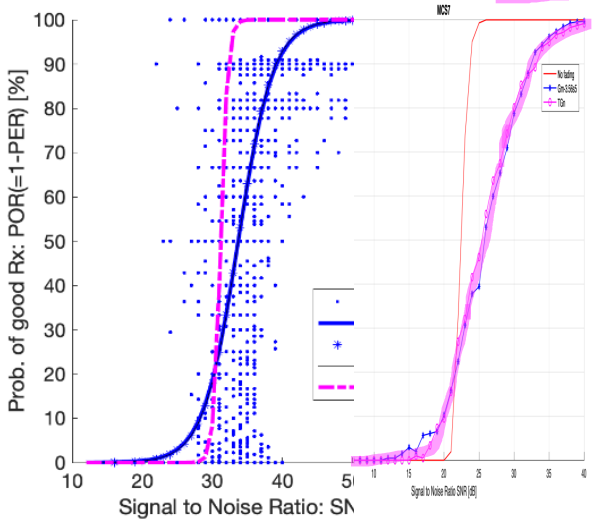
PER-SNR

AnglovaB = POR-vs-SNR with fading obtained **from outdoor measurements**

$$\mathrm{POR} = 100 \cdot \left(\frac{1}{1 + e^{\frac{-(SINR - SINR05)}{deltaSINR}}} \right)$$ — AnglovaB:SNR05=33.7,dSNR=2.5

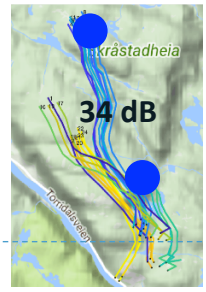
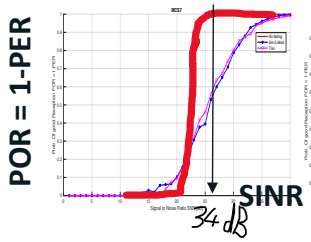
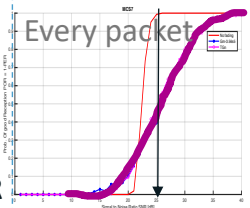
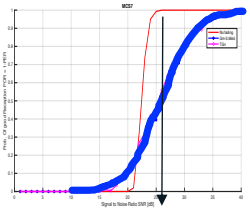
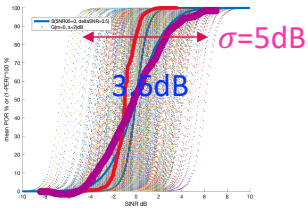


AnglovaB TGnB

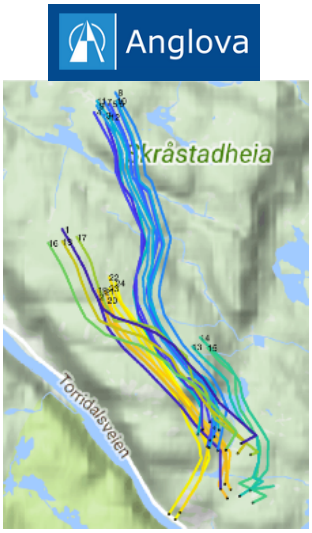


How accurate needs the POR=(1-PER)-vs-SINR needs to be ? … no results yet

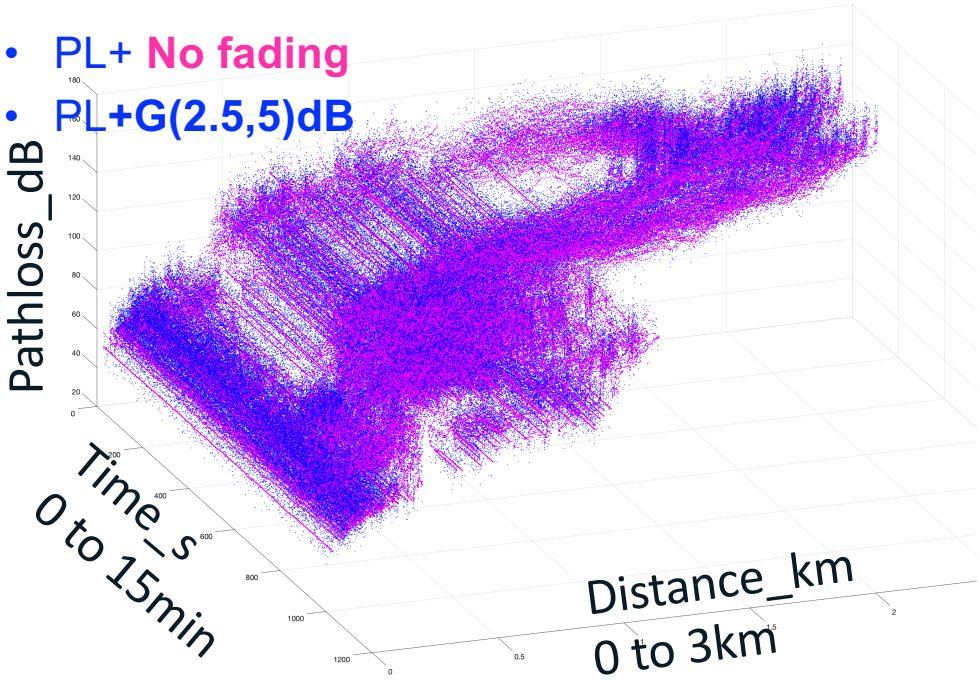
How accurate m and σ using G(m,σ) needs to be? … G(2.5,5)dB & G(3.6,5)dB compared later

No fading	AnglovaB Change POR	S_{dBm}-G(3.6,σ=5) Every packet	S_{dBm}-G(3.6,σ=5) slower: every second
SNR=34 dB		34 dB - G(3.6,5)dB every packet	34 dB-G(3.6,5)dB every second
No fading 			Change pathloss every sec. 
CR for "2 nodes" with SNR=34 dB when no fading:			
CR = 100%	50%	50%	50% ☺
CR for 24 nodes in Anglova (see "results" slide later):			
CR = 74%	73% ☺	not yet implemented	73% ☺

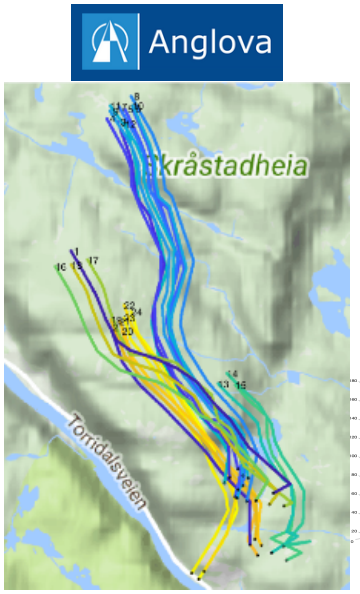
Anglova scenario: Pathloss node i-node j(t)



- PL+ No fading
- PL+G(2.5,5)dB

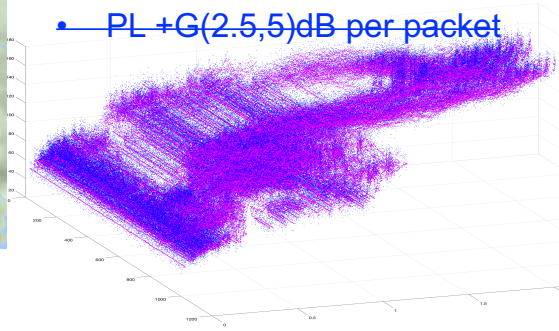


For MANET real time emulations



Several test cases

- No fading
- PL+AnglovaB
- PL+G(2.5,5)dB per s
- PL +G(3.6,5)dB per s
- ~~PL +G(2.5,5)dB per packet~~



24 MANET nodes

Realistic Real Time Emulation of Packet Transmissions in Real Environments

to benchmark real Acked Message Service

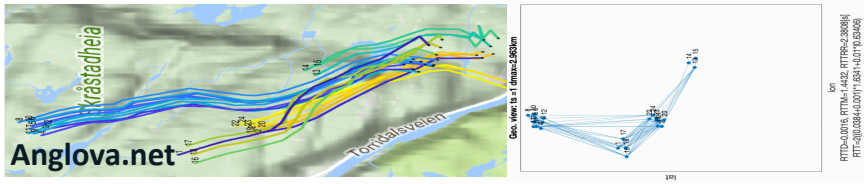
One LXC per node

One **LinuX Container** per node

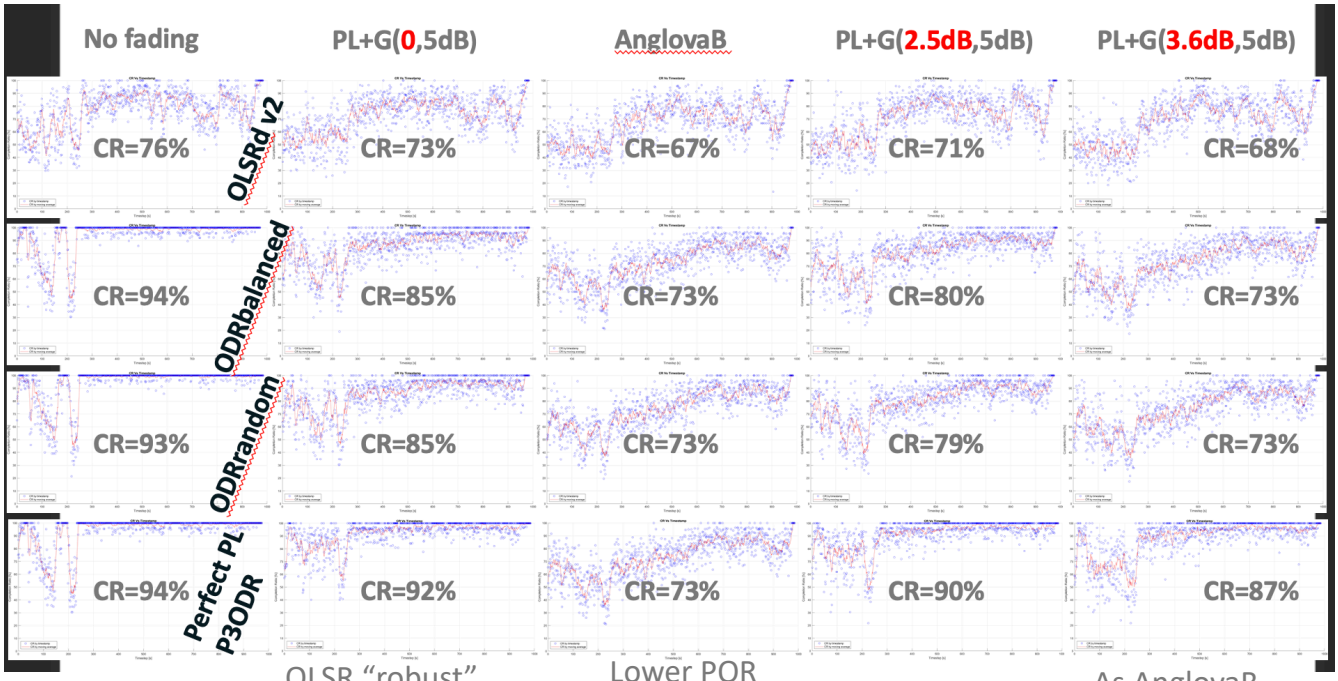
Real time emulation of packet errors and TDMA radio
using a cluster of 24 LinuX Containers:
1 LXC = 1 radio node

realistic MANET scenario

5W radios; 3km/15 min



All Completion Ratios for acked msg service



OLSR "robust"
ODR not "robust"
P3ODR "good"

Lower POR
Lower CR
expected

Too "good"

As AnglovaB
P3ODR does not
Compensate: to
be expected

Effect of fading on Completion Ratio …

	No fading Pathloss PL	AnglovaB PER-vs-SNR	PL+G(3.6,5dB) Every second	??
OLSRd v2	76%	67%	68% Expected 67% ☺	
ODR balanced	94%	73%	73% Expected 73% ☺	
Perfect PL Predic. P3ODR	As Above	As above	87% Pathloss+3.6dB => more disconnections => Smaller CR than 94% to be expected ☺	

Claim: no need for better model

Conclusions

- **Fading must be included:** Decreases Completion Ratio.
- PL_dBm + G(3.6,5)dB every packet ≈ TGn B OK for link simulation.
- **PL + G(3.6,5)dB every second ≈ AnglovaB PER-SINR.**
- PL + G(μ,σ)dB every second depending on enviro: is it worth it ?
- PL + G(μ,σ)dB every packet: remains to be investigated

- **We will share our**
  - **Pathloss Adjacency Matrix (eel or txt) and**
  - **PER-SINR curves (S-curve and/or linear curve fit: txt).**

Annexe:
Recommendations for system simulations

1) PL(i,j,t) per s ~~(or faster if … , it depends)~~,
2) compute SINR,
3) compute PER-vs-SINR ~~(enviro ?, Packet size ?)~~
4) Packet OK or NOK, ~~(correlated fading => ???)~~

is it really OK to neglect these effects ?

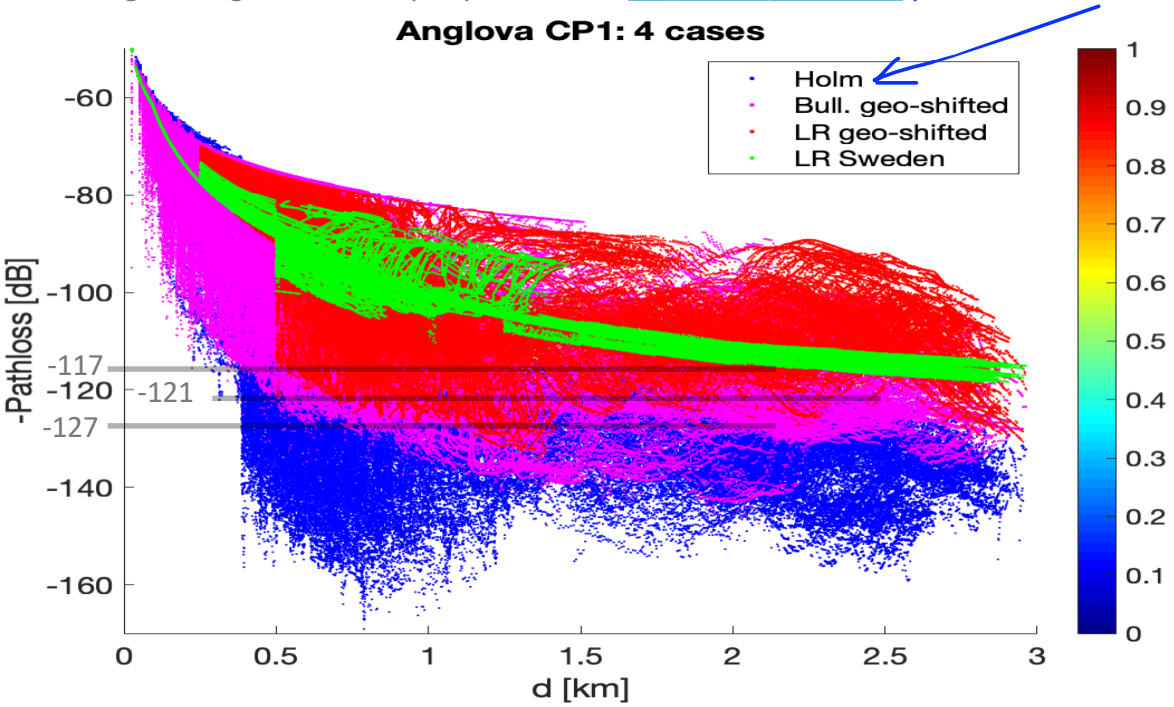
5) simulate or emulate the IP, UDP/TCP/…, Applications,
6) monitor the performance (e.g., TD(22)02083).

Note: *1) Could use Rx power – **G(m,σ)** per s, 2) SINR and then 3) PER-vs-SINR* ***for LOS***

BUT sensitivity to 0< PER < 10^{-1} ? TBFI

Annexe: on Anglova.net pathloss

The Anglova Vignette 2 Company 1 scenario https://anglova.net/ pathloss in blue

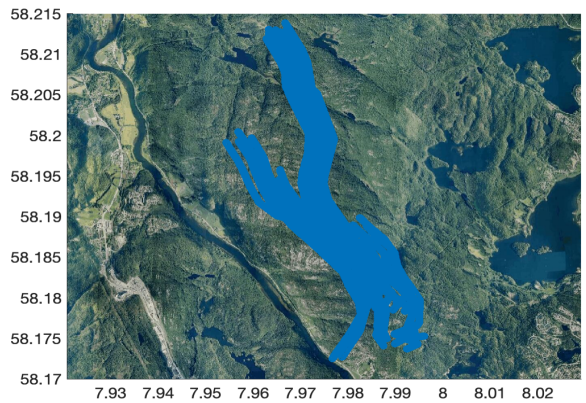


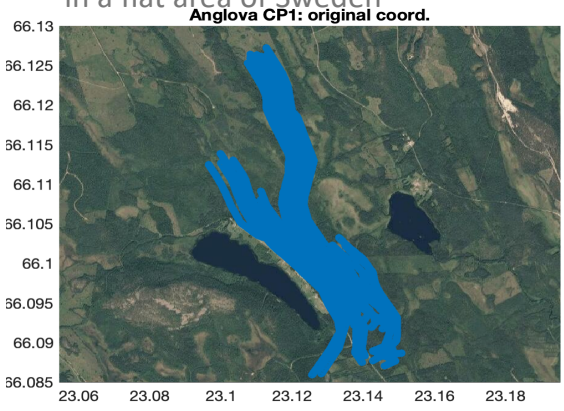
The Holm's model for path loss was used to provide the pathloss for Anglova.net.

The high pathloss compared to Longley-Rice (LR) or Bullington's model might be due to trees (?)

Annex: Anglova.net … original coord.

in a flat area of Sweden



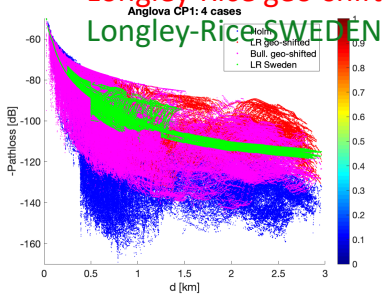


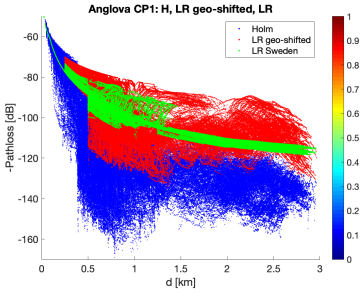
Anglova PL from Holm's model

Bullington's model

Longley-Rice geo-shifted to Anglova

Longley-Rice SWEDEN





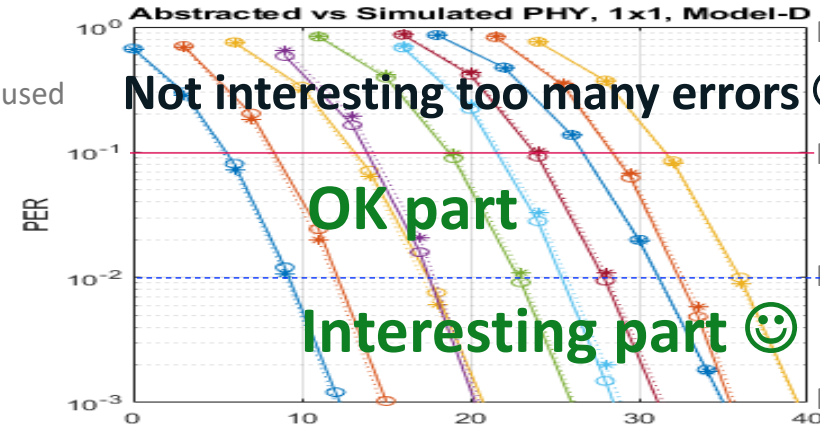
Annex: Packet Error Rate or POR = 1-PER ?

Usually PER is used

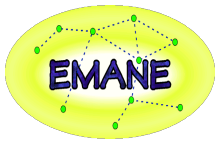
PER

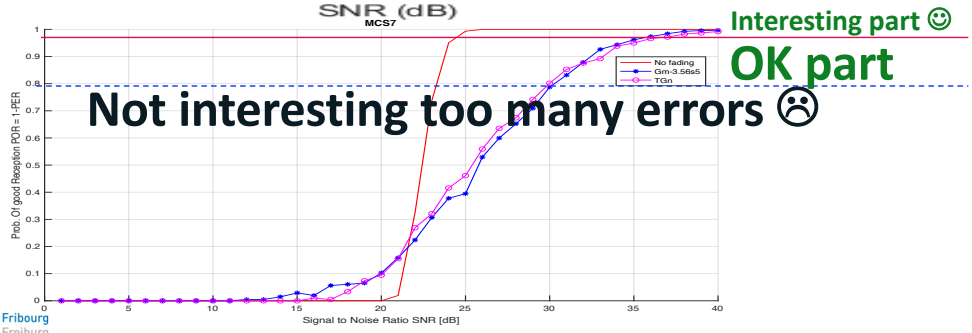
=

1-POR

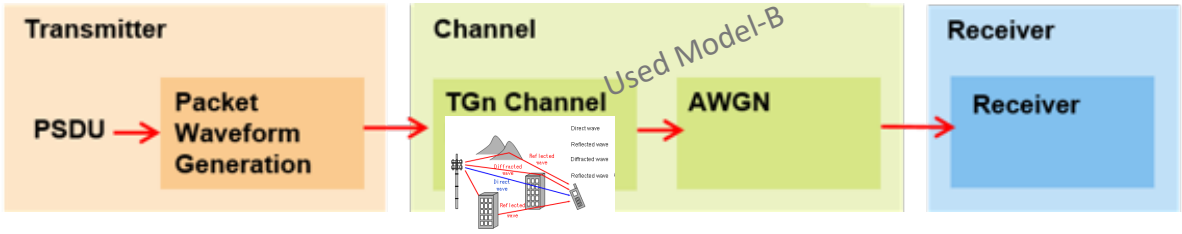


EMANE uses POR





Annex: Packet Error Rate or POR = 1-PER ?



https://ch.mathworks.com/help/wlan/examples/802-11n-packet-error-rate-simulation-for-2x2-tgn-channel.html

Propagation Channel Models
Channel models for 802.11™

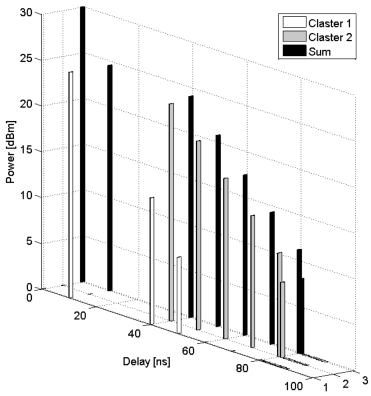
https://ch.mathworks.com/help/wlan/ref/wlan**tgn**channel-system-object.html

WLAN Toolbox™ provides functions that let you model SISO and MIMO transmit-receive li els.

Objects

`wlanTGnChannel`	Filter signal through

`DelayProfile` — Delay profile model
`'Model-B'` (default) | `'Model-A'` | `'Model-C'` | `'Model-D'` | `'Mod`



http://www.jpier.org/PIER/pier137/19.13011006.pdf
Fig 7

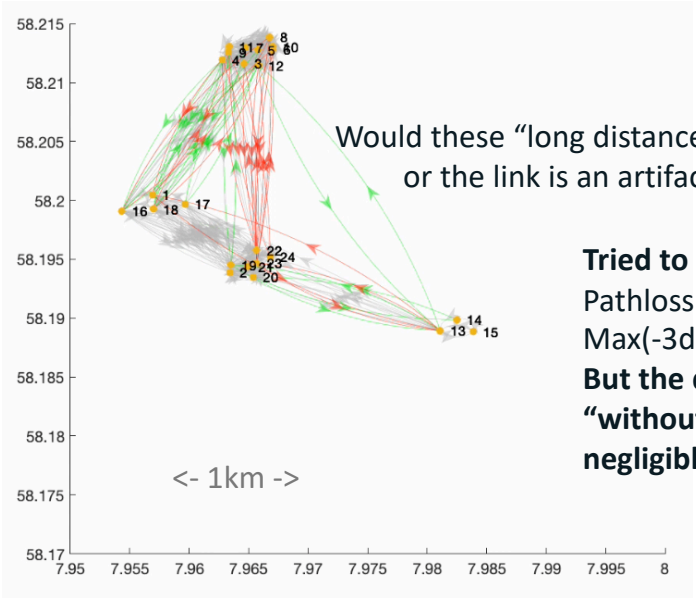
Annexe: from TD(22)019093
Route with/without "fading": an example

"new route"-links due to smaller path loss

"dropped route"-links due to larger path loss

… compared to no fading

"unchanged route"-links



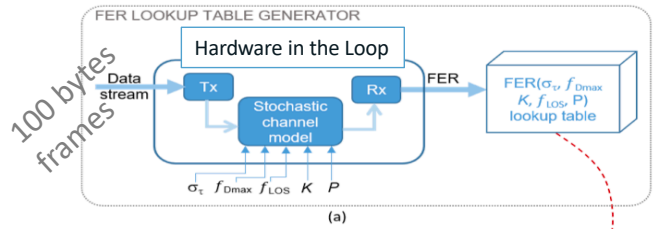
Would these "long distance" link really exists ?
or the link is an artifact of G(0,5dB) model

Tried to limit fading gain
Pathloss +
Max(-3db, any fading_dB)
But the difference with "without limit" seems negligible

Annex: 2 interesting references
TD(21)14026 => FER from open street maps ☺

Real-Time Vehicular Wireless System-Level Simulation **Reproduced without permission: sorry**

Anja Dakić, Markus Hofer, Benjamin Rainer, Stefan Zelenbaba, Laura Bernadó, Thomas Zemen



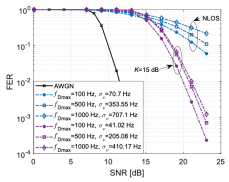
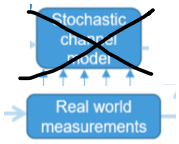
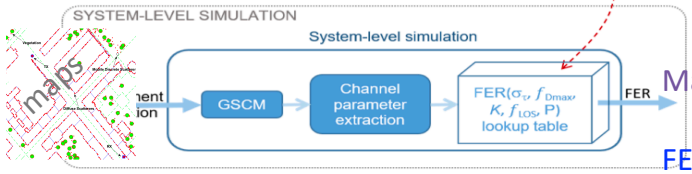


Fig. 11. Measurement results of FER vs. SNR using an exponential PDP with Doppler bandwidth $f_{Dmax} \in \{100, 500, 1000\}$ Hz, K-factors $K \in \{-\infty, 15\}$ dB and RMS delay spread $\sigma_\tau = 82$ ns, having $f_{LOS} = 0$ Hz.

FER table validated by meas.





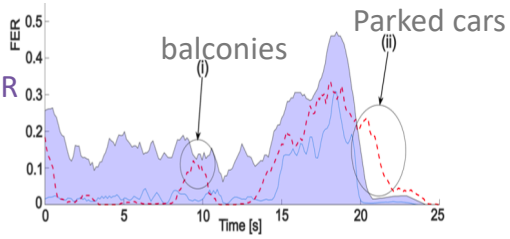
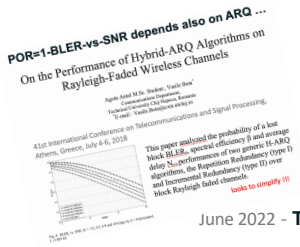


Fig. 16. FERs obtained by using the FER lookup table using our GSCM compared to the FERs obtained by emulating a measurement conducted for an inner city intersection scenario.

condensed channel parameter vector Ψ
[RMS delay spread σ_τ,
Doppler bandwidth f_{Dmax},
LOS Doppler shift f_{LOS},
K-factor K, and
received power P]



other moving cars have a huge impact