Master's thesis seminar

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Radio channel modelling in different outdoor environments for WLAN systems

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Agenda

- thesis objectives
- theoretical background
  - WLAN systems
  - radio wave propagation
- existing channel models
- channel modelling methods
- channel modelling of WLAN systems
  - case: BVS's Yellowjacket
- conclusions and future work

Thesis objectives

- use of WLAN outdoors outside urban city
  - WLAN characteristics
  - impact of ”new” operating environments
- the *process* of *determining* wideband radio channel models in different outdoor environments for WLAN systems
- expected results
  - means to conduct the actual channel modelling
- means of the study
  - literature research, empirical measurements

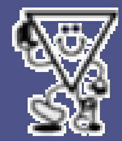
Theoretical background - WLAN systems

IEEE 802.11 and IEEE 802.11b

- only 2 bottom layers of OSI model:
  - medium access control (MAC) layer
  - physical layer (PHY)
- spread spectrum systems (FHSS, DSSS)
  - transfer rates: 1, 2, 5.5 or 11 Mbit/s
  - baseband symbol rates: 1 Ms/s of 1.375 Ms/s
- operates at 2.4 GHz ISM band
  - licence-free, max EIRP 20 dBm
- RF signal bandwidth 22 MHz

Theoretical background - propagation

- Maxwell's equations ➔ too complicated



- four basic phenomena
  - free space loss
  - reflectation and penetration
  - diffraction
  - scattering

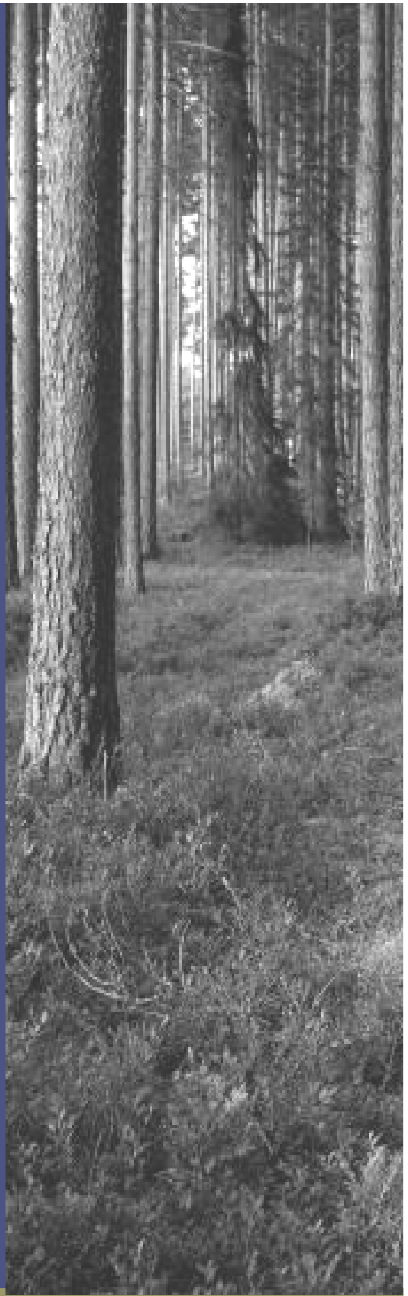
everything else is based on these

Existing channel models

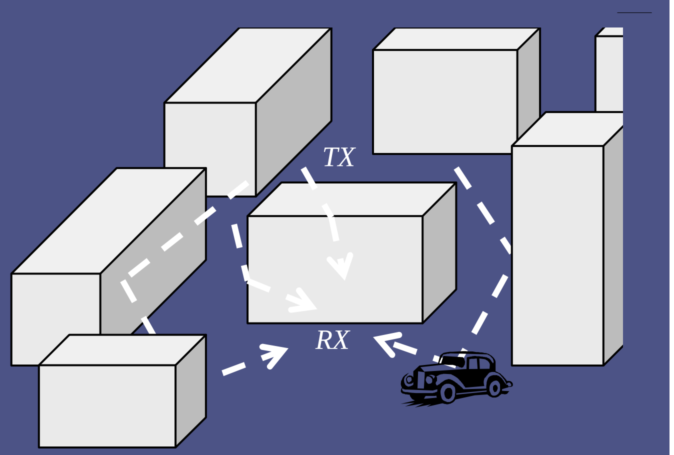
Distinction to large and small-scale

Large-scale models

- broadminded models for distance path loss and shadowing losses
  - Hata, Walfisch-Ikegami for mobile systems
  - ITU-R P.833, QinetiQ model for attenuation in vegetation

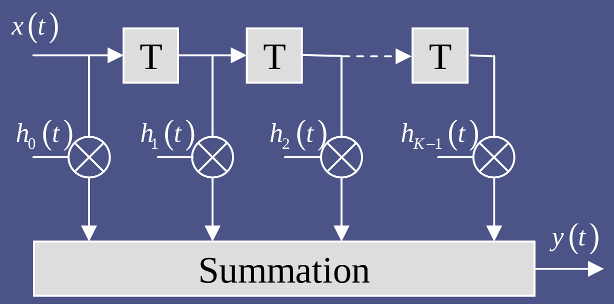


Existing channel models



Small-scale models

- detailed wideband models for *multipath propagation*
- based on systems functions of LTV-channel
  - time-variant impulse response etc. (WSSUS)
- empirical and deterministic models
- very environment specific
- tapped delay-line models
  - GSM and UTMS model



Existing channel models

Large-scale models:

- focused on urban city or indoor environments below 2 GHz
- impact of vegetation and terrain changes largerly neglected, need to use additional model

Small-scale models:

- lot's of measurements at 2 GHz for UMTS
- measurements at 2.4 GHz only indoors or urban environments

➔accurate suitable model not found

Channel modelling methods

Computer aided methods (deterministic)

- ray tracing
  - each ray and its propagation path is predicted
- methos based of Maxwell’s equations
  - Finite difference time-domain (FDTD)
  - Finite element method (FEM)

- need of measurements for result verification
- increase of details multiplies needed calculation capacity
- unablity to predict propagation in vegetation

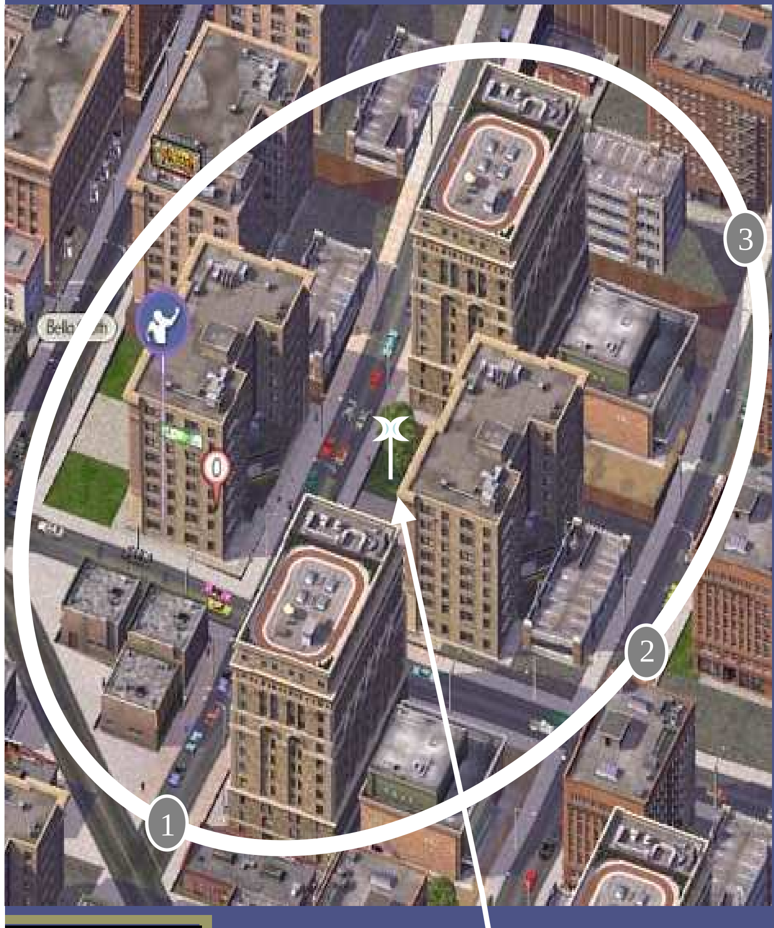
Channel modelling methods

Empirical channel modelling

- based on measurements
- no restrictions to environments
- need of statistical post-prosessing

- narrowband measurements
  - distance path loss, shadowing
- wideband multipath propagation measurement campaign

Channel modelling methods



Narrowband measurements

- RX moved along a circle, or a block
- several measurements per location

- averaging to local mean
  - filters multipath components with highest peaks and deepest notches

- Results
  - distance path loss
  - various shadowing environments

Channel modelling methods

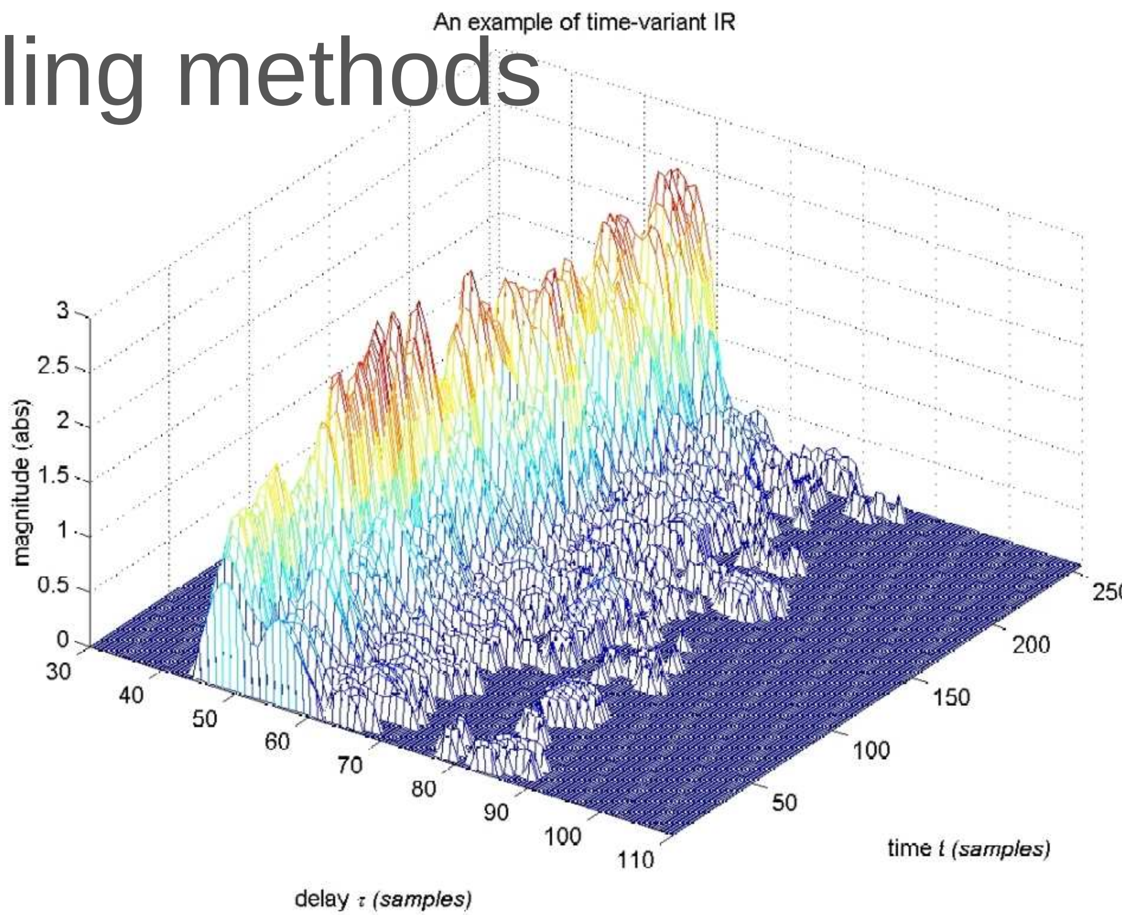
Multipath propagation measurement campaign

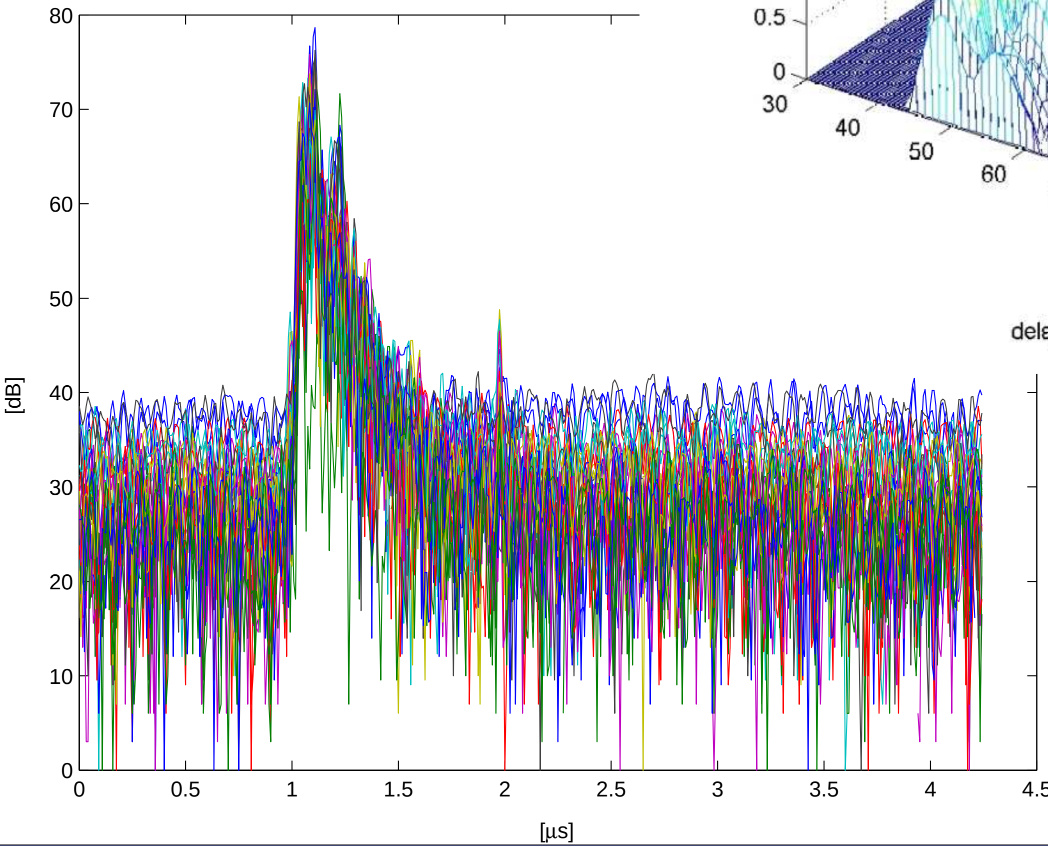
- impulse response measurement
  - sliding correlator / DSP techniques
  - use of highly advanced channel sounder equipment

- HUT channel sounder
  - chip sequences: 31-2047 chip
  - chip rates: 2.5 MHz – 60 MHz
  - measured delay: 516ns - 818µs
  - sample resolution: 16.7ns – 400ns

Channel modelling methods

examples of measured IR's





heavy statistical post-processing from raw data needed

Channel modelling of WLAN systems

Impact of outdoor environment

- fewer multipath components, larger delay spreads
- example: a reflection from a surface 1 km away
  - additional propagation of 2 km ⇔ 3.33 µs
  - attenuation due free space loss ~ 106 dB
  - RX level ~ -80 dBm; well within RX dynamic range

WLAN characteristics

- symbol rate: 1 Ms/s pf 1.375 Ms/s
- symbol duration: 1 µs of 727 ns
  - after each symbol duration, next symbol arrive

➔ RX in trouble after symbol duration without advanced countermeasures: major restrictiong to WLAN systems

➔unable to use WLAN signal in channel sounding

Case: BVS's Yellowjacket

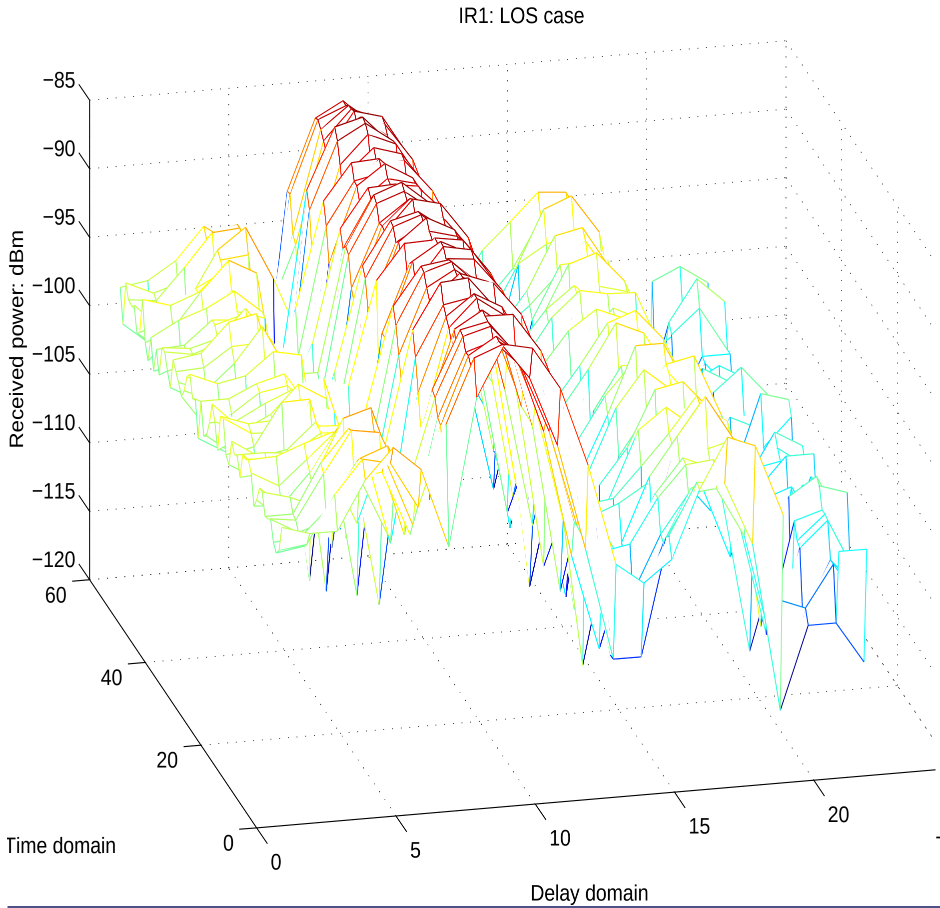
Hand-size measurement tool for optimising and analysing WLAN
- built on Compaq IPAQ PocketPC
- ability to measure:
  - all 14 WLAN channels
  - RSSI (dBm)
  - packer error rate (PER)
  - MAC address
  - SSID
  - multipath correlated power
  - also spectrum analyser function

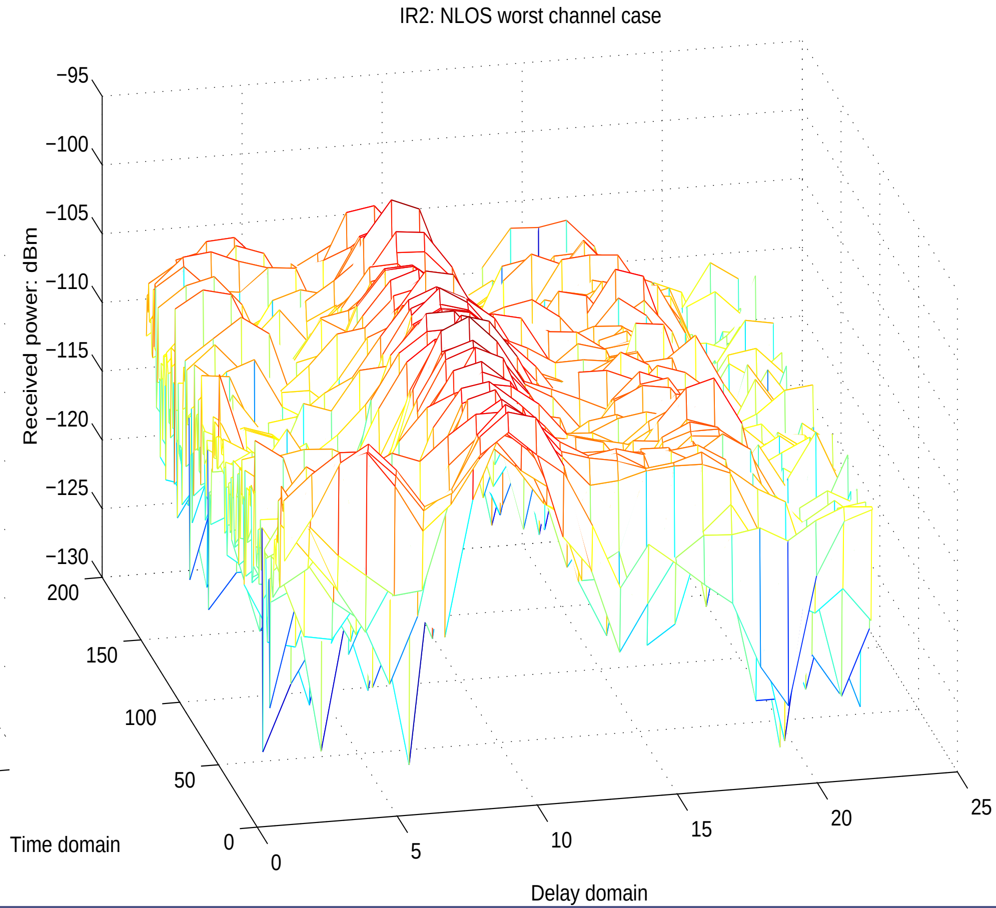
Case: BVS's Yellowjacket

test measurements to test the device:

- *case 1*: LOS, RX in the middle of the alley
- *case 2*: worst NLOS, RX under the concrete stairs
- *case 3*: NLOS, RX behind the corner

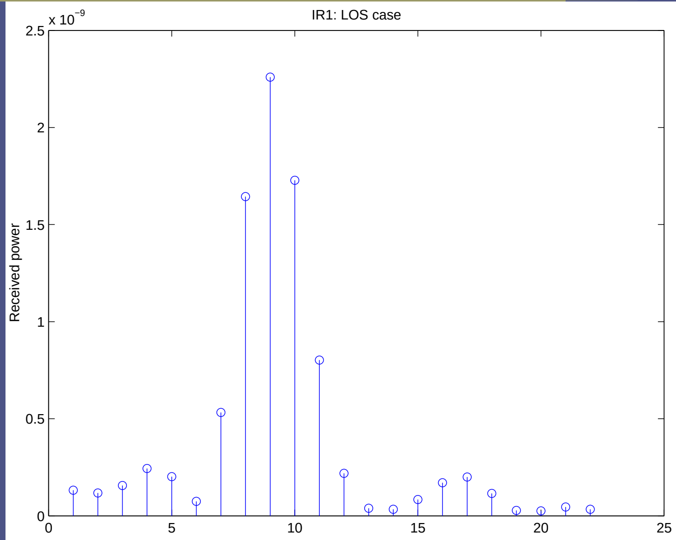
Case: BVS’s Yellowjacket

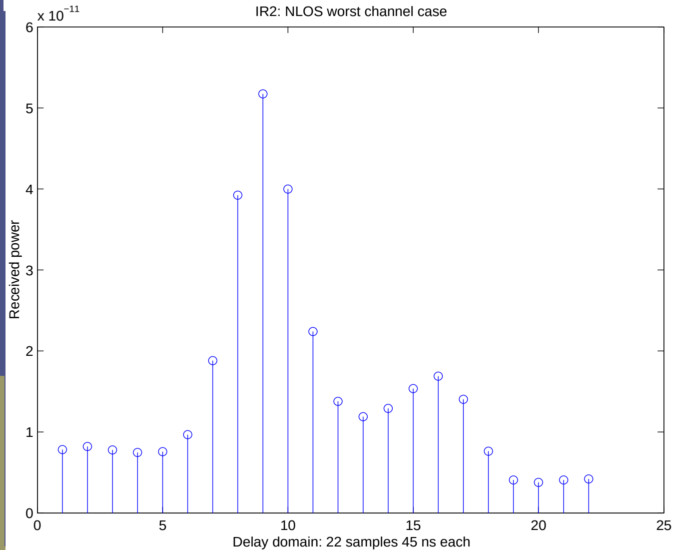




measurements results

Case: BVS's yellowjacket





Results seem the same

- peak at 9th sample
  - ➔ no information on first 8
  - ➔ more reduction on DS window
  - ➔ no absolute delays
  - ➔ RX locks to first strong component
- in fact, two consecutive IRs of too narrow bandpass filter
  - ➔ taps correlated

Yellowjacket able to construct 2-tap model, unrealiable delay

Conclusions and future work

Lack of suitable existing channel model...

- Large-scale models lack environments outside urban city and neglects the effect of vegetation
- Small-scale propagation models lack models at 2.4 GHz outside urban city environment

...and unsuitability of computer-aided methods...

- ray tracing, FDTD and FEM unable to predict scattering caused by vegetation
- increase in details multiplies the need for calculation capacity

Conclusions and future work

...leads to need of heavy measurement campaign.

- channel sounder equipment needed
  - requirements for delay spread window and fast acquisition
- measurement both in summer and winter
  - effect of leaves to he measurements
- heavy post-processing

Other interesting research topics:

- WLAN behaviour in channel with large delay spread
  - PER vs. percentage of energy received after 1 µs (727ns)
- simulations of different WLAN receiver types

Questions...?

Thank you!