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Bluetooth Low Energy (BLE) for Covid-19 Contact Tracing Using Smartphones in Four Different Scenarios

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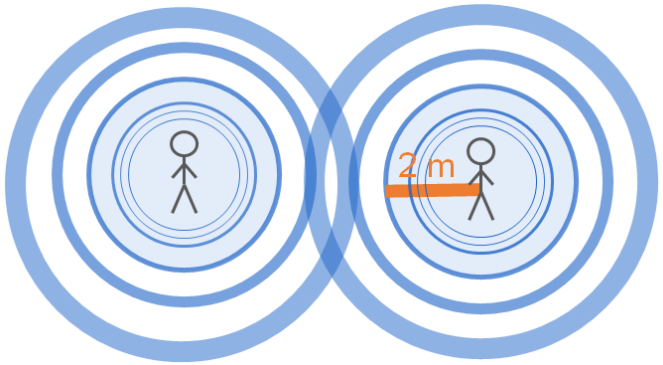
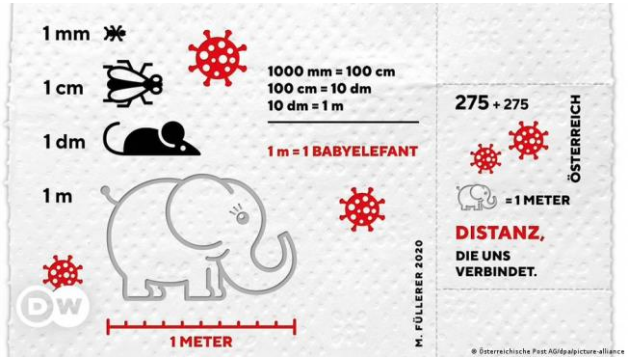
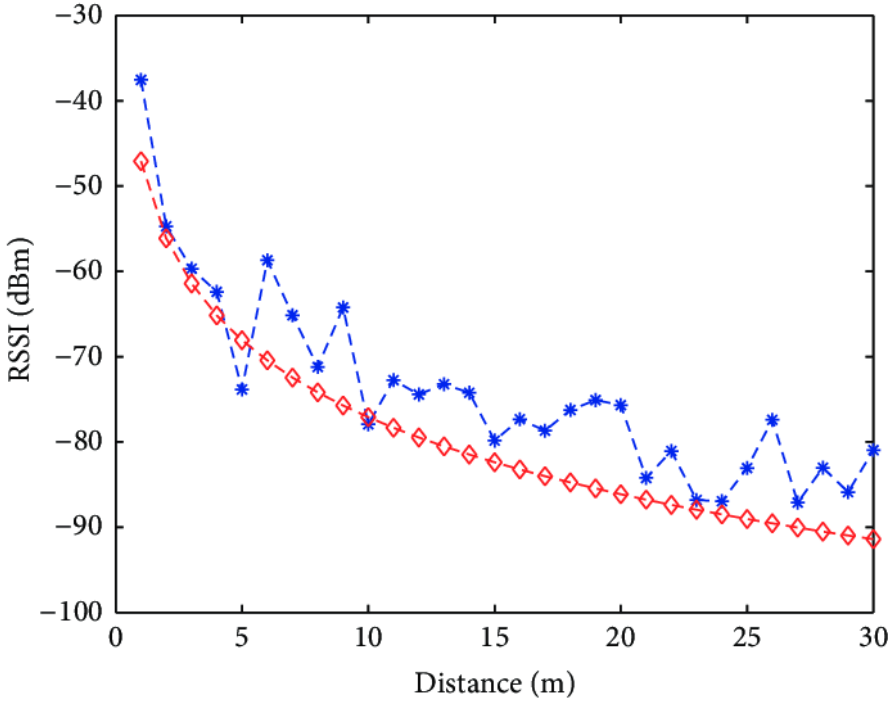
Social Distancing – Exposure Notification

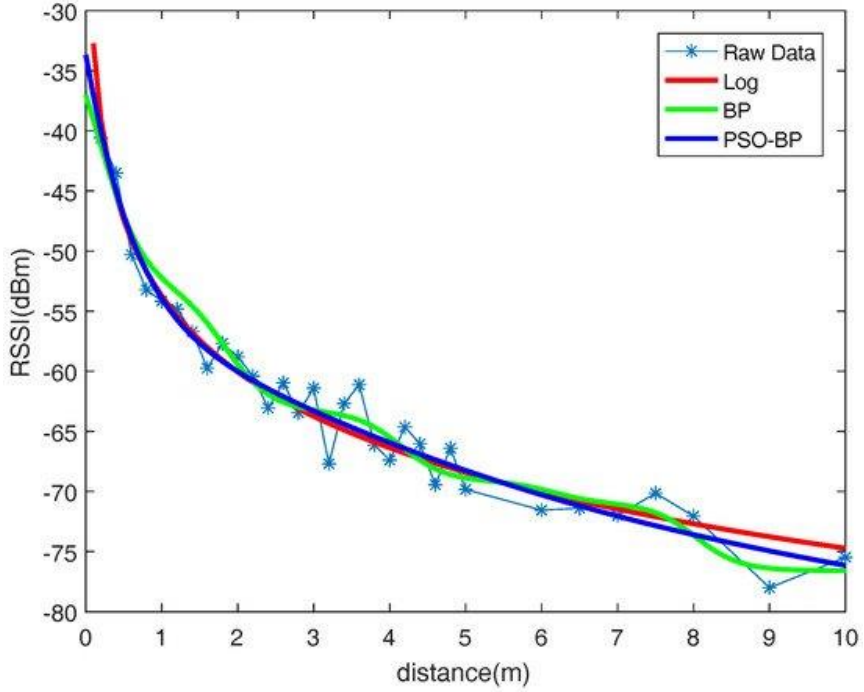




- Bluetooth LE (BLE) is suggested to measure social distance in contact tracing Apps
- Phones send out BLE-signals, picked up by other phones
- Different states such as standby, **scanning**, **advertising**, initiating and connection
- The higher the signal strength, the smaller the BT-distance
- Signal attenuation, multipath and RSSI fluctuations have significant effect

Ideal RSSI Path Loss Patterns





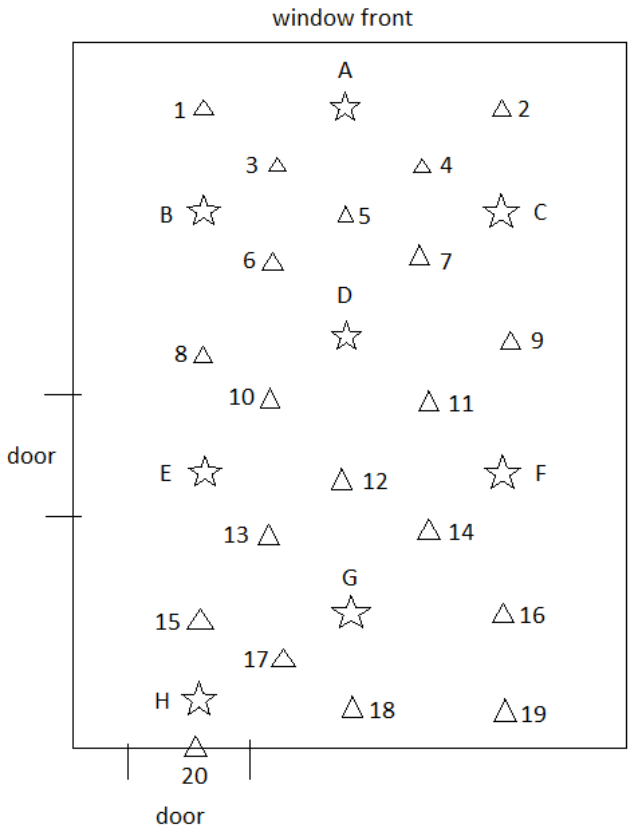
Free Space Path Loss (FSPL)

$$FSPL\ [\mathrm{dB}] = 10 \cdot log_{10}\left(\frac{4 \cdot \pi \cdot d \cdot f}{c}\right)^2$$

One-slope model

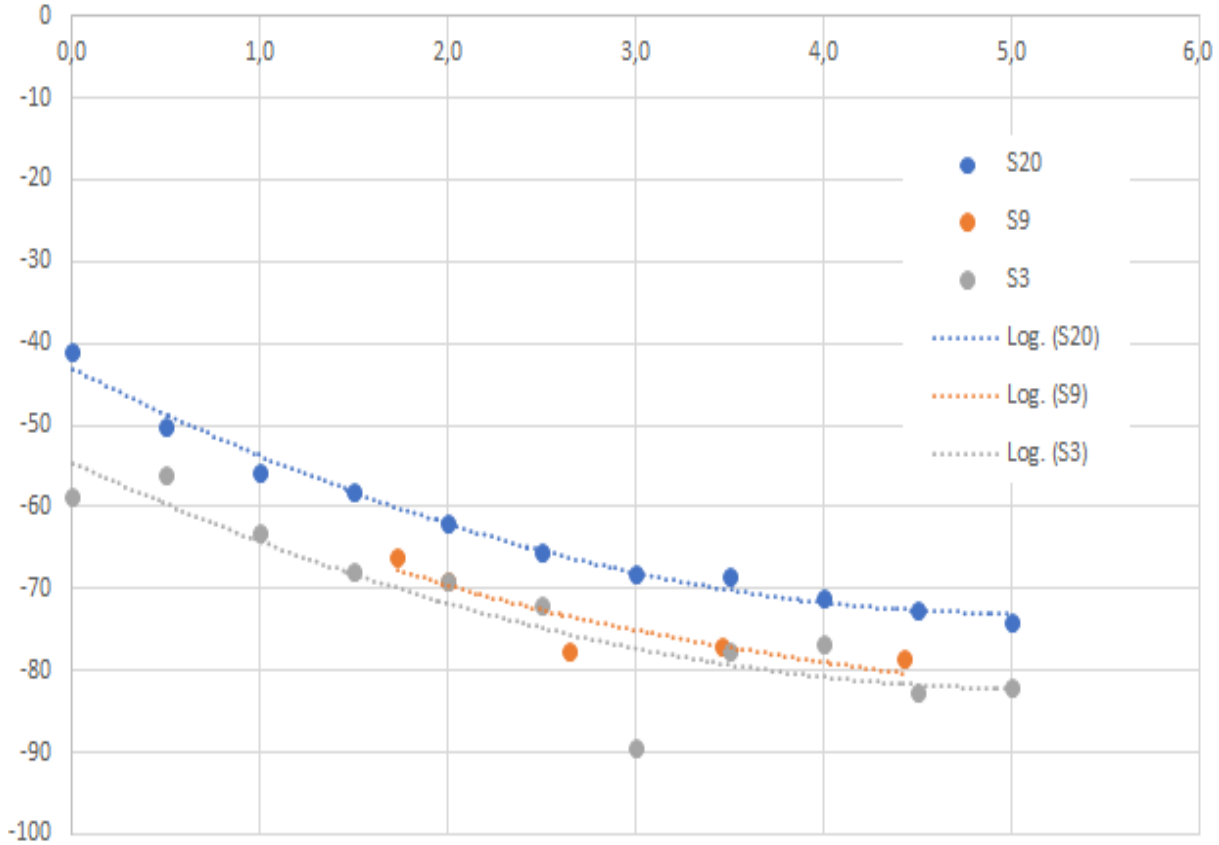
$$P(d) = P_0 + 10 \cdot \gamma * log_{10}(d)$$

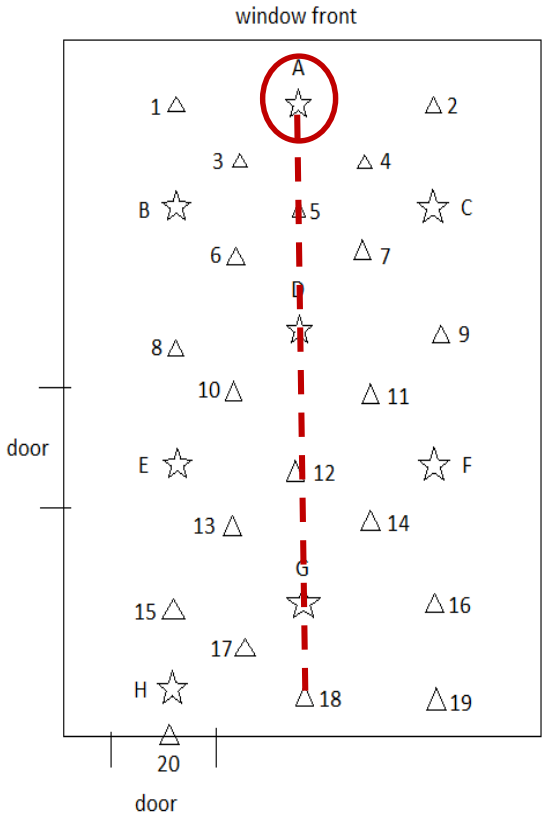
Indoor Test Area



Position	Phone
A	Samsung Tablet A6
B	Sony Xperia Z3
C	LG Nexus
D	Samsung Galaxy S8
E	Samsung Edge S6
F	Samsung Galaxy S7
G	Sony Xperia Z5
H	Google Pixel 3

RSSI to Distance Relationship: Device Comparision (1)





3 smartphones:

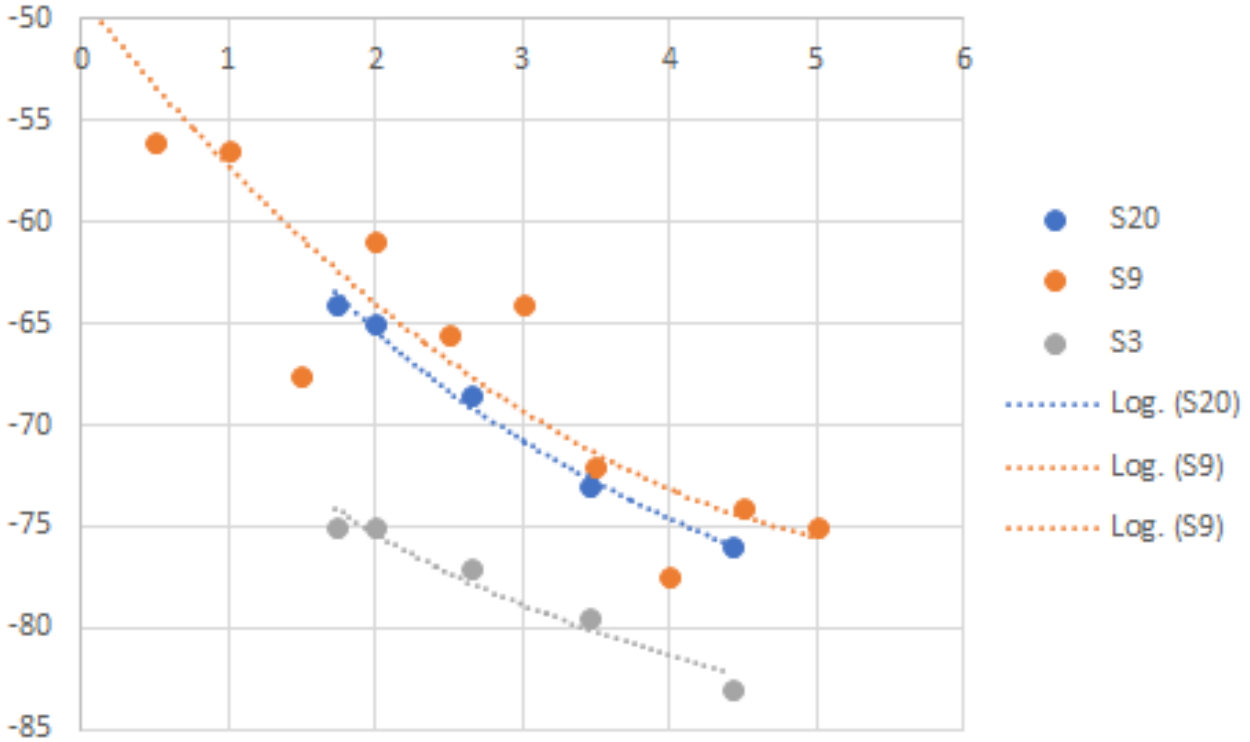
Samsung S20, S9 and S3

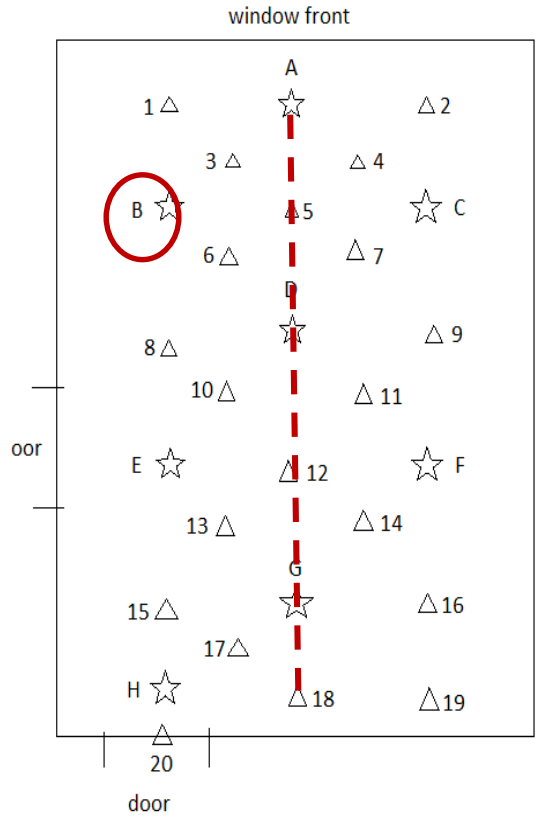
Baseline point A –18

Recordings of

Samsung Tablet A6 at location A

RSSI to Distance Relationship: Device Comparision (2)



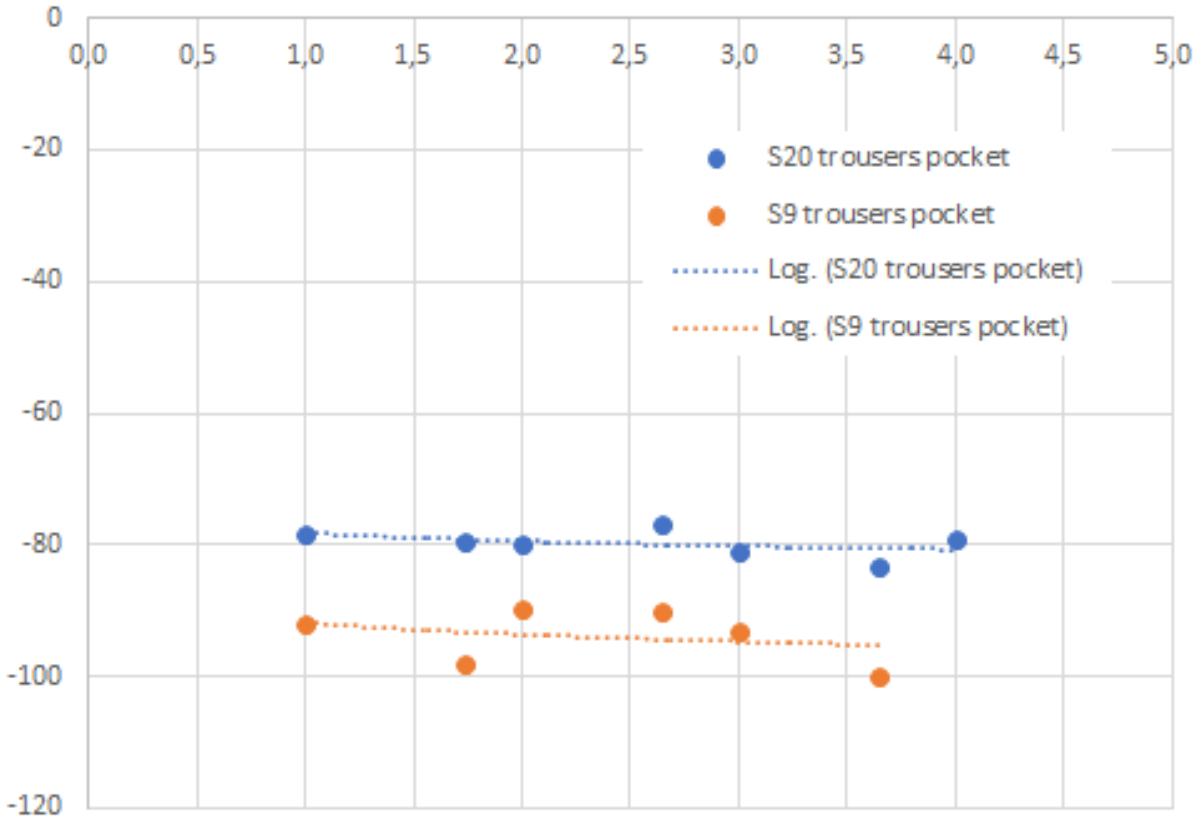


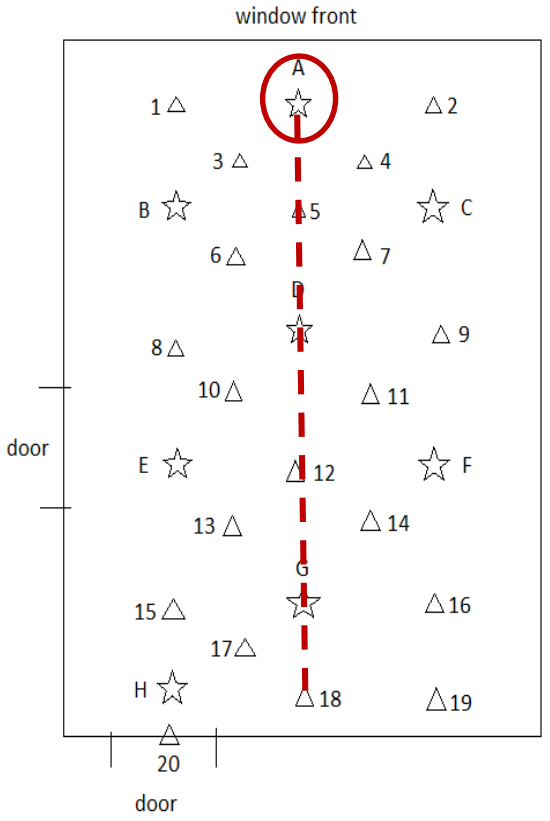
3 smartphones:
Samsung S20, S9 and S3

Baseline point A –18

Recordings of
Sony Xperia Z3
at location B

RSSI to Distance Relationship: 2 Devices in Trousers Pocket



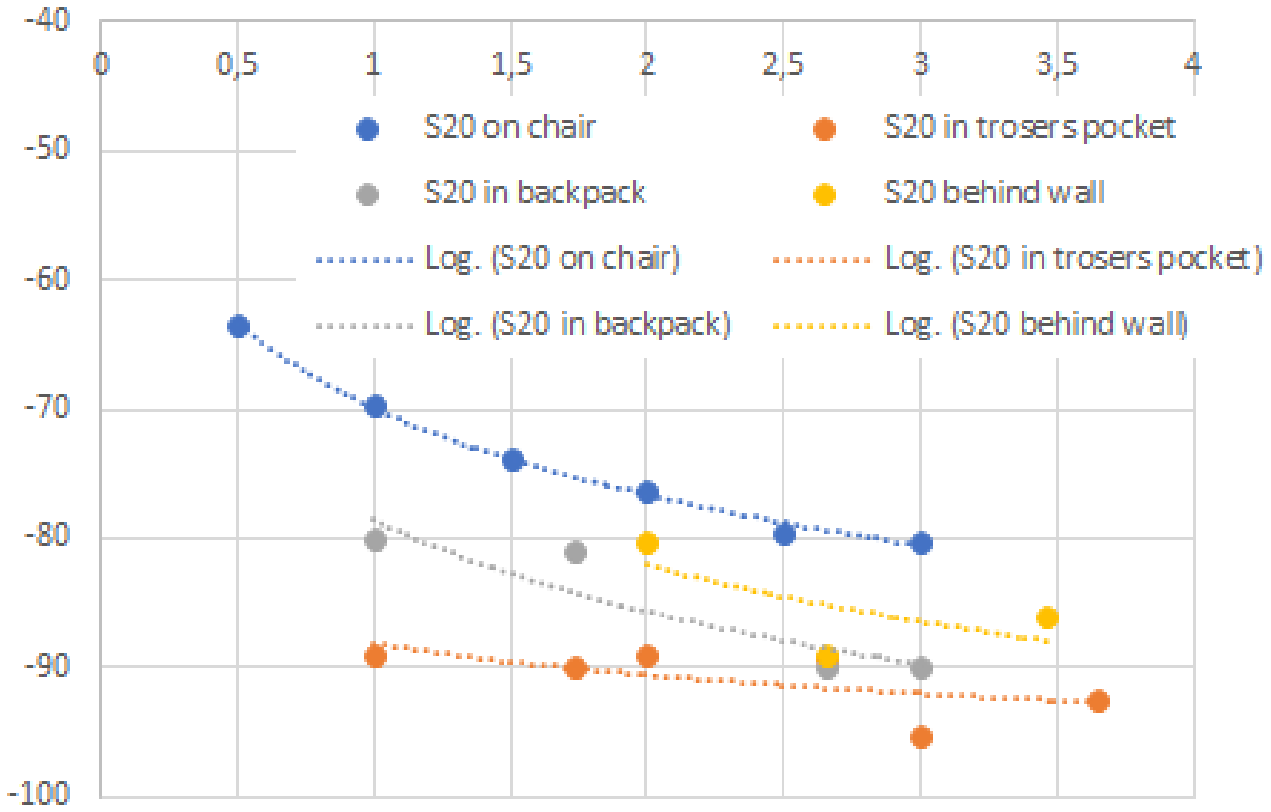


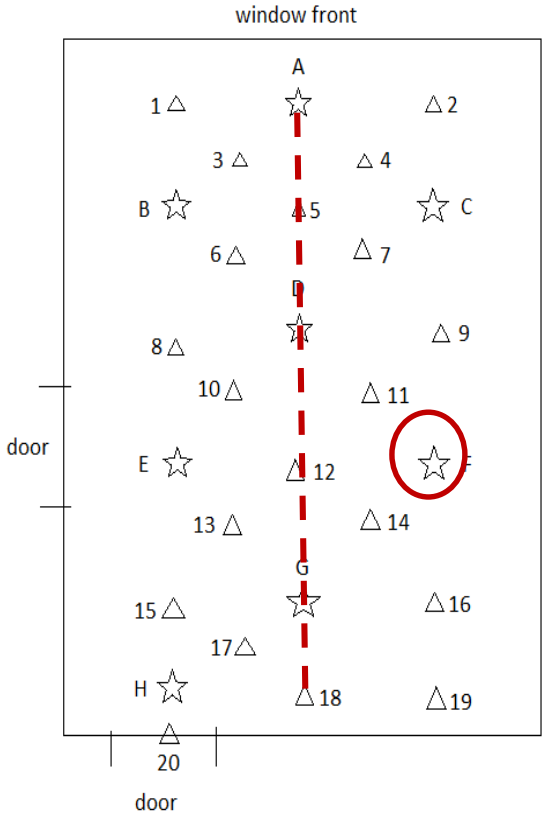
2 smartphones:
Samsung S20 and S9

Baseline point A –18

Recordings of
Samsung Tablet A6 at location A

RSSI to Distance Relationship: Device on Chair, Trousers Pocket, Backpack, Wall





1 smartphone:

Samsung S20

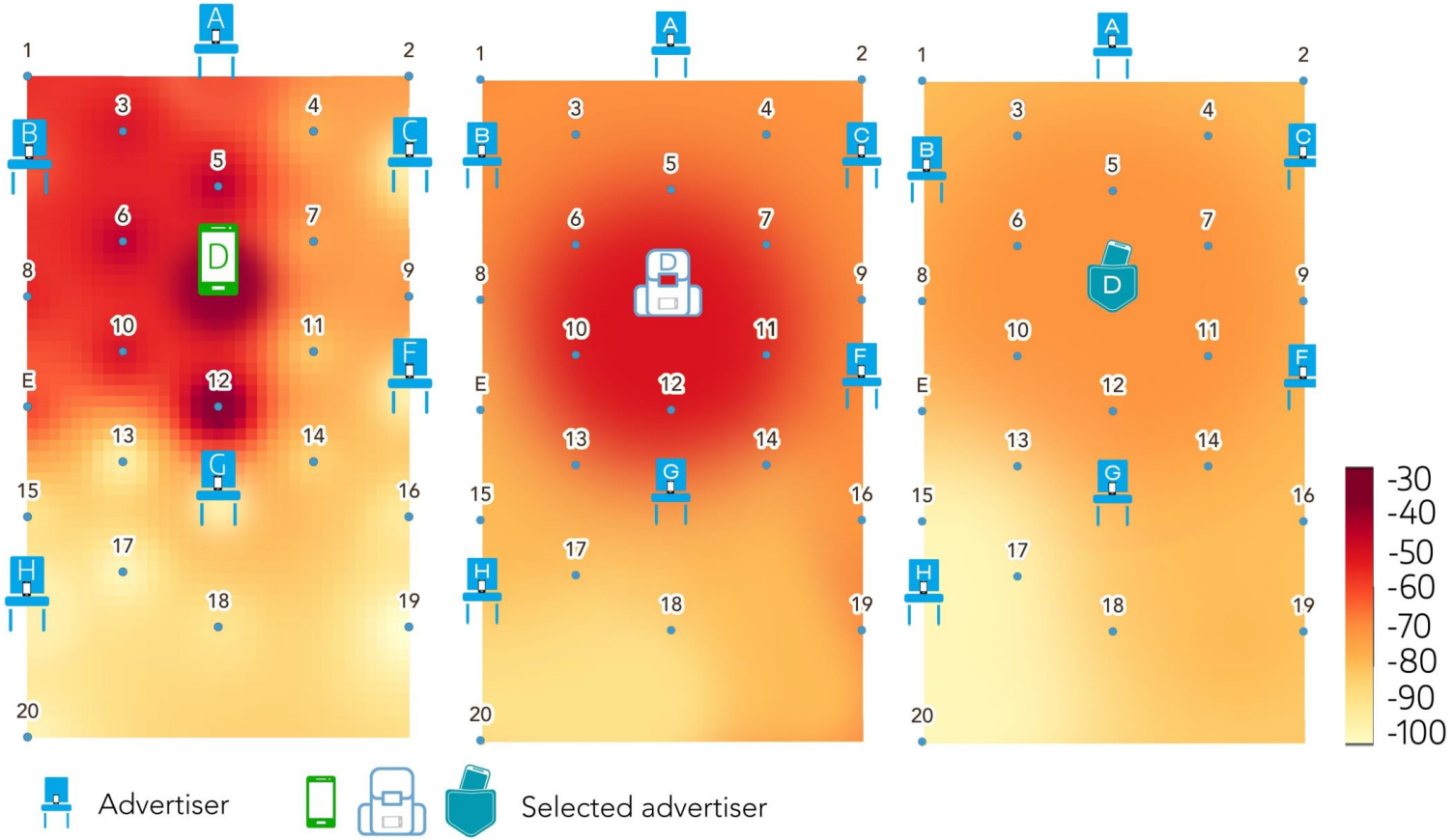
Baseline point A –18

Recordings of

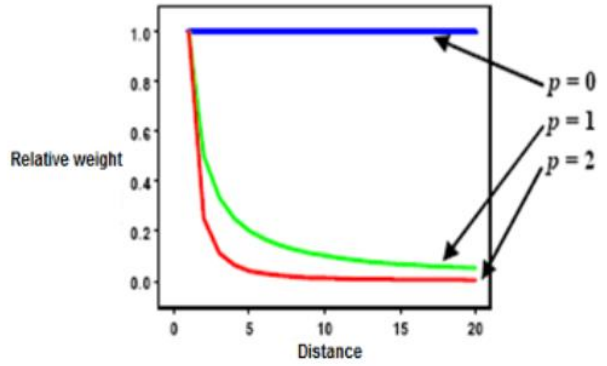
Samsung S7 at location F along baseline and

behind wall

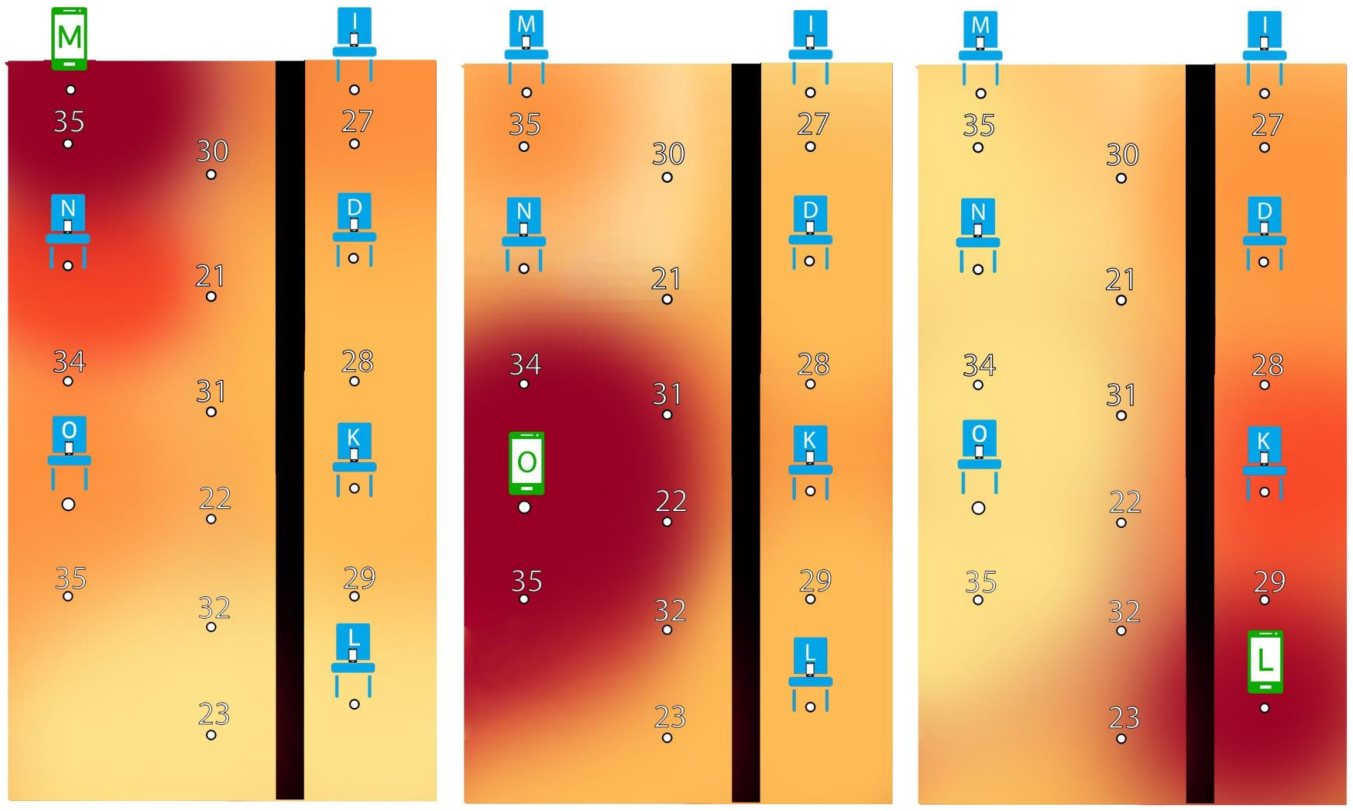
Derivation of RSSI Distributions: Radio Maps with Different Location of Advertisers

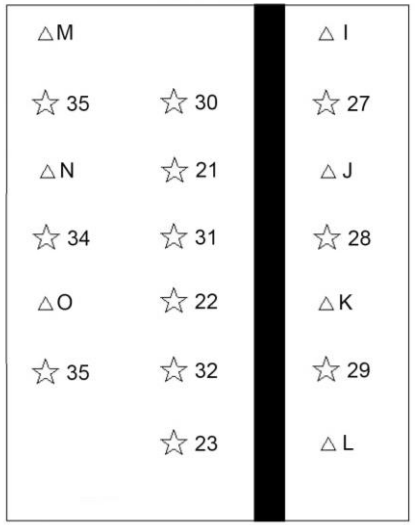


- Aim is spatial modelling of the RSSI distributions
- Use of inverse distance weighted (IDW) interpolation method
- Weighted average of values from the known points depending on their distance is assigned at the unknown point
- Weights are proportional to the inversed distance raised to the power value *p*



Derivation of RSSI Distributions: Radio Maps with Devices Behind Wall





Location of Bluetooth advertisers:

- M Samsung Galaxy S7
- N Samsung Galaxy S8
- O LG Nexus
- I Sony Xperia Z5
- J Samsung Galaxy S6
- K Sony Xperia Z3
- L Sony Xperia Z5

Identifying and Detecting Contact Risks – Sensitivity and Specificity

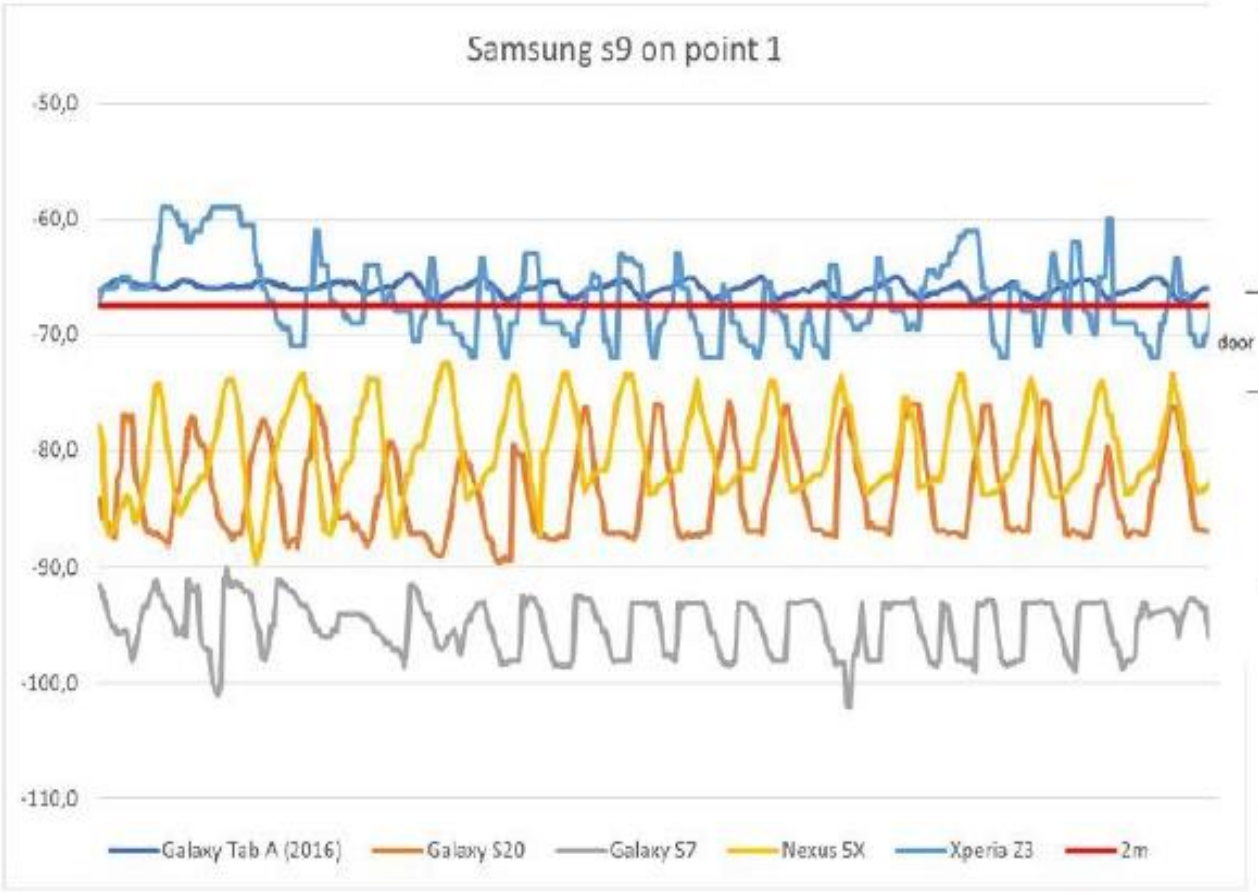
- **Sensitivity** (true positive rate) measures the proportion of actual positives that are correctly identified as such

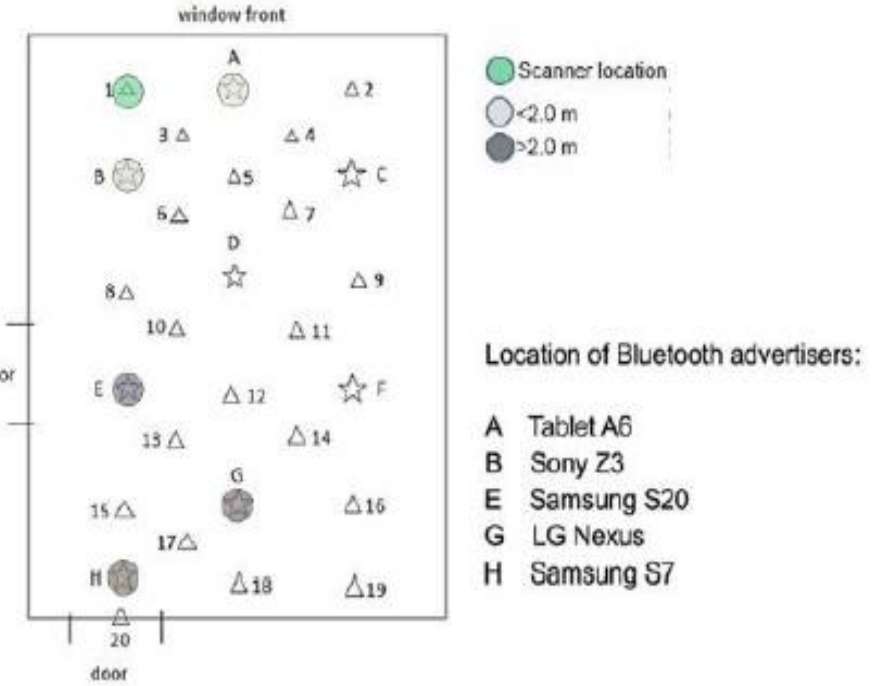
$$\begin{aligned}\text{sensitivity} &= \frac{\text{number of true positives}}{\text{number of true positives} + \text{number of false negatives}} \\ &= \frac{\text{number of true positives}}{\text{total number of sick individuals in population}} \\ &= \text{probability of a positive test given that the patient has the disease}\end{aligned}$$

- **Specificity** (true negative rate) measures the proportion of actual negatives that are correctly identified as such

$$\begin{aligned}\text{specificity} &= \frac{\text{number of true negatives}}{\text{number of true negatives} + \text{number of false positives}} \\ &= \frac{\text{number of true negatives}}{\text{total number of well individuals in population}} \\ &= \text{probability of a negative test given that the patient is well}\end{aligned}$$

Sensitivity and Specificity: Smartphones on Chair



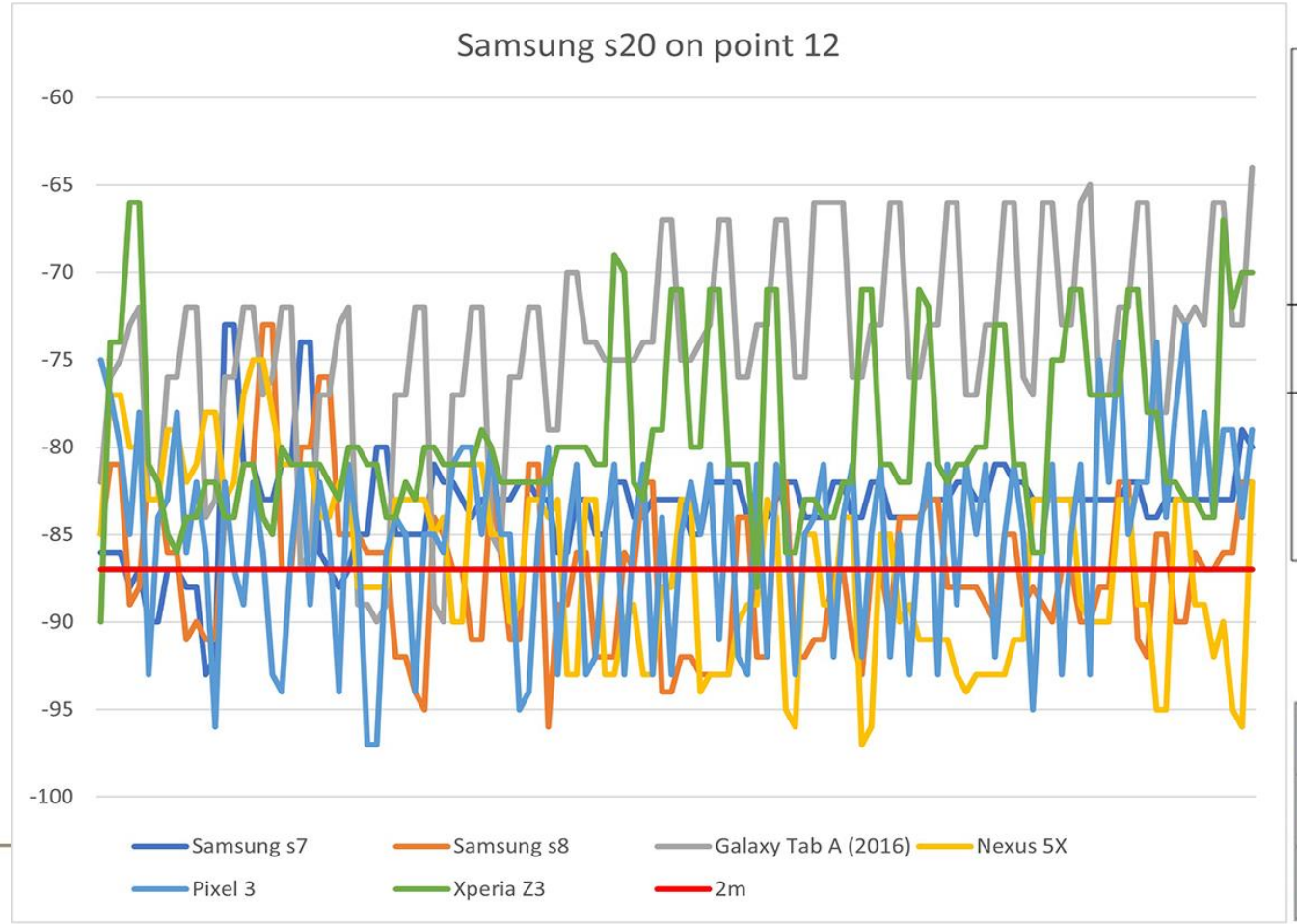


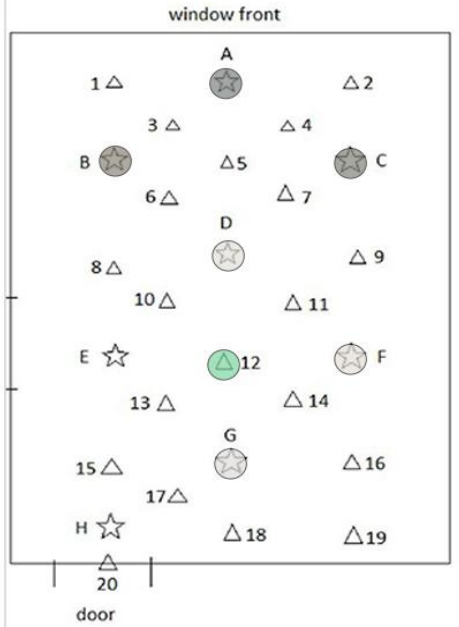
Location of Bluetooth advertisers:

- A Tablet A6
- B Sony Z3
- E Samsung S20
- G LG Nexus
- H Samsung S7

Statistic	Value
Sensitivity	74.67%
Specificity	100.00%

Sensitivity and Specificity: Smartphones in Trousers Pocket





Scanner location
<2.0 m
>2.0 m

Location of Bluetooth advertisers:

A Tablet A6
B Samsung S7
C Nexus X5
D Pixel 3
F Xperia Z3
G Samsung S8

Statistic	Value
Sensitivity	40.54%
Specificity	46.00%

Trimble.

Conclusions

- Bluetooth measurements are noisy, device dependent and sensitive to location of the mobile devices
- Relationship between the RSSI values and models based on an approximation follows not always a logarithmic path loss model
- Phone placement in the trousers pocket has the most impact on the obtained RSSIs
- Radio maps derived from RSSI values in the whole test area are usually coherent to the distance from each selected advertiser
- From the spatial modelling of the RSSI distributions correction parameters shall be derived in future work
- The parameters sensitivity and specificity indicate that many false predictions can occur, especially when phones are in trousers pocket

Acknowlegments

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More information about Exposure Notification @
https://www.youtube.com/watch?v=x6y8W80qH8M&t=10s