STUDY OF ATTENUATION DUE TO WET ANTENNA IN MICROWAVE RADIO COMMUNICATION

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1 Background

The principle of wet antenna detection leans on the idea that the measured attenuation in microwave radio communication is caused as a result of the layer of water directly on the antenna itself. Thus, when the interference is measured simultaneously across a large number of microwave links (MWLs) in the same area, it will be independent of path length.

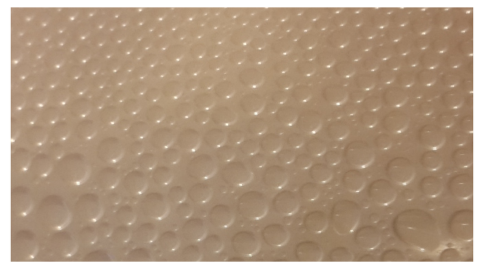

Figure 1: Illustration of s water layer accumulated directly on a surface

Of the various wireless communication systems, we focus on the microwave point-to-point links which are used for backhaul communication in cellular networks (Figure 2), as they seem to have the most suitable properties for our purposes:

- Fixed, Line-Of-Sight
- Built close to the ground
- Operate at frequencies of tens GHz
- Operate 24 hours a day with no supervision and additional cost
- Commercial microwave communication networks are widespread over the world

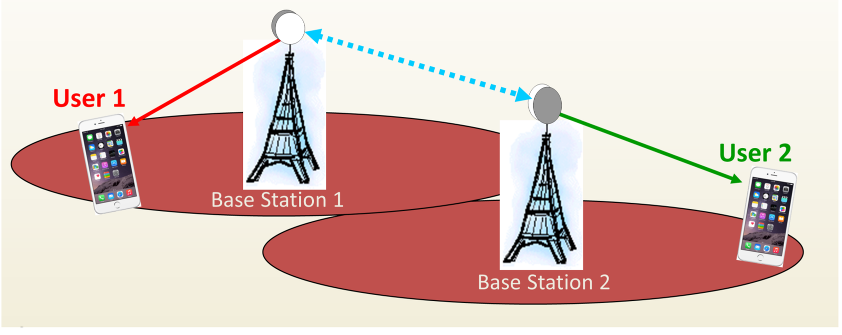

Figure 2: Microwave point-to-point static links

2 Method

2.1 The Model

Backhaul links in cellular networks operate at frequencies of tens of GHz, and are attenuated by atmospheric phenomena and by wetting of the antennas. Let us define a set of $n = 1, \cdots, N$ samples for each MWL, while L is the propagation path length. The attenuation γ [dB] due each atmospheric phenomenon, is well studied and can be evaluated using known relations (Recommendations ITU-R P.676-6, 2005; ITU- R P. 838-2, 2004; ITU-R P. 840, 2009) :

(1) $$\gamma[n,L] = \gamma_p[n,L] + \gamma_w[n] + \gamma_v[n,L] + \gamma_0[L] + r[n] + q[n] \qquad dB$$

γ_p: - Specific attenuation due to rainfall; γ_v: Attenuation due to other-than-rain (mainly due to water vapor,); γ_w: Wet antenna (dew) attenuation; γ_0: Free space loss; q: Quantization error of the microwave system; r- White noise.

Let us define a binary hypothesis test that seeks to detect wet antenna using measurements from $i = 1, \cdots, M$ MWLs

(2) $$\mathcal{H}_0 : L_i \cdot \gamma_v[n] + \gamma_{0i}[L] + r_i[n] + q_i[n]$$

$$\mathcal{H}_1 : \gamma_w[n] + L_i \cdot \gamma_v[n] + \gamma_{0i}[L] + r_i[n] + q_i[n]$$

Where: $\mathcal{H}_0$ is the null hypothesis (and is ascribed to the attenuation fluctuations induced by variations in the atmospheric humidity); $\mathcal{H}_1$ is the wet antenna attenuation hypothesis.

2.2 Detection and Estimation using GLRT

No prior information regarding the probabilities of the various hypotheses exists in this detection problem, and one can see that the probability density function (PDF) for each assumed hypothesis is not completely known. The uncertainty is expressed by including unknown non random parameters in the PDF. In cases such as this the GLRT is commonly used to provide a solution. The ln version of the GLRT is thus:

(3) $$L_G(\underline{X}) = \ln\left(\frac{P(\underline{X};\hat{\underline{\theta}}_1,\mathcal{H}_1)}{P(\underline{X};\hat{\underline{\theta}}_0,\mathcal{H}_0)}\right) \underset{\mathcal{H}_0}{\overset{\mathcal{H}_1}{\gtrless}} \eta$$

$P(\underline{X};\hat{\underline{\theta}}_1,\mathcal{H}_1)$ is the PDF of the received signal under $\mathcal{H}_1$, with the unknown parameters $\underline{\theta}_1$ while $\underline{X}$ is the received signal vector (comprised of the measurements received from all MWLs). $P(\underline{X};\hat{\underline{\theta}}_0,\mathcal{H}_0)$ is the received signal PDF under $\mathcal{H}_0$ with the unknown parameters $\underline{\theta}_0$. $\hat{\underline{\theta}}_1$ is the MLE of $\underline{\theta}$ assuming $\mathcal{H}_1$ is true, and $\hat{\underline{\theta}}_0$ is the MLE of $\underline{\theta}$ assuming $\mathcal{H}_0$ is true. The procedure for estimating MLE under each hypothesis described in detail in Harel et al (2015).

3 Results

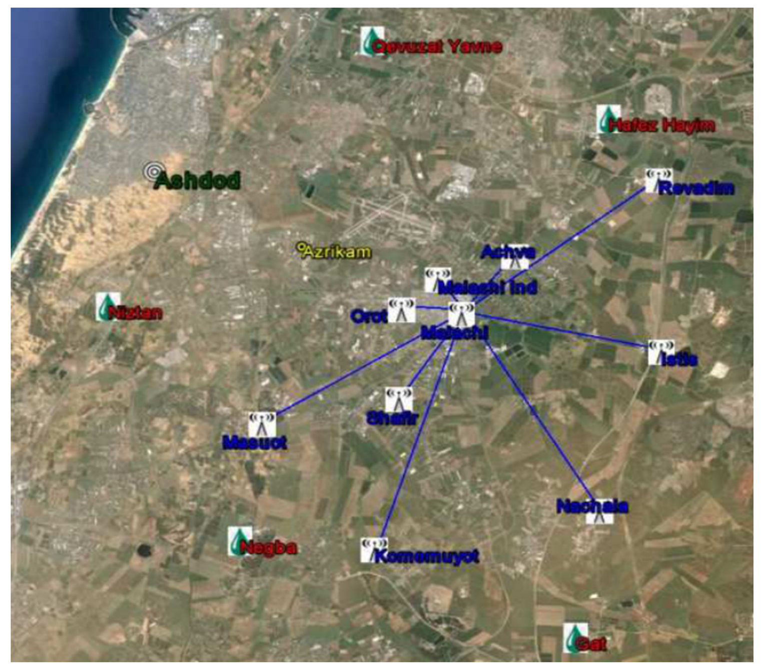

Figure 3: The test region

Figure 3 presents the region where the test took place, in the southern coastal plain of Israel. An 18 commercial MWL system was deployed in the area operating in the frequency range between 18 and 24 GHz, and providing RSL measurements for each link at one minute intervals. Five Relative Humidity (RH) gauges are also located in the area (marked in red) as well as a Leaf Wetness Sensor (LWS) that detects accumulation of liquid water, i.e. dew and indicated whether or not the phenomenon occurred on each night of the test (LWS location is marked in yellow). The LWS and the humidity gauges were used as our ground truth against which the performance of the proposed method for detecting cases of antenna wettings was compared. A night was considered dewy when all of the humidity gauges measured RH greater than 90%, and the LWS simultaneously detected the phenomenon.

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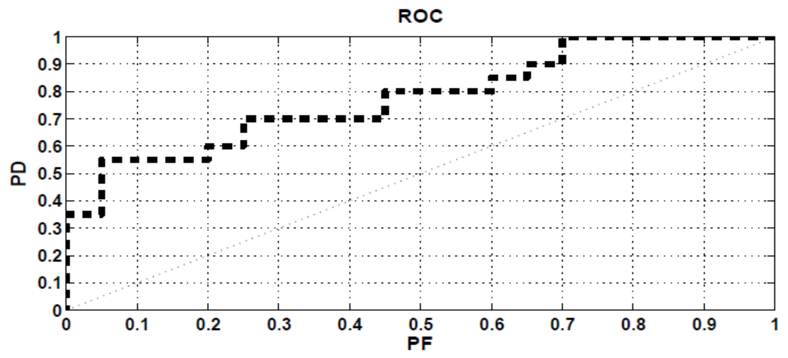

Figure 4: Receiver Operating Characteristic Curve

We selected 40 nights between the months of February and July 2010. Of them, the proprietary sensors (humidity gauges and LWS) identified 20 as dewy, and 20 as not. We then applied the algorithm on those same 40 nights. The observation interval *N* (i.e. the duration of the event) was chosen to be 14 hours (*N* = 840 samples) a sufficient period to accommodate the variations in the atmospheric phenomena observed (dew, water vapor). The figure presents the Receiver Operating Characteristic (ROC) curve describing the probability of detection – P_D against the probability of false alarm - P_F using the GLRT.

Date	$\hat{\gamma}_w$ dB	Date	$\hat{\gamma}_w$ dB
17.7.10 - 18.7.10	0	9.3.10 - 10.3.10	−0.06
31.5.10 - 1.6.10	−0.74	12.3.10 - 13.3.10	−0.26
28.5.10 - 29.5.10	−0.15	18.3.10 - 19.3.10	0
3.6.10 - 4.6.10	−0.34	23.3.10 - 24.3.10	−0.28
6.4.10 - 7.4.10	−0.52	26.3.10 - 27.3.10	−0.67
5.3.10 - 6.3.10	−0.32	27.3.10 - 28.3.10	−0.07
10.5.10 - 11.5.10	0	4.7.10 - 5.7.10	−0.05
11.5.10 - 12.5.10	−0.05	12.7.10 - 13.7.10	−0.06
13.5.10 - 14.5.10	−0.1	13.7.10 - 14.7.10	0
4.4.10 - 5.4.10	−0.26	19.2.10 - 20.2.10	−0.37

Figure 5: Estimates of attenuation due to wet antenna

Table 1 shows the results of the moist antenna induced attenuation estimations during the 20 events where dew was detected to have occurred.

5 Summary

- The results indicate the potential of existing commercial MWLs for detecting dew, and estimating the attenuation induced by moistening of the antennas.
- Figure4 shows a moderate ability to detect between the two hypotheses H_0 and H_1. The reason is stemming from both environmental and technical factors affecting the system's capabilities [Harel et al., 2015]. For example, the quantization error built into the system detracts from its performance in detecting the phenomenon and estimating its attenuation. Notably, the atmospheric humidity and moist antenna excess attenuation are of the same order of magnitude as that of the quantization step, which leads to suboptimal performances. Thus, the goal was to derive an order of magnitude of the attenuation induced by the liquid water film.
- Most of the International Telecommunication Union (ITU) recommendations regarding hydrometeors, deal with the effects of rain fog and humidity. Based on the results reached here, moist antenna induced attenuation is on a similar order of magnitude as the interference caused by fog and humidity. The proposed method, then, can shed light on this topic.
- Estimating the induced attenuation caused by the phenomenon can potentially provide a basis for estimating the amount of dew collecting on the antennas, and further research in this direction is needed.
- Furthermore, estimating the amount of wet antenna induced attenuation is interesting in order to allow adjusting for its effect when using commercial microwave systems as ESNs for measurement of other atmospheric parameters, such as fog that occurs, like dew does, during periods of high RH.

Reference: Harel, O., David, N., Alpert, P., & Messer, H. (2015). The Potential of Microwave Communication Networks to Detect Dew—Experimental Study. Selected Topics in Applied Earth Observations and Remote Sensing, IEEE Journal of, 8(9), 4396-4404.