A study on the effect of temperature on cellular signal strength quality

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***Abstract*— As the world is getting more connected through cell phones, Cellular Signal Strength metrics demand more attention as parameters linked to everyday life. This paper focuses on the effects of temperature on cellular signal strength quality. In telecommunications, Received Signal Strength Indicator (RSSI) is a measure of the power present in a received radio signal. This work looks into the variation of RSSI values over temperature and its effects on cellular communication networks. The study on the effect of temperature on RSSI is performed by measuring the temperature and signal strength over a region simultaneously. Signal strength values is collected using Android Packaging Index (API) of Android smartphones and temperature using a custom made weather station.**

Keywords—RSSI; Temperature; Cellular Signal Strength

I. INTRODUCTION

Temperature is a major parameter that affects the global weather patterns. Weather change is an important matter of human concern as they affect man's daily life in many ways. These changes are generally measurable using simple gauging instruments or by observing subsequent changes in a parameter dependent on the weather metric being monitored. One way to do this is by measuring the radio link quality [1]. Major telecommunication network providers have deployed cellular voice and data networks over most of the inhabited areas of earth. Cellular telecommunication transmission facilities [2] are the physical means of communicating large amounts of information over distance in developing countries. Thus any effect on Cellular Communication Network is crucial. In this paper an analysis on the effect of temperature on Cellular Signal Strength Quality is performed [1] [3]. In telecommunications, Received Signal Strength Indicator (RSSI) is a metric of the power present in a received radio signal [4]. We use Signal Strength Android API to get real-time RSSI readings from a smartphone [5].This helps us to get an awareness of signal strength measurement values at the user end varying over atmospheric conditions [5].

II.RELATED WORKS

Since temperature affects the performance of the most basic elements in electrical and electronic circuits [6], assessing its effect on individual devices is a usual practice in industries. A few studies have investigated the effect of temperature on network operations. Jari Luomala et al [1] studied the effect of temperature on radio signal strength and concluded that temperature has an inverse linear relationship with signal strength in general. He also observed that the correlation between signal strength and the weather variable depended on the radio channel and link. Carlo et al. [7] showed that temperature significantly affects the signal strength and link quality, and that up to 16% less power may be required to maintain a reliable communication at a lower temperature. Bannister et al [8] experimentally confirmed the decrease in RSSI to be linear and ranging up to 8dB when temperature rose from 25 C to 65 C. They showed the implications this has for the communication range and network connectivity. Wennerstrom et al [9] showed PRR (Packet Reception Ratio) and RSSI correlate with temperature, absolute humidity, precipitation and sunlight. Their results show that PRR and RSSI correlate mostly with temperature. Along with temperature, other weather parameters like humidity, rainfall and snowfall related issues have also received a lot of attention among research communities. Thelen et al [10] experiment concluded that radio waves propagate better in high humidity conditions especially at night and during rain. Capsuto et.al [11] conducted experiments and observed that cold weather had no noticeable effect on links while rainfall and overall moisture had a noticeable impact on RSSI.

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III. Effect of temperature on cellular signal quality

Changes in weather conditions affect radio signal strength. Multipath fading and propagation loss cause received signal strength to vary over time, and it is known that temperature has a significant effect on the performance of radio transceivers. Higher temperature is not good for signals. Temperature dependent transceiver properties like gain means that these can be used as physical mechanisms to measure the variations. Fundamentally, transistors are the key elements in providing the gain in an amplifier and the dominant thermal effect on CMOS transistors is the decrease of electron mobility with temperature. This inverse relationship has the effect of reducing the trans-conductance gain with temperature and thus increasing the noise figure. Experiments [12] showed that these changes in gain and noise figures are the two most likely reasons of variations in signal strength. Reduced signal strength readings at the transmitter side are due to the decrease in gain combined with the reduced input signal level; and at the receiver side are due to the thermal properties of the transmitter's power amplifier and the receivers low noise amplifier. The decrease in RSSI, however does not depend on the rate of the temperature change [3]. [8] and [13] showed that one can safely decrease the transmission power without deteriorating the performance the network. Decrease of temperature helps in better transmission of network signals and thus helps in designing efficient transmission system with negligible power loss.

IV. RSSI as an assessment of link quality

RSSI (Received Signal Strength Indication) SINR (Signal to Interference plus Noise Ratio), BER (Bit Error Rate) and PDR (Packet Delivery Ratio) are the most popularly used signal strength measurement metrics, but RSSI is easily available from android phones.

$$\mathrm{RSSI} = (E_b/n_0) + \mathrm{Noisepower}$$

Where (Eb) is the average energy per bit of the received signal and n0 is the variance of the noise. According to this equation the dimensions of Received signal strength is that of power (Watts or dB). However, RSSI is often represented as a scaled version of this, and hence as a dimensionless indicator value within this scale, specified by the chipset vendor. It may be specified in a positive or a negative scale. IEEE 802.11 standard talks about the RSSI metric as a measure of the power level being received by the receiver radio during packet reception. Therefore, the higher the RSSI value, the stronger the signal. This parameter is a measure by the PHY sublayer of the energy observed at the antenna used to receive the current PLCP (Physical Layer Convergence Protocol) Data Unit. RSSI is measured between the beginning of the Start Frame Delimiter (SFD) and at the end of the PLCP Header Error Check (HEC) of packet reception [14]. RSSI is a metric intended to be used in a relative manner. Absolute accuracy of the RSSI values is not expected.

V. Materials and Methods

The schematic block diagram of the entire system is shown in Fig 1. CrisisSignal Android App, a product of OpenSignal for assessing network quality in a region, was used for data extraction (GUI shown in Fig. 2). Three Android smartphones (Micromax make) of Mediatek chipsets were used for the study. CrisisSignal App was installed in the phones and RSSI readings were continuously acquired. Temperature measurements were acquired using a custom made Arduino based mini weather station in which a digital temperature sensor AM2302 was interfaced with the Arduino. Real time readings were obtained on serial monitor which was written to an excel sheet. Co-relation based analysis was primarily used to analyse this data, using MS Excel.

VI. Observations

RSSI readings were collected from a smartphone at different intervals of time, and correlation studies were conducted on the collected data from the cellphone and the weather station. In this context, a linear relationship was inferred between two quantities only if the correlation factor was very close to unity (greater than 0.9).

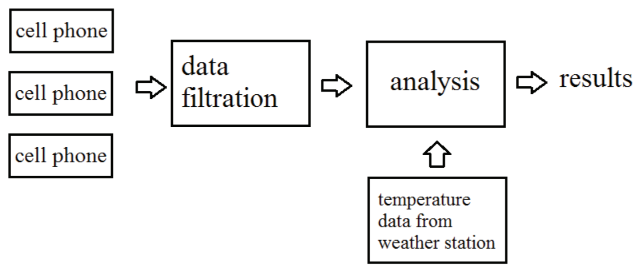

Fig. 1: Schematic block diagram of the system

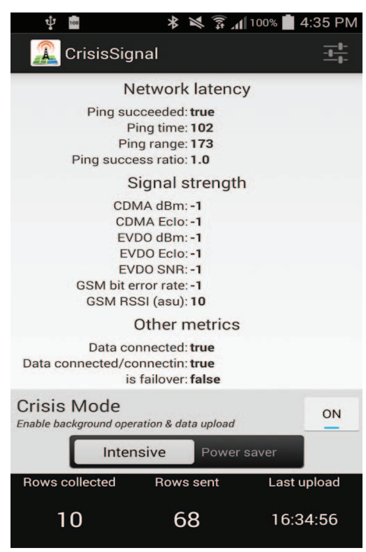

Fig. 2: GUI of CrisisSignal Android Application

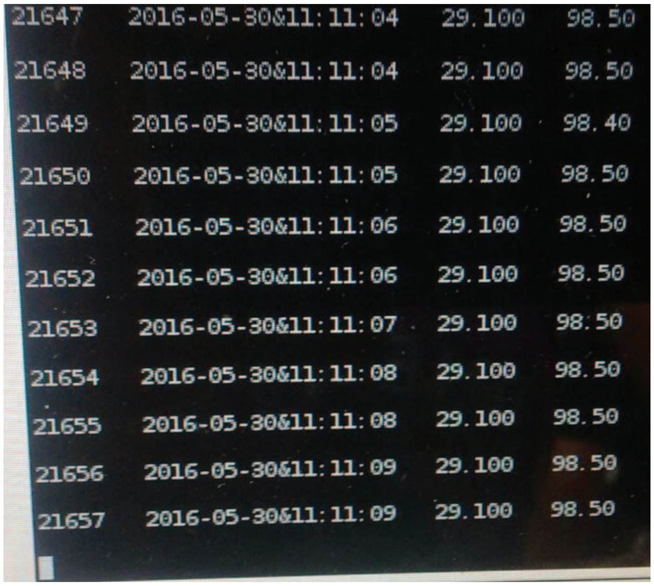

Fig. 3: Temperature and humidity readings from the UI of Arduino based weather station

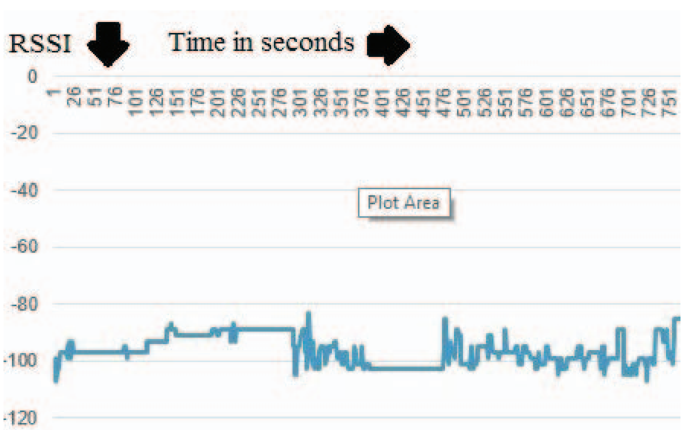

Fig. 4: RSSI readings obtained from the cell phones mapped with respect to time in seconds

A. By observing variations over different times of a day-horizontal correlation

This was done by observing the sample pair (average temperature and RSSI values) over one hour time intervals on different times of single day (Table 1). These timings were selected due to the strong variation of temperature during a day. A weak direct correlation was observed between temperature and RSSI values when a graph was plotted between these two parameters. The correlation values ranged from 0.17 to 0.8 for different days, in contrast to the expected inverse linear relation. This anomaly could be because of the fact that RSSI values are also influenced by other factors which vary over different times of a day.

B. By observing variations over a few days on the same times-vertical correlation.

This was done by observing variations in the temperature and the average RSSI values in one hour time intervals when taken across different days which were similar and consecutive (like the weekdays) (Table 2). The vertical correlation studies yielded strong inverse linear relation in 50% cases (these samples were concentrated at noon and in the evening). The other 50% cases yielded a weak positive correlation (or no correlation at all). It could be observed that the first 50% cases were the only scenario during the course of the study when temperature and signal strength values were linearly related at all- and it showed an inverse linear relation.

VII. Conclusions

Cellphones, not being standard signal strength measuring devices, cannot be expected to provide fully accurate RSSI readings. Also, RSSI and other commonly used signal strength metrics have a drawback of not being able to effectively express the network quality [14]. This is a limitation that was faced during this study. But the growing number and density of cell phones raise the potential of the collected data as they can provide deeper insight when gathered collectively. Frequency range of the 2G band used for the study are less prone to temperature related noises. This study was conducted on adjacent days to rule out the effects of other weather phenomenon that can get included in a long

TABLE I. HORIZONTAL CORRELATION

No	Horizontal Co-relation of RSSI and Temperature	
	Date	**Co-Relation**
1	28/12/2016	0.819
2	29/12/2016	0.359
3	30/12/2016	0.4513
4	31/12/2016	0.1741
I.	Horizontal Co-relation of Signal Strength Values with Surrounding Temperature	

TABLE II. VERTICAL CORRELATION

No	Vertical Co-relation of RSSI and Temperature	
	Time of the day	**Co-Relation**
1	8 am to 9 am	0.7646
2	12 pm to 1 pm	-1
3	4 pm to 5 pm	-0.95154
4	9 pm to 10 pm	0.274351
II.	Vertical Co-relation of Signal Strength Values with Surrounding Temperature	

term study. From horizontal correlation studies a weak positive relation was experienced, this could be the effect of other factors like fluctuations in network traffic during different times of a day. These variations of other parameters over a day were ruled out by conducting a vertical correlation study on similar consecutive days. This study can be used as a first step on using cellular network strength data as an input for high resolution weather analysis. Collecting data from a large number of phones through data crowdsourcing and big data analysis can increase the precision of studies.

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