A brief description on measurement data from an operational microwave network in Gothenburg, Sweden

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Abstract

The idea of using operational wireless communication links as a widely deployed sensor network for environmental monitoring has been successfully accepted both in academia and industry since the first papers from the early 2000s. Over ten years of research has shown promising results in various applications, primarily rainfall but also e.g. evaporation and fog. In this paper we will present measurement data from a joint pilot project by Ericsson, Hi3G Sweden and SMHI (Swedish Meteorological and Hydrological Institute). It includes a set of over 20 months' measurement of transmitted and received signal strength from an operational network of 364 bi-directional microwave hops in the Gothenburg area, Sweden. In total there are close to 7.5 billion measurement points with a time resolution of 10s. The purpose of this paper is to present key characteristics of the data set and to make some data available to research institutes around the world to encourage more cross disciplinary works in research topics such as environmental monitoring, sensor networks, big data analytics, machine learning etc. Researchers from different disciplines are encouraged to verify their models and algorithms on data from real communication networks.

Keywords: Wireless communication network, environmental monitoring, sensor network, data set

1. Introduction

The idea of using operational wireless communication links as a widely deployed sensor network for environmental monitoring has been successfully accepted both in academia and industry since the first papers by (Messer, *et al*., 2006), (Leijnse, Uijlenhoet, & Stricker, 2007) etc. The methodology to measure rainfall using microwave links exploits power attenuation of an electromagnetic wave when it propagates through water drops. The rain rate prediction based on microwave links complements the conventional rainfall measurement using rain gauges and weather radars, with improved resolution in space and time. The total amount of microwave links worldwide is more than 10 million. Hence, there is a tremendous potential globally for increasing the number of measurement locations/points and thus improving the quality of hydrological measurements, flood warnings, and weather monitoring and forecasts. The value to the society is well recognized, especially in developing parts of the world, where a large part of the society is based on agriculture and are often lacking rain monitoring infrastructure. They would benefit strongly from improved rainfall measurements given by operational communication networks. Over one decade's research effort has shown promising results in precipitation estimation and prediction. In recent years, many successful trials using operational links in real networks are reported, e.g., (Ravitsfeld, *et al*., 2012), (Overeem, *et al*, 2013), (Fencl, *et al*., 2015) etc. Besides rainfall monitoring, the similar idea has also been applied to monitoring other water vapor related phenomena such as humidity (David, Alpert, & Messer), dense fog (David, Alpert, & Messer, 2013), dew (Harel, *et al*, 2015), drainage modelling (Fencl, *et al*., 2013), and vegetation characterization (Hunt, *et al*., 2011). Although the recent progress and positive feedbacks from the field trials around the world, there are still many open issues regarding the accuracy of estimation using practical networks, as described in e.g., (Messer & Sendik, 2015), (Chwala, Keis, & Kunstmann, 2016) and (Overeem, Leijnse, & Uijlenhoet, 2016). A wide range of data processing challenges were identified and discussed, such as the detection of outliers, the determination of dry and rainy periods, the calibration of wet antenna effect, the assimilation of links of different locations, frequencies, path lengths and resolution in time and power. The multiple sources of errors should be handled in great care during data acquisition and data processing. Moreover, the development of efficient network topologies and data logging algorithms are also important research topics. As the number of links increases, the issues with data size, processing time and storage will be critical. In this paper we will present a set of measurement data collected from a joint pilot project by Ericsson, Hi3G Sweden and SMHI. This is a set of over 20 months' measurement (2015-2016) of transmitted and received signal strength from an operational network of 364 microwave hops in the Gothenburg area, Sweden.

2. Microwave link network

Figure 1: A map of the Hi3G microwave link network in Gothenburg area (Map data: Google, DigitalGlobe).

The measurements in the pilot project have been performed on the commercial microwave mobile backhaul network of Hi3G Sweden. The operator Hi3G provides the access to its microwave network. SMHI is responsible for retrieval of rainfall estimates from raw power data. The telecommunication company Ericsson delivers the hardware equipment and provides the solution for data collection and mediation. In this paper we briefly describe the measurement data set and the data collection method. We refer the reader to (Andersson, et. al., 2017) for the rainfall estimation results of the pilot project.

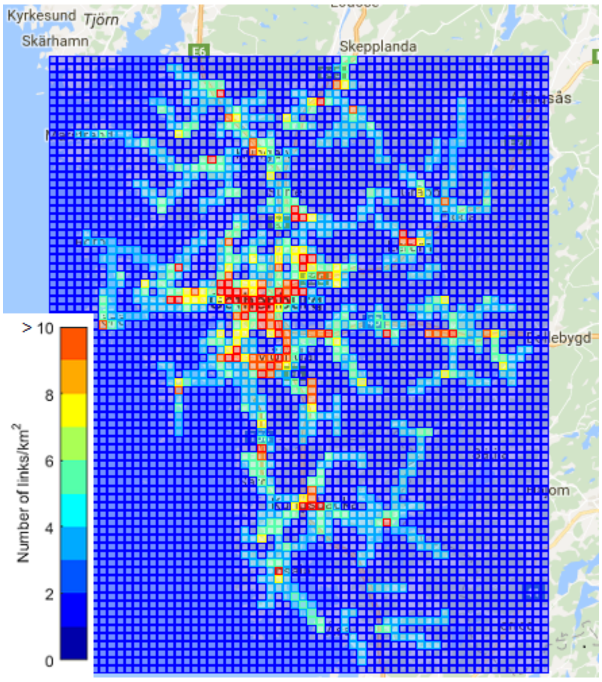

Figure 2: The link density map of the Hi3G microwave link network in Gothenburg area (Map data: Google, DigitalGlobe).

The network consists of 364 bi-directional hops, i.e. 728 microwave links, in the larger Gothenburg region, which spans across an area of 4070 km^2. An overview map of this network is depicted in **Error! Reference source not found.**. Each line in Figure 1 represent a two directional hop, i.e. 2 microwave links. The frequency difference between the forward and reverse direction is typically from a few hundreds of MHz to 1.5GHz. This network has a clear star topology with many links going out from some larger nodes. As the density of the network is often closely related to the accuracy of the spatial rain representation, the corresponding link density map is shown in **Figure *2***, with each grid represents $1km^2$. The number of links are quickly reduced when moving from the city center to the rural area. The network contains links operating using vertical polarization, in frequencies from 7GHz to 38GHz. It is well known that radio signal above 10GHz are sensitive to rain and the resulting power attenuation increases as frequency increases (ITU-R P.530-16, 2015). Depicted in Figure 3 is the histogram of carrier frequencies which shows that the majority of the links are above 20GHz. The antenna size in the network varies between 0.2m to 1.2m, and the corresponding antenna gain is within a range from 31dBi to 47dBi. In general, antenna gain increases as antenna size and carrier frequency increase. The distribution of the hop length can be found in **Figure *4*** which also shows that most links are shorter than 5km. In addition, depicted in Figure 5 is the relation between the carrier frequency and hop length. Due to the severe rain attenuation at higher frequencies, links above 20GHz are normally below 5km.

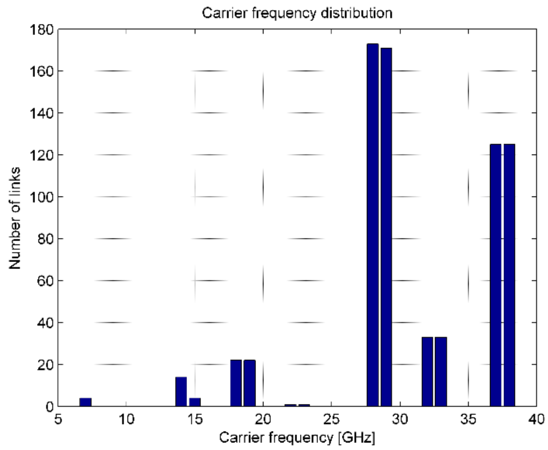

Figure 3: Distribution of the carrier frequency.

As observed by several works (e.g., (Messer & Sendik, 2015)), the accuracy of rain rate estimation varies with the hop length. How to compensate the path length bias is important to the quality of the reconstructed rain map. It has been long recognized that the height of the measurement equipment affects rain rate measurement (Curtis & Burnash, 1996). This is particularly a problem for radar measurements (e.g. measuring at 1.2km above ground in Gothenburg). In Figure 6 and Figure 7 we present the distributions of the antenna height above ground level and above sea level, where the information of the ground level is obtained from Google Earth. Most

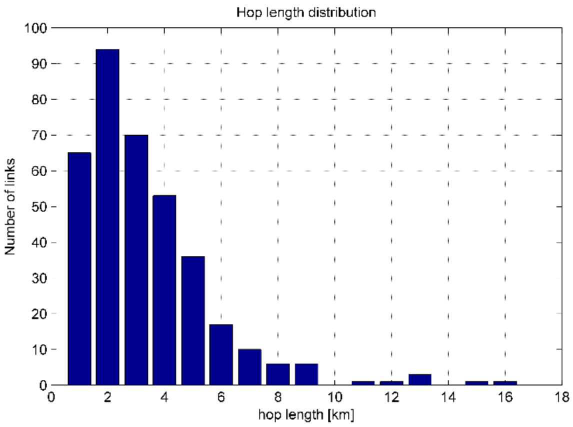

Figure 4: Distribution of hop length.

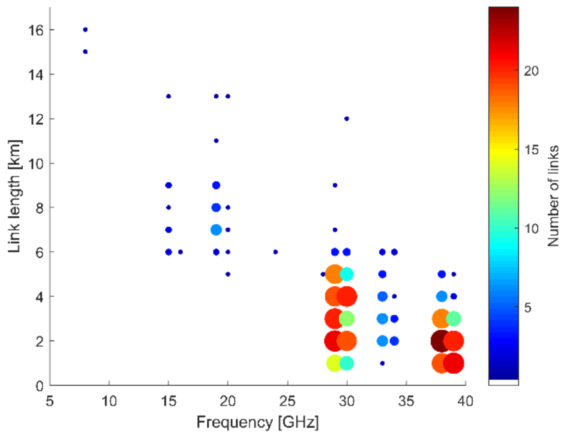

Figure 5: Hop length versus carrier frequency.

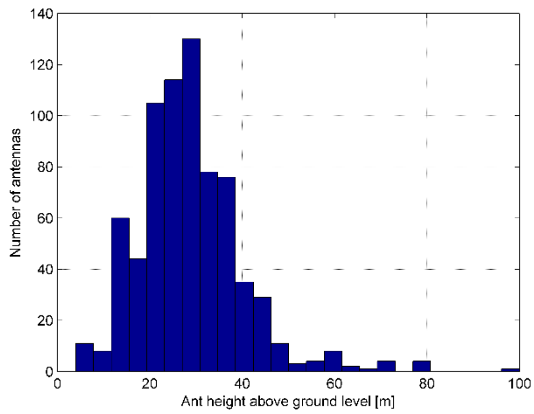

Figure 6: Distribution of the antenna height above ground level.

antennas are installed 30-40m above the ground level, and below 100m above the sea level.

3. Data collection and mediation

The data collection system consists of both data collection and data mediation services. These services provide automated procedures towards Hi3G's network at one end, and SMHI at the other as shown in Figure 8.

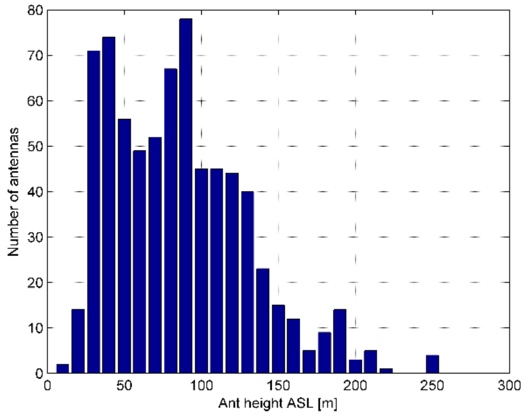

Figure 7: Distribution of antenna height above sea level (ASL).

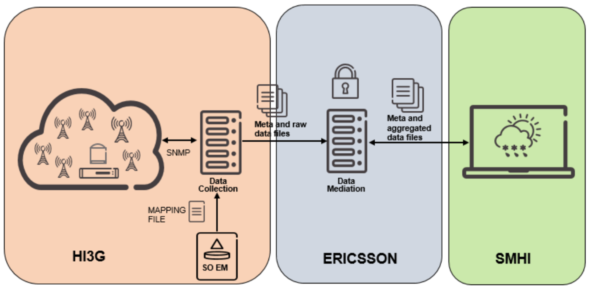

Figure 8: The data collection architecture.

The data collection service, located inside the Hi3G network, continuously fetches the transmitted power (TX) and received power (RX) levels from a predefined subset of microwave nodes within Hi3G's network. The collection procedure utilizes the mapping files from the existing element management solution, and fetch the required data for each link within a predefined sampling interval of 10 seconds. In principle, the data is ready in the data collector within 1-3 seconds, while in the pilot project the data is written into minute files, zipped and securely transferred to the data mediation server. The data mediation service, located inside Ericsson's network, receives the meta data and the minute files containing data necessary for rainfall calculation. The mediation service is responsible for assuring that the TX and RX values are within a reasonable range, and for consolidating all minute raw data files into the required format. The consolidated files are then transferred to SMHI. The data collection system is designed to allow scaling of the network size and adjusting sampling interval with minimal configuration effort on both collection and mediation services, and therefore it is flexible to improve the geographical coverage and measurement resolution by for example increasing the number of links. Similar to the previously mentioned works, the data collection unit has also identified a number of challenges in terms of signal processing, calibration, filtering of the collected raw data, network latency and minimizing impact on DCN and network nodes from the data collection. Different digital signal processing algorithms have been developed to mitigate hardware impairments and measurement uncertainties. On the other hand, power attenuation caused by factors other than rain, such as dense fog, wet snow, multipath from ground, roof, water surface, construction cranes, have not been filtered out.

4. Data hit rate

The data collection started by the end of April 2015, and it is still running. There are totally 20-months data available from May 2015 to December 2016. The data has been collected every 10 seconds and each hop is measured in both directions, leading to a total number of over 6 million measurements per day. A data sample consists of one pair of TX and RX power levels, and the quantization is 1 dB for the TX power and 0.3dB for the RX power. Since the feature Adaptive Transmit Power Control (ATPC) is disabled the TX-level is nearly constant. Even though the total number of measurements is over 1.5 billion, the corresponding amount of data is not huge, only 6.3GB in zipped format. Since each data sample is very small and the extra load on the network is insignificant. There is no negative impact observed in the network over the project period.

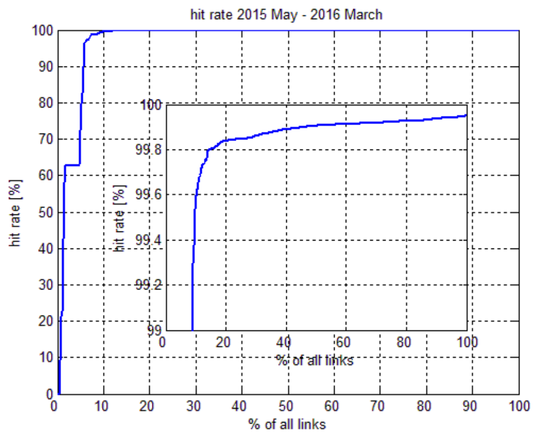

Figure 9: Hit rate per link between 2015 May and 2016 March. The inset graph is a zoom-in at the high-end of the scale.

The data collection hit rate accumulated in the first year (May to December 2015) is very high, 97.3%, considering all nodes in the subset. The hit rate here is referred to as the total number of successfully collected TX/RX pairs of the total number of sample collection attempts. For operational networks, regular maintenance work is needed. Over the measurement period, some of the nodes were switched to maintenance mode for varying time intervals. Therefore, the hit rate reaches even a higher value (99.6%) when such nodes are excluded. Figure 9 exemplifies the hit rate for each individual link in the period between 2015 May and 2016 March. The x-axis represents the total number of links and the y-axis represents the hit rate for each link. Over 90% of links have a hit rate more than 99.5%. The TX and RX power measurement over the 20 months has generated more than 160GB unzipped raw data. Since rainfall is an intermittent event, most of the time the power levels stay unchanged. Data collection and storage can be performed in much more efficient way, for example by only recording the change of the power level. The dimension of the network can also be optimized by only using sufficiently many links which can assure a certain quality. At the time of the paper preparation the exact data set to be made available and the way it will be published is not yet finalized.

5. Conclusion

In this paper we present measurement data from a joint pilot project by Ericsson, Hi3G Sweden and SMHI. This is a set of over 20 months' measurement from an operational network of 364 microwave hops in the Gothenburg area, Sweden. The data was measured in a wide variety of weather conditions such as heavy rain, wet snow, strong wind, dense fog and with other environmental influences such as water reflection path. The purpose is to make data available to support a broad range of related research topics, such as modeling in environmental monitoring, efficient deployment and faulty detection of large sensor networks, secure data transmission and storage of big data, to improve the quality of environmental monitoring using telecommunication networks.

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