Environmental monitoring by wireless

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Environmental Monitoring by Wireless Communication Networks

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High-resolution, continuous, accurate monitoring of the environment is of great importance for many applications—from weather forecasting to pollution regulation. We propose to use measurements from existing wireless communication networks for environmental studies, complementing existing monitoring systems such as weather radars. Weather, atmospheric conditions, and constituents cause propagation impairments on radio links. As such, similar to global positioning systems (GPS) (*1*), cellular networks provide built-in monitoring facilities and can be considered as a widely distributed, high-resolution atmospheric observation network, operating in real time with minimum supervision and without additional cost.

Meteorological monitoring of rainfall by radar is less accurate at surface levels (*2*), whereas rain gauges, although quite accurate, are expensive and do not provide sufficient spatial resolution. We demonstrate the feasibility of environmental monitoring with wireless communication networks by estimating the surface rainfall using standard data collected from a cellular network, and show its improved accuracy compared with radar-based estimates.

There are a variety of wireless communication systems, and we focus on the digital fixed radio systems (DFRS) that have a number of useful properties: They work at up to a few tens of meters above the ground, they operate at frequencies of tens of GHz, and they are impaired mainly by near-surface precipitation. DFRS have already established themselves as the premier cellular backhaul technology in Europe and Asia, accounting for the majority of cellular base-station connections.

The years of research by telecommunication specialists (*3*) generated tools for modeling and interpretation of atmosphere-induced impairments on radio links. The rain attenuation depends on the size and distribution of the water droplets. There are several models relating the attenuation rate A (given in dB/km) with the rain intensity. The common approach is a power law model for the attenuation, $A = aR^b$, where R is the rain rate and the constants a and b are functions of frequency and polarization. Given measurements of the received signal level (RSL), we estimated the rain-induced attenuation A, and then the average rainfall rate over each time frame (*4*).

Based on the data collected every 15 min from a few DFRS cellular backhaul links during a rain event in Israel in January 2005, we have estimated local rainfall. Figure 1 compares the rainfall estimates from the cellular backhauls, from radar, and from rain gauges. The skill of our method (correlation with rain gauges) is 0.86 for a 15-min-interval rain intensity and 0.9 for an hourly interval, versus 0.81 and 0.85, respectively, for radar, when evaluated from the maximal value over a 3×7 km^2 area. However, the corresponding correlation values from the literature at 3-km gauge-separation distance with radar are 0.59 and 0.71, respectively (*5*).

The density of the DFRS cellular backhaul links, according to the data from one Israeli cellular provider, varies in average from 3 links per km^2 to 0.3 links per km^2 in urban areas, and is less in suburban and rural areas. That allows, for example, the creation of rainfall intensity maps at an average spatial resolution of 1 to 3 km, using tomographic reconstruction.

Our results suggest that cellular rainfall measurements have features in between those of gauges and of radar. Cellular measurement can either replace existing techniques or colaborate with them to achieve better performance. However, the potential of the cellular environmental monitoring is not limited to rainfall measurements. Solid particles, fog, snow, sleet, and hail can be detected by microwaves. In particular, the capabilities of cellular networks (measuring of the refraction index of the atmosphere) may provide valuable facilities for studying water vapor, which plays a key role in weather and the global climate system.

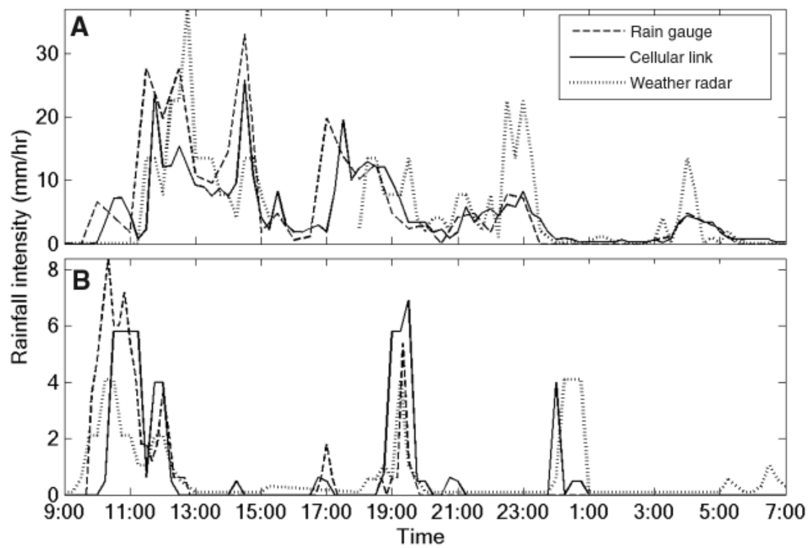

Fig. 1. Comparison of the time series of rainfall intensity measured by cellular links, rain gauges, and a weather radar, in two areas in Israel: (**A**) Tel-Aviv and (**B**) Haifa. The rainfall event was observed on 19 to 20 January 2005. The location of the radar is given in Movie S1. The rain gauges work at temporal resolutions of 30 min (A) and 10 min (B), whereas the wireless links provide measurements every 15 min. Temporal lags between the cellular data and the rain gauges are partly due to differences in locations of the links and the rain gauges (they are separated in space by about 2 km). Disparities, such as time lags, are also caused by the different nature of observations, i.e., line-integrated data in the cellular links versus point measurements in the rain gauges.

References and Notes

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Supporting Online Material

www.sciencemag.org/cgi/content/full/312/5774/713/DC1
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