Statistic Properties of Rainfall in Tokyo for Millimeter-Wave Wireless Network

- Rain Duration Analysis -

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***Abstract*—Statistic properties of rainfall in Tokyo are presented in this paper. Average rain duration as a function of rain rate is analyzed for future route switching technique to increase network availability. In case of strong rain (>100 mm/h), minimum and maximum duration were 20 sec. and 335 sec., respectively. It was found that even in the campus within 1 km, rain rate is different at each site and rain rate is 40 % - 70 % at another site in case of strong rain.**

Keywords—rainfall, rain rate, duration, statistic, millimeter-wave

I. Introduction

Millimeter-wave model network had been developed in Ookayama campus, Tokyo Institute of Technology [1][2] in order to investigate the applicability of millimeter-wave fixed wireless access (FWA) systems. Main factor which dominates millimeter-wave propagation characteristic is rain, and it is necessary to overcome rain attenuation by route diversity or some other techniques to realize robust network. Recently, localized heavy rains are frequently observed in metropolis, such as Tokyo. The rainfall intensity of the localized heavy rain is too strong to maintain millimeter-wave wireless link.

Statistic properties of rainfall in Tokyo are presented in this paper. Especially, rain duration as a function of rain rate is analyzed for future route selection technique to increase network available rate.

II. Millimeter-Wave Model Network

The Tokyo Tech millimeter-wave model network [1] consists of 7 fixed wireless access (FWA) sites on rooftops of 7 buildings (S3, W8, I1, M1, I6, 100, H) with 10 lines connecting two sites, as shown in Fig. 1. The minimum and maximum distance of the FWA lines are 77 m and 1,020 m, respectively. The 25GHz FWA wireless terminals (WTs) (80Mbps) [1] and 38GHz FWA WTs (600Mbps) [2] are installed in parallel. The interface of the FWA WTs is Ethernet. The FWA WTs are connected each other using 1000BASE-T switches. Rain rates are measured by Tipping-bucket rain gauges with 0.2 mm resolution and 1-minute time intervals are installed in all sites.

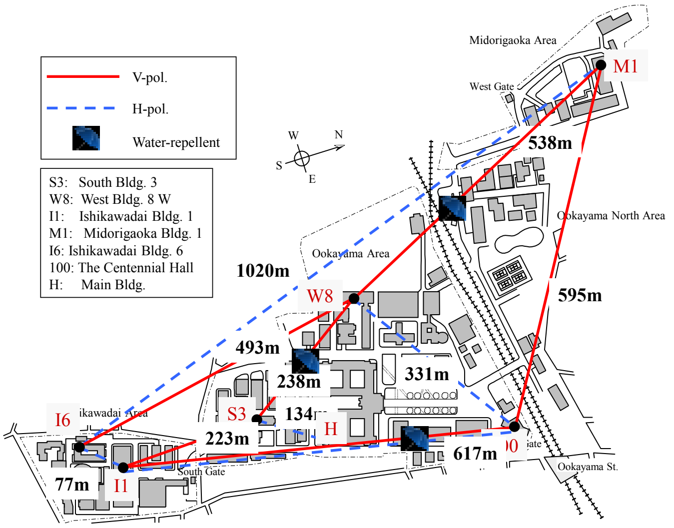

Fig. 1. Tokyo Tech millimeter-wave model network.

Rain rate at each site is measured and logged every 5 seconds via the network as shown in Fig. 2. Properties of rainfall [3][4] and possibility of route switching [5] have been investigated by the authors.

III. Statistic Properties of Rainfall

Statistic properties of rainfall in Tokyo over five years from 2010 to 2014 are analyzed using the millimeter-wave model

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network in Sec. II. TABLE I. lists available data of the system, number of events, rainy days, total rainy time, rainfall level in each year and maximum rain rate. Available data is not 100 % due to system downs and maintenances. A rain event is defined as a time series of continued rain. If 1-minite no-rain time occur, later rain event is separated from the former one.

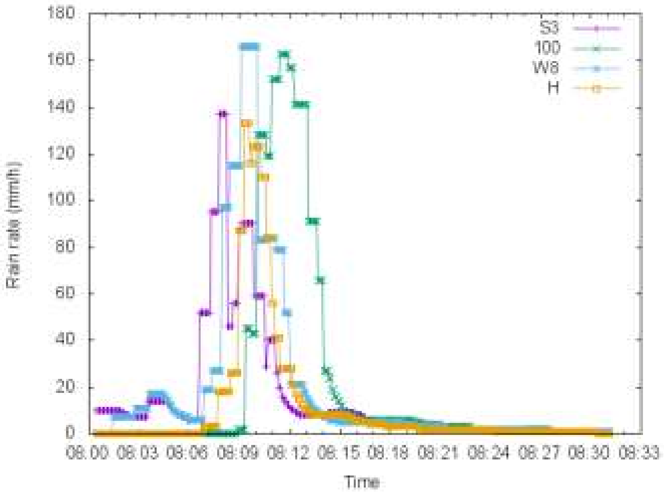

Fig. 2. Time series of rain rate on September 8, 2012.

Fig. 3 shows histogram of rain events by the maximum rain rate in the event at Bldg. S3. It can be seen from Fig. 3 that the number of strong rain event is smaller than weak rain event. Fig. 4 shows average rain duration of rain event in which rain rate exceeds threshold. In case of strong rain (>100 mm/h), minimum and maximum duration were 20 sec. and 335 sec., respectively, with five-year (2010-2014) data. This result would be used for route switching technique in future. Fig. 5 shows minimum of the maximum rain rate at each site. It can be seen from the figure that even in the campus in Fig. 1, rain rate is different at each site and rain rate is 40 % - 70 % at another site in case of strong rain.

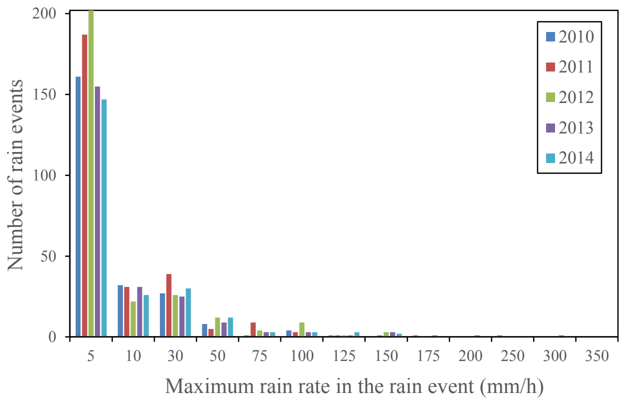

Fig. 3. Histogram of rain events by the maximum rain rate in the event from 2010 to 2014 at Bldg. S3.

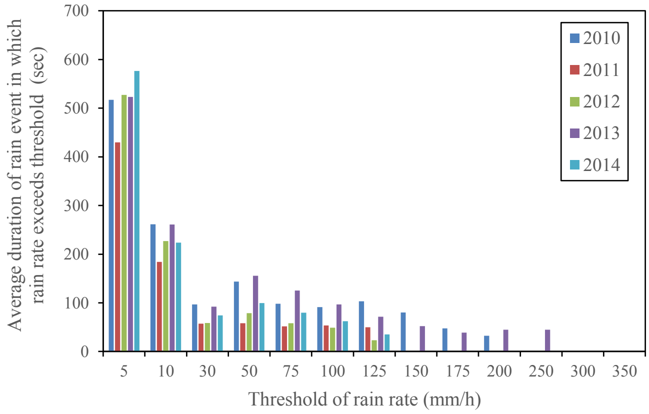

Fig. 4. Average rain duration of rain event in which rain rate exceeds threshold (at Bldg. S3).

TABLE I. STATISTIC PROPERTIES OF RAINFALL (AT BLDG. S3 IN FIG. 1)

Year	Available data (%)	No. of rain events, rainy days	Total rainy time (hour)	Rainfall level in a year (mm)	Max. rain rate (mm/h)
2010	77.6	236 times 88 days	245	840	225
2011	95.3	276 times 86 days	246	829	131
2012	88.4	279 times 86 days	283	1018	137
2013	88.6	233 times 80 days	229	1066	266
2014	76.8	226 times 74 days	245	1073	138

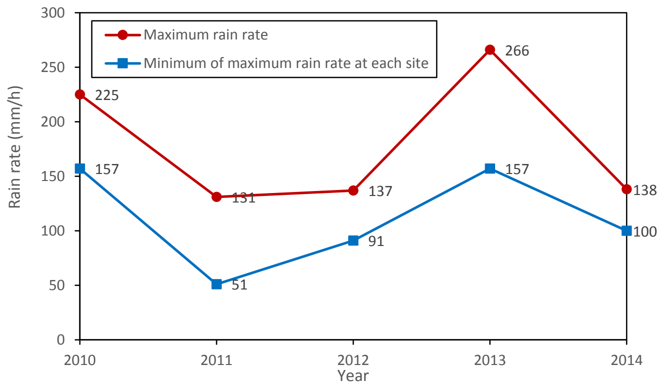

Fig. 5. Minimum of maximum rain rate at each site.

IV. RELATION BETWEEN RAINFALL INTENSITY AND RAIN ATTENUATION

Rain attenuation of radio wave can be approximated by ITU-R model [6][7] as follows.

$$\gamma = kR^{\alpha} \quad (1)$$

where γ (dB/km) is the specific rain attenuation and R is the rain rate (mm/h). The k and α are constants which are functions of frequency and polarization.

The rain attenuation γd (dB) can be calculated using (1) if the distance of the link d (km) is determined. Therefore, the link down duration can be calculated from Fig. 4 if the system performance is determined.

V. CONCLUSION

Statistic properties of rainfall in Tokyo were presented. Average rain duration as a function of rain rate was analyzed for future route switching technique to increase network availability. In case of strong rain (>100 mm/h), minimum and maximum duration were 20 sec. and 335 sec., respectively. It was found that even in the campus within 1 km, rain rate is different at each site and rain rate is 40 % - 70 % at another site in case of strong rain.

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