# sensing of rainfall using opportunistic data from Satellite communication terminals

AYECKA
SATELLITE TECHNOLOGIES

The Iby and Aladar Fleischman Faculty of Engineering
Tel Aviv University

Israel Innovation Authority

www.opensenseaction.eu

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Baruch Kagan - baruchk@ayecka.com

# Abstract

- Rainfall is part of the Earth's water cycle
- In many areas of the world the density of rain gauges is very low
- There is high correlation between these areas and where IoT over satellite is in use
- To use Satellite IoT terminals link quality to estimate rainfall - Every terminal is virtual rain gauges
- Ayecka make Satellite terminals for IoT and sale them to operators in these regions
- Ayecka expects 100Ks of terminals around the globe
- TAU algorithms convert link quality values to rainfall estimations

# About TAU team - Cellular Environmental Monitoring and Processing Lab

PIs: Prof. Hagit Messer; Prof. Pinhas Alpert; Dr. Jonatan Ostrometzky

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The team deals with opportunistic sensing using CMLs from 2005.

- Ten active graduate level students
- Past 4 Ph.D. graduates and 25+ M.Sc. graduates.

https://cellenmonlab.tau.ac.il/

# About Ayecka

- Est. 2005
- Founded, fully owned and run by engineers
- In House skills – full spectrum of skills required for Satcom – Algorithms, HW, SW, RF, System etc
- Advanced, and Cost-Effective Satellite Connectivity Solutions
  - Broadband (up to 2Gbps)
  - Narrowband (IoT) – On LEO and GEO
- RFModem® - All outdoor satellite modem – Integration of RF, Digital and Metal into single outdoor unit
- Provider of IP over DVB-S2 receivers  for the Eumetcast network

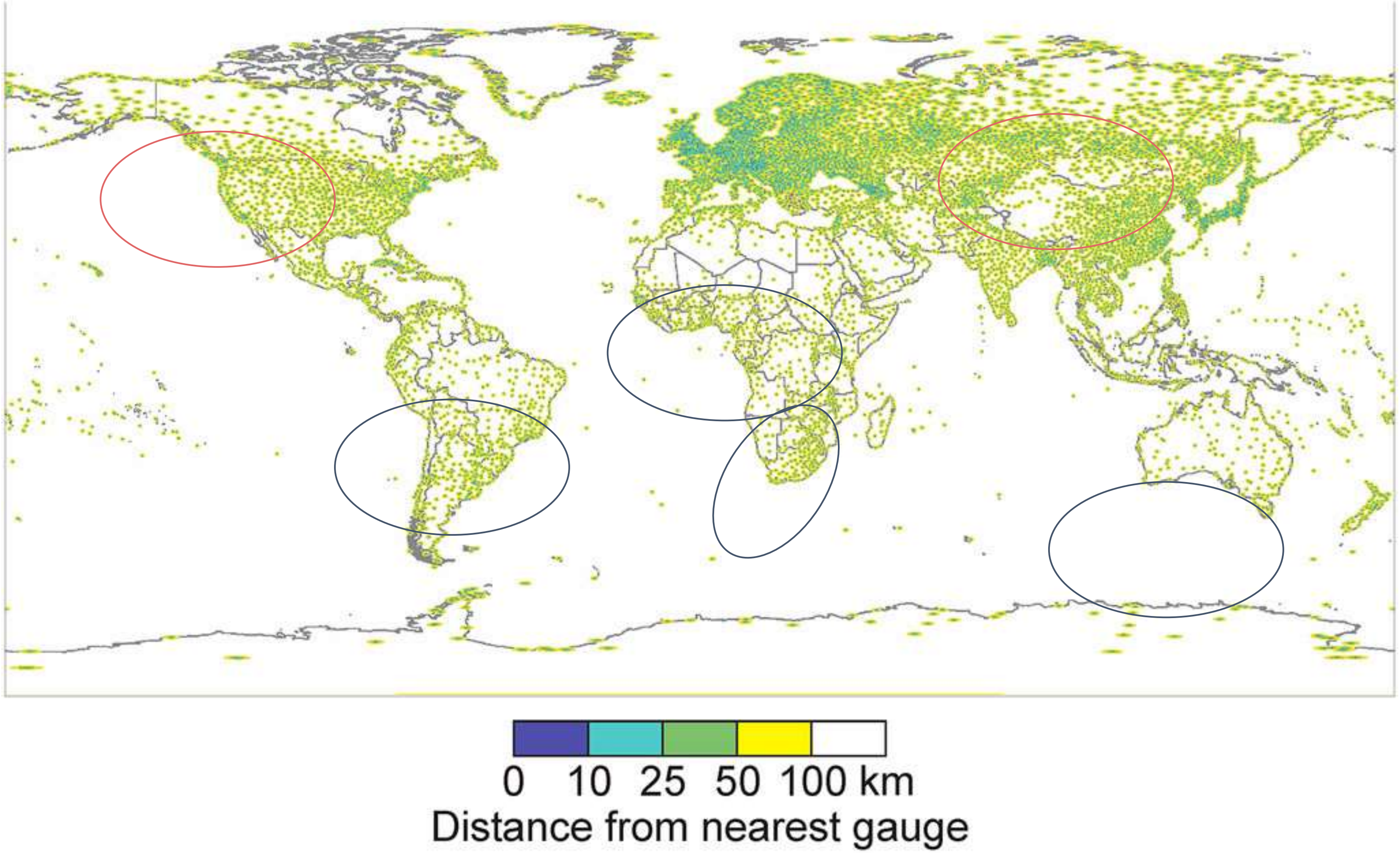
But the Lord God called to the man, “Where are you?” Genesis [3: 9]

וַיִּקְרָא יְהוָה אֱלֹהִים, אֶל-הָאָדָם ; וַיֹּאמֶר לוֹ, אַיֶּכָּה. בראשית פרק ג פסוק ט

# Rain gauge meters distribution

Low density regions

- Rural
- Low density population
- Emerging markets
- Rain RADAR - similar situation



# IoT

## IoT

a. Low volume of data , very large number of terminals - large number of sensors
b. Low bit rate transmission - Low power transmission - Low cost decisive - Large number of sensors

## Application in rural areas

a. Agro - Accurate agriculture (Irrigation, fertilization etc) - Farming regions are rural and loosely populated
b. FinTech - ATM, Electronic wallet - providing financial services in areas with poor infrastructure, mainly in emerging markets
c. Surveillance - Smart fence, border control - in rural areas

**All are existing business to support the Satellite IoT infras**


## The connectivity challenge

a. Cellular networks offers poor service in rural areas
b. Cost of Cellular infrastructure is high compare to traffic in rural areas

## Proposed solution – Satellite, in Ku band

# Satellite communication in Ku

## Satellite communication

a. A communications satellite relays and amplifies radio telecommunication signals via a transponder
b. It creates a communication channel between a source transmitter and a receiver at different locations on Earth

## Geostationary satellites

a. A satellite at 35,786 km and fixed position when viewed from earth

## Radio spectrum Ku

a. Down **10.7-12.75 GHz**
b. Up **13.75-14.5 GHz**

## The technology of Satellite TV

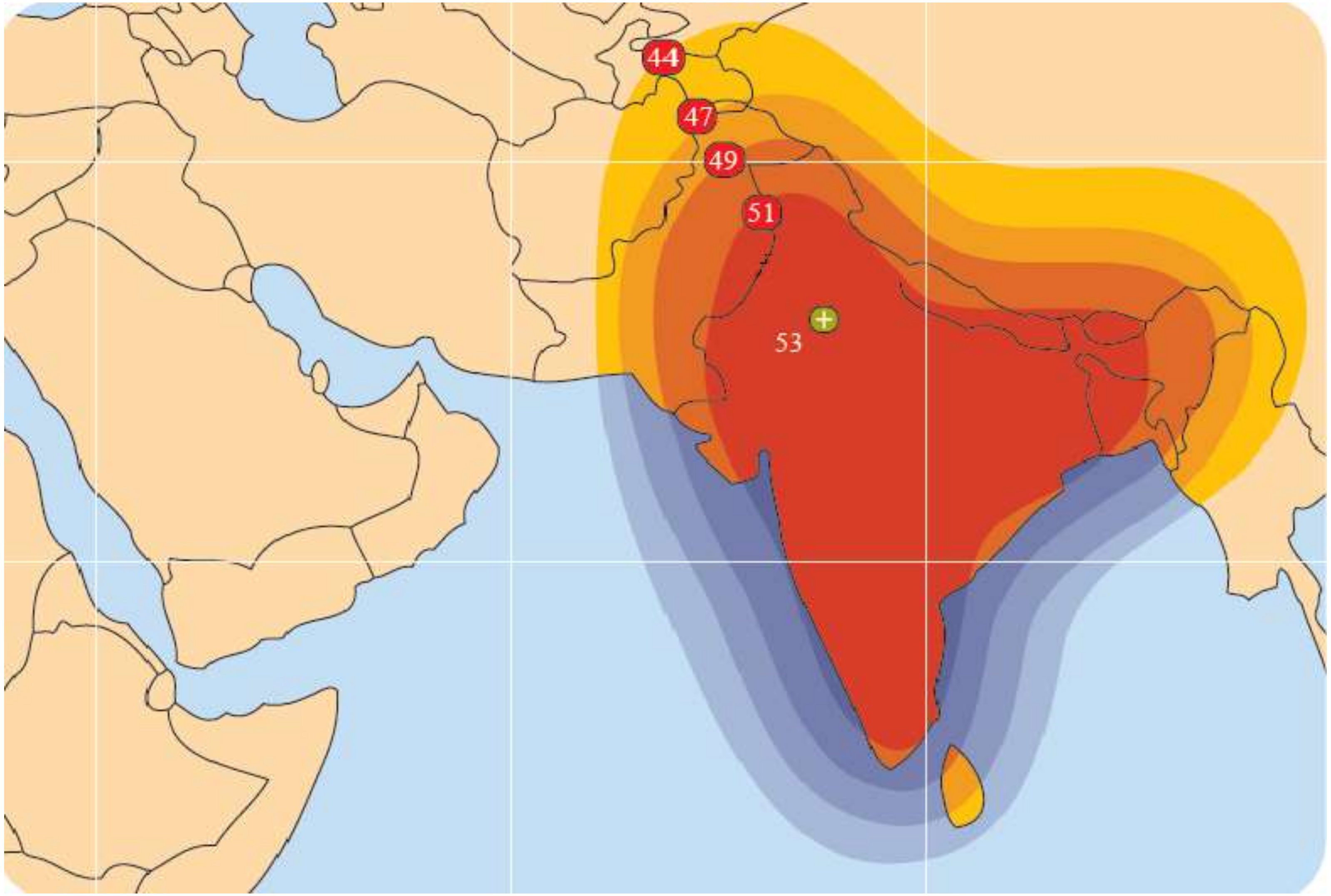
a. Common around the globe - especially in emerging markets
b. Low cost - cables, antennas, installation

# Satellite in Ku band - Coverage areas

**Coverage**

Wide areas - States and continents

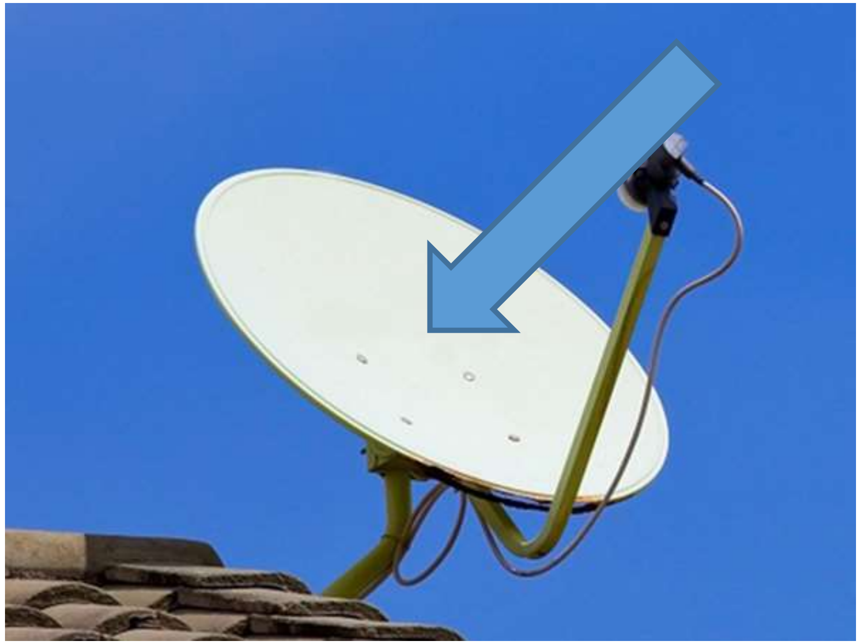
Example - Amos 4 Amos 4 India beam



# Satellite IoT vs Satellite TV

- Similar
  - Use of Ku Satellite to achieve wide area coverage
  - Same satellite are used for IoT and TV- no need for new satellites
  - Simple antenna dish and cabling
  - Installation and pointing

- Different
  - TV is one **way**, IoT **two-way**
  - Signal quality data is delivered on the return channel
  - IoT terminals are constantly monitored by the network – opportunistic data is available
  - Satellite IoT terminals are under tighter regulation
    - Technical – ITU and satellite operator
    - Legal – Communication service provider license



Data collected from Terminals - CNIR (EsNo) in both directions - Opportunistic data that is used to manage the network

Optimized algorithms for the raw data are developed by TAU

# AR-1100 - Satellite communication terminal for IoT

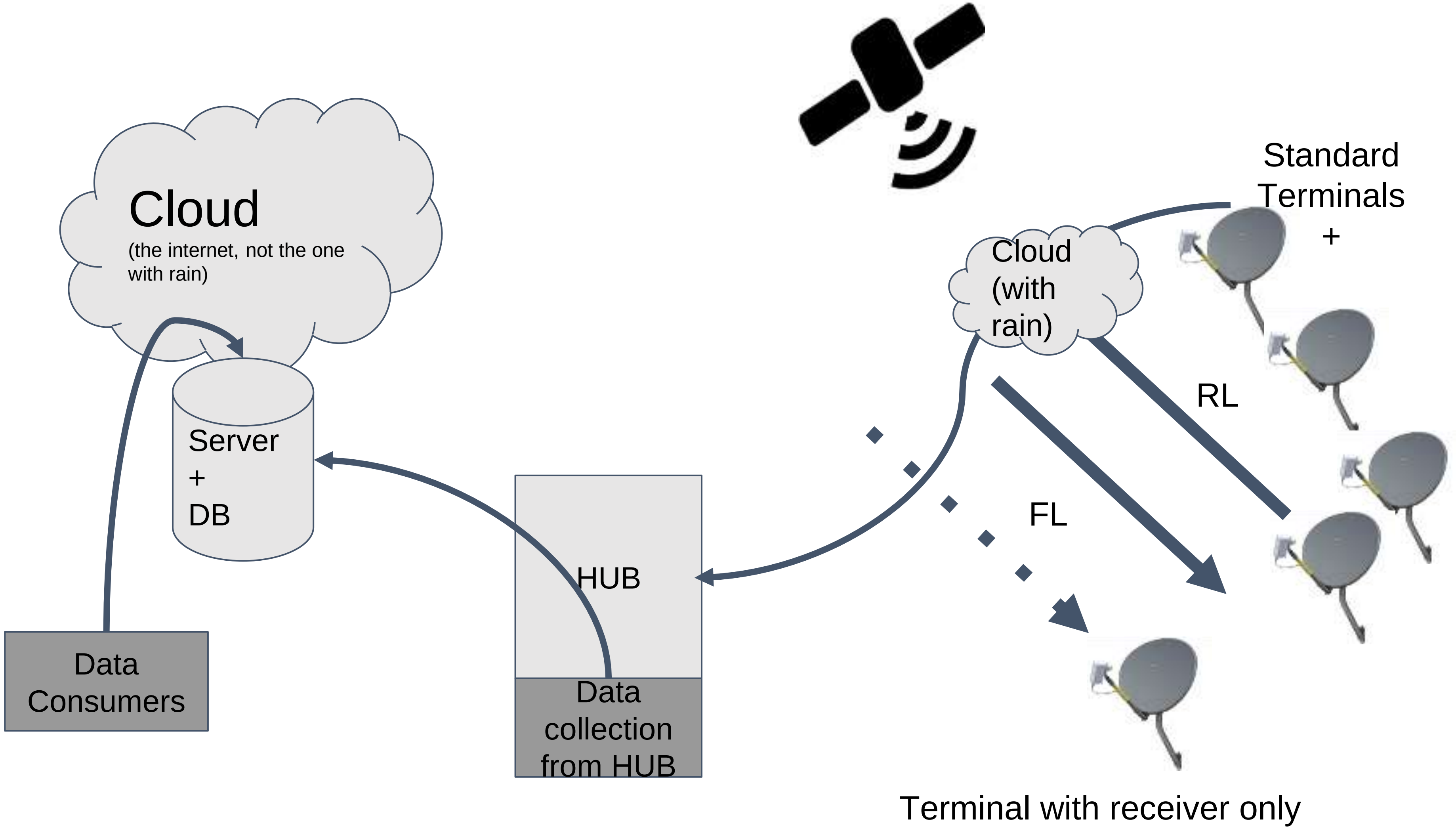
- All outdoor satellite terminal - High integration
- In Ku – Satellites with wide area coverage
- Max total consumption 20 Watt
- Dish size ~70cm
- Low cost – Modem, Dish and cables for 250$
- Simple Installation - Satellite TV level
- Optimized for IoT with NOMA based Return channel

- Service is available in Americas, Africa, India and Asia-pacific
- Ayecka estimates 100Ks of terminals in rural areas

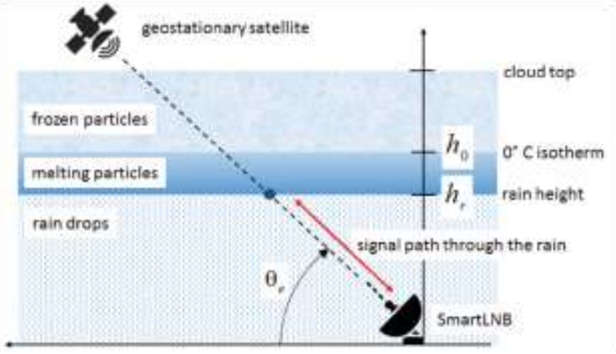
AR-1100 can be used in other precipitation observations applications - Connecting sensors like ground humidity, or water flow in rivers, to the cloud

# Data collection system

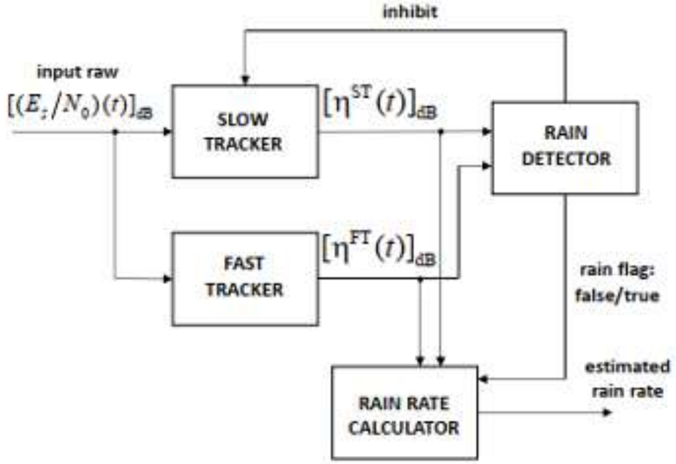
- Terminals constantly communicate with HUB
- EsNo of FL From terminals is sent to hub
- Hub Estimate EsNo from each terminal
- Data is available at the HUB



# From near ground CMLs to Satellite links




FROM: Giannetti, Filippo, et al. "Real-time rain rate evaluation via satellite downlink signal attenuation measurement." *Sensors* 17.8 (2017): 1864.




## Rain Rate Estimation :

$$r = \alpha\, L^{\beta}{}_{1,d.}$$

α and β are coefficients depending on frequency and on the climatic zone of the receiver location. Based on Giannetti et al, we took α=~28 and β =~0.8.

$$L_{1,dB} = L_{dB} \sin\theta_e /$$

H_r = Rain Height ( Km ) – bottom of melting layer
$\theta_e$ = elevation angle of the antenna, in Israel – ~ 31 degrees.
$L_{dB} = 10 \log L$ overall attenuation (dB) undergone by the received signal along the path through the rain

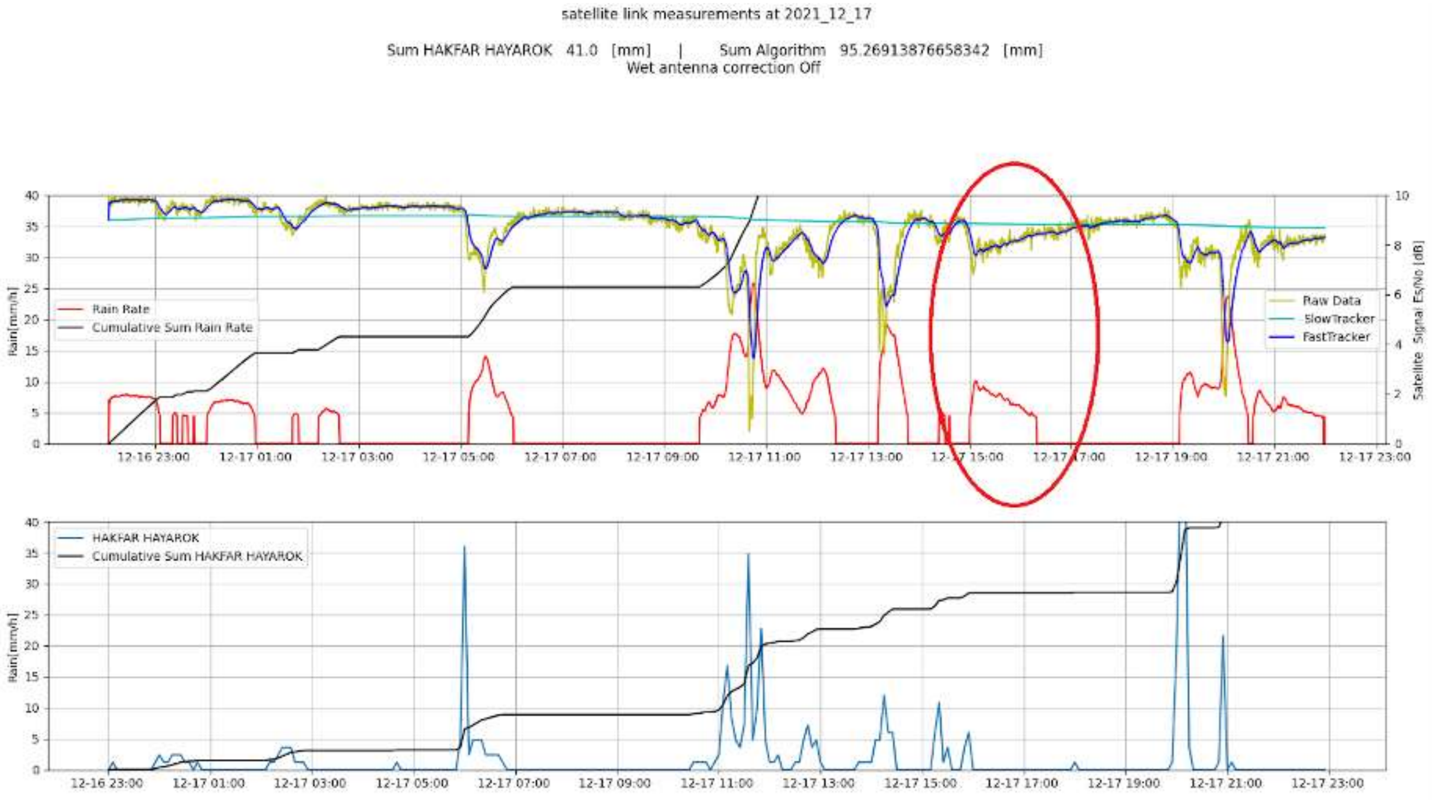
$$h_r = h_0^C - \Delta h$$

H_r – rain high
H_0^c - height of the 0 ◦C isotherm
Dh = 400 m

$$L(t) = \frac{\left[\frac{\eta^{ST}(t)}{\eta^{FT}(t)}\right]\left[\frac{T_C}{L_A} + T_M\left(1 - \frac{1}{L_A}\right) + T_G + T_R\right] + \frac{T_M - T_C}{L_A}}{T_M + T_G + T_R},$$

η_ ST – Slow tracker output
η_ FT – Fast tracker output
L_A- atmospheric attenuation
*T_C* - Noise temperature
T_M-Meteorological formations
T_G-Ground noise
T_R- Receiver Hardware

# Time Series and Rain Estimates



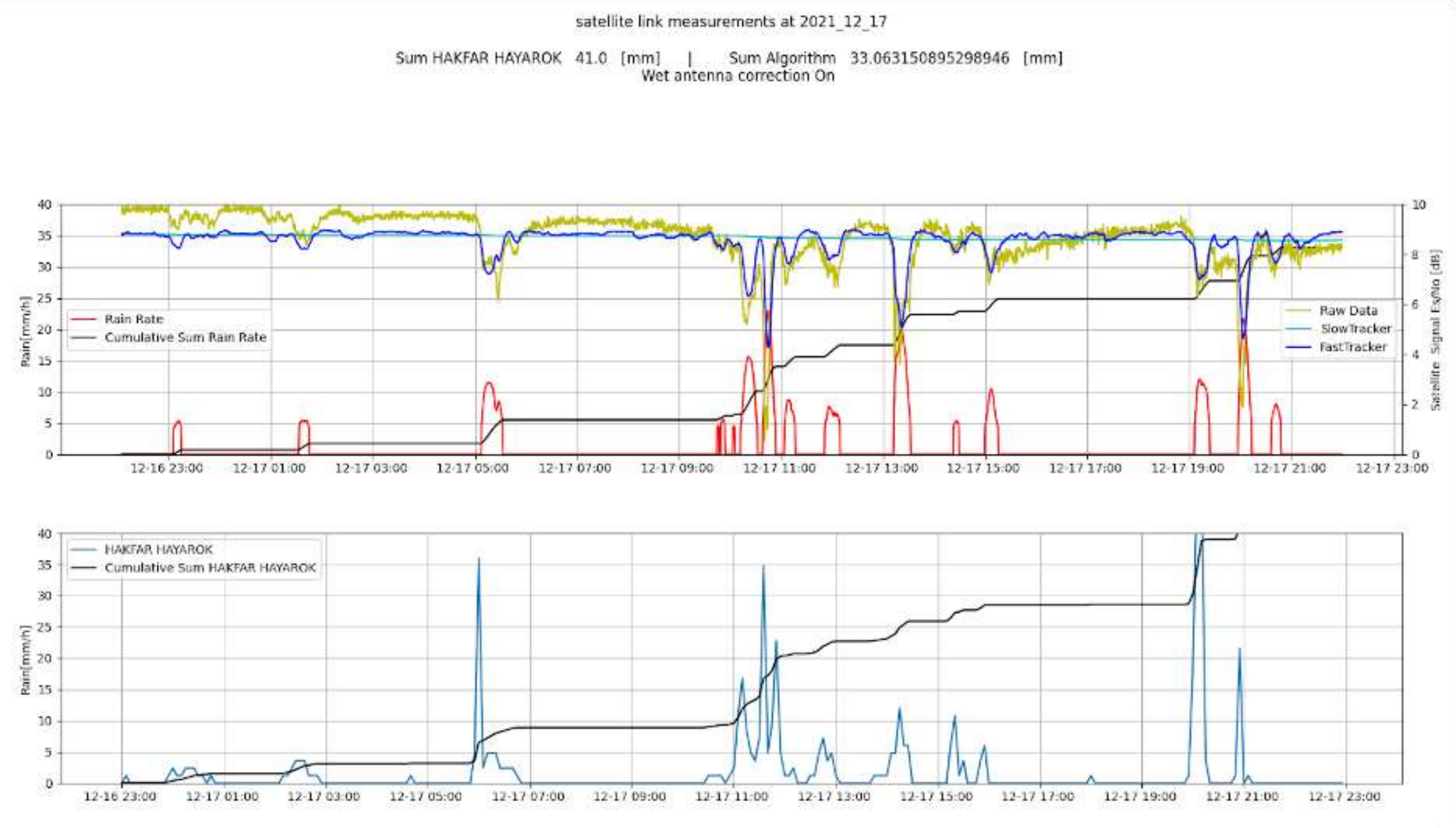

**Rain estimation along 24 hours on the 17-12-2021**

Raw Es/No Data [dB]
KF Fast Tracker output [dB]
KF Slow Tracker output [dB]
Rain Estimation results [mm\h]
Cumulative sum of rain estimation

IMS rain gauge records
CumSum of rain measurements

# Time Series and Rain Estimates

+ Using CML-designed algorithm for other-than-rain attenuation removal

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Ostrometzky, J., & Messer, H. (2017). Dynamic determination of the baseline level in microwave links for rain monitoring from minimum attenuation values. *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing*, *11*(1), 24-33

# Time Series and Rain Estimates

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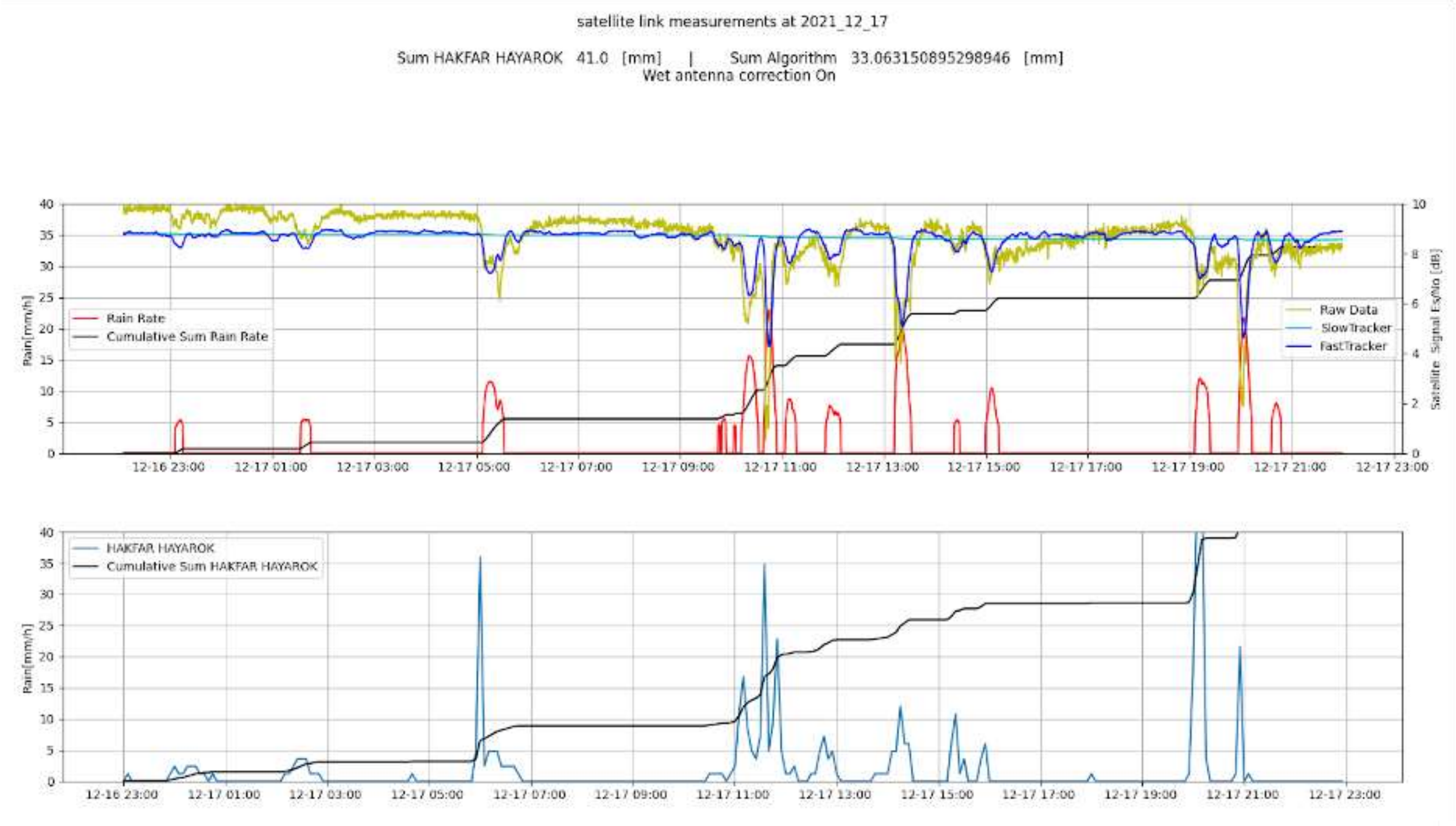


Although not the same, at least some properties, uncertainties, and other physical phenomena are common between CMLs and Sat-links.

This gives us a great head-start!

# Conclusions

- The need to collect rainfall data in rural areas is correlated with deployment of Satellite based IoT terminals
- Number of satellite terminals in Ku, for IoT is expected to be in 100Ks in rural areas
- Satellite IoT networks collect signal quality values rom the terminals – Opportunistic data is available
- Data driven algorithms will provide the estimations

- The IoT over Ku Satellite is a real and growing business. Rainfall estimation part is in early stages
- Ayecka evaluate possible way to share the data and open to cooperate with the community

# Thank you

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