# Towards the Use of Commercial Flights for Data Collection in Wide White Area Networks

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# Outline

**Wide White Areas (WWAs)**

**Data Collection Problems**

**Opportunistic Data Collection Method**

# Wide White Areas (WWA)

- ❑ Wide areas (> $10^4$ km²)
- ❑ Little infrastructures

- ❑ Strategic activities
- ❑ Data collection and analysis need
    - Climate monitoring system
    - Bushfire warning system
    - Pipeline system monitoring
    - Territorial surveillance
    - Mining sites monitoring

Fig.1: Forest type area

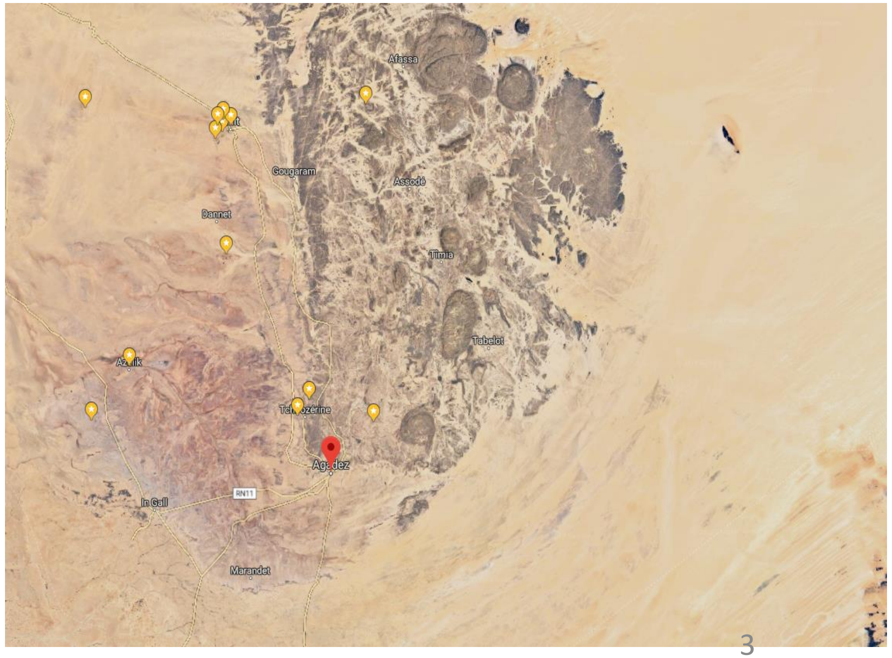



Fig.2: Desert type area

# Data Collection Problems

- ❑ Wireless Sensor Networks and LPWANs
- ❑ Impossible to deploy unique connected network
- ❑ Mobile base station/sink

  vehicle, drones, balloons, satellite

- ❖ Lifetime depends on the mobile collector
- ❖ NP-hard path optimization problem
- ❖ Collector cost

[1] W. Wen, “Energy efficient data collection scheme in mobile wireless sensor networks,” WAINA , Taipei, Mar. 2017.
[2] Mathur, R. H. Nielsen, N. R. Prasad, and R. Prasad, “Data collection using miniature aerial vehicles in wireless sensor networks,” IET Wireless Sensor Systems , vol. 6, no. 1, pp. 17–25, Feb. 2016

# Opportunistic Data Collection Method

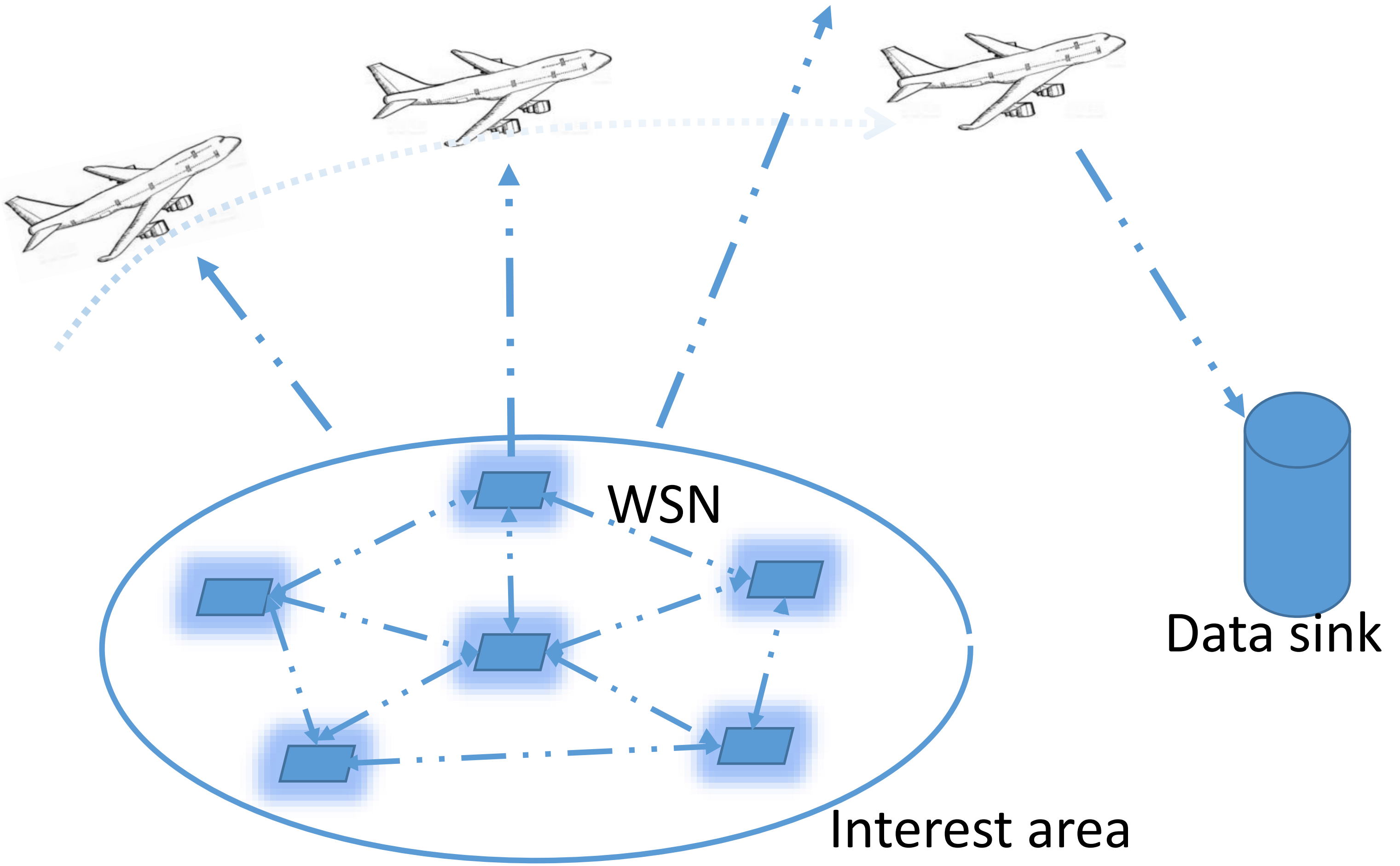



Fig.3: system overview

- Commercial flights
- Navigation real information
- Lora type communication

**Not limited**

**area accessibility**

**embedded energy**

**storage capacity**

# Data Collection Method

## Communication Model

**Background on LoRaWAN technology**

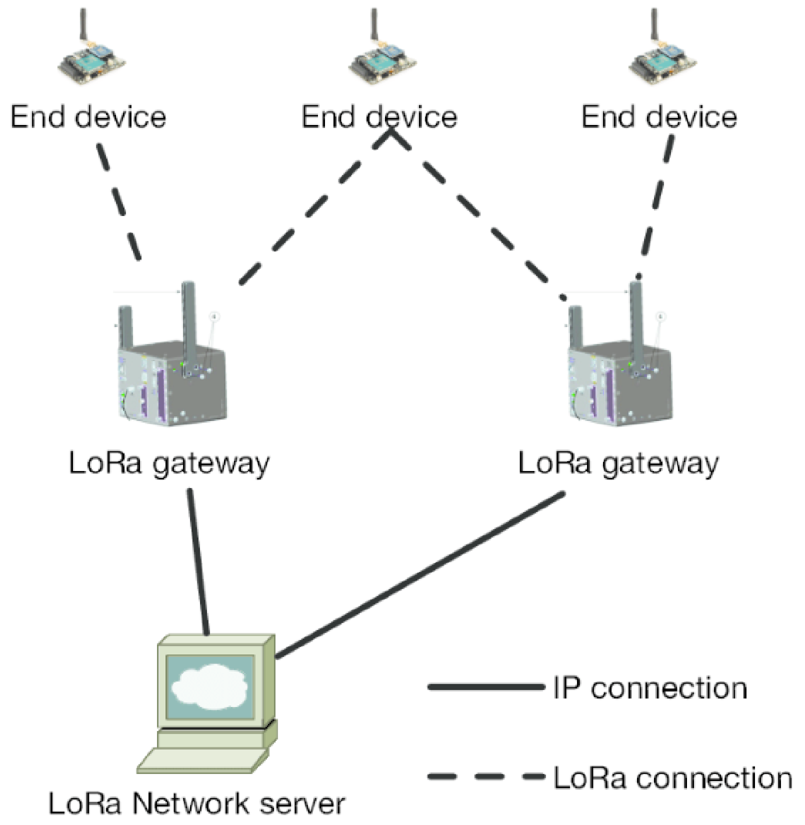
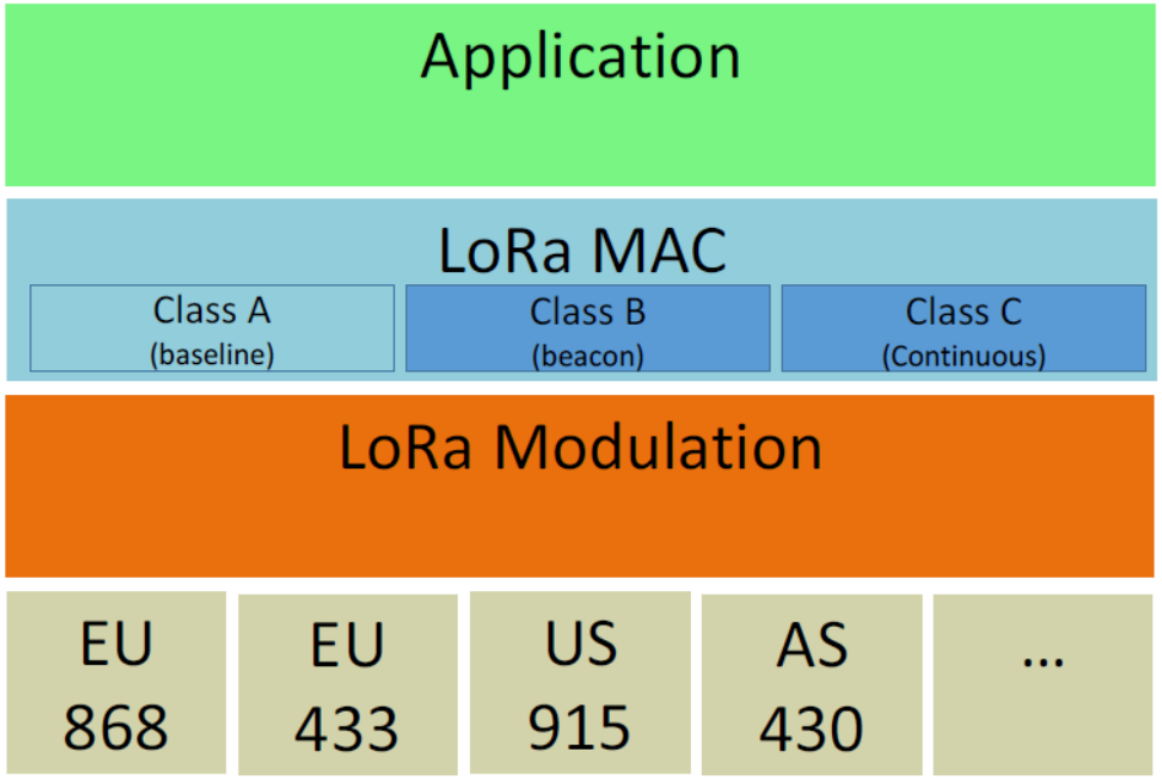



Fig.4: LoRa topology

Fig.5: LoRa layers



# Data Collection Method

## Communication Model

**Background on LoRaWAN technology**

- ❑ LoRa modulation
- ❑ Chirp Spread Spectrum modulation
- ❑ Coding rate (CR)
- ❑ Different spreading factors (SF), 7 to 12
- ❑ Bandwidth (BW), 125 kHz, 500 kHz
- ❑ Adaptive data rate (DR)

Data rate

$$DR = \frac{SF.CR}{\frac{2^{SF}}{BW}} \qquad (1)$$

Sensitivity

$$\psi_r = -174 + 10\log(BW) + NF + SNR \qquad (2)$$

Link budget

$$P_r = P_t + G - L_c - F_m - L_p \qquad (3)$$

Path loss

$$L_p = \overline{L}_p + 10\gamma log(\frac{d}{d_0}) \qquad (4)$$

# Data Collection Method

## Communication Model

| | $SF$=7 | | $SF$=8 | | $SF$=9 | | $SF$=10 | | $SF$=11 | | $SF$=12 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $BW$ (kHz) | 125 | 500 | 125 | 500 | 125 | 500 | 125 | 500 | 125 | 500 | 125 | 500 |
| $\psi$ (dBm) | -123 | -117 | -126 | -120 | -129 | -123 | -131 | -126 | -134.5 | -128.5 | -137 | -131 |
| $L_p$ (dB) | 148.8 | 142 | 151.3 | 145.3 | 153.8 | 147.7 | 149 | 143 | 151.5 | 145.5 | 154 | 148 |
| $d$ (Km) | 10.07 | 9.07 | 11.7 | 9.9 | 12.53 | 10.74 | 13.38 | 11.47 | 14.3 | 12.25 | 15.29 | 13.11 |
| $DR$ (Kbps) | 5.46 | 21.87 | 3.12 | 12.5 | 1.76 | 7.03 | 0.976 | 3.91 | 0.537 | 2.14 | 0.292 | 1.17 |

Tab.1: LoRa parameters trad-off

# Data Collection Method

## Aircraft Mobility Model

### Real route information

- Open Flights : 68 000 routes, 4 000 aéroports
- Route= set of waypoints (VOR and DME)

### Aircraft position over a route

$$M(t) = V(t - t_0) + M_0 \qquad (5)$$

### Coordinates system

ECEF: Earth-Centered, Earth-Fixed

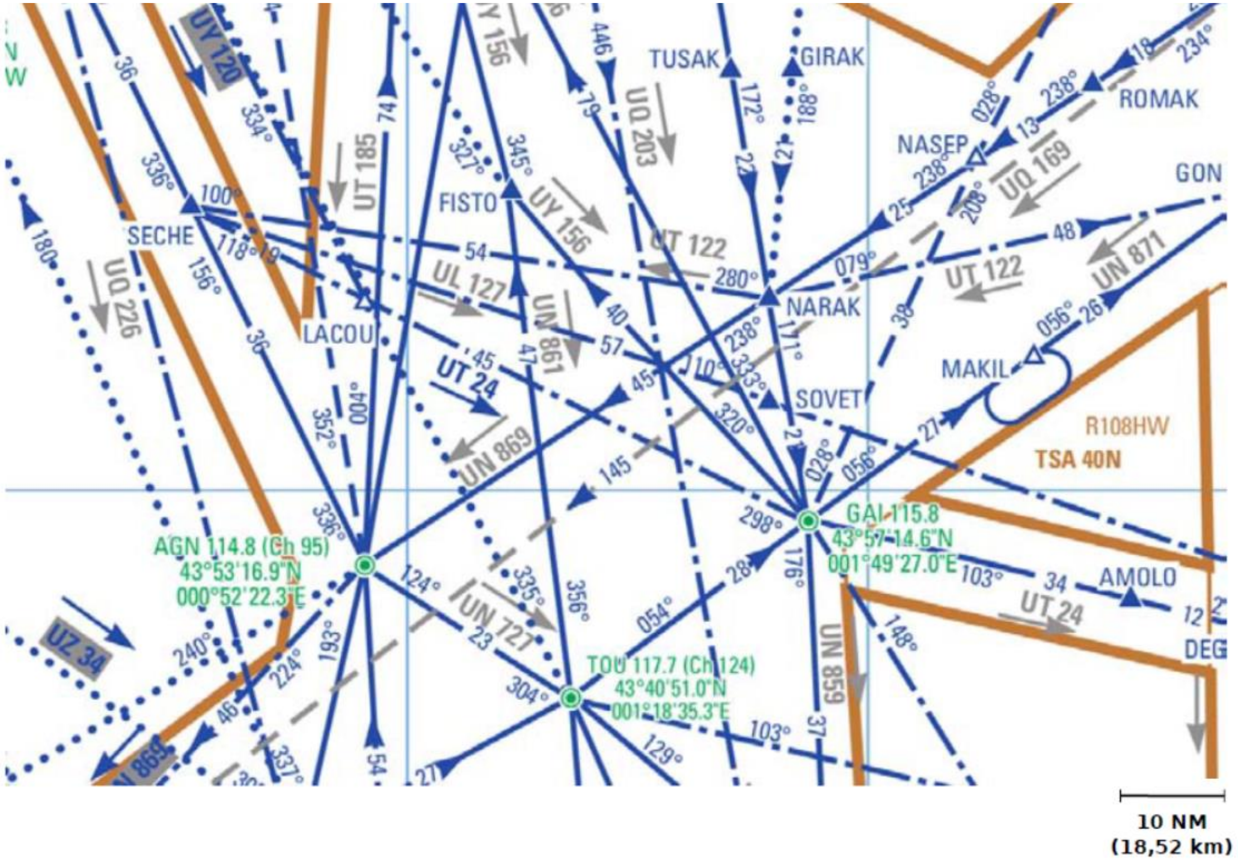



Fig.6: Route planning around Toulouse

[3] Brunilde GIRARDET . « Trafic Aérien : Détermination optimale et globale des trajectoires d'avions en présence de vent ». Thèse de doct. Institut National des Sciences Appliquées de Toulouse (INSA de Toulouse), 2014.

# Data Collection Method

## Communication Window: CW

Aircraft trajectory

$$\begin{cases} X(t) = V_x(t - t_0) + X_0 \\ Y(t) = V_y(t - t_0) + Y_0 \\ Z(t) = V_z(t - t_0) + Z_0 \end{cases} \qquad t > 0 \qquad (6)$$

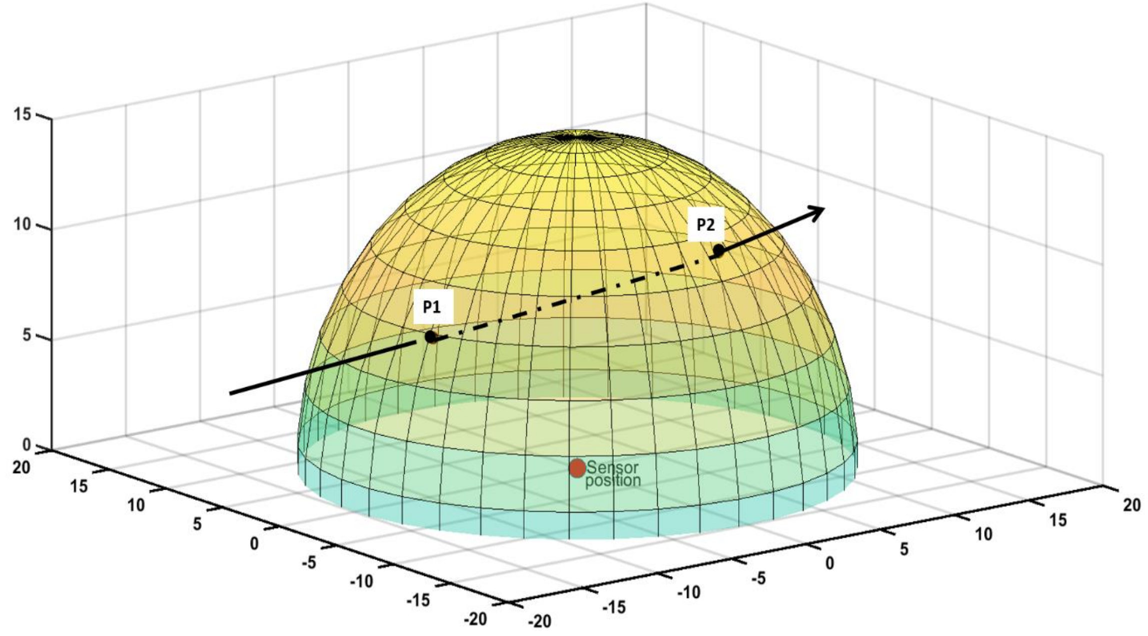



Fig.7: Sensor range

Sensor communication range

$$(X(t) - C_x)^2 + \left(Y(t) - C_y\right)^2 + (Z(t) - C_z)^2 = d^2 \qquad (7)$$

$$\boldsymbol{CW = |t_1 - t_2|} \qquad \textbf{(8)}$$

# Data Collection Method

## Collection Volume CC

- Data Rate $DR$
- Communication Windows $CW$

$$cc = \sum_{i \in N} DR_i . CW_i$$

## Collection Throughput CT

- Aircraft number $N_A$,
- Observation duration $O_d$

$$CT_i = CC_i . \frac{N_A}{O_d}$$

# Interest Area

**African Sahara Desert: Wide White Area**

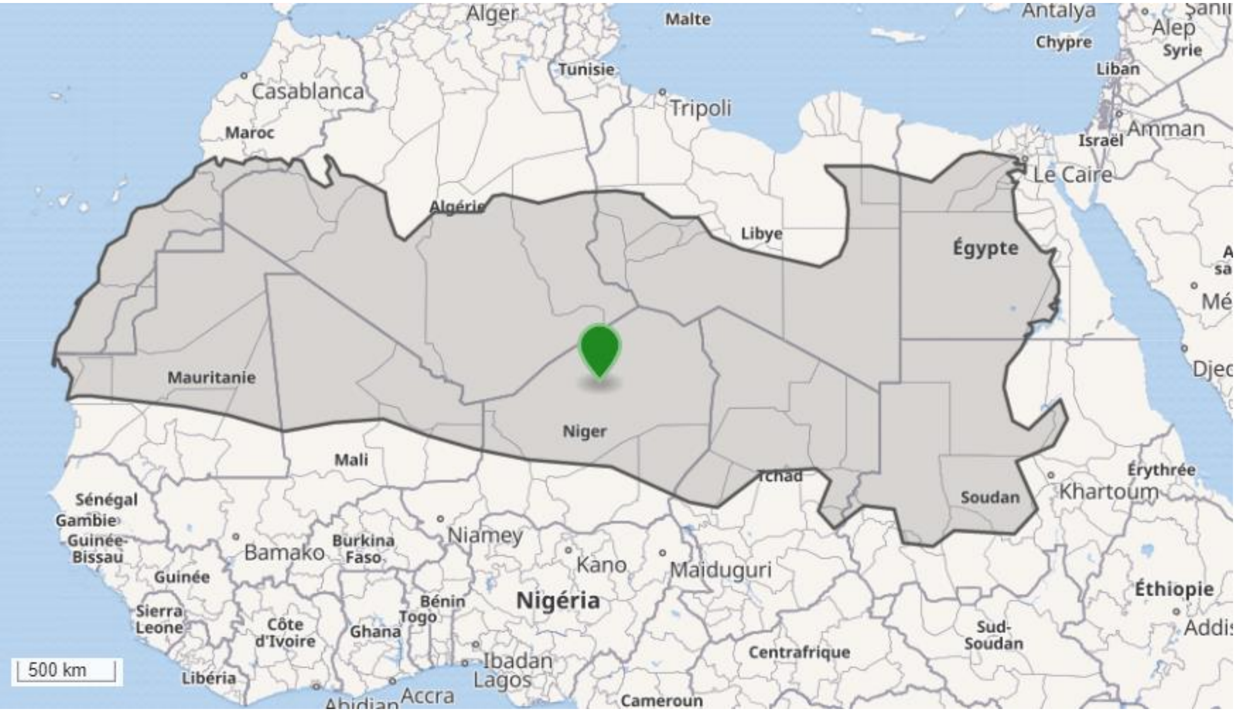



Fig.8: Sahara desert

Dimensions

- Length 4800 km
- Width 2000 km
- >9 200 000 km²

**Potentials**

Mineral resources

More then 2000 billions m³ of freshwater

**Needs**

Protect from radioactive dust

Climate studies

Secure people

Logistic for soldiers

**Barriers**

Few communication infrastructures

[4] J. Gonçalvès et al. « Quantifying the modern recharge of the "fossil" Sahara aquifers ». In : Geophysical Research Letters 40.11 (juin 2013), p. 2673–2678
[5] Nappe https ://www.iaea.org/sites/default/files/18/07/sahelniger-160712.pdf, retrieved 19-06-2019

# Evaluation

## Scenario

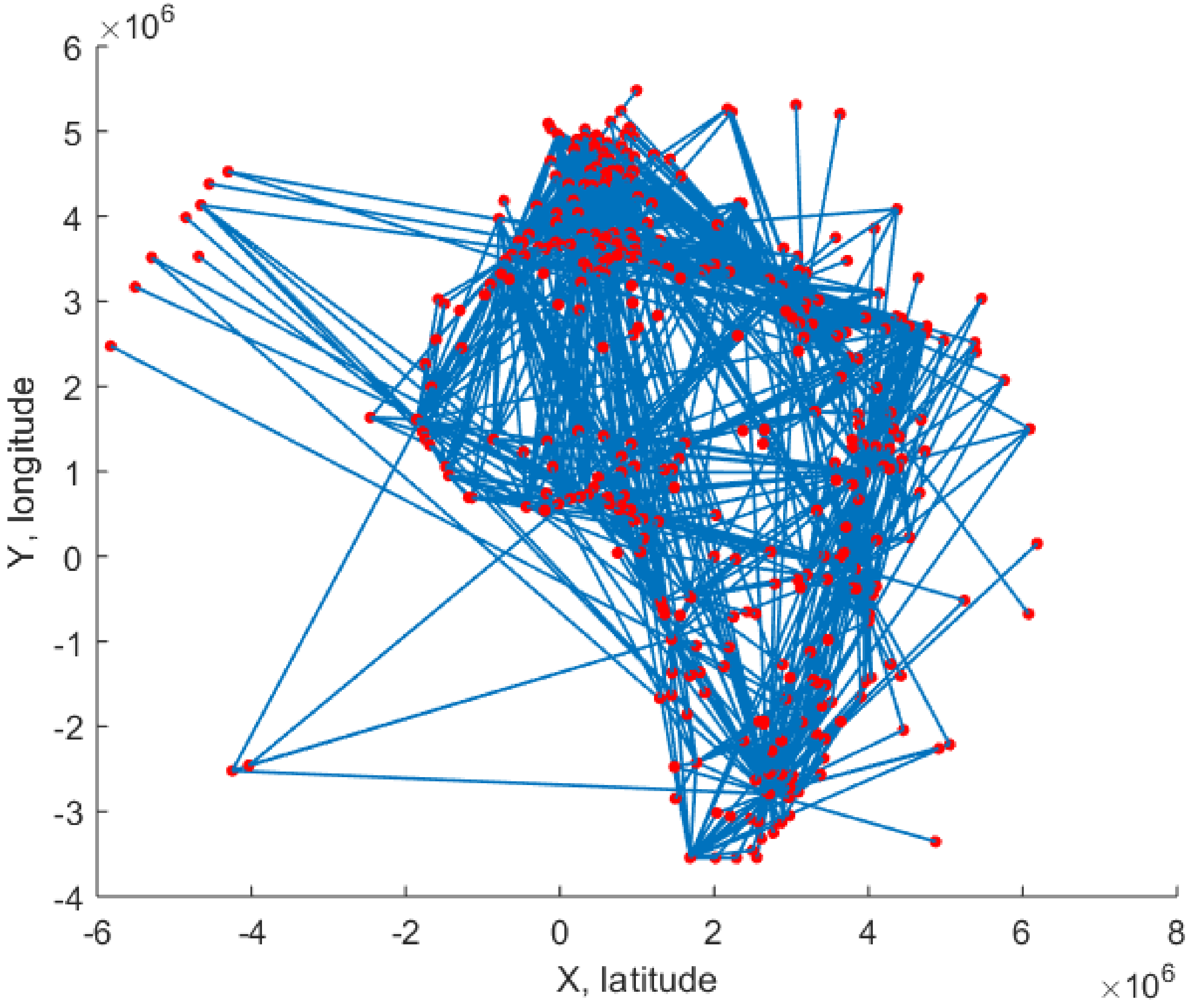



Fig.9: Routes crossing over Africa

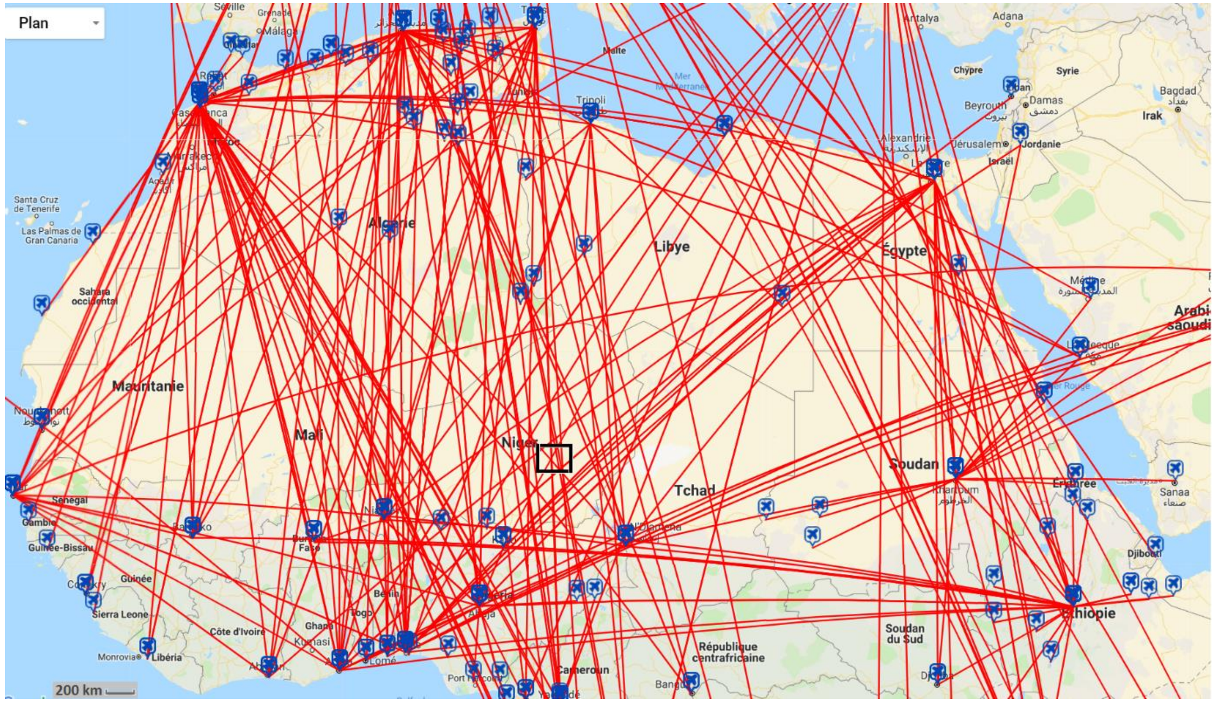
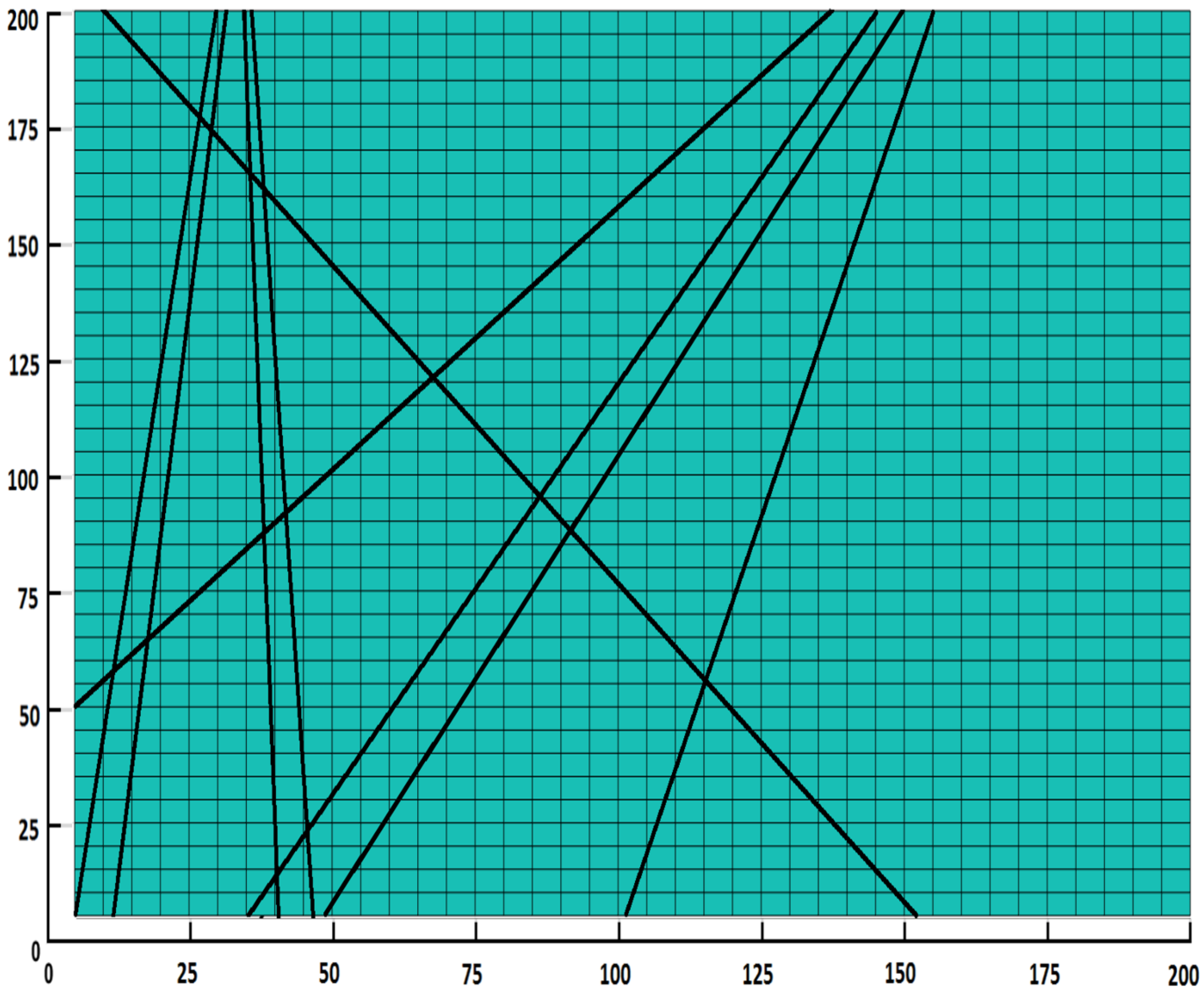



Fig.10: Routes over Sahara

# Evaluation

## Scenario: Over 40 000 km²

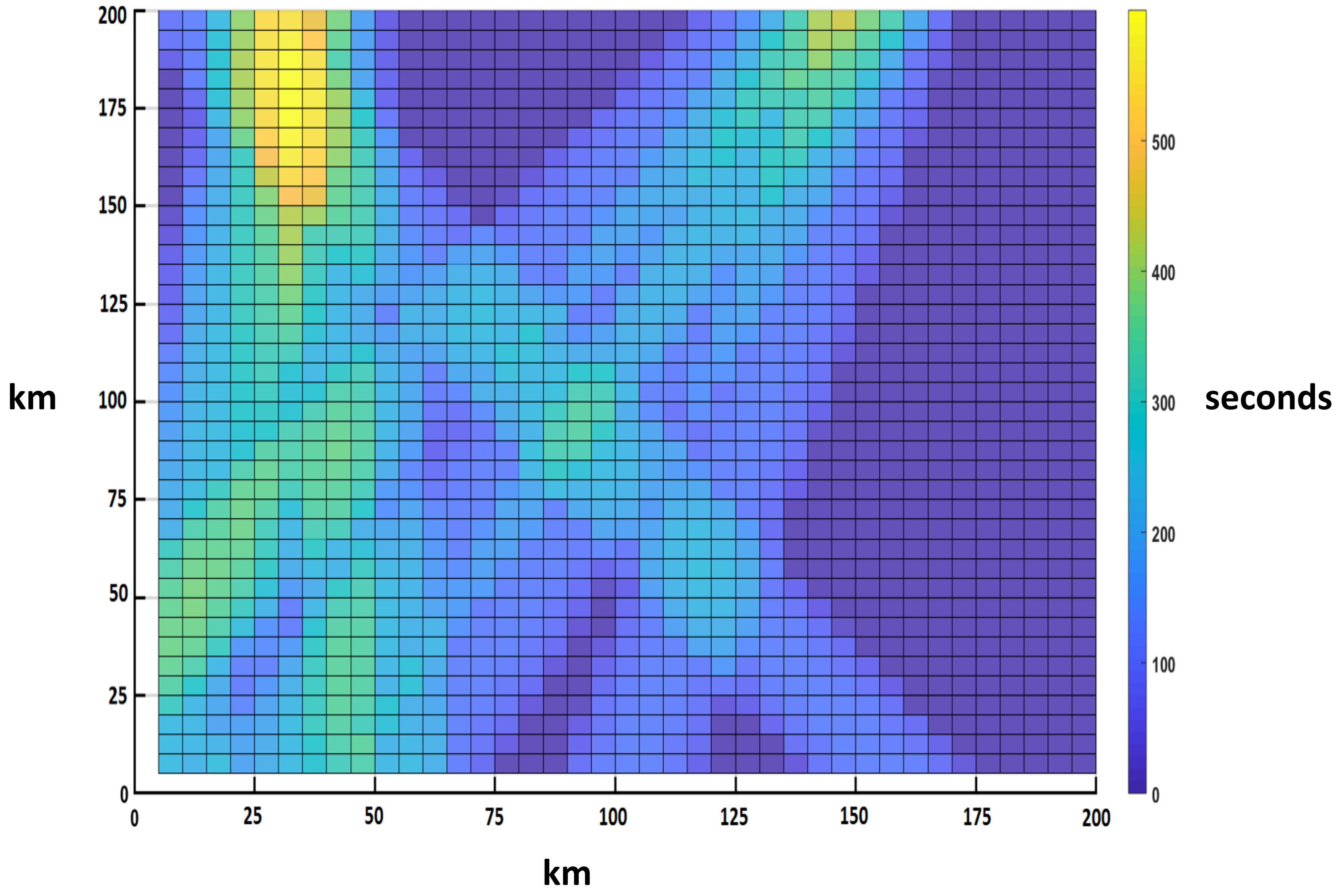



## Metrics

- Pixels coverage rate;
- Communication window;
- Collected data volume;
- Mean throughput.

# Results

## Contact time (Communication Window)




- 500 seconds
- Yellow pixels: best coverage
- Some uncovered pixels

# Results

## Throughput comparison in the same bandwidth

Fig.11: SF=7

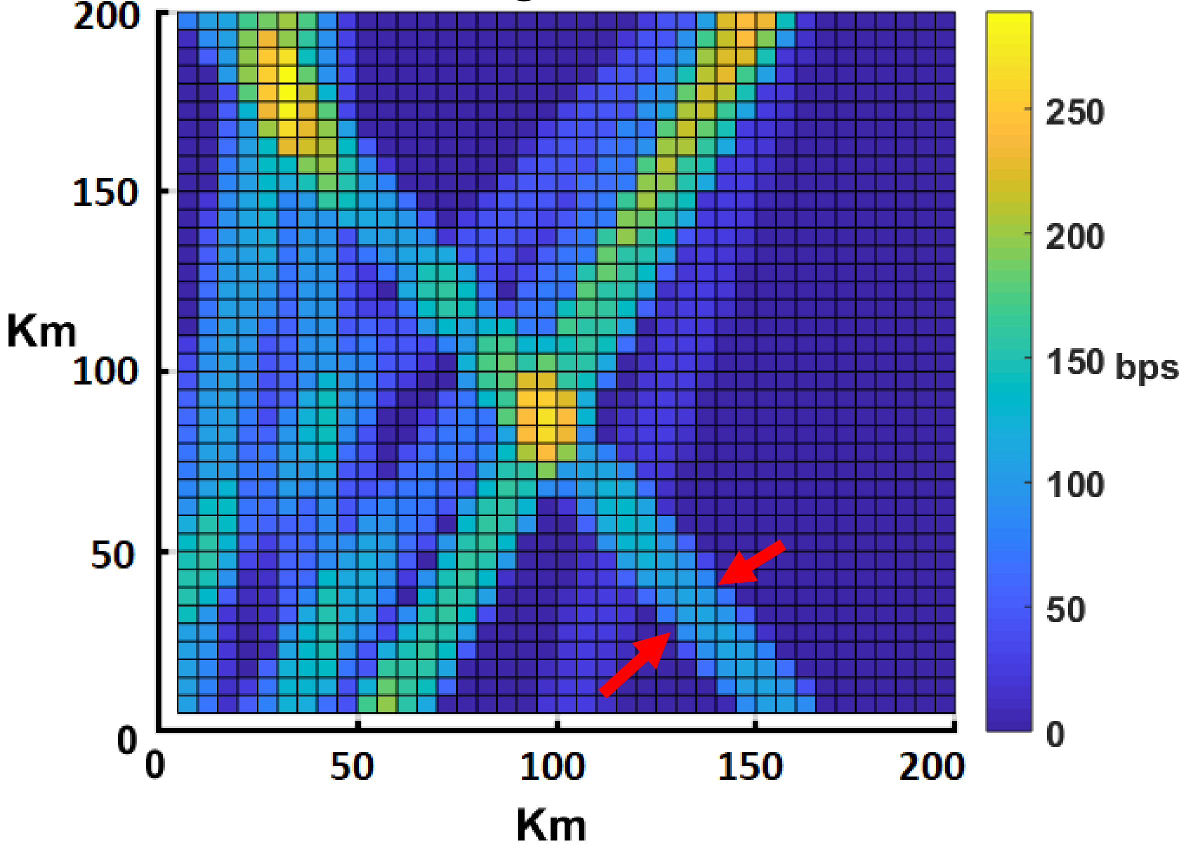
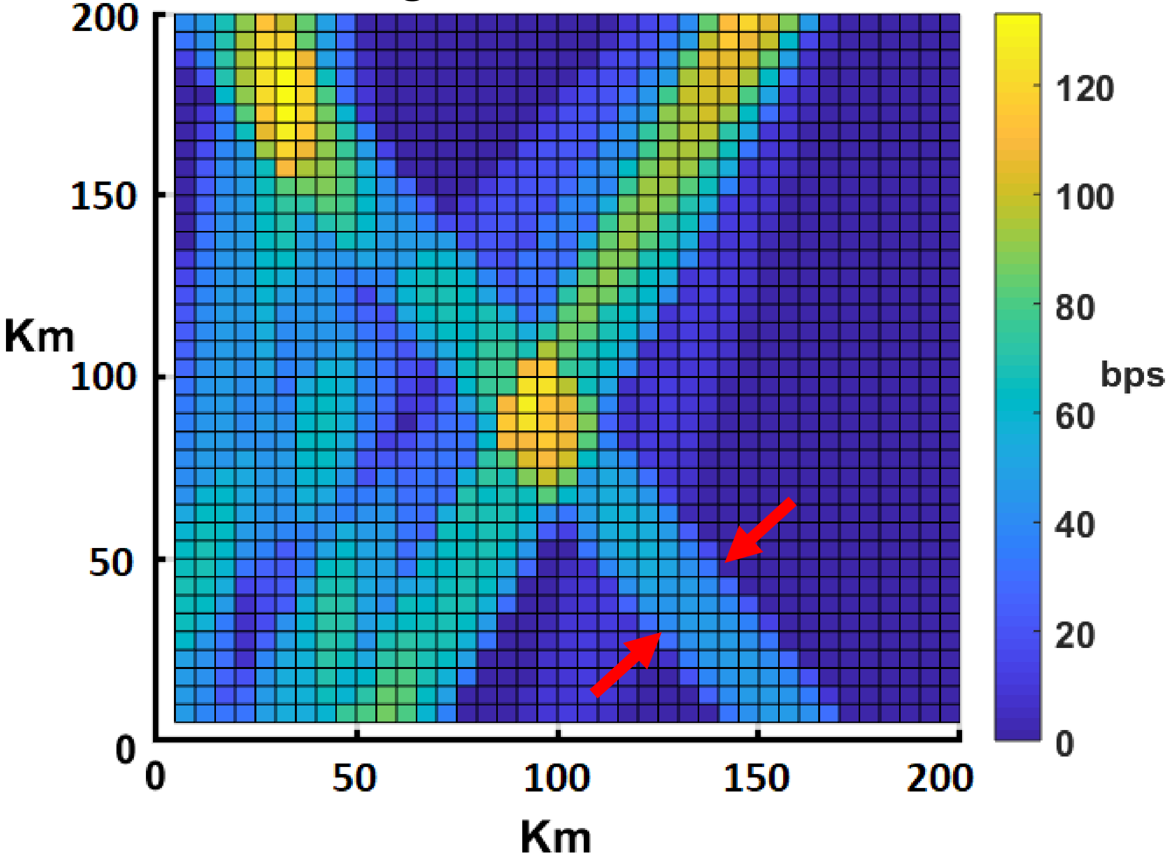


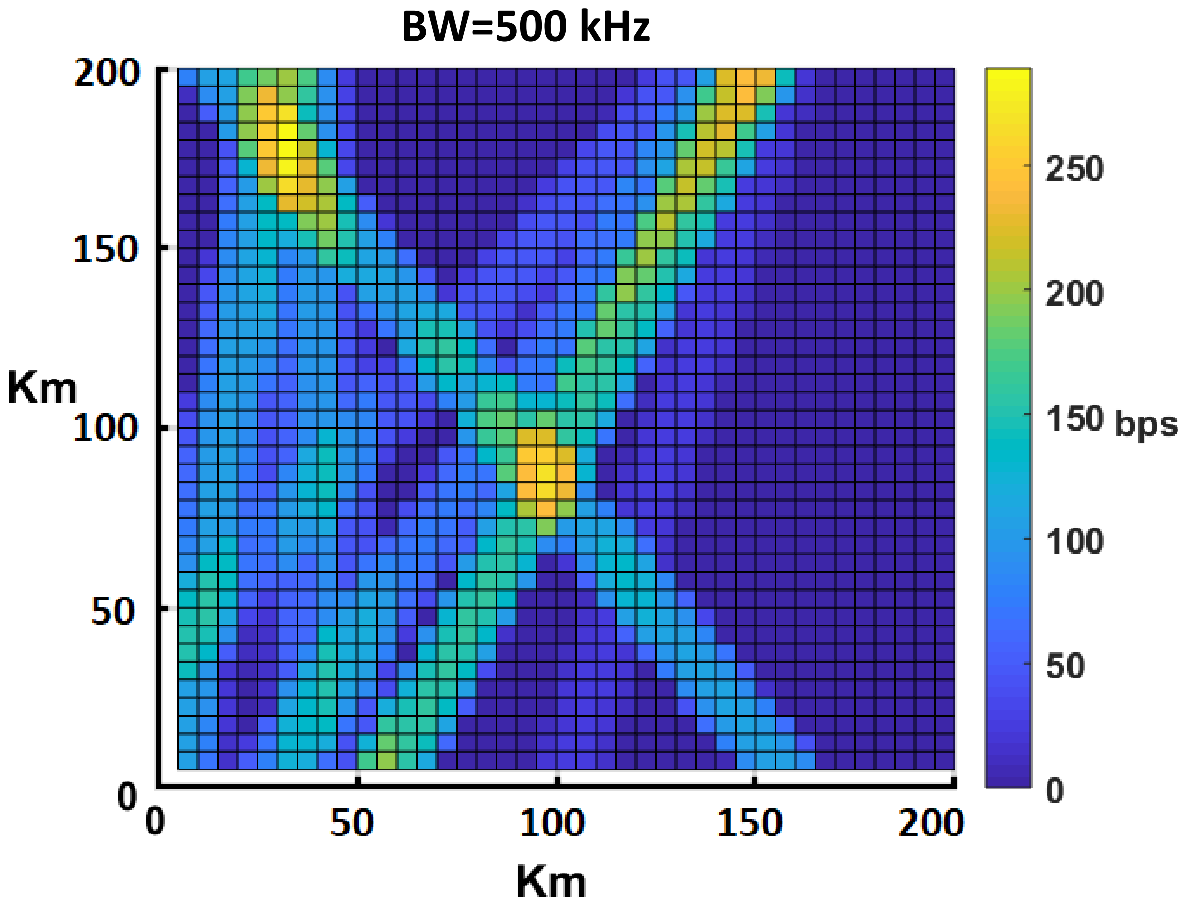

Fig.12: SF=10

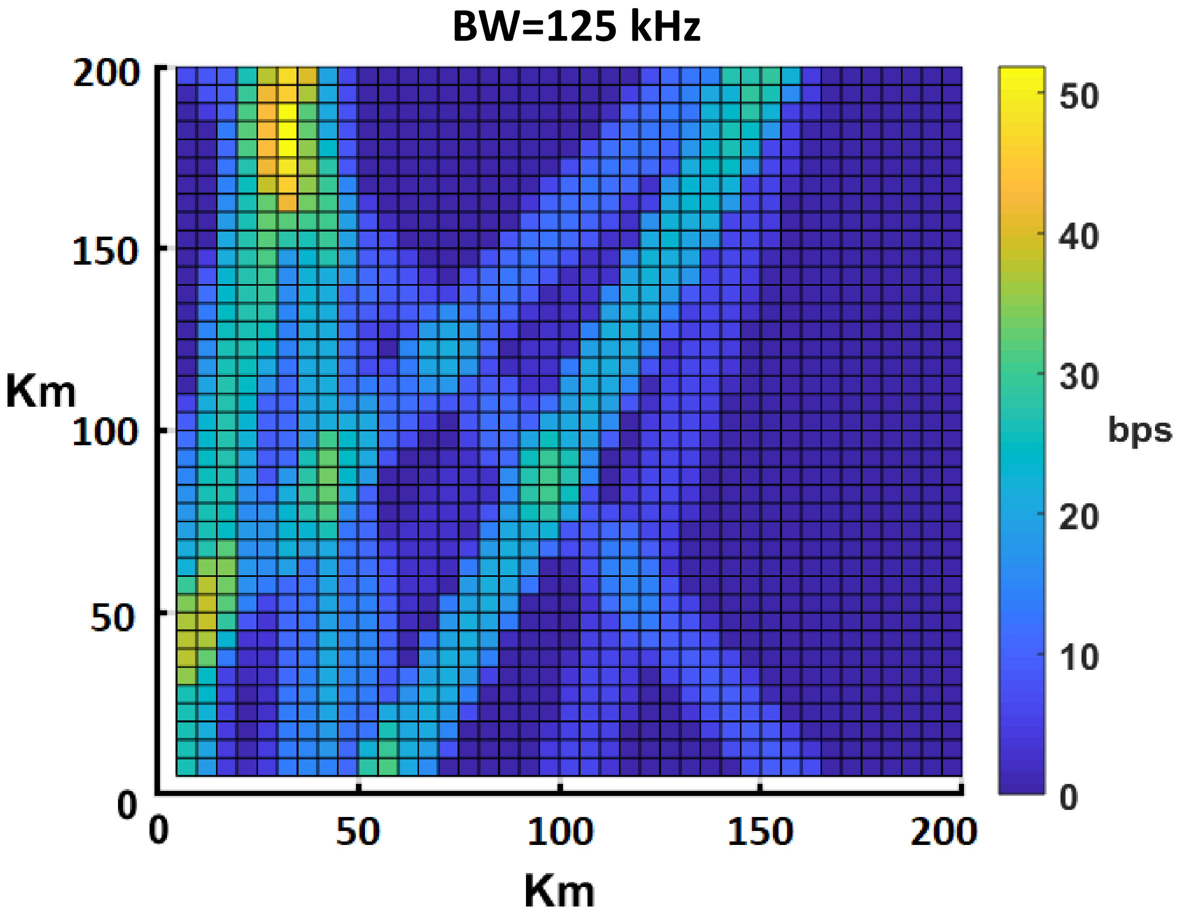



- High SF, more range
- Low SF, high throughput

# Results

## Throughput comparison for fixed spread factor (SF=7)

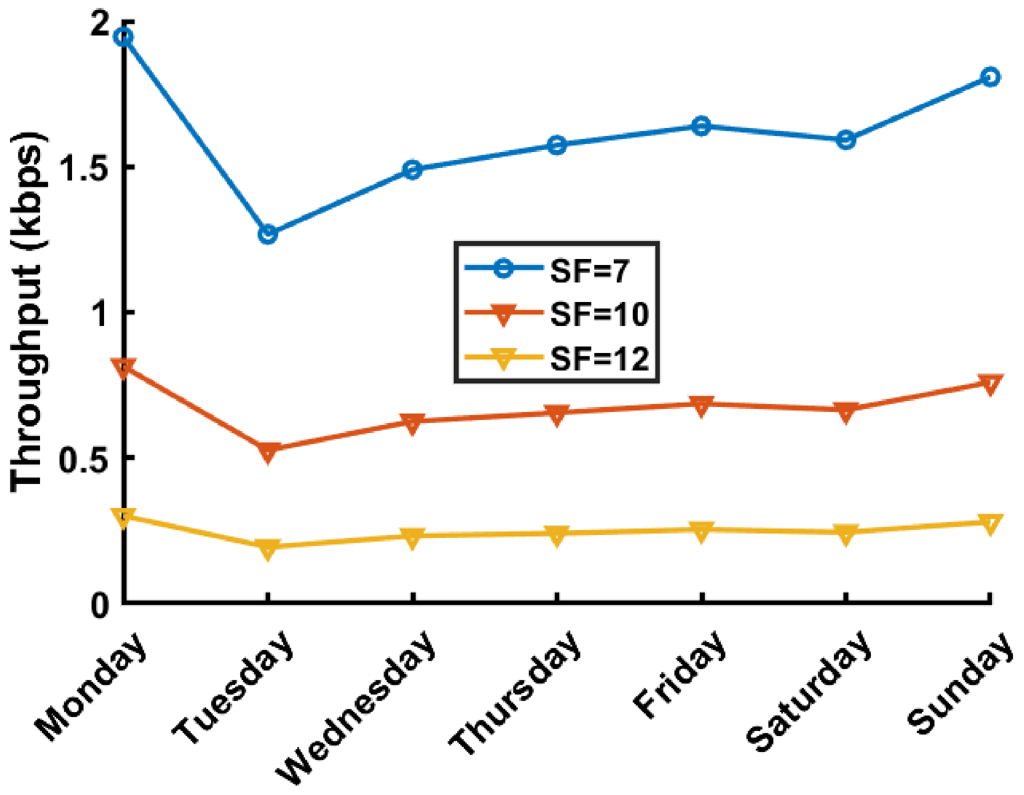


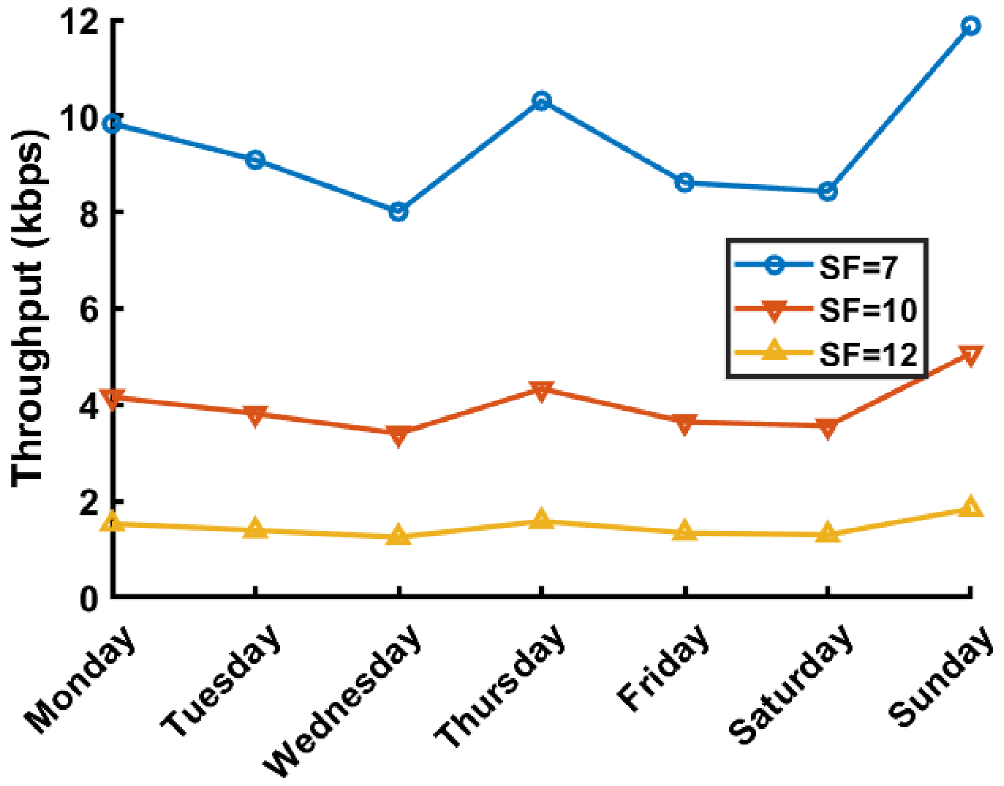

- Collection efficiency, SF=7 and BW=500 kHz

# Results

## Throughput during an observation duration of a week




BW=125 kHz




BW=500 kHz

# Conclusion

- ❑ Data collection in Wide White Area Networks
- ❑ Use of commercial flights.
- ❑ Contact time; Collected data volume; Collection throughput.
- ❑ International Conference on Wireless and Mobile Computing, Networking and Communications (WiMob 2019).

## On going work

- The hole Sahara desert as interest area.
- Scenario for data delivery
- Improving the area coverage

# Thank you