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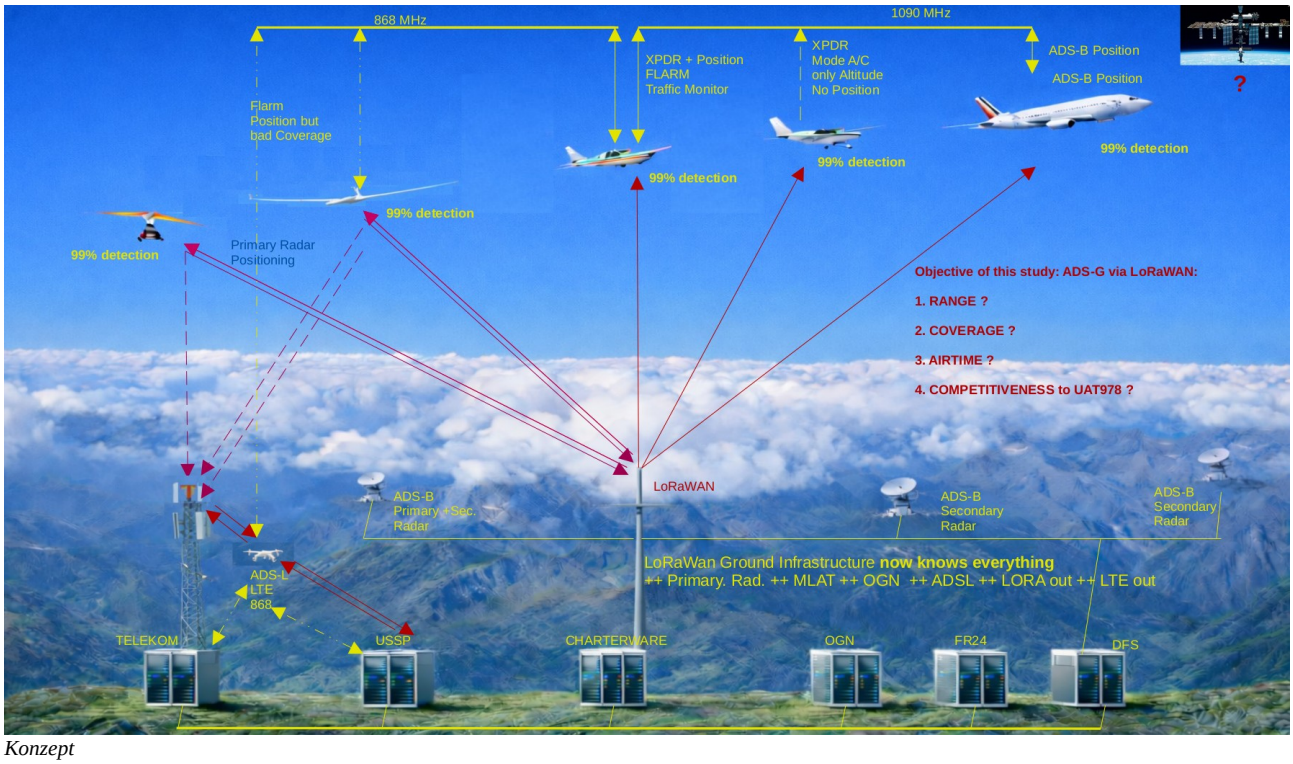
Kofinanziert vom
Land Rheinland-Pfalz

R&D Project ADS-G
Interoperable Traffic Monitoring
for all plane categories in all air spaces

(short form summary)



Konzept

The problem regarding today's incompatibility of different collission avoidance systems is commonly known. There is (yellow lines) 1090 MHz carriers for ADS-B and old Mode A/C Transponders and there is 868MHz which contains ADS-L and FLARM information. On the ground there is receivers for those data on air as well, but even more data based on Primary Radar, Multilateration, Glider networks or USSP Server are available. If migrated together the ground has a more complete traffic picture but still gaps when it comes to low flying altitudes.

There is already a US originated single directed broadcast transceiver technology available called UAT978 to transfer migrated ground information into the air. But the IoT solution would be a bidirectional private internet link between planes and ground. That would not only be applicable for weather and traffic but also for other purposes like a low

altitude transponder enhancement, an ELT function, a flight logger and even a slow SATCOM replacement. Also the mass produced transceivers and base stations are a lot cheaper. The goal of this research project was to find out wether the IoT technologies LTE NB-IOT and LoRaWAN as internet radio carrier can fulfil the requirements regarding range, coverage and legal airtime consumption to implement a powerful anti collission assistance system.

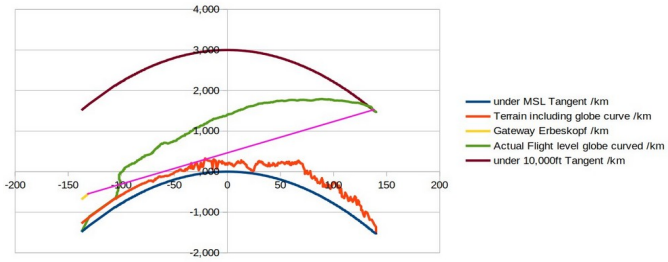
To check about the archievable range and coverage a mobile base station was placed on the Erbeskopf on Hunsrück and a plane was equipped with device transceivers for IOT-NB and LoRaWAN together with their suitable antenna.

Testhardware

We did 3 range test flights. After some optimizations we archieved reliable 280km maximum distance.

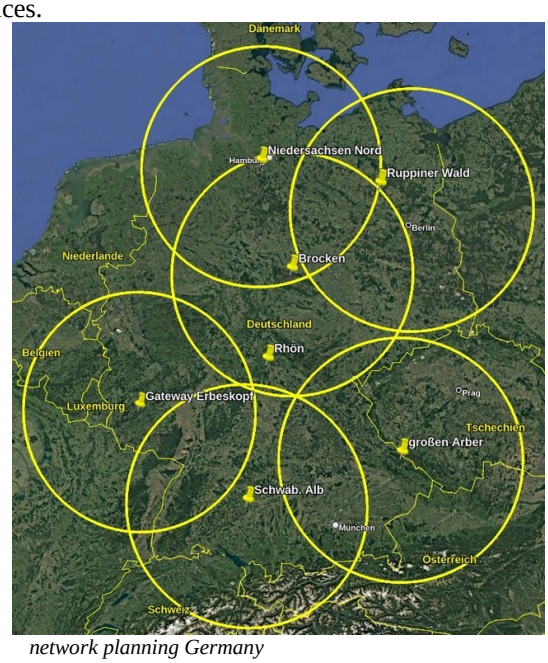
Tracks of range test flights received on the internet server

Further analyzing the logs on the Server we found that the receive signal strength is not the limit but only the horizon. One can see this in the following graph where the magenta free line of sight was interupted by terrain above globe curve after 280km.



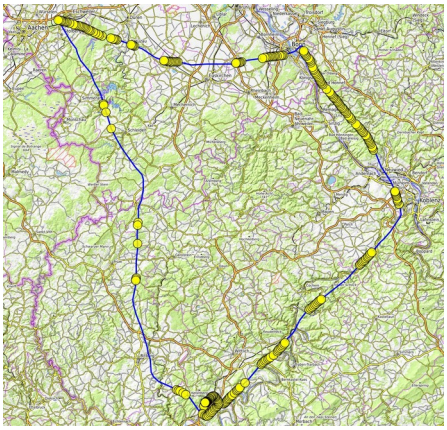
only the Interuption of the free line of sight limits the range.

In practise from a range point of view only 5 stations will be needed to cover Germany. As mass produced transceivers their basic cost is just 600€/piece. They are low power devices consuming just 1,5W and can therefore be powered solar and connected to the internet via an LTE mobile network. The total cost of an autonomous gateway trailer solution is around 3000€. The cost for the transceiver in the plane is derived from cheap components which are in use in other mass produced IoT devices.

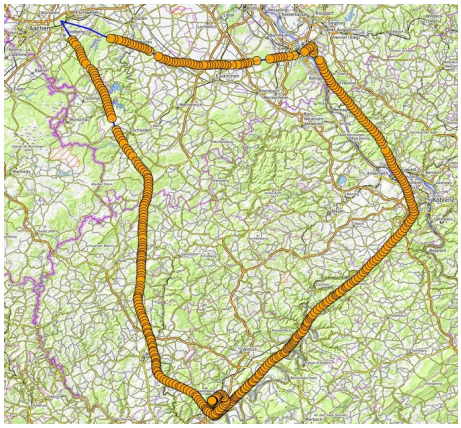


network planning Germany

Next a coverage test flight was done around Eifel at variing 3000-6000ft Gnd altitude.



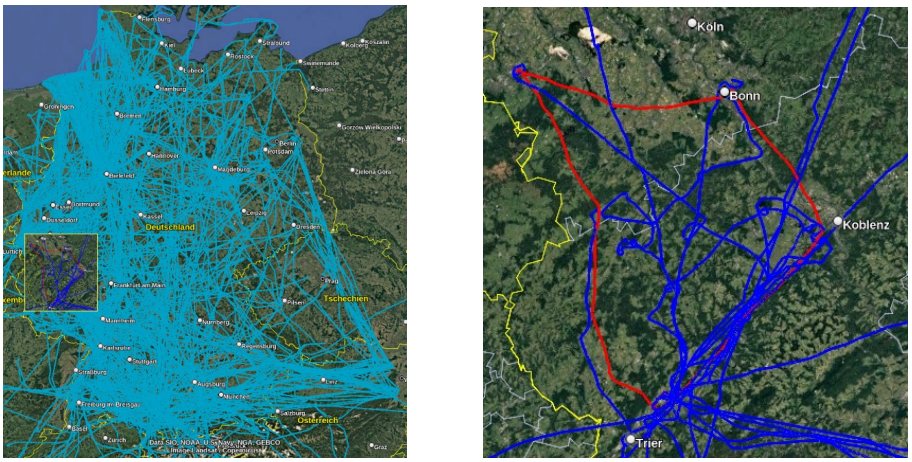
coverage IOT-NB



LoRaWAN

The coverage test flight from Trier via Koblenz, Bonn, Achen back to Trier showed that IOT-NB is only available above cities or highways up to 3000ft whereas LoRaWAN fully covers higher altitudes. Both systems together archieved 97% coverage and can be further enhanced to 100% when using a public LoRaWAN for the 3% gap.

The last point of clarification was the traffic capability of LoRaWAN. ETSI legally limited a maximum airtime consumption of 10% for base station warnings and 2,7% for the plane's transmissions. We defined some rules to deal with that shortage and set up a simulation to verify their performance.



Traffic und subset of tracks who's plane appeared in 10km distance only

We used 1300 flight tracks and replayed them simultaneous with our coverage test flight. The left picture shows the traffic image, the right one shows only those flight tracks which appeared in the 10km environment of our plane on it's coverage test flight. We could vary the availability of a mobile network, the speed of the LoRa connection and the traffic as different inputs.

CASE	INPUTS			1 GATEWAY serving 25 planes			1 PLANE no XPNDR		
						# per 2h40 flight	times per h		
	PLMN Access	SF	TRA	# WARN PLMN	# WARN LOR	Time WARN LoR *25/h	#POS OUT PLMN	#POS OUT LOR	POS time LoR /h
1. BASIC	logs	logs	0	0	0	0	9	22	12s=0,3%
2. SF12	logs	12	0	0	0	0	9	22	14s=0,4%
3. NONET	no	logs	0	0	0	0	0	31	16s=0,4%
4. TYPICAL	logs	logs	1300	13	21	175s=4,8%	15	110	65s=1,8%
5. WORST	no	12	1300	0	34	300s=8,3%	1	124	77s= 2,1%

Simulation results

We assumed 20 gateways in Germany at the time of subscriber saturation and 1300 planes in the airspace of Germany. The gateway was considered to talk to 25 planes via Lora and 25 planes via IOT-NB. None of our simulation test cases violated the legal allowed airtimes in both direction under these settings. That means, the system cannot only be used as ground2air warning link but also as a transponder enhancement or the poor man's or drohne's only position out system. In low flying altitudes it can still provide tracking when primary and secondary radar fail.