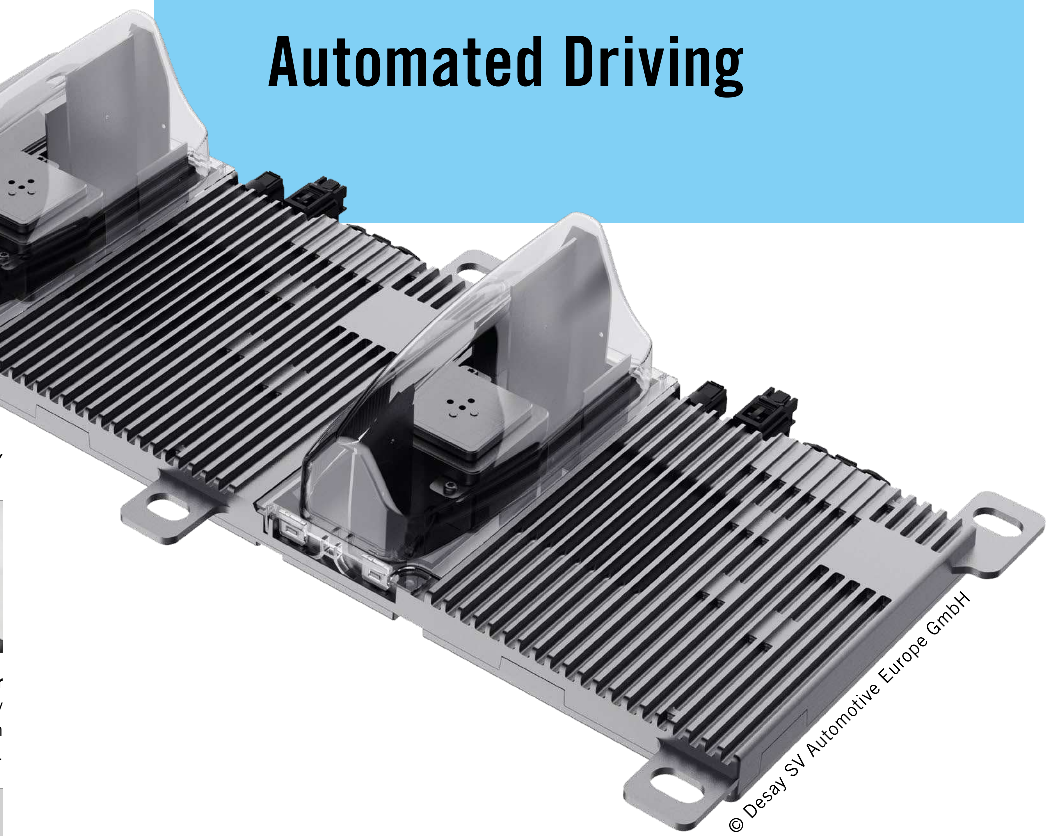
Redundant Telematics Control Unit for Automated Driving



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A redundant data connection plays an important role for automated driving functions. In order to evaluate the advantages of such a system, VW Commercial Vehicles commissioned Desay SV to develop a telematics and measurement concept and test it in practice.

Data coverage plays an important role in the development of telematic units for vehicles with automated driving functions, especially at levels 4 and 5 [1, 2]. The redundancy of the system is required by legislative demands and ensures a comprehensive solution. For example, the German legislator has stipulated that motor vehicles with Autonomous Driving (AD) functions must be able to “ensure sufficiently stable radio connections that are protected against unauthorized interference, in particular to the technical supervisor, and independently put the motor vehicle in a state that minimizes risk if this radio connection is interrupted or accessed without authorization” [3, 4]. To evaluate the overall reliability of the system, the measurement system and further data post-processing are very important.

The performance evaluation of telematics systems is predominantly digital or semi-digital [5, 6]. The results of such tests depend heavily on the accuracy of the digital models. While telematics control units (T-box), MIMO antennas and the dynamic radio channel can be modeled very well digitally [7, 8], this does not apply to the configuration of the base stations of different network operators. The reason for this is that the data is not publicly available. This article therefore presents a telematics and measurement concept that has been verified by road tests in a real network environment

Redundant data connection becomes the standard for vehicles with automated driving functions at levels 4 and 5. A single modem solution presents significant risks, as continuous data coverage may not be ensured. Some level of system redundancy is necessary; however, it leads to higher investment costs for development and an increased unit price of the product. To compare the benefits of the developed redundant system, a unique measurement tool was created by Desay SV. To conduct the tests, a project team was set up in 2024 including experts from VW Nutzfahrzeuge and Desay SV. The measurement tool enabled real-time data collection, followed by post-processing. The reliability of the system was tested under various conditions. Primarily major cities in Germany were investigated, but also rural areas and highways. This article considers the results in an urban environment.

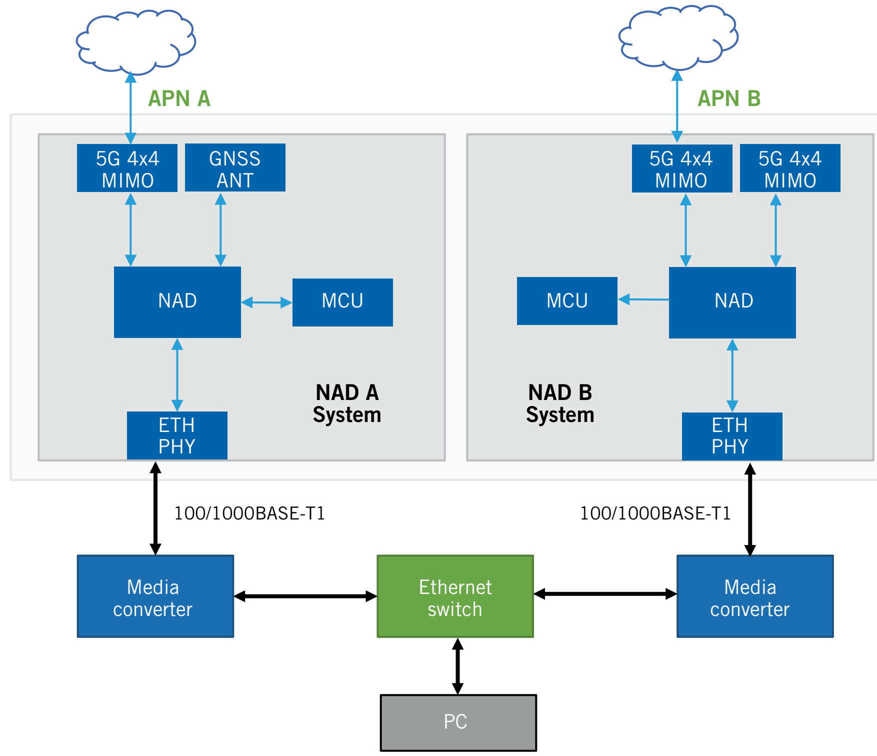

FIGURE 1 System interface diagram (© Desay SV Automotive Europe GmbH)

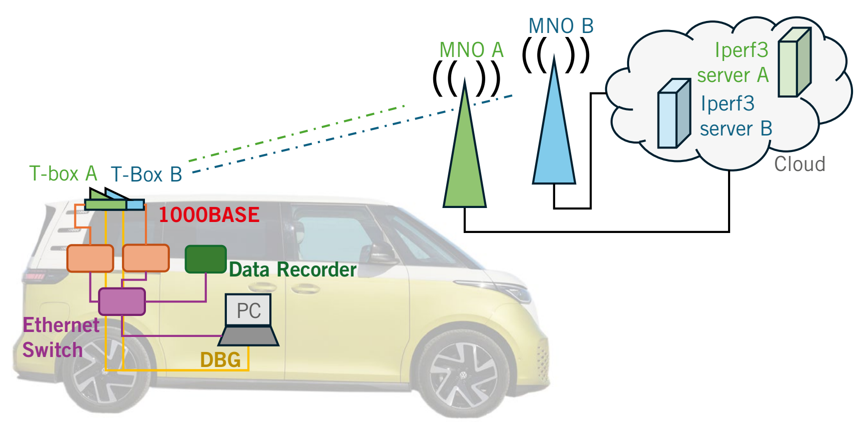

FIGURE 2 Schematic of measurement setup (© Desay SV Automotive Europe GmbH)

SYSTEM LEVEL DIAGRAM

Two identical NAD systems were used to form the dual Network Access Device (NAD) system for this project. **FIGURE 1** shows the complete system concept for this dual NAD solution. The NADs are connected through an ethernet switch to a PC, which is symbolic for the vehicle with its AD data signal processing, up- and download. The PC is used for running all tests and data logging of test results. Both NADs use 5G USIM each for cellular connectivity through a 4x4 MIMO antenna system. Two dedicated EU APNs of major MNOs, namely APN-A and APN-B are configured in NAD-A and NAD-B, respectively for connectivity with the backend servers.

MEASUREMENT SETUP AND TEST CONCEPT

FIGURE 2 shows a sketch of the measurement setup for the full vehicle road tests. Integrated in the car roof are two T-Boxes inside a common housing, where each T-Box has its own SIM-card, using Vodafone MNO for the first, and T-Mobile MNO for the second. The measurement PC is connected to the T-Boxes via USB to access the debugging interface for retrieval of system and network parameters. Additionally, 1GB ethernet connects the T-Boxes with the PC via an ethernet switch. Media converter in the network translates from automotive 1000Base-T1 to Gigabit ethernet. A data logger records the temperatures of the T-Boxes and NADs sensors, as well as voltage and current. Each T-Box connects to its MNO and can access a dedicated iperf3 server in the cloud. The measurement setup is powered by a DC/AC (12 to 220 V) converter.

The main focus of mobile communication data transfer has been the downlink so far. Automated driving algorithms for level 4 and 5 require a strong data connection to the backend. The uplink data rate gets more and more important because the tremendous amounts of data produced by the cars sensors such as camera, lidar, radar shall be processed in the backend to make AD decisions but

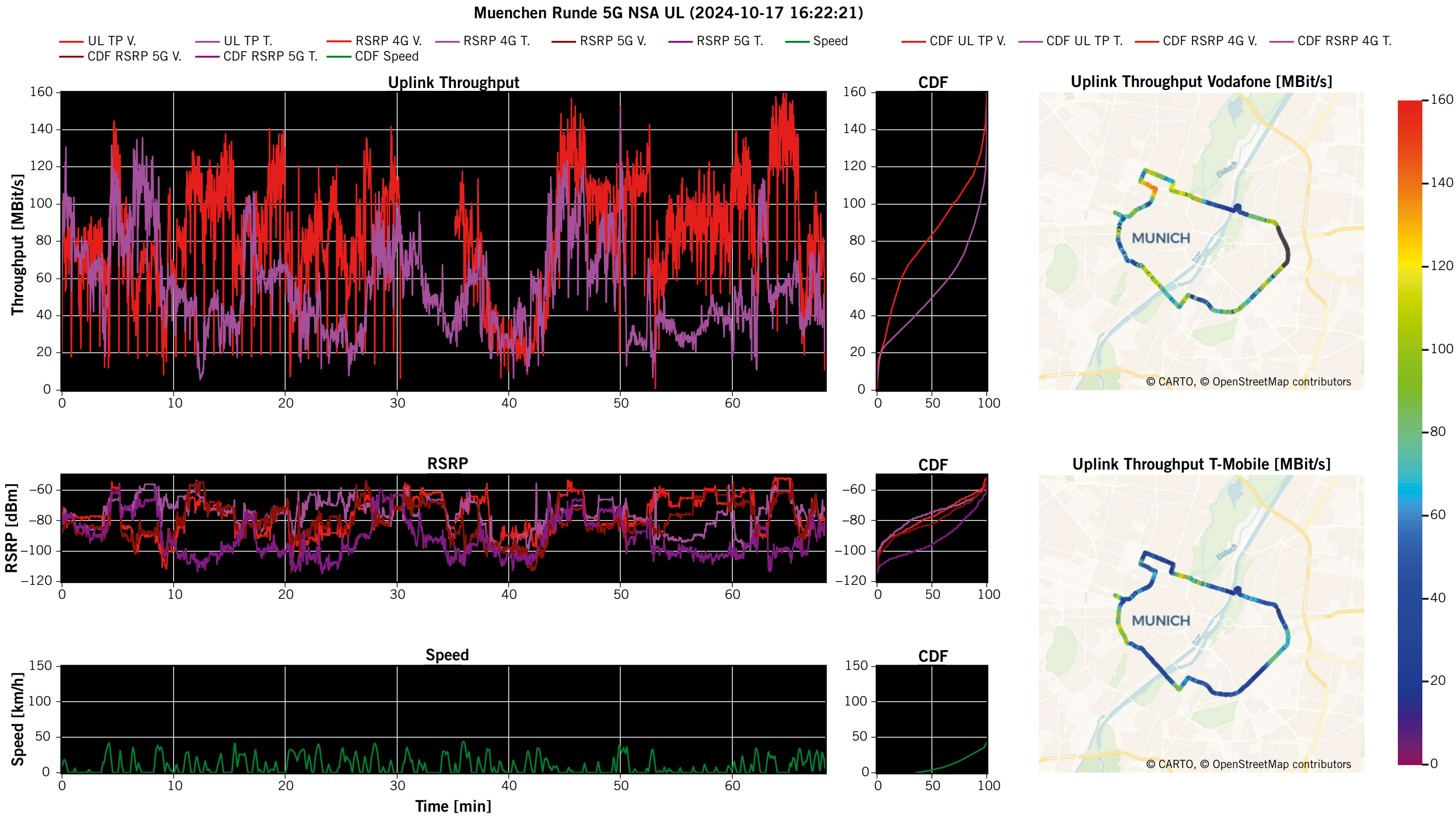

FIGURE 3 Measurement graphical user interface (GUI) for live measurement evaluation (© Desay SV Automotive Europe GmbH)

also use the data for analysis and training to improve AD safety.

This test concept foresees uplink data measurements mainly in major German cities, rural areas and highways. The redundancy aspect of the two NADs is mainly to ensure fail safety: If one NAD is not functional, the other NAD can still ensure data connectivity to the backend. With double NADs two more benefits arise: when both NADs are functional, merging the traffic, for example using the Multi-Path TCP (MPTCP) will increase the data throughput. Additionally, if one NADs MNO has a coverage issue, the other one may be able to fill the coverage gap. To evaluate the benefit of redundant NADs, the uplink data rate of each T-Box/NAD will be monitored along a predefined measurement track. Measurements will be performed in 4G mode and in 5G/auto mode. The data to be recorded is (among others):

- uplink throughput T-Box/NAD A
- uplink throughput T-Box/NAD B
- latency (Ping) of T-Box/NAD A and B
- GNSS location (longitude, latitude, altitude)
- time stamp
- signal strength RSRP, RSSI, RSRQ for each NAD
- communication standard (4G/5G).

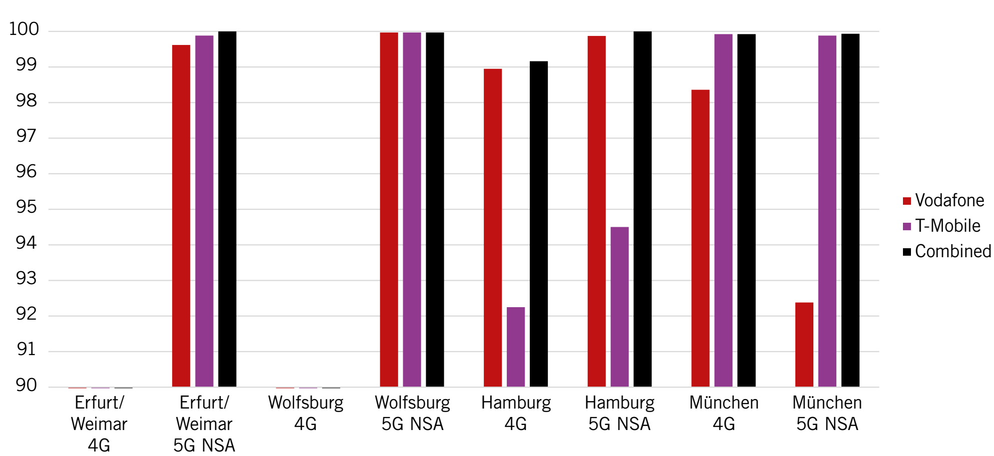

FIGURE 4 Individual and combined network coverage in percent (if the value is zero, then the item was not measured) (© Desay SV Automotive Europe GmbH)

Coverage Dynamic road tests	4G Vodafone	4G T-Mobile	4G combined	5G NSA Vodafone	5G NSA T-Mobile	5G NSA combined
Wolfsburg	-/-	-/-	-/-	99.97 %	99.97 %	99.97 %
Hamburg	98.95 %	92.25 %	99.16 %	99.87 %	94.50 %	100.00 %
München	98.36 %	99.92 %	99.92 %	92.38 %	99.88 %	99.93 %
Erfurt/Weimar	-/-	-/-	-/-	99.62 %	99.88 %	100.00 %

TABLE 1 Network coverage statistics (values with -/- were not measured) (© Desay SV Automotive Europe GmbH)

FIGURE 3 shows a snapshot of the Desay SV live measurement evaluation software, that was used to track and to analyze the data during the drive tests. For evaluating system performance, it is indispensable to have an immediate view into the data for measurement failure detection and validation.

DYNAMIC ROAD TEST RESULTS

Road tests in major German cities were conducted to analyze the performance of the developed solution and to assess network coverage and available uplink data throughput for automated driving at the levels 4 and 5. Network coverage is only a factor that indicates network availability and does not indicate the actual uplink data throughput. The results indicate a clear benefit of combining two independent networks, in our solution Vodafone and T-Mobile. In all cases, a combined network coverage of more than 99 % was achieved. A significant improvement is evident in Hamburg, where T-Mobile's 4G network alone provided only 92 % coverage. The same observation applies to the 5G network, **FIGURE 4**, **TABLE 1**.

The uplink data throughput was on average above the targeted 50Mbit/s in the focused cities Hamburg, München and Erfurt area for the 5G non standalone standard, **FIGURE 5** and **TABLE 2**. With pure 4G LTE the 50 Mbit/s could not always been reached. The data for Wolfsburg area were measured with an initial measurement setup and different iperf configuration, so those result values produced a too pessimistic throughput value, **FIGURE 5**, **TABLE 2**.

SUMMARY AND OUTLOOK

A redundant data connection offers two advantages. First, two independent NADs ensure fail-safety: if one NAD is not functional, the other NAD can still maintain data connectivity. The second advantage is the robustness of data coverage and uplink data throughput. To evaluate these benefits, a dual smart antenna concept was developed by Desay SV and tested together with VW Nutzfahrzeuge. A specially created measurement tool enabled real-time data col-

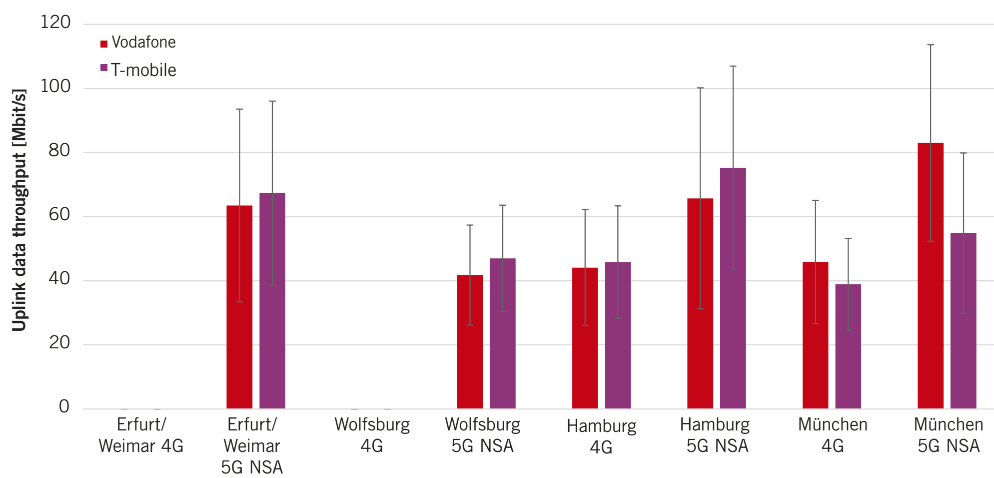

FIGURE 5 Average/mean uplink data throughput including standard deviation (if the value is zero, then the item was not measured) (© Desay SV Automotive Europe GmbH)

Measuring location	Distance [km]	Mean uplink Vodafone 4G [Mbit/s]	Mean uplink Vodafone 5G NSA [Mbit/s]	Standard deviation Vodafone 4G [Mbit/s]	Standard deviation Vodafone 5G NSA [Mbit/s]	Mean uplink T-Mobile 4G [Mbit/s]	Mean uplink T-Mobile 5G NSA [Mbit/s]	Standard deviation T-Mobile 4G [Mbit/s]	Standard deviation T-Mobile 5G NSA [Mbit/s]
Wolfsburg	4.8	-/-	41.8	-/-	15.6	-/-	47.0	-/-	16.6
Hamburg	44.4	44.1	65.7	18.1	34.5	45.8	75.2	17.6	31.8
München	11	45.9	83	19.2	30.7	38.9	54.9	14.3	25.0
Erfurt/Weimar	74	-/-	63.5	-/-	30.1	-/-	67.4	-/-	28.7

TABLE 2 Throughput statistics (values with -/- were not measured) (© Desay SV Automotive Europe GmbH)

lection with subsequent post-processing. This concept was validated in major German cities. A combined network coverage of almost 100 % was achieved. The uplink data throughput consistently averaged above the targeted 50 Mbit/s. The results presented prove to the necessity of redundancy for vehicles with automated driving at the levels 4 and 5. Such a concept requires mechanical engineering, software and RF expertise to master in particular thermal and RF challenges. The next project development step will be the validation of the concept in other European cities outside of Germany in 2025.

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