WHITE PAPER

5G Test Infrastructures

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Content

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01 Introduction

5G test infrastructures (test beds) are making a contribution to the implementation of the 5G strategy in Germany. In this light, it is necessary to survey them systematically and raise their profile. A method for structured recording or description of test beds has been developed. Existing test beds were identified and contacted to obtain specific information in accordance with the method developed. On this basis, a systematic survey and analysis of the test beds is now possible.

The “Information platform for 5G” will continue to make a contribution to the implementation of the action required in the framework of the BMBF research project of the same name.

Visions of the future such as “Industry 4.0”, “autonomous driving”, “virtual reality” and “the Internet of Things” require an efficient communications structure that meets demand. 5G promises to be an important component in the design of the necessary communication networks and technologies, in particular for industry with its extremely heterogeneous applications, with the extremes of Enhanced Mobile Broadband (eMBB), Massive Machine Type Communication (mMTC), and Ultra Reliable Low Latency Communication (uRLLC). The variety of applications requires a corresponding flexibility of the technological solutions, which, in the absence of the relevant domain knowledge and a concerted approach by everyone involved, can quickly lead to a wide range of non-interoperable technologies and solutions.

A concerted approach can be motivated and promoted by, among other things, establishing publicly accessible test infrastructures (test beds) with coordinated standards. With the aid of a systematic overview of all publicly available test beds in Germany and the EU, development focal points, application-related 5G ecosystems and the technologies and standards used can be made visible. The particular target audience is the stakeholders in the 5G value creation chain. The quantitative and qualitative development of the test bed can also serve as an early indicator of the degree of implementation of 5G in the industrial context within the framework of a monitoring system.

With the advance of 5G standardization and the resulting opportunities for trying out 5G technologies, the demand for 5G test infrastructures is increasing. The test beds are aimed, in particular, at the user industries and their equipment suppliers, but also at startups and communities. They allow testing of new technologies and components in the various application scenarios and can also act as a “playground” with low-threshold access for innovations involving 5G. Examples of best practice emerge in this way, which accelerate broad application of 5G in new areas. Test beds can also be used for certification of technologies and testing of safety requirements and quality. Creating these opportunities in Germany and Europe is necessary, as many products come from abroad and may not meet our own requirements.

For the effectiveness of the test beds, the various interest groups must be brought up to a consistent level of knowledge to allow them to identify the test beds suitable for them. Common classification and documentation of the 5G test infrastructures are necessary for the various target groups, along with a consistent data structure and uniform meta information.

In this context, the 5G test bed map has been developed and made publicly available online in German and English. The methodological approach, the survey and representation of the test beds and an initial evaluation of the database including an action plan derived from it are presented below.

02 Methodological Approach to Characterization

The methodological approach to surveying and characterizing existing 5G test infrastructures in German and Europe has been developed within the framework of research project IP45G "Information platform for 5G". The starting point was identifying and developing **technical and economic cross-sectional topics**, including the issues of standardization and norms through the research projects of the BMBF research initiative "5G – Industrial communication of the future".

On this basis, a list of questions was drawn up to record the relevant parameters of the various test beds. The following three main categories emerged in this process:

- Application
- Administration
- Technical specification

For the communication and identification process between test beds, companies, startups and communities to work, these main categories must be expanded. A guideline for further sub-division was provided by questions from the perspective of potential users of the test beds. The following characterization structure emerged from this:

Application

- Aim/purpose
- Applications
- Target groups
- Research areas

Administration

- Management/leadership
- Partners involved
- Project embedding
- Access
- Location and duration

Technical specifications

- Parameters
- Topology
- Technology
- Test equipment
- Boundary conditions

This structure is the basis for the test bed profiles that currently characterize a test bed. An example of a profile is shown in Fig. 3.01. All of the relevant information is summarized clearly on a double page. These profiles form the starting point for digital implementation of the test bed map. On this basis, a targeted analysis and evaluation of test beds can be carried out.

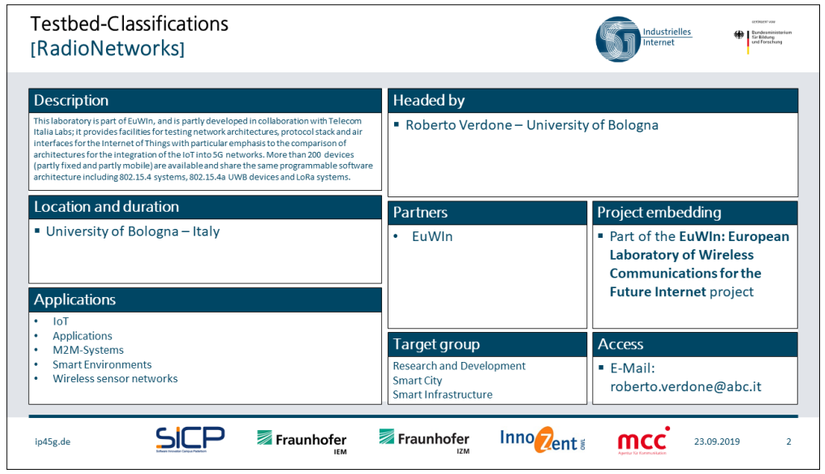


Fig. 2.01
Example of a test bed profile

03 Survey and Presentation of the Test Beds

For data collection, the operators of the test beds were sent the profile already drawn up by means of research for checking and approval. A total of **40 test beds** were contacted, **26 of which were in Germany**. The ongoing recording of the test beds uses the categories “Identified”, “Public information”, and “Agreed information”.

The category “Identified” means that the information in the profile is very limited and there has been no contact as yet with those in charge. This is the result of the fact that the test bed operators have not released any public information and no responsible institution or contact can be identified. The status “Public information” means that the information in the profile is adequate to good and those responsible have not responded to our inquiry. The final category “Agreed information” indicates that the information in the profile has been checked and verified by those in charge.

To date there have been **37 responses**, which have been adjusted and verified. There was no response for three test beds and these were given the status “Identified”. Although the majority of test beds identified do not allow public access, the inquiries were answered almost completely and the concept of the test bed map was taken on and accepted in a very positive way. The process of surveying and describing test beds is ongoing.

To make the information available to as large a group of interested parties as possible, the format of a **digital and interactive map** was chosen for presentation. The technical concept is divided into an administration and evaluation level (backend) and a user view level (frontend). The frontend (see Figure 2) informs the user about the status and geographical position of all test beds identified. For the first time, this type of presentation allows any interested party to find out about 5G test infrastructures online at any time in a systematic way.

The 5G test bed map can be accessed at the following URL:
https://www.ip45g.de/testbeds/

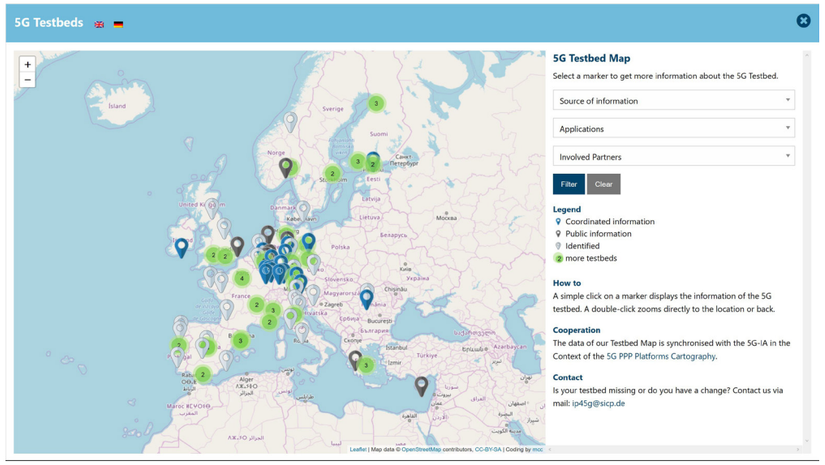


Fig. 3.01
Screenshot of the 5G test bed map

Each test bed is represented by one or more pins, the colors of which represent their survey status. Clicking on a pin displays all the information about the test bed concerned. Two examples are shown in the screenshots below (Fig. 4.01 and Fig. 4.02).

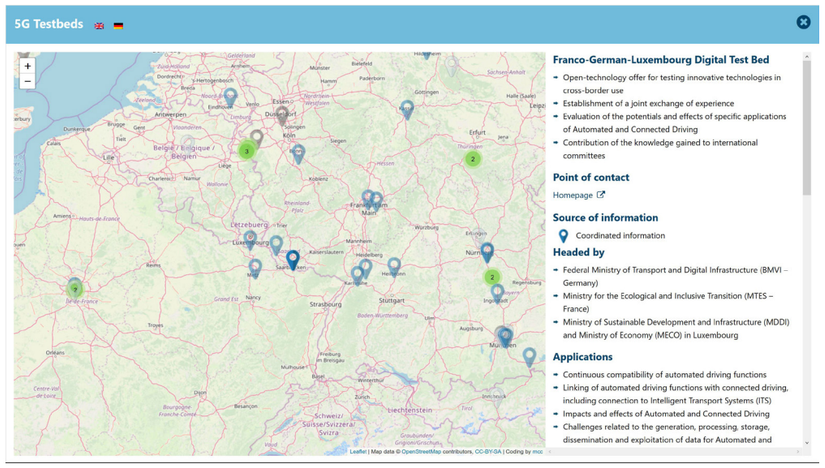
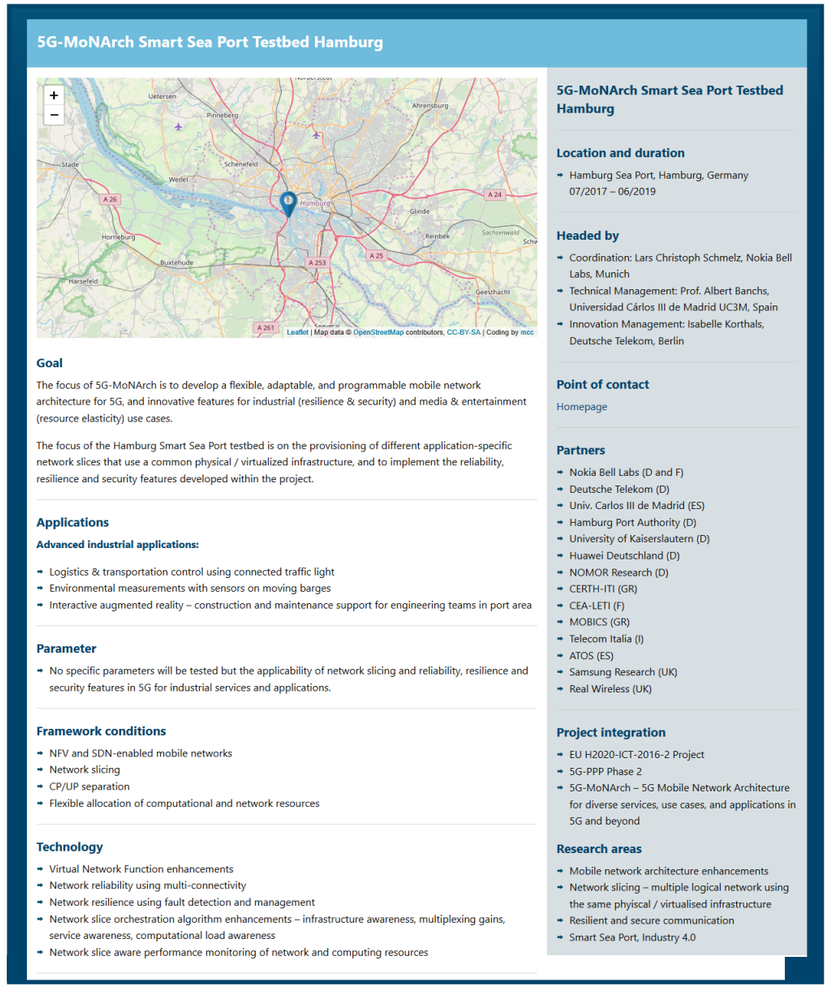


Fig. 3.02
Example of the test bed “Digital test bed Germany-France-Luxembourg”



5G-MoNArch Smart Sea Port Testbed Hamburg

Goal

The focus of 5G-MoNArch is to develop a flexible, adaptable, and programmable mobile network architecture for 5G, and innovative features for industrial (resilience & security) and media & entertainment (resource elasticity) use cases.

The focus of the Hamburg Smart Sea Port testbed is on the provisioning of different application-specific network slices that use a common physical / virtualized infrastructure, and to implement the reliability, resilience and security features developed within the project.

Applications

Advanced industrial applications:

- Logistics & transportation control using connected traffic light
- Environmental measurements with sensors on moving barges
- Interactive augmented reality – construction and maintenance support for engineering teams in port area

Parameter

- No specific parameters will be tested but the applicability of network slicing and reliability, resilience and security features in 5G for industrial services and applications.

Framework conditions

- NFV and SDN-enabled mobile networks
- Network slicing
- CP/UP separation
- Flexible allocation of computational and network resources

Technology

- Virtual Network Function enhancements
- Network reliability using multi-connectivity
- Network resilience using fault detection and management
- Network slice orchestration algorithm enhancements – infrastructure awareness, multiplexing gains, service awareness, computational load awareness
- Network slice aware performance monitoring of network and computing resources

5G-MoNArch Smart Sea Port Testbed Hamburg

Location and duration

- Hamburg Sea Port, Hamburg, Germany
  07/2017 – 06/2019

Headed by

- Coordination: Lars Christoph Schmelz, Nokia Bell Labs, Munich
- Technical Management: Prof. Albert Banchs, Universidad Cárlos III de Madrid UC3M, Spain
- Innovation Management: Isabelle Korthals, Deutsche Telekom, Berlin

Point of contact

Homepage

Partners

- Nokia Bell Labs (D and F)
- Deutsche Telekom (D)
- Univ. Carlos III de Madrid (ES)
- Hamburg Port Authority (D)
- University of Kaiserslautern (D)
- Huawei Deutschland (D)
- NOMOR Research (D)
- CERTH-ITI (GR)
- CEA-LETI (F)
- MOBICS (GR)
- Telecom Italia (I)
- ATOS (ES)
- Samsung Research (UK)
- Real Wireless (UK)

Project integration

- EU H2020-ICT-2016-2 Project
- 5G-PPP Phase 2
- 5G-MoNArch – 5G Mobile Network Architecture for diverse services, use cases, and applications in 5G and beyond

Research areas

- Mobile network architecture enhancements
- Network slicing – multiple logical network using the same phyiscal / virtualised infrastructure
- Resilient and secure communication
- Smart Sea Port, Industry 4.0

Fig. 3.03
Sample detailed view of the 5G-MoNArch Smart Sea Port test bed Hamburg

Evaluation of the Database 04

In addition to the presentation of the existing test beds, the priority is to analyze the database that has been created and is growing all the time. The basic distribution of the field of application, technical orientation, location and type of business model are the particular points of interest.

A distinction is made between the test environments according to their intended application. In the evaluation of the test beds, the following areas of application have been identified:

Autonomous driving

5G technology opens up new opportunities for autonomous driving, such as outsourcing of complex calculations to the cloud. Integration, networking, operation and application are being researched in test environments. Prototypes are being developed and being tested on test tracks under realistic conditions.

Industry 4.0

5G is essential for the implementation of Industry 4.0, since large data volumes must be transmitted wirelessly and reliably with small latencies, among other things. In addition to the 700 MHz bands, which are primarily suitable for large-area provision in rural regions because of the good propagation characteristics, the frequencies in the 3.4 to 3.8 GHz range are required for this. The frequencies from 3.7 to 3.8 GHz play a particular role here, as they would allow operation by local and regional networks. This is particularly important for industrial networking of systems. Some test environments are specifically testing a 5G network of this sort and its industrial application.

Logistics

Digital data are already being collected and processed in real time in logistics. Thanks to the high bandwidth and availability of 5G, the logistics sector is anticipating greater efficiency and more precise data evaluations, together with genuine online tracking in which all the relevant data, such as temperatures, humidity, etc., can be accessed consistently at any time. Systems are being equipped with the technology required for this and tested in existing test environments.

Traffic management/control

Processing digital data in real time is particularly important for traffic management and control. Thus, for example, parking spaces can be used more efficiently, minimizing unnecessary searches. In addition, the traffic flow can be adapted dynamically to the current circumstances if the corresponding information, such as destinations and speeds, is available. In the test environments, these new application scenarios are tried out under realistic traffic situations. The data acquired form the basis for further optimization potential, for example through simulation with inclusion of real-time data.

Tourism

The integration of virtual reality (VR) and augmented reality (AR) into the physical world opens up new opportunities for the tourism industry. Applications are developed in test environments that require the fast data exchange of 5G to transmit a VR environment to a real location in real time. Extensive information can also be provided with 5G technology, such as an audiovisual display of all the relevant tourist attractions of a city.

Fig. 5.01 shows the percentage distribution of areas of application in Germany. It is evident that 68 % of the test beds are dedicated to autonomous driving as an area of application. Industrial networking is represented with just 14 %, even though a large demand is anticipated in this area in the short term. In comparison to test environments in other European countries (see Fig. 5.02), a more even distribution of the area of application is apparent. In relation to the important lead market for Germany of mechanical and plant engineering, a critical analysis of whether the existing number of test beds is adequate for this sector is required.

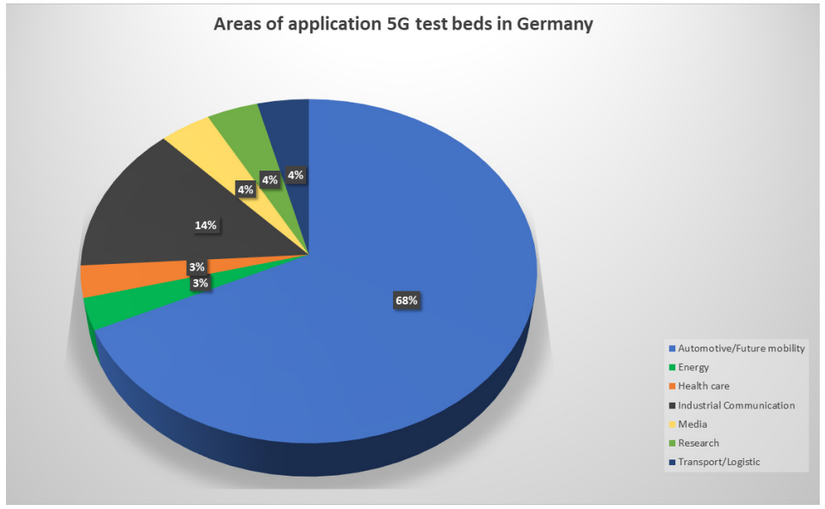


Fig. 4.01
Percentage distribution of test beds by area of application in Germany

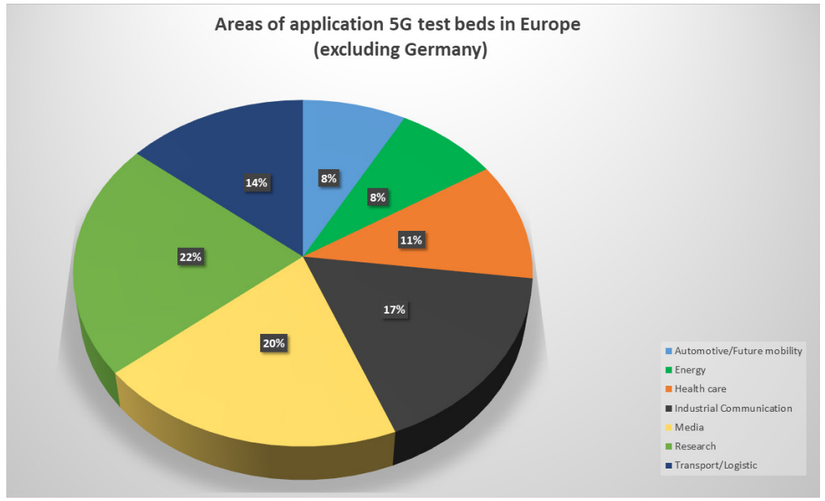


Fig. 4.02
Percentage distribution of test beds by area of application in Europe (not including Germany)

The evaluations also show that existing test beds are **extremely heterogeneous in terms of technological and measurement equipment**. This is presumably the result in part of the fact that some key hardware elements are not yet commercially available and thus have been put in place by the stakeholders in very different ways. Some test beds have also come about from existing or extended telecommunications test environments. The various target groups and the technological focus is probably also a reason for this. The focus can range, for example, from pure antenna design with beamforming through to redundant cloud computing. It is clearly difficult to provide an all-encompassing test environment that can cope with all the requirements of the various applications within the individual areas of application.

On the basis of the test beds identified, a fundamental distinction has been made between the following **access options**:

- free public use
- hybrid public/private use
- hybrid public/private use with fees
- use with restrictions (with/without fees)
- other (with/without fees)

A large proportion of test beds investigated in Germany operate privately and offer no public access. These test beds are set up in the context of specific research projects in many cases and are operated for the duration of the project. But test infrastructures are also being created at universities, research institutions and in companies that are intended to run for a longer period and are made available to a broader group of users and a variety of projects. Fundamentally it is clear, however, that, irrespective of the business model, there is a large interest on the part of the test beds in becoming more visible. This is also evident in the great resonance with which the publication of the test bed map met in the context of the second anniversary of the 5G BMBF research initiative under the BMBF program “ICT 2020 – Research for innovation” and the close cooperation with the EU 5G PPP initiative. There are continuous active inquiries from test beds with a view to including them on the test bed map.

05 Outlook and Action Plan

The work to date shows that a continuation of the ongoing, structured recording and evaluation of further test beds is an important component in implementing the 5G strategy. It is therefore a matter of continuing to research, record and raise the profile of test beds and their classification. In future, the test beds could be asked about relevant technical and market-related influences and cross-sectional topics from their perspective. Additional insights can be provided by filter functions that allow geographical and content searches for specific test beds. The access and collaboration opportunities for startups, companies and communities can thus be simplified and promoted. Technologically innovative small and medium-sized enterprises should come into clearer focus and be supported in their development activities. The growing database for test beds should be used for further analysis to identify the real needs of industry. The orientation and, above all, the development of the test beds are sensitive indicators of the implementation of 5G in Germany, even with the inclusion of developments of test beds in Europe. In addition, it may be advisable to initiate and encourage interaction between the test beds. Standardization could define the functions of test beds in order to create a consistent standard. Tests and certifications of new technologies would therefore be easier and more cost-effective to carry out. The standardization in EMC testing could serve as a model.

In summary, the following action is envisaged for the immediate future:

- A continuation of the ongoing, structured recording and evaluation
- of further test beds
- An intensification of the research and a higher profile for industrial test beds
- Initiation of interaction between test beds
- A higher profile through a filter function for better geographical and content searches
- Use of the database to identify the real needs of industry
- Survey and publication of relevant technical and market-related influences and cross-sectional topics from the perspective of the test beds. Facilitation of access to test beds for users so that they can identify individual benefits of 5G.

Test beds that have not been included can be registered at the following email address: ip45g@sicp.de.

Imprint 06

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