EVARILOS Open Challenge: Track 3

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Abstract:
This document overviews different components of TKN testbed infrastructure and shortly describes TKN testbed's environment. Furthermore, the document details how listed infrastructural components can be instantiated for performing experiments for objective evaluation and benchmarking of different indoor localization solutions and algorithms.

Note:
This is a tentative version of the document and it is expected to be changed or extended in the future. All subscribers of the EVARILOS mailing lists will be notified about all future changes in the document.

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List of Acronyms

AP Access Point

CS Carrier Sensing

EBH EVARILOS Benchmarking Handbook

EBP EVARILOS Benchmarking Platform

ISO/IEC International Org. for Standardization / Int. Electrotechnical Commission

LTE Long Term Evolution

OMF cOntrol and Management Framework

OS Operating System

PC Personal Computer

RF Radio Frequency

ROS Robot Operating System

SSH Secure Shell

SUT System Under Test

TCP Transmission Control Protocol

TKN Telecommunication Network Group

TUB Technische Universität Berlin

TWIST TKN Wireless Indoor Sensor Network Testbed

UDP User Datagram Protocol

URI Uniform Resource Identifier

VPN Virtual Private Network

WiFi Wireless Fidelity

WMP Wireless Mac Processor

WLAN Wireless Local Area Network

1 Track 3 - Evaluation of RF-based Indoor Localization Algorithms

The track, organized by the EVARILOS consortium, is an online competition for RF-based indoor localization algorithms in which participating teams compete in precise localization under the influence of different RF-interference scenarios. The competing localization algorithms will have to be implemented through remote access on top of the existing hardware resources available at the EVARILOS experimental facilities at TU Berlin and iMinds, including large number of IEEE 802.11g/n access points and IEEE 802.15.4 sensor nodes, deployed in a typical multi-floor office space context. As in Track 2, the competing localization algorithms in Track 3 will be evaluated following the EVARILOS benchmarking methodology, aligned with the upcoming ISO/IEC 18305 standard “Test and evaluation of localization and tracking systems”. This online track will provide contestants with unique opportunity to:

- Test and compare the performance of their RF-based indoor localization algorithms following a standardized evaluation methodology;
- Test the sensitivity of their algorithms to radio interference under controlled conditions;
- Disseminate information about their localization solution as part of the competition workshop, website and the published proceedings and contribute towards the establishment of a public repository of experimental traces from localization solutions.

Important: This version of the annex will be refined with the feedback of the competitors. Refined versions will be timely distributed to the competitors by means of the following mailing lists:

EvarilosCompetition@tkn.tu-berlin.de

Submission Details:

Candidate competitors are invited to submit an extended abstract describing their system, where a "competitor" can be any individual or group of individuals working as a single team, associated to a single or a number of organisations. The extended abstracts need to follow the LNCS/CCIS one-column page format. The length of the extended abstracts should not exceed four pages, including figures and tables. The extended abstracts will undergo a peer review by the technical program committee members. The extended abstracts must include a description of the deployment, and algorithms that will be used, and the description of the internal data produced and processed by the system.

After the competition there is possibility to expand the abstracts to full papers that will be published.

Prizes:

Winners will be declared for three categories, providing there are sufficient number of candidates. Categories are as follows: best accuracy, best latency, best interference robustness. For each category the winner will be awarded with 500 €.

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2 Introduction

This document describes the Track 3 of the EVARILOS Open Challenge, which aims on objective and comparable comparable evaluation of RF-based indoor localization algorithms. Track 3 of the challenge encourages researchers to deploy and evaluate their localization algorithms on the hardware that is provided in the TKN testbed environment.

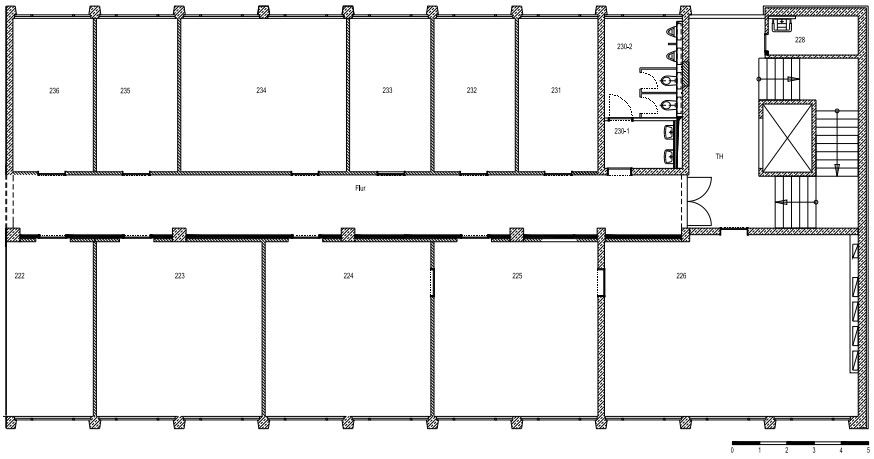
This document is structured as follows. Chapter 2 describes the TKN testbed environment, while Chapter 3 gives the short generic description of different components that are part of the testbed infrastructure. Chapter 4 describes how those generic components are instantiated for specific purpose of experimental evaluation and benchmarking of Radio Frequency (RF) based indoor localization solutions and algorithms. Chapter 5 gives detailed instructions for competitors of Track 3 of the challenge, ranging from requirements for the Systems Under Test (SUTs) algorithms to the guidelines for using different infrastructural nodes. Chapter 6 describes four evaluation scenarios, namely the reference scenario and three interference scenarios. Chapter 7 gives the description of the evaluation procedure, together with all metrics used for evaluation, how these metrics are calculated and how the final scores are produced. Chapter 8 shortly describes the evaluated algorithms, while Chapter 9 presents the results of Track 3 of the challenge.

3 TKN Testbed Environment

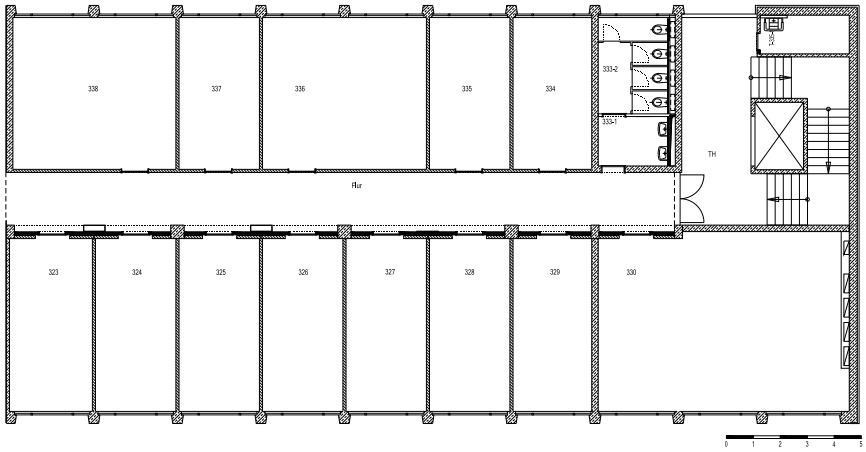
Telecommunication Network Group (TKN) testbed is located at the 2nd, 3rd and 4th floor of the Telecommunication Network Group building in Berlin. According to the EVARILOS Benchmarking Handbook (EBH) [13], TKN testbed environment can be characterised as "Big" with "'Brick walls", i.e. more than 1500 m^2 area with more than 50 rooms. TKN testbed is an office environment mostly comprising of three types of rooms, namely small offices ($14m^2$), big offices ($28m^2$) and laboratories ($42m^2$), as shown in Figure 3.2. Furthermore, TKN testbed is a dynamic environment, meaning that there is a number of people moving in the premises, constant opening of doors or slight movement of infrastructure (chairs, tables, etc.) are expected and usual. Furthermore, uncontrolled wireless interference typical for office environments can be expected, as presented in Figure 3.1.

TYPES OF INTERFERENCE SOURCE	
Microwave	✔
WiFi	✔
DECT	✔
Bluetooth	✔
Zigbee	✔

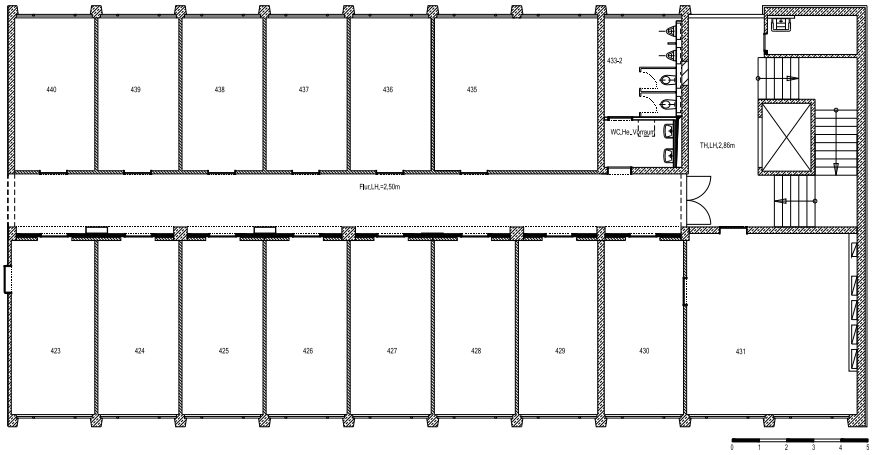
Figure 3.1: Sources of uncontrolled interference



(a) 2nd floor



(b) 3rd floor



(c) 4th floor

Figure 3.2: Footprints of the TKN testbed environment

4 TKN Hardware Overview

This chapter gives a short generic description of different types of hardware that are part of the TKN infrastructure and are currently available for experimentation in TKN testbed, namely:

- TKN Wireless Indoor Sensor Network Testbed;
- Turtlebot II Robotic Platform;
- WLAN Access Points;
- WMP on Alix2D2 Embedded PCs;
- Low-Cost Spectrum Analysers (WiSpys);
- R&S FSV7 Spectrum Analyser;
- R&S SMBV100A Signal Generator.

4.1 TKN Wireless Indoor Sensor Network Testbed

The TKN Wireless Indoor Sensor Network Testbed (TWIST) is a multiplatform, hierarchical testbed architecture developed at the TKN. The selfconfiguration capability, the use of hardware with standardized interfaces and open source software make the TWIST architecture scalable, affordable, and easily replicable (Figure 4.2). The TWIST instance at the TKN office building is one of the largest remotely accessible testbeds with 204 SUT sockets, currently populated with 102 eyesIFX and 102 Tmote Sky nodes (Figure 4.1). The nodes are deployed in a 3D grid spanning 3 floors of an office building at the Technische Universität Berlin (TUB) campus, resulting in more than 1500 m^2 of instrumented office space. In small rooms, two nodes of each platform are deployed, while the larger ones have four nodes. This setup results in a fairly regular grid deployment pattern with intra node distance of 3 m,

as shown in Figure 4.3. Within the rooms the sensor nodes are attached to the ceiling.

Figure 4.1: Tmote Sky, eyes IFXv2, NLSU2 supernode / USB Hub

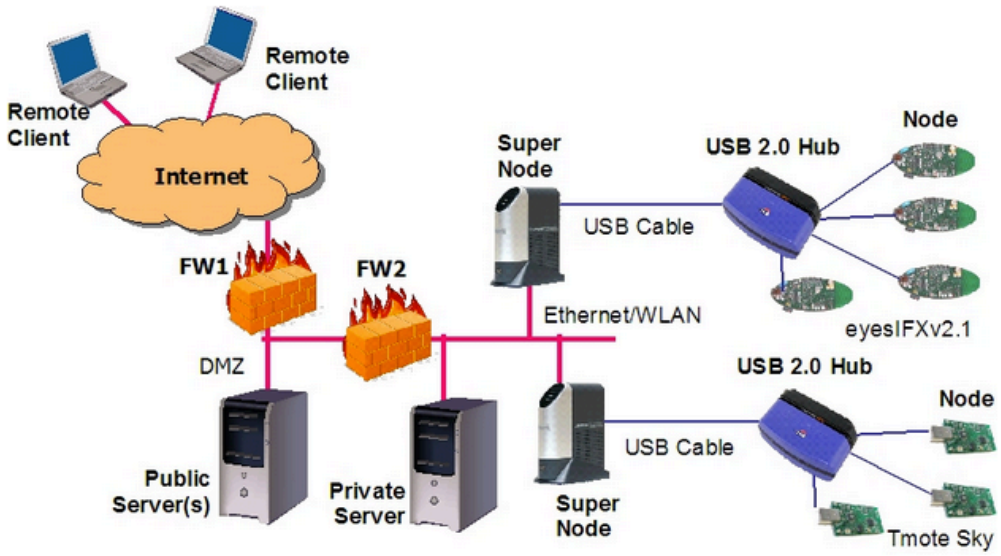


Figure 4.2: Hardware components of TWIST testbed

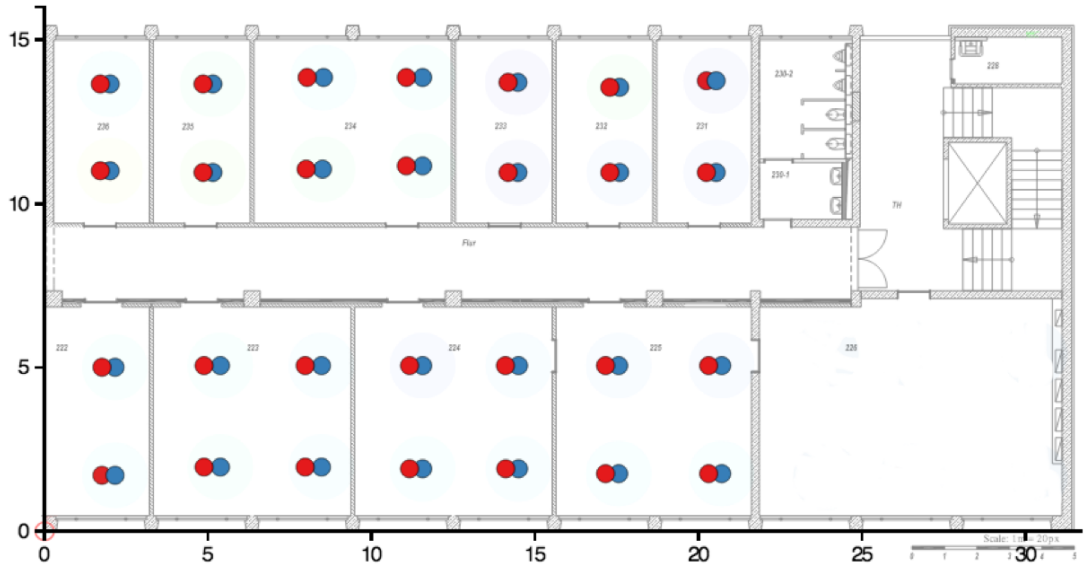


Figure 4.3: Locations of sensor nodes in the 2nd floor of TWIST testbed

4.2 Turtlebot II Robotic Platform

Turtlebot II robotic platform [8] comprises of a mobile base called Kobuki, a laptop, a router and a Microsoft Kinect 3D camera sensor (Figure 4.4). On the software side we are using Robot Operating System (ROS) [11], an open source approach for robots. ROS comes with numerous drivers and libraries that cover everything from low-level communication with hardware as well as higher layer tasks, such as mapping, navigation and obstacle avoidance. Besides that, ROS is also a communication middleware that transports information between components in ROS. The dominating scheme is topic oriented asynchronous message exchange in the fashion of publish-subscribe, but it also has means for synchronous communication. It is easily extendible through either publishing or subscribing to existing topics or through creating new ones. By doing so, ROS can also be used to transport arbitrary data. This allows to use ROS for controlling robots and extends the system by adding components on top of that.

We have set up an autonomous testbed environment in which we use the Turtlebot to position the SUT at different locations 4.5. To do that we leverage the navigational capabilities of ROS that also includes obstacle avoidance. ROS uses a a-priori given map and localizes itself by matching the depth information of the Kinect 3D camera with the outline of the

known map. ROS provides a simple interface to request the robot to drive autonomously to a given coordinate, so called goal, and a path planer is calculating the best path towards it. We have embedded these calls to move the robot to the next location into a higher schedule. First we define a set of waypoints that have to be covered in the survey, then the robot iterates autonomously over each one of them. The whole procedure is followed in an unstructured office environment with dynamic obstacles, like humans, opening / closing the doors, etc.

For communicating with the rest of the infrastructure the mobile platform is equipped with a Wireless Local Area Network (WLAN) Access Point (AP) that operates in client mode and connects to one of the six APs deployed on every floor in our building. We are controlling the robot's AP by a ROS component that is location aware and selects the most appropriate AP in the different parts of the floor.

Figure 4.4: Turtlebot Robotic Platform

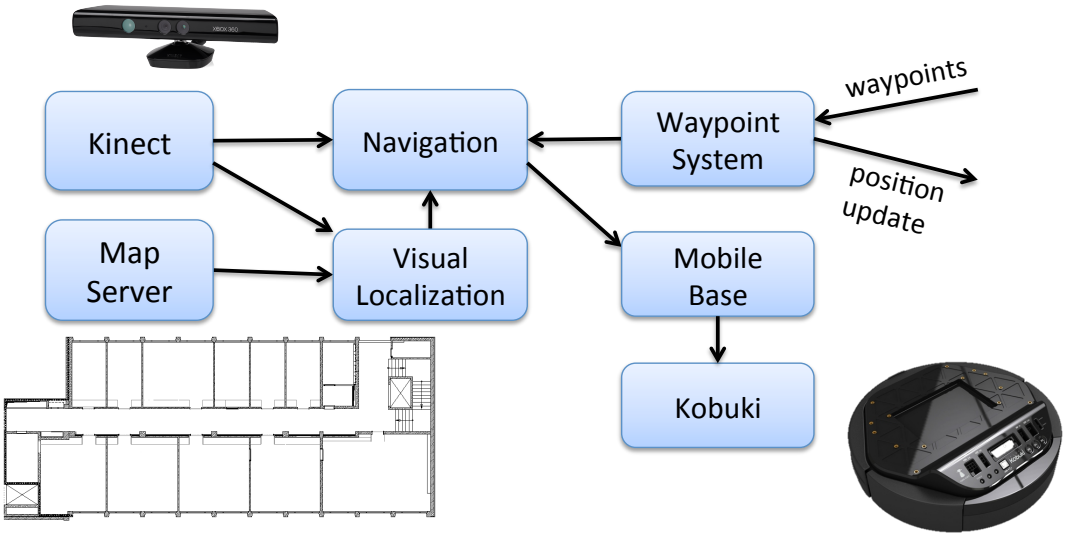


Figure 4.5: Robotic Platform Design

4.3 WLAN Access Points

TKN tesbed is equipped with 18 dualband TP-link N750 APs (model TL-WDR4300) [4] (Figure 4.6). They run OpenWRT as Operating System (OS) (and cOntrol and Management Framework (OMF) as control and measurement plane. Positions of the WLAN APs in the 2nd floor of TKN testbed are given in Figure 4.7.

Figure 4.6: TL-WDR4300 WLAN Access Point

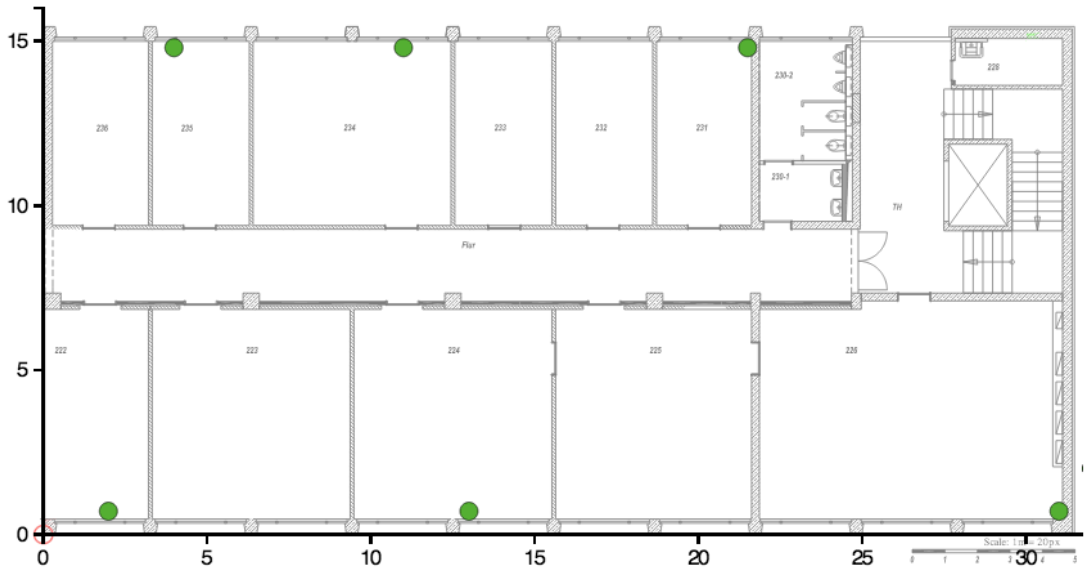


Figure 4.7: Locations of WLAN routers in the 2nd floor of TKN testbed

4.4 WMP on Alix2D2 Embedded PCs

Wireless Mac Processor (WMP) is a customizable WLAN 802.11b/g MAC [12]. It is running on ALIX2D2 embedded PCs [1] equipped with Broadcom WL5011S 802.11b/g cards and shown in Figure 4.8. In our infrastructure three ALIX2D2 exist. The customization of the MAC protocol is done via JAVA GUI. At the ALIX2D2 the firmware is loaded by the so called "bytecode-manager" on the Broadcom cards.

Figure 4.8: Alix2D2 Embedded PC

agestylescrheadings

4.5 Low-Cost Spectrum Analysers

The TKN infrastructure also comprises several WiSpy sensing devices (Figure 4.9). These are low-cost spectrum scanners that monitor activity in the 868 MHz, 2.4 and 5 GHz spectrum, and output the measured RF energy and the quality of the received signals.

Figure 4.9: WiSpy USB dongle

4.6 R&S FSV7 Spectrum Analyser

Rhode&Schwarz FSV7 signal and spectrum analyser [6] (Figure 4.10) is a very flexible and fast signal and spectrum analyser covering the frequency range between 9kHz and 7 GHz. It is simple extendible by several measurement applications and toolboxes. Furthermore, it is possible, by buying appropriate license, to add complete receiver chains like Bluetooth, LTE, WiMAX or WLAN.

Figure 4.10: R&S FSV7 spectrum analyser

4.7 R&S SMBV100A Signal Generator

Rhode&Schwarz SMBV100A is a very flexible signal generator [7] (Figure 4.11). It provides transmissions of baseband signals in the range of 9 kHz to 6 GHz. It is possible send any generated or stored signal with up to 120 MHz bandwidth. By applying toolboxes, the SMBV100A signal generator allows to generate different standards conform signals like e.g., WiMAX, WLAN or LTE. Together with the R&S FSV7 Spectrum Analyser complete transmissions chains can be set up.

Figure 4.11: R&S SMBV100A Signal Generator

5 Instantiation of TKN Infrastructure for Indoor Localization Experiments

sd fds fdsf dsf dsfs d We have instantiated our testbed infrastructure for specific purpose of evaluation and benchmarking of different indoor localization solutions and algorithms. The overview of different capabilities of TKN tested for this specific purpose is given in Figure 5.1The TKN infrastructure leverages a robotic mobility platform which enables autonomous, accurate and repeatable positioning of localization devices in the environment. Furthermore, it integrates devices for generating controlled RF interference, which can be used to evaluate the influence of RF interference on the performance of the localization SUT. With the TKN infrastructure it is currently possible to create different types of wireless interference, such as IEEE 802.11 (WiFi), IEEE 802.15.4 (ZigBee) or IEEE 802.15 (Bluetooth). For validation of the resulting RF context, the infrastructure features devices that monitor the RF spectrum at different measurement points in order to guarantee equal conditions for all SUTs. Finally, testbed enables deployment of different indoor localization algorithms or solutions to be tested into the already existing infrastructural components.

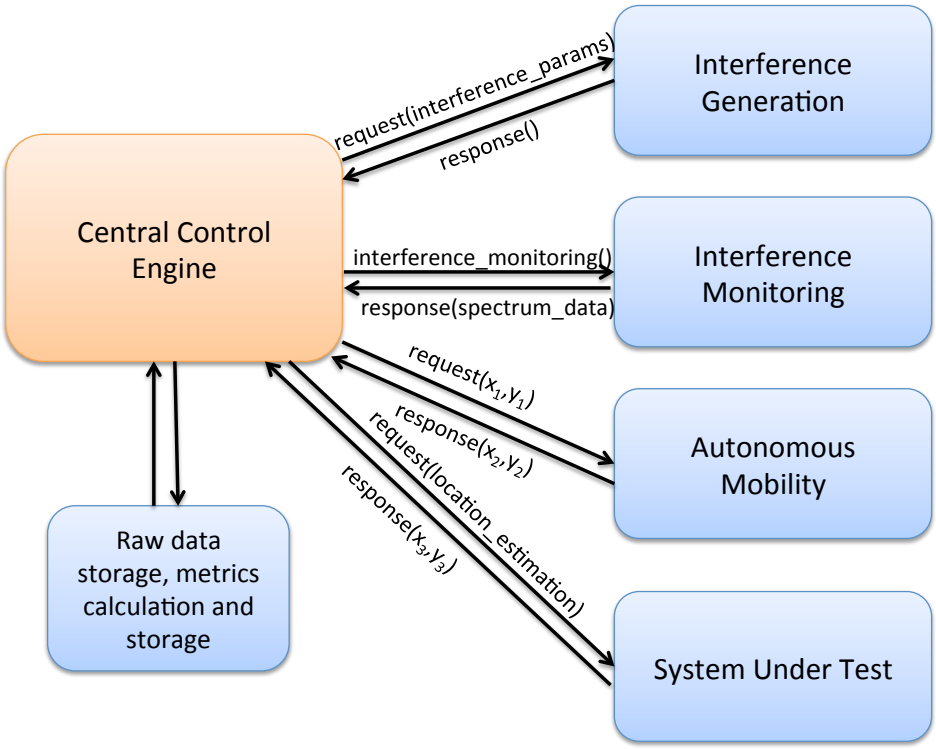


Figure 5.1: Overview of TKN testbed for evaluation and benchmarking of different indoor localization SUTs

5.1 Autonomous Mobility Platform

For automatic transportation of the localized device of the SUT to different evaluation points, without the presence of a human test-person and in a repeatable way, we use the Turtlebot II robotic platform. Turtlebot provides an interface to request the robot to drive autonomously to a given coordinate. For an experiment one can define a set of measurement points and the robot iterates over each of them. When a measurement point is reached, this event and the current location and orientation of the robot is reported back the experimenter. The location estimations provided by the robot are highly accurate, achieving the mean localization errors of around 20 cm, so these location estimations can be considered as ground truths for indoor localization experiments.

5.2 Interference Generation

During an evaluation of the proposed localization solution the impact of external interference is mostly not considered. However, it can have an influence on the performance of the indoor localization SUT. For this reason we have developed means to generate various types of interference scenarios, as presented in Figure 5.2. The most common type of wireless activity in the 2.4 GHz is the WiFi traffic. We have adapted the interference scenarios from [10, 2] and using the OMF [5] we are able to create in our testbed the interference context of typical home or office environments. This type of interference can be created using TKN WLAN routers and Alix PC devices (Figure 5.3), but also additional devices such as laptops can be used to extend the infrastructure. Furthermore, it is possible to use R&S signal generator for creating different interference patterns, such as jamming on the WiFi channel, WiFI traffic, Bluetooth traffic, etc. For generating IEEE 802.15.4 interference patterns, some TWIST sensor nodes can be used, where the locations of these nodes are given in Figure 5.4.

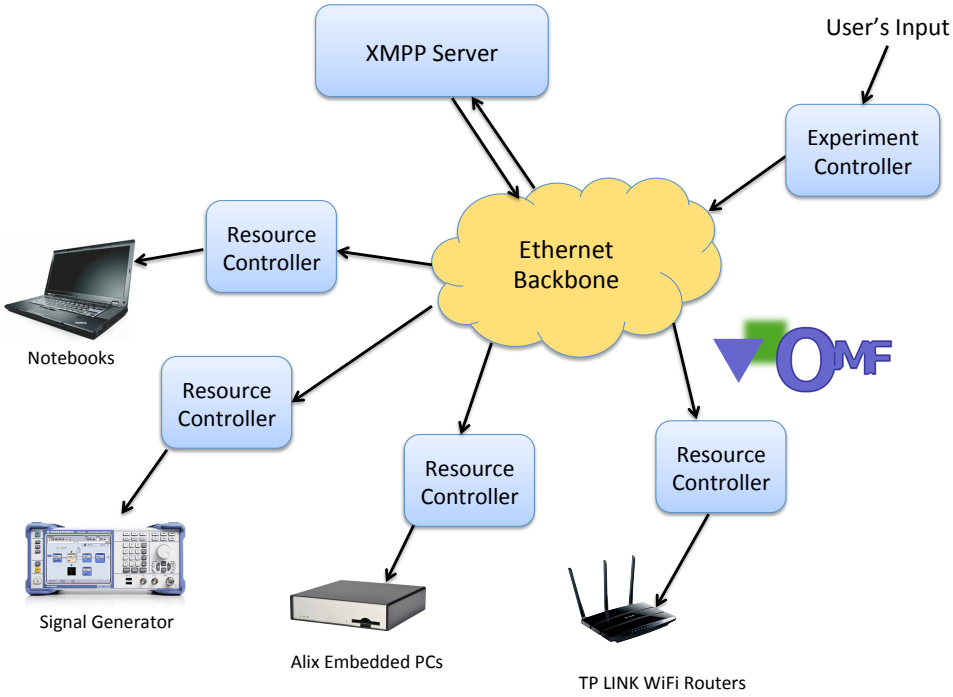


Figure 5.2: Interference generation

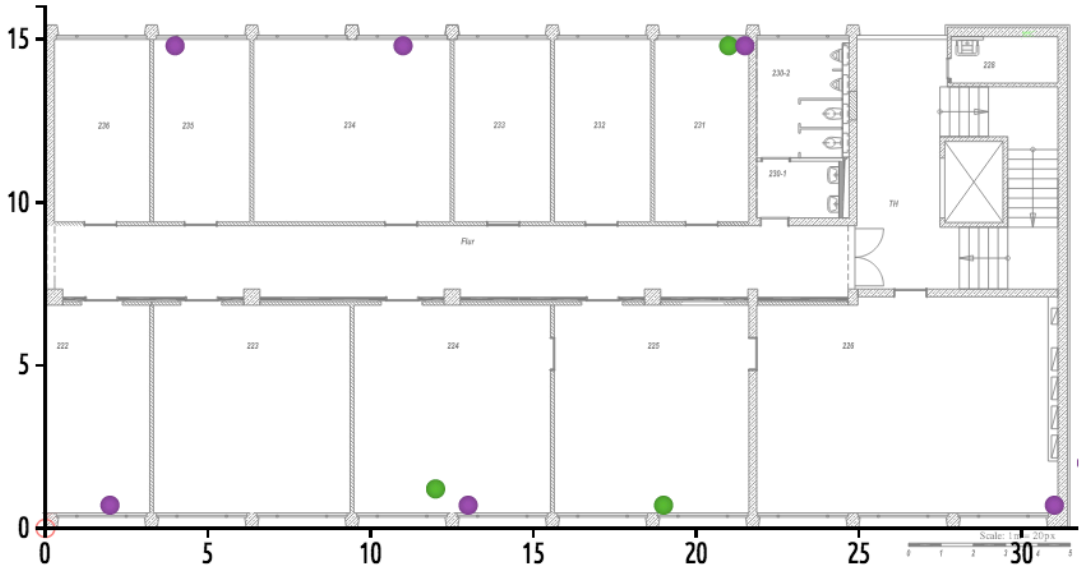


Figure 5.3: Locations of Alix Embedded PCs (green dots) and TPLINK WLAN routers (purple dots) that can be used for interference generation in the 2nd floor of TKN testbed

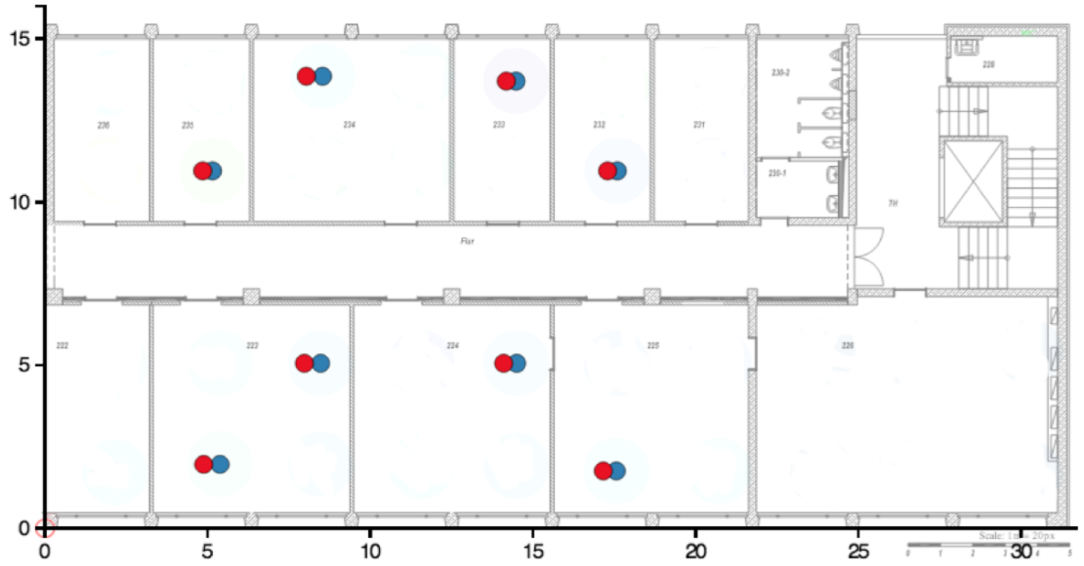


Figure 5.4: Locations of sensor nodes that can be used for interference generation in the 2nd floor of TKN testbed

5.3 Interference Monitoring

In the previous section we have described that we can generate different interference scenarios based on the needs of an experiment. Still, the spectrum in the ISM 2.4 GHz band is free for use and we do not have full control over all devices operating in those frequencies. We have disabled the university infrastructure WiFi network in the 2.4 GHz band in the building but the signal from the surroundings can still be received, as summarized in Figure 5.5. That is why it is necessary to monitor the spectral environment to tell if it is looking as expected. We can use OMF to orchestrate WiSpy [3] devices to perform spectrum sensing. We are using one of them connected to the robot to make sure that the measured interference is not exceeding planned one. Furthermore, for monitoring the wireless spectrum with much finer granularity R&S spectrum analyser can be used. Same as WiSpy devices, it is controlled using OMF. Finally, some nodes of the TWIST tesbed can be used as the distributed spectrum analyser, where the locations of nodes are given in Fgure 5.6.

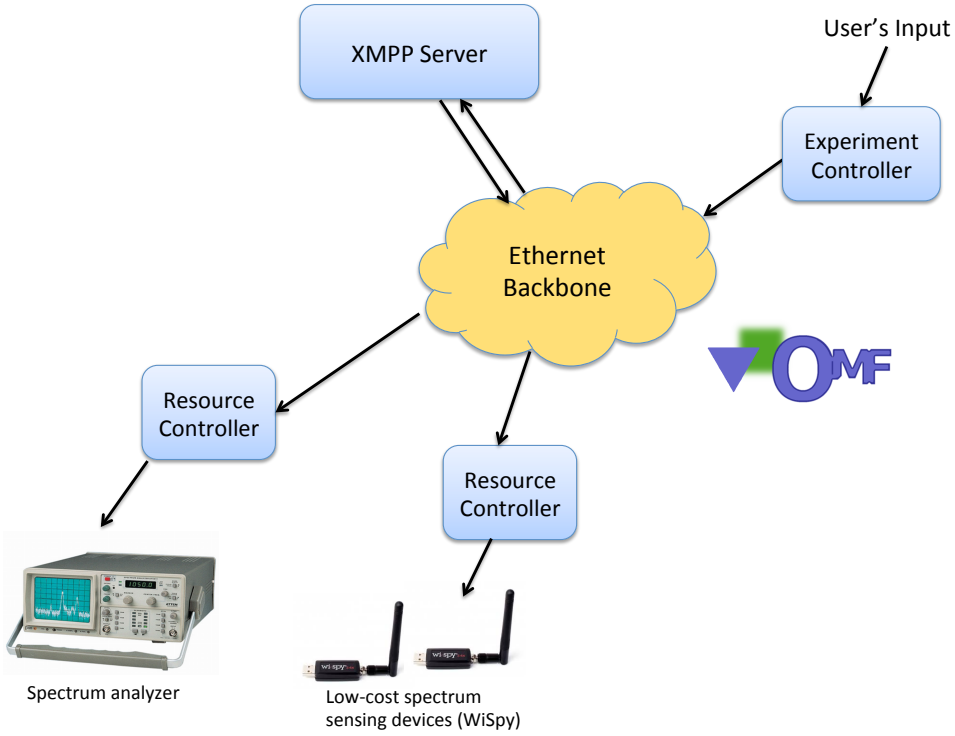


Figure 5.5: Interference monitoring

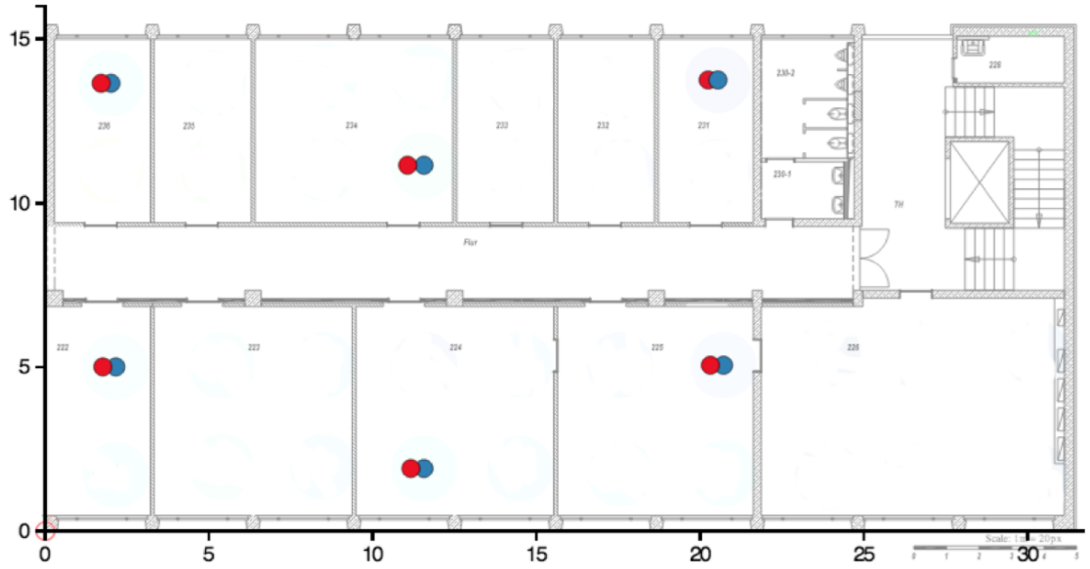


Figure 5.6: Locations of sensor nodes that can be used as distributed spectrum analyser in the 2nd floor of TKN testbed

5.4 System Under Test

Parts of TKN testbed infrastructure can be used for deploying different SUTs devices to be evaluated. Namely, mobile part of the SUT can be mounted on the Turtlebot robotic platform and the devices that we can provide as a mobile part of the SUT are given as follows:

- TmoteSky low power sensor node;
- EyesIFX low power sensor node;
- Shimmer low power sensor node;
- Smartphone Nexus S (GT-I9023);
- Tablet Nexus 7, 2013 version;
- Notebook Lenovo ThinkPad;
- Notebook Asus 1215n.

Furthermore, for static parts (anchor nodes) of SUTs TP LINK WLAN access points can be used, and their locations are given in Figure 5.7. Finally, some TWIST sensor nodes (TmoteSky nodes in 2.4 GHz ISM band or EyesIFX nodes in 868 MHz ISM band) can be used as anchor points for deployment of different SUTs, with locations given in Figure 5.8.

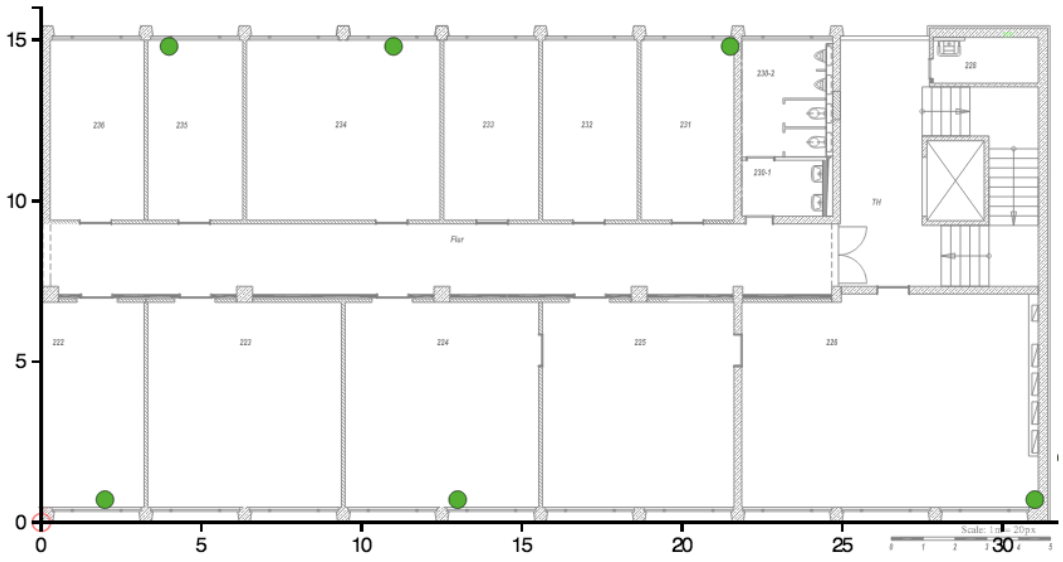


Figure 5.7: Locations of TP LINK WLAN routers that can be used as a part of SUTs in the 2nd floor of TKN testbed

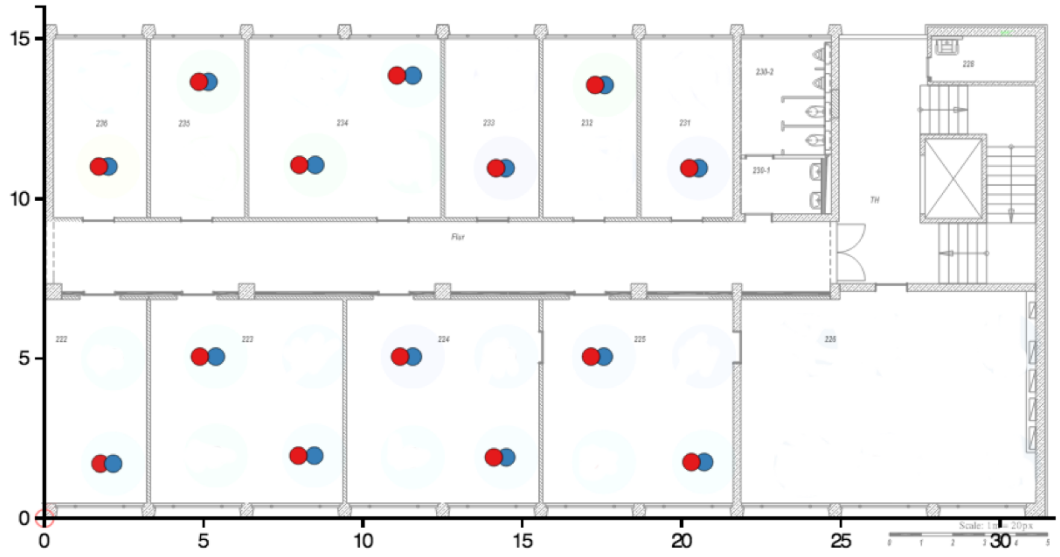


Figure 5.8: Locations of sensor nodes that can be used as a part of SUTs in the 2nd floor of TKN testbed

6 Instructions for Competitors

This chapter gives instructions for competitors for adapting their algorithms and using the hardware provided in the TKN testbed.

6.1 Interfacing with the SUT

All competitors have to deploy their algorithm on one of the devices intended for deploying SUTs and described previously in the document. Further, competitors have to provide an HTTP Uniform Resource Identifier (URI) on which their algorithm listens for requests for location estimation. Upon request, the algorithms must be able to provide the location estimate as a JSON response in the following format:

```
{
        "coordinate_x":    'Estimated location: coordinate x',
        "coordinate_y":    'Estimated location: coordinate y',
        "coordinate_z":    'Estimated location: coordinate z',
        "room_label":      'Estimated location: room'
}
```

JSON parameters *coordinate_x* and *coordinate_y* are required parameters and as such they must be reported upon request. Parameter *coordinate_z* is an optional parameter, due to the 2D evaluation environment. If this parameter is provided from a SUT, evaluation team will also calculate 3D localization error, although this information will not be used in final scoring. Finally, parameter *room_label* is an optional parameter and if it is not provided the EVARILOS Benchmarking Platform will automatically map the room estimate from the estimated coordinates x and y.

Coordinates (x, y) or (x, y, z) of the location estimates have to be calculated according to the predefined *zero-point* coordinate $(x, y, z) = (0, 0, 0)$, given in Figure 6.1. Furthermore,

room labels have to be the same as ones indicated in figure. The technical team will provide a footprint of the environment in vector format to all competitors.

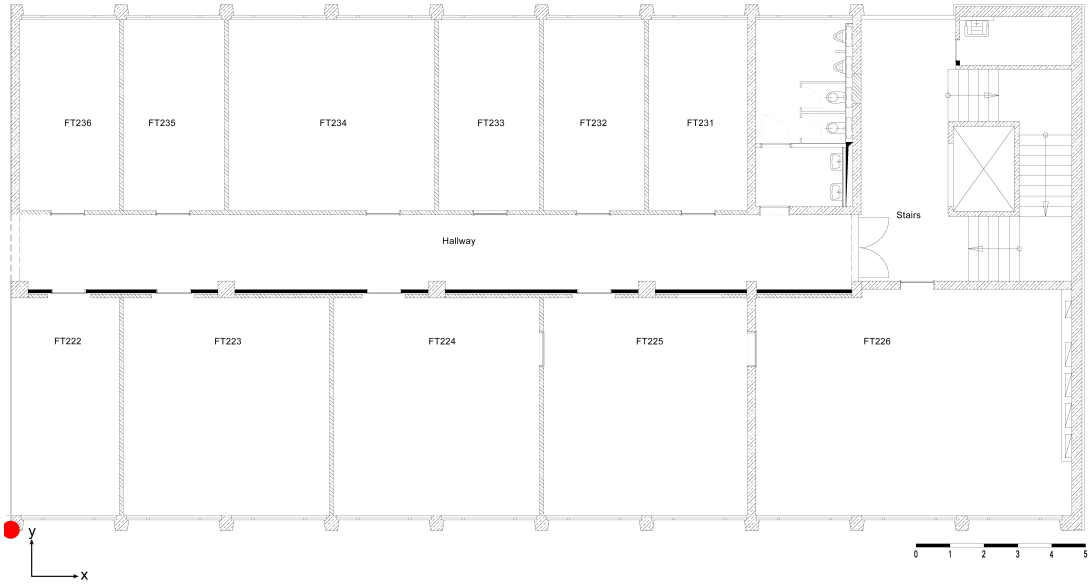


Figure 6.1: *Zero-point location and room labels*

The technical team will support the competitors in deploying their algorithms on desired hardware, interfacing SUT with the EVARILOS Benchmarking Platform, controlling the robotic mobility platform, generating different interference scenarios and interference monitoring. Furthermore, each competitor will be given 4 hours in order to train their algorithms in the TKN testbed environment, before the evaluation process starts. During that time competitors will also be supported by the technical team.

6.2 Usage of Different Hardware Components

This section shortly describes how TKN testbed users can use the hardware for their experiments and fine-tuning of their indoor localization algorithms. All competitors will be provided with the Virtual Private Network (VPN) access to the testbed's network. For the deployment and training part each competitor will be able to generate the desired interference scenarios, navigate the robotic platform, etc. as described bellow. On the other side, for the evaluation part the evaluation committee will decide on the locations of interferers and evaluation points.

6.2.1 SUT Mobile Nodes

Different devices can be used as mobile parts of SUTs. Users will be able to use Secure Shell (SSH) tunnels to the desired devices and will be able to deploy their algorithms on those devices. Furthermore, for some devices competitors will be able to completely change the firmware of the device (mostly for low-power sensor nodes). All additional requests have to be mentioned in advance and the technical committee will decide to allow them or not.

6.2.2 SUT Infrastructure Nodes

As mentioned before, as infrastructural parts of SUTs the wireless sensor network of WLAN routers can be used, depending on the requirements of algorithms. Locations of infrastructural nodes will be known to the competitors in advance. The TKN Wireless Indoor Sensor Network Testbed (TWIST) is accessible through the web interface. More details and instructions on how to use testbed can be found on following URL address:

`http://www.twist.tu-berlin.de/wiki`

Different possibilities exist for using the WLAN routers as SUT infrastructural nodes. All routers are running OpenWRT, a Linux distribution for embedded devices [9]. First possibility of usage of WLAN APs is using them in a access point mode, where parameters on an AP, such as transmission power or wireless channel, can be set using a script that will be provided. Furthermore, competitors will be given an SSH access to all WLAN routers where they will be able to deploy their scripts or anything else necessary for running their SUT. Finally, competitors will be able to change the entire firmware of WLAN routers if needed.

6.2.3 Autonomous Mobility

Autonomous mobility platform will be accessible over the web interface where competitors will be able to click on the location where they want to position the robotic platform and their SUT. As second way of usage, competitors will be able to send the robot to a location by setting the coordinates of desired location. Finally, it will be possible to provide a set of waypoints to the robotic platform in order to fully automate even the training phase for

different indoor localization algorithms. Robot will provide its current location or adequate messages if the desired location is currently not reachable.

6.2.4 Interference Generation

Competitors will to the certain degree be able to generate the interference scenarios using the above described devices. Namely, the code for generating three interference scenarios described bellow will be provided by technical team, and the users will be able to select the nodes on which the code should run.

6.2.5 Interference Monitoring

Competitors will be able to use different devices for monitoring interference levels. They will be able to obtain the dumps of wireless spectrum from the WiSpy device on the robot or WiSpy devices on multiple other locations. Furthermore, competitors will be able to use TWIST nodes for distributed spectrum sensing. Finally, competitors will also be able to use spectrum analyzer for collecting the spectrum traces with much finer granularity than the one achieved with low-cost WiSpy devices. The code for spectrum monitoring will also be provided by the technical team.

7 Evaluation Scenarios

This chapter presents interference scenarios that will be artificially generated in TWIST testbed in order to evaluate different indoor localization algorithms. The goal is to determine if and to which extend different types and amounts of RF interference can influence the indoor localization performance. The text below presents the reference scenario and describes three interference scenarios that will be used for evaluation in TKN testbed.

7.1 Reference Scenario

This reference scenario is instantiated on the 2nd floor of the TKN testbed in Berlin. It is called Reference scenario, since no artificial interference is generated and the presence of uncontrolled interference is minimized. According to the EVARILOS Benchmarking Handbook (EBH), this scenario is an instance of the “Small office” type of scenarios. In this scenario 20 evaluation points are defined (the example locations are given in Figure 7.1, different evaluation points will be used for open challenge evaluation).

At each evaluation point, the indoor localization SUT will be requested to estimate the location. The SUT device will be carried to each evaluation point using the robotic platform. The navigation stack of the robotic platform gives an order of magnitude more accurate location estimation than the SUTs and the location obtained from the robotic platform will be considered as ground truth for the evaluation.

The experiments will be performed in the afternoons, so the influence of uncontrolled interference will be minimized. Furthermore, the wireless spectrum will be monitored using the WiSpy device attached to the robotic platform and all measurements with the interference threshold above certain level will be repeated. Finally, during each experiment a measurement of the wireless spectrum will be taken with the spectrum analyser at a predefined

location.

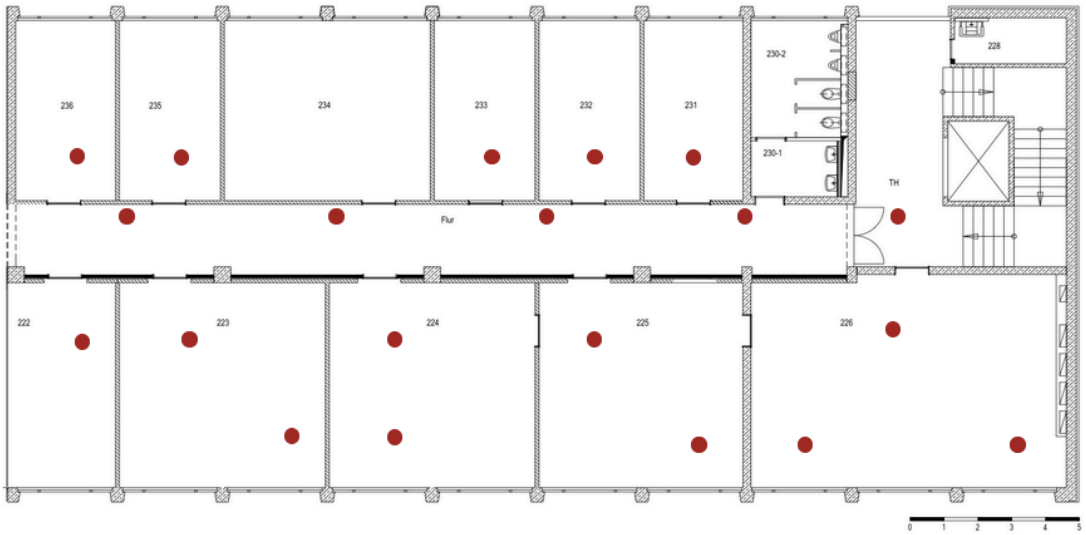


Figure 7.1: Example set of evaluation points

7.2 Interference Scenario 1

In this interference scenario instantiated in the TKN testbed interference is created using the IEEE 802.15.4 Tmote Sky nodes. The interference type is jamming on one IEEE 802.15.4 channel with a constant transmit power equal to 0 dBm. Five of these jamming nodes will be present in the testbed environment. Summary of this interference scenario is given in Table 7.1.

Table 7.1: Interference scenario 1 summary

Types of interference		**Parameters of interference sources**	
WiFi	✖	Number of sources	5
Microwave	✖	Interferers locations	Revealed after evaluation
DECT	✖	Power	0 dBm
Bluetooth	✖	Waveform	Carrier jamming
ZigBee	✔	Start & stop time	Beginning & end of experiment
Synthetic	✖	Traffic model	IEEE 802.15.4 radio

7.3 Interference Scenario 2

Second interference scenario instantiated in the TKN testbed defines interference types that is usual for the office or home environments. Namely, interference is emulated using 4 Wireless Fidelity (WiFi) embedded Personal Computers (PCs): server, access point, data client, and video client. The server acts as a gateway for the emulated services. The data client is emulated as a TCP client continuously sending data over the AP to the server. Similarly, the video client is emulated as a continuous UDP stream source of 500 kbps with the bandwidth of 50 Mbps. The AP is working on a WiFi channel overlapping with the SUT's channel and with the transmission power set to 20 dBm (100 mW). Summary of a described interference scenario is given in Table 7.2.

Table 7.2: Interference scenario 2 summary

Types of interference		**Parameters of interference sources**	
WiFi	✔	Number of sources	3
Microwave	✖	Interferers locations	Revealed after the evaluation
DECT	✖	Power	20 dBm
Bluetooth	✖	Waveform	WiFi signals
ZigBee	✖	Start & stop time	Beginning & end of experiment
Synthetic	✖	Traffic model	IEEE 802.11 traffic

7.4 Interference Scenario 3

For the third interference scenario instantiated in the TKN testbed signal generator will be used for generation of synthetic interference. The generated synthetic interference will have an envelope of the characteristic WiFi signals, but without any Carrier Sensing (CS). The summary of interference scenario 3 is given in Table 7.3.

Table 7.3: Interference scenario 3 summary

Types of interference		**Parameters of interference sources**	
WiFi	✖	Number of sources	1
Microwave	✖	Interferers locations	Revealed after the evaluation
DECT	✖	Power	20 dBm
Bluetooth	✖	Waveform	Power envelope
ZigBee	✖	Start & stop time	Beginning & end of experiment
Synthetic	✔	Traffic model	Synthetic IEEE 802.11 traffic

8 Evaluation Procedure

Track 3 of the challenge evaluates RF-based indoor localization algorithms deployed on top of the existing hardware in TKN testbed. This chapter describes the evaluation procedure that will be followed for Track 3 of the challenge.

8.1 Evaluation Process

Indoor localization algorithms will be evaluated in 20 different evaluation points under four interference scenarios. The evaluation points will be selected by the evaluation team and will be the same for all evaluated algorithms. In the first run, all algorithms will be evaluated in the environment without controlled interference and the metrics will be calculated. The following three runs of evaluation will be done in the environment with three different interference scenarios described before. The locations of interference sources will be selected by the evaluation team and will be the same for all evaluated algorithms. For each location at each measurement point, the EVARILOS Benchmarking Platform will request a location estimate from the SUT. The evaluated data at each location will be automatically stored and metrics will be calculated and presented in real-time.

8.2 Evaluation Metrics

For the Track 3 of the challenge the following metrics will be calculated:

- Performance metrics - obtained from the experiment:
  - Geometric or point level accuracy of location estimation;
  - Room level accuracy of location estimation;

  - Latency or delay of location estimation.

- Derived metric - calculated from the performance metrics:
  - Interference robustness of indoor localization algorithm.

8.2.1 Point Level Accuracy

Point level accuracy at one evaluation point is defined as the Euclidean distance between the ground truth provided by the robotic platform (x_{GT}, y_{GT}) and the location estimated by indoor localization algorithm (x_{EST}, y_{EST}), given with the following equation:

$$PointAccuracy = \sqrt{(x_{GT} - x_{EST})^2 + (y_{GT} - y_{EST})^2}\,[m] \tag{8.1}$$

8.2.2 Room Level Accuracy

Room level accuracy of location estimation is a binary metrics stating the correctness of the estimated room, given with the following equation:

$$RoomAccuracy = \begin{cases} 1 & \text{if the estimated room is correct;} \\ 0 & \text{if the estimated room is not correct or not estimated;} \end{cases} \tag{8.2}$$

8.2.3 Latency of Location Estimation

Latency or delay of location estimation is the time that the SUT needs to report the location estimate when requested. The time that will be measured in the evaluation is the difference between the moment when the request for indoor localization has been sent to the SUT ($t_{request}$) and the moment when the response arrives ($t_{response}$), given with the equation:

$$Latency = t_{response} - t_{request}\,[s] \tag{8.3}$$

8.2.4 Interference Robustness

Interference robustness of indoor localization algorithm in metric that reflects the influence of different interference types to the performance of the indoor localization algorithm. In this evaluation, interference robustness will be expressed as the percentage of change in

other metrics in the scenarios with interference in comparison to the performance in the scenario without interference (reference scenario). For the case of generalized metric (M), the interference robustness is given with the following equation:

$$InterferenceRobustness = \frac{M_{reference} - M_{interference}}{M_{reference}} \cdot 100\ [\%] \tag{8.4}$$

where $M_{reference}$ is the value of metric M in the reference scenario, while $M_{interference}$ is the value of metric M in the scenario with interference. Note that if the performance of an algorithm for the performance metric M is better in the scenario with interference, in comparison to the reference scenario, then the interference robustness metric will be set to 0 %.

8.3 Capturing the Evaluation Metrics

The evaluation procedure will be done in four steps, namely in four interference scenarios. In each step, for each of the 20 evaluation points, the set of metrics (point accuracy, room accuracy, latency) will be obtained. For each set, the 75th percentile of point level accuracy and latency will be calculated, together with percentage of correctly estimated rooms, as shown in Figure 8.1.

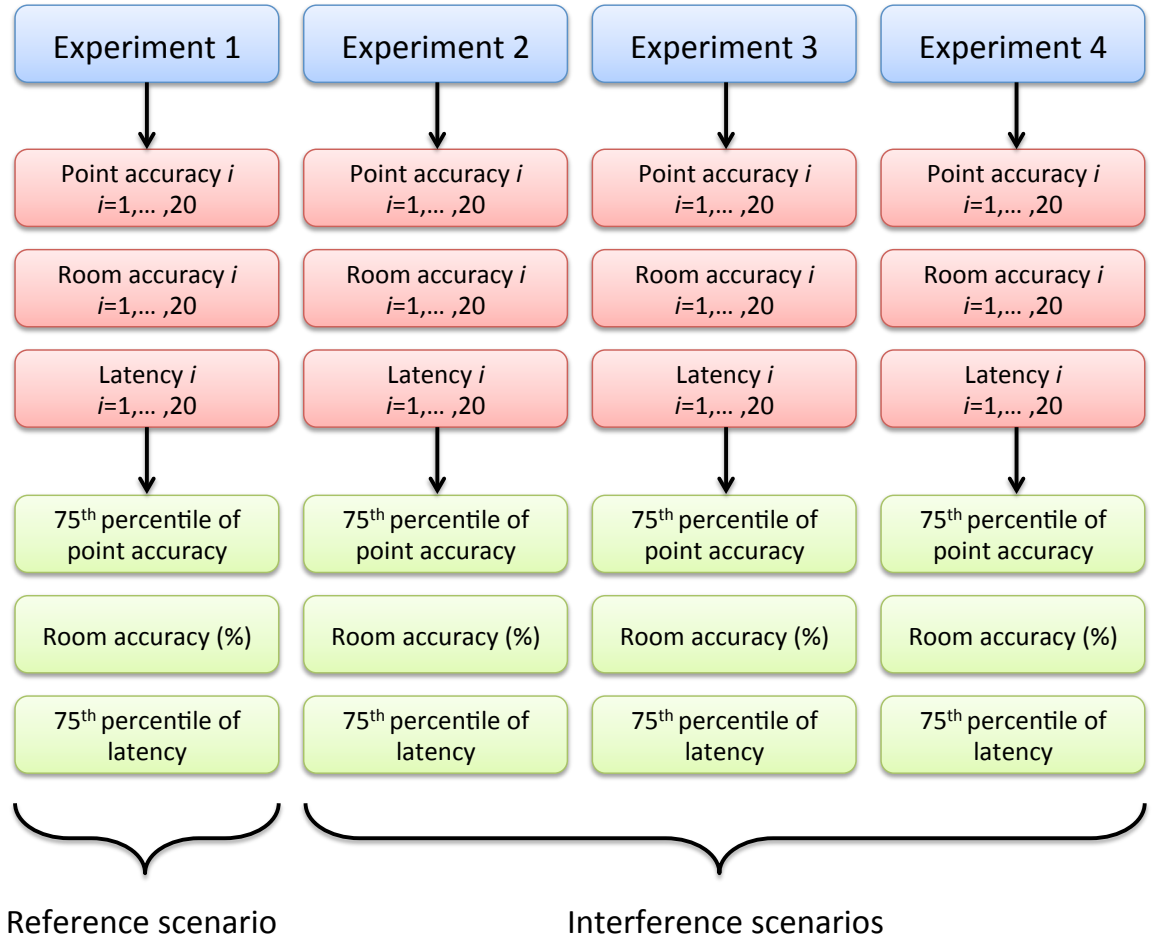


Figure 8.1: Procedure of capturing performance metrics

Interference robustness is calculated using the principle given in Figure 8.2. For each interference scenario the interference robustness is calculated for each performance metric, using the Equation 8.4. The overall interference robustness is the averaged interference robustness over all interference scenarios and all performance metrics, given with following equation:

$$\overline{M} = \frac{1}{9}\sum_{i=1}^{3}(M_1(i) + M_2(i) + M_3(i)) \tag{8.5}$$

In the equation the sum goes over all three interference scenarios ($i = 1, 2, 3$), and $M_1(i)$, $M_2(i)$ and $M_3(i)$ are interference robustness of 75th percentile of point accuracy, interference robustness of percentage of room level accuracy and interference robustness of 75th percentile of latency for scenario i, respectively.

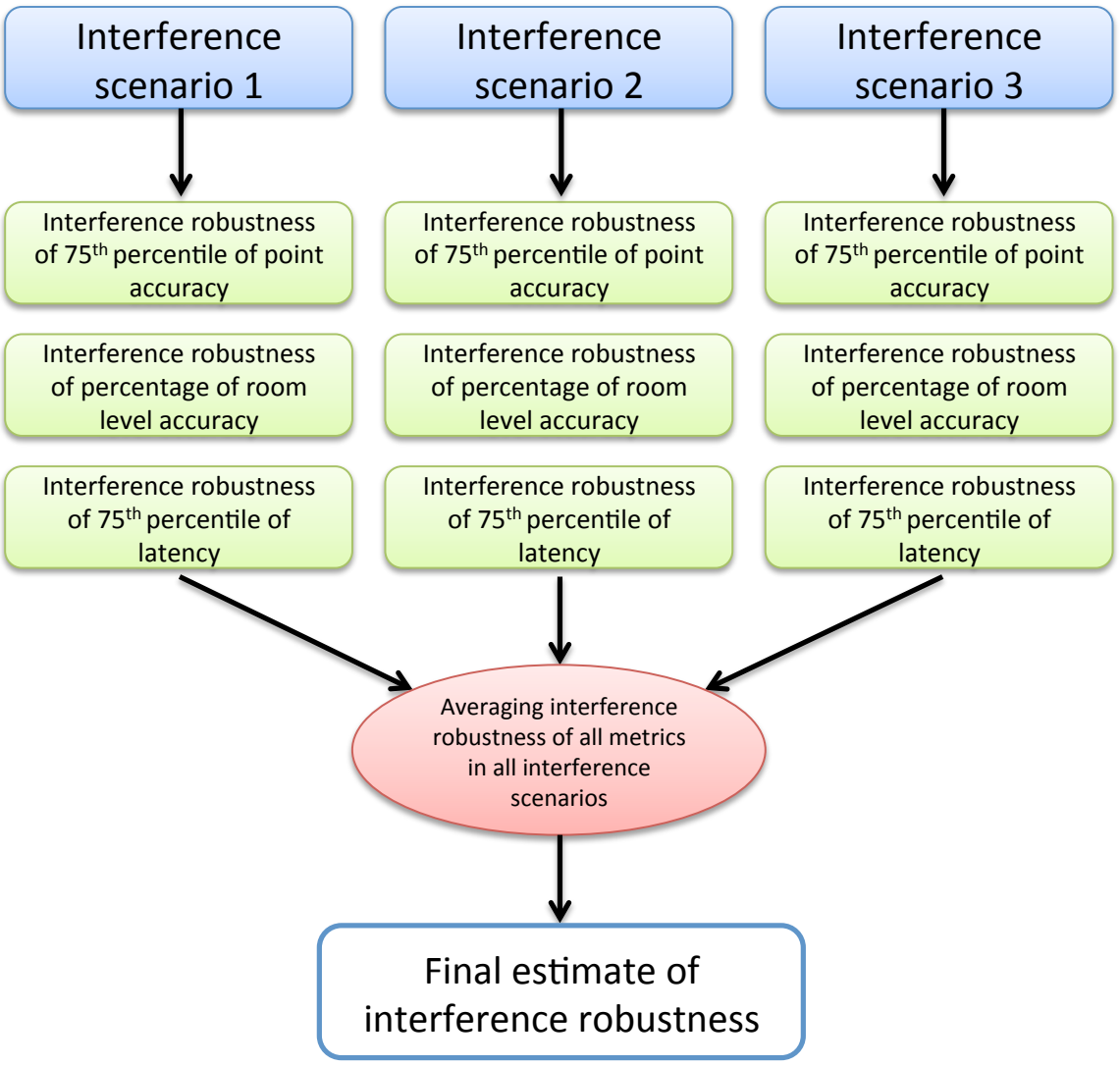


Figure 8.2: Procedure of capturing derived metric - interference robustness

8.4 Calculation of Final Score

Final scores will be calculated according to the approach described in the EVARILOS Benchmarking Handbook and presented in Figure 8.3. EBH proposes the calculation of the score for each metric according to a linear function that is defined by specifying minimal and maximal acceptable value for the metric. Furthermore, EBH proposes the use of weighting factors for defining the importance of each metric for a given use-case.

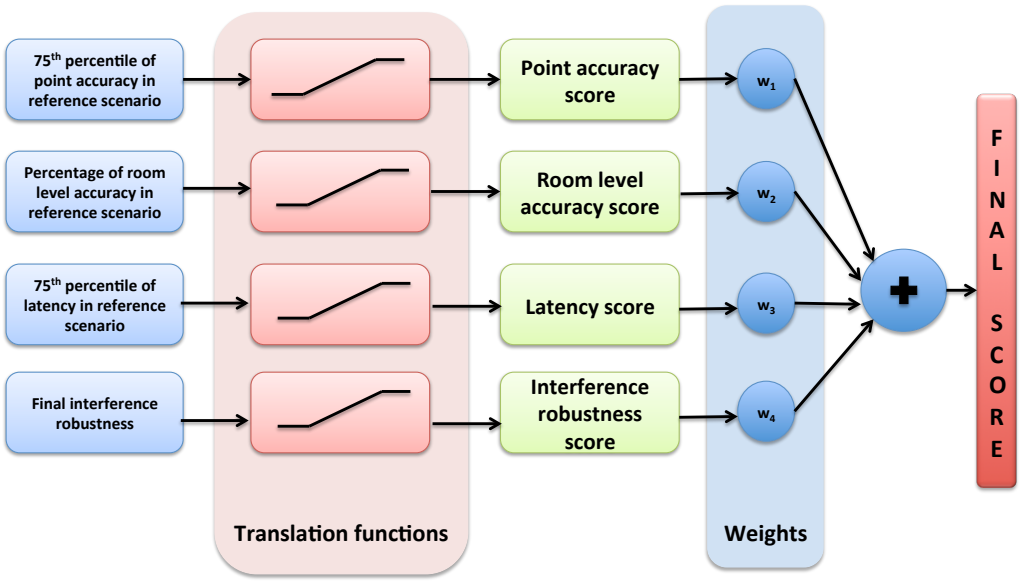


Figure 8.3: Calculation of the final score

In general, the linear translation function for calculating the score of each particular metric is given in Figure 8.6, where score can vary from 0 to 10. Minimal and maximal acceptable values are defined with M_{min} and M_{max}, respectively. Note that M_{min} can be bigger than M_{max}, e.g. in defining the acceptable point accuracy values one can discuss about acceptable localization error margins. Here M_{min} is the biggest acceptable error, while M_{max} is the desired average localization error.

$$Score = \max\left(0, \min\left(10, \frac{m - M_{min}}{M_{max} - M_{min}}\right)\right) \tag{8.6}$$

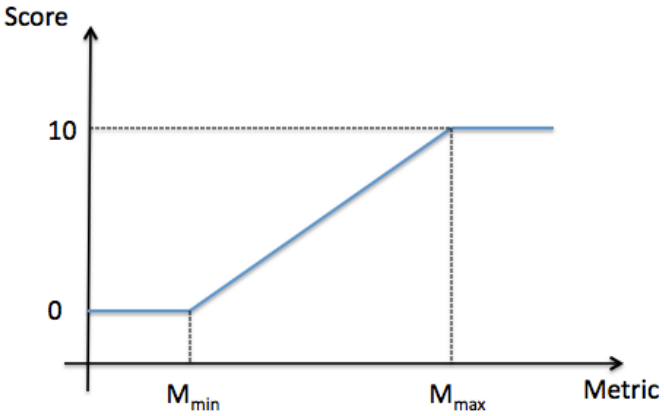


Figure 8.4: Linear translation function for each metric in case when $M_{min} < M_{max}$

In the Track 3 of the Open Challenge three winners will be declared, based on the final

scores for three different sets of marginal values and weights. For the calculation of final scores in the Track 3 of the challenge, the sets of marginal values and weights that will be used for different metrics in each category are given in Table 8.1, Table 8.2 and Table 8.3.

Table 8.1: Marginal values and weights for the first category

Metric	**Acceptable value (M_{min})**	**Desired value (M_{max})**	**Weight**
Point accuracy	10 m	1 m	0.40
Room level accuracy	50 %	90 %	0.40
Latency	20 sec	1 sec	0.10
Interference robustness	50 %	10 %	0.10

Table 8.2: Marginal values and weights for the second category

Metric	**Acceptable value (M_{min})**	**Desired value (M_{max})**	**Weight**
Point accuracy	10 m	1 m	0.20
Room level accuracy	50 %	90 %	0.20
Latency	20 sec	1 sec	0.50
Interference robustness	50 %	10 %	0.10

Table 8.3: Marginal values and weights for the third category

Metric	**Acceptable value (M_{min})**	**Desired value (M_{max})**	**Weight**
Point accuracy	10 m	1 m	0.20
Room level accuracy	50 %	90 %	0.20
Latency	20 sec	1 sec	0.10
Interference robustness	50 %	10 %	0.50

9 Evaluated Systems Under Test

Descriptions will follow after the selection of competitors (May 2014).

10 Results of Track 3 of the EVARILOS Open Challenge

Results will follow after the end of competition (July 12, 2014).

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