SEVENTH FRAMEWORK PROGRAMME
THEME 3
Information and Communication Technologies

Grant agreement for:
Collaborative project, Small and medium-scale focused research project (STREP)

Deliverable D1.5:

Hardware Capabilities, Maintenance and Future Dimensions

Project acronym: WISEBED
Project full title: Wireless Sensor Network Testbeds
Grant agreement no.: 224460

Responsible Partner: FUB
Report Preparation Date: May 31, 2011

Contents

1 Introduction

The WISEBED project aims to provide a federation of large wireless sensor network testbeds across Europe. The WISEBED research facility is available over the Internet. The resources deployed in the project, include different types of hardware platforms for wireless sensor networks in terms of wireless interfaces, memory size, CPU, and available sensors. The general architecture of a wireless sensor testbed is shown in Figure 1.

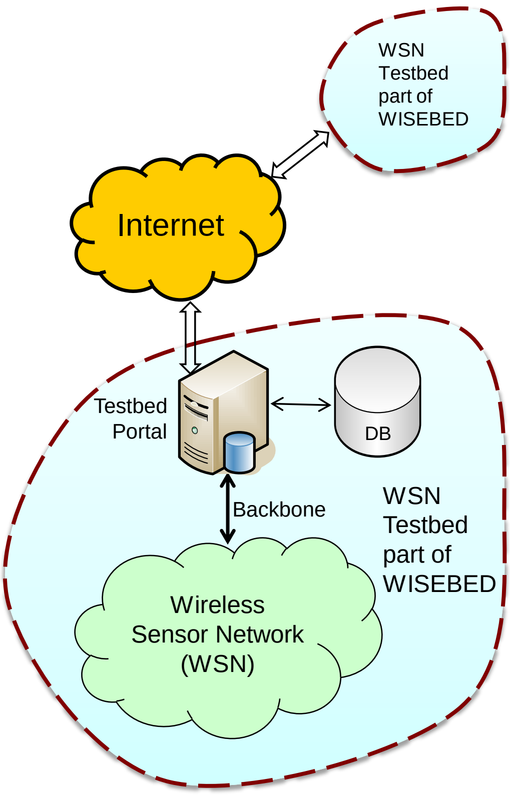

Figure 1: General testbed architecture. The figure shows the interconnection of wireless sensor testbeds via the Internet with the help of a Portal server. The Testbed Portal is connected with the testbed with a wired or wireless backbone.

The maintenance of such a federation of testbeds, needs rigorous mechanisms to ensure reliability of the whole network. The maintenance of individual sensor nodes at each testbed, plays a vital role in providing a reliable experimentation facility to its user. It is important, since the failing of individual sensor nodes can severely affect the results of the experiments being executed. Each partner has placed a self-monitoring mechanism to avoid such adverse affects. These self-monitoring mechanisms are tailored to suit the individual needs of their respective testbed.

In WISEBED there are three kinds of wireless sensor nodes, namely the indoor stationary, outdoor stationary and indoor mobile nodes. The number of stationary indoor and mobile wireless sensor nodes have increased since the last year. Moreover, there are also some outdoor wireless sensor node deployments at different partners.

This deliverable focuses on range of hardware capabilities deployed for this project. Moreover, maintenance issues are also discussed. The report is concluded with some discussion on future dimensions.

2 Hardware Capabilities

The heterogeneous hardware deployed at all WISEBED partners ensures wide range of application scenarios. Moreover, it also illustrates the range of capabilities of all the testbeds. In this section, we briefly discuss the range of hardware capabilities with focus on heterogeneity of these testbeds.

2.1 Overview

Table 1 shows the summary of the stationary indoor wireless sensor nodes deployed at each WISEBED partner. There are nine different types of wireless sensor nodes deployed including iSense [2], Tmote Sky [4], MicaZ [3], MSB-A2 [1], etc. The processor types also varies from CISC architecture to modern RISC architecture. Each wireless sensor node type presents a whole new range of application scenarios for its user. Their technical specifications allows the user to select appropriate type for highest performance or energy-efficiency. The trade-off depends upon the requirement of the user and the scenario.

The variety of platforms also ensure availability of a variety of operating systems. Different platforms support the range of operating systems such as the popular TinyOS supported by Tmote Sky nodes. Contiki is supported by Mica2 nodes currently deployed at different partners. Other emerging operating systems are also available to serve users who are interesting in experimenting with those operating systems. It helps to widen the number of users using WISEBED.

The range of the sensors is also worth mentioning. Currently, there are more than seven different sensors at different sites. They range from most simple and commonly used, such as temperature, humidity etc., to most sophisticated sensors like Anisotropic Magneto Resistive (AMR), 3-axis accelerometer, etc. The different sensors cover diverse application areas and therefore they provide more usability for the users.

Table 2 shows the summary of the mobile indoor wireless sensor nodes deployed at each WISEBED partner. The addition of mobile wireless sensor nodes further diversify the capabilities to attract more end-users for WISEBED. At present, there

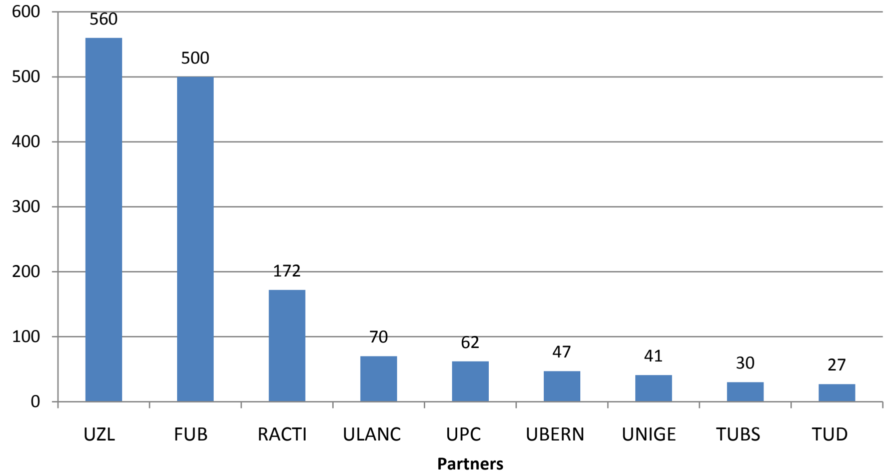

Figure 2: Number of wireless sensor nodes at partners. The graph shows the total number of persistent and non-persistent wireless sensor nodes at partners.

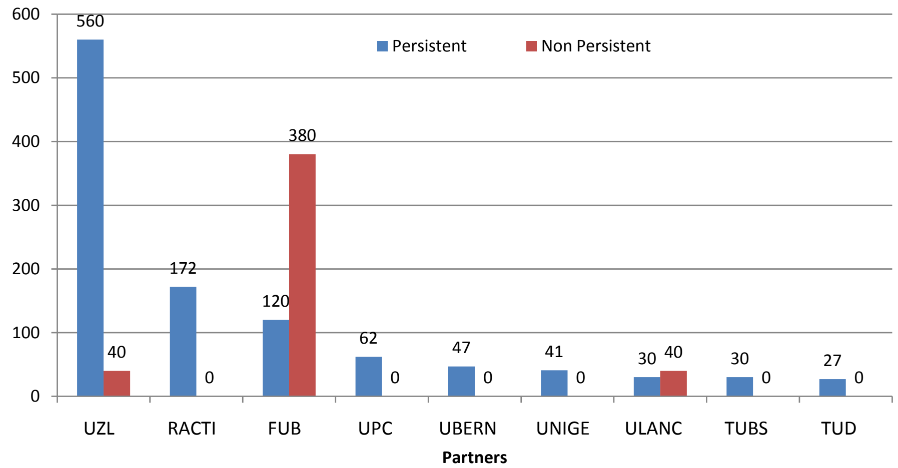

Figure 3: Number of persistent and non-persistent wireless sensor nodes at partners. The graph shows the total number of available persistent and non-persistent wireless sensor nodes at partners.

are about 50 mobile wireless sensor nodes. It is a promising feature which enables the user to run and test their algorithms on low-mobility mobile wireless sensor nodes.

2.2 Analysis

The number of wireless sensor nodes deployed at partners is shown in Figure 2. The total number of these nodes exceeds 1500 wireless sensor nodes. Figure 3 illustrates the number of *persistent* and *non-persistent* wireless sensor nodes of different types at partners. The *persistent wireless sensor nodes* are defined as the wireless sensor nodes permanently attached to a testbed at partner. The *non-persistent wireless sensor nodes* are the wireless sensor nodes available on the request of the user and are not permanent part of any testbed. In the remainder of this deliverable, we consider only the *persistent wireless sensor nodes* at partners.

The wireless sensor nodes deployed at different sites are divided into three types

Stationary Sensor Node Deployments					
Partner	Nodes	Sensors	Wireless Interface	Backbone Type	Quantity
UZL	Pacemate	None	Xemics RF (868 MHz)	Wired (Ethernet)	180
	iSense	Temperature, light, PIR, accelerometer	IEEE 802.15.4 (2.4GHz)		180
	TelosB	Temperature, humidity, light	IEEE 802.15.4 CC2420 (2.4GHz)		180
ULANC	Tmote/TelosB	Temperature, humidity, light	IEEE 802.15.4 CC2420 (2.4GHz)	WiFi (IEEE 802.11)	40
UBERN	TelosB	Temperature, humidity, light	IEEE 802.15.4 CC2420 (2.4GHz)	Wired (Ethernet)	40
	MSB430	Temperature, humidity			7
RACTI	TelosB	Temperature, humidity, light	IEEE 802.15.4 CC2420 (2.4GHz)	WiFi (IEEE 802.11)	20
	MicaZ	Temperature, light, accelerometer, acoustic, and magnetic fields	IEEE 802.15.4 (2.4GHz)		20
	iSense	Temperature, humidity, PIR	IEEE 802.15.4 (2.4GHz)		75
	SunSPOT	Light	IEEE 802.15.4 (2.4GHz)		57
UPC	SunSPOT	Temperature, light, accelerometer	IEEE 802.15.4 (2.4GHz)	Wired (Ethernet)	36
	iSense	Temperature, humidity, PIR	IEEE 802.15.4 (2.4GHz)		14
	iSense	Solar harvesting	IEEE 802.15.4 (2.4GHz)		5
UNIGE	iSense	Temperature, light, PIR, AMR, accelerometer	IEEE 802.15.4 (2.4GHz)	Wired (Ethernet)	36
	MicaZ	Temperature, light, accelerometer, acoustic, and magnetic fields			2
TUD	TNode	Temperature, humidity	CC1000 (868 MHz)	Wired (Ethernet)	24
	Tmote Sky	Temperature, humidity, light	IEEE 802.15.4 CC2420 (2.4GHz)		8
	G-Node		IEEE 802.15.4 (2.4GHz)		108
FUB	MSB-A2	Temperature, humidity	CC1100 (864-970MHz)	Wired (Ethernet)	110
TUBS	iSense	Pressure , infrared	None	Wired (Ethernet)	30

Table 1: Summary of the stationary sensor node deployments at WISEBED

Mobile Sensor Node Deployments					
Partner	Nodes	Sensors	Wireless Interface	Backbone Type	Quantity
UZL	iSense+Roomba 530	Touch, cliff, dirt	IEEE 802.15.4 @ 2.4GHz	IEEE 802.15.4 @ 2.4GHz	10
	Lego Mindstrom NXT robot	Ultrasonic, light	-	-	10
TUBS	iSense+Roomba 530	Touch, cliff, dirt	IEEE 802.15.4 @ 2.4GHz	IEEE 802.15.4 @ 2.4GHz	10
RACTI	SunSPOT + Moway	Temperature, light, accelerometer, infrared	IEEE 802.15.4 @ 2.4GHz	IEEE 802.15.4 @ 2.4GHz	10
	iSense+Arm Band	Temperature, light	IEEE 802.15.4 @ 2.4GHz	IEEE 802.15.4 @ 2.4GHz	10
UPC	SunSPOT + Moway	Temperature, light, accelerometer, infrared	IEEE 802.15.4 @ 2.4GHz	IEEE 802.15.4 @ 2.4GHz	6
	Lego Mindstrom NXT robot	Ultrasonic, light	-	-	1
UNIGE	Surveyor SRV-1	Video camera (160x180), laser pointer, ultrasonic ranging	IEEE 802.15.4 @ 2.4GHz	IEEE 802.15.4 @ 2.4GHz	2
	Crane-Line Construction + iSense	iSense compatible	IEEE 802.15.4 @ 2.4GHz	IEEE 802.15.4 @ 2.4GHz	1
FUB	EZ430-Chronos Watch	Temperature, 3axis, pressure, accelerometer	CC1111 (868MHz)	CC1111 (868MHz)	5
	Lego Mindstrom NXT robot	Temperature, 3axis, pressure, accelerometer	CC1111 (868MHz)	CC1111 (868MHz)	5

Table 2: Summary of the mobile sensor node deployments at WISEBED

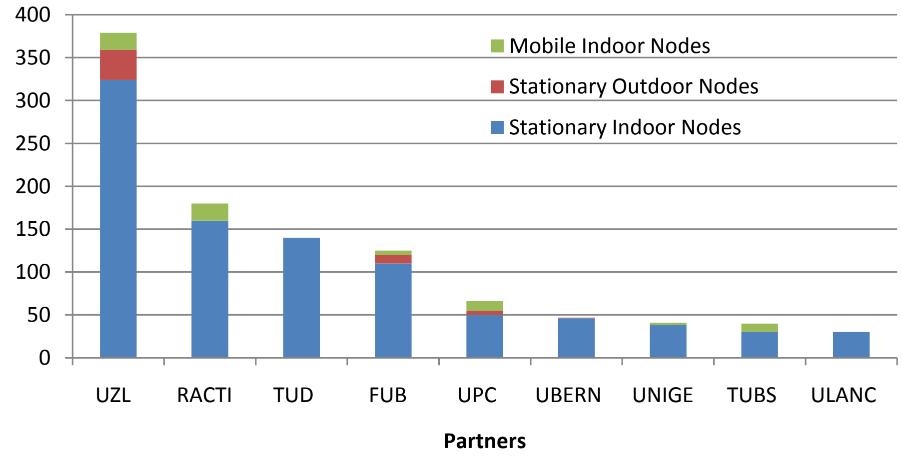

Figure 4: Number of nodes at partners. The graph shows the number stationary, mobile, and outdoor wireless sensor nodes.

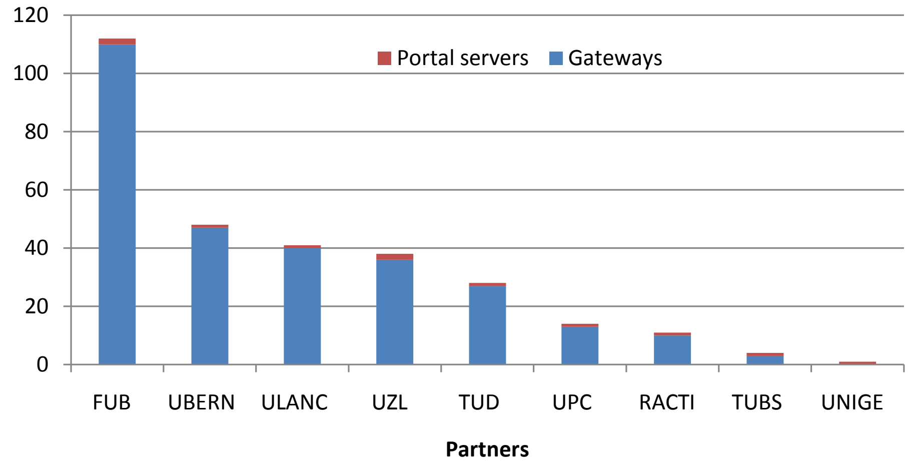

Figure 5: Number of gateways and portal servers at partners. The graph shows the number gateways and portal servers used at each partner.

namely stationary indoor, stationary outdoor, and mobile wireless sensor nodes. All the mobile nodes are deployed indoors only. Figure 4 shows the present number of wireless sensor nodes of different types at all partners. The total number of mobile nodes is 70. There are about 60 stationary outdoor nodes in all the testbeds, whereas the total number of stationary indoor nodes is around 1000.

The nodes deployed at different partners need additional infrastructure to enable them to become accessible over the Internet. Figure 5 shows the present number of gateways and portal servers used in deploying the respective testbed at each partner. It is worth noting that the number of gateways required for setting up the infrastructure is around 300. The large number of gateways contribute to communicating with the portal server at each site. Most partners have only a single portal server to enable their testbed to be accessible to the Internet.

The analysis of the different types of wireless sensor network platforms suggests a range of wireless sensor platforms. Figure 6 shows the complete picture of differ-

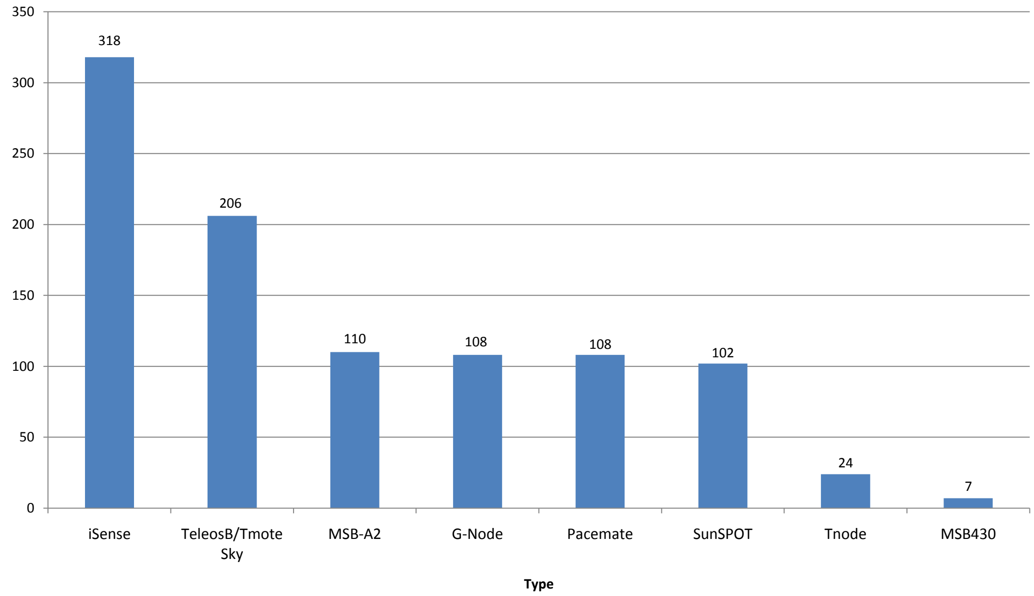

Figure 6: Number of different wireless sensor nodes at partners. The graph shows the total number of wireless sensors of different types at partners.

ent types of wireless sensor platforms at partners. The range of different platforms, including some popular platforms, ensures a wide range of users for WISEBED.

The different types of sensors are an important part of wireless sensor network testbeds. Currently, there are more than 8 types of sensors deployed of different types. The quantity of each is illustrated in Figure 7. The most commonly used temperature and humidity sensors are higher than the other specialized sensors such as AMR sensor etc.

Figure 8 illustrates the evolution in the number of wireless sensor nodes at all partners. The graph clearly suggest a smooth increase in the number of wireless sensor nodes deployed. The large number of indoor mobile nodes is encouraging, since it offers the users to develop and test algorithm for wireless sensor networks under low mobility. Different algorithms developed for such networks can be extensively tested using WISEBED. The stationary outdoor nodes also provide an avenue for the users to understand the dynamics of wireless sensor networks deployed outdoors. The performance parameters differ with respect to the indoor counterpart and hence is very important to consider those parameters in developing algorithms specifically targeted for them.

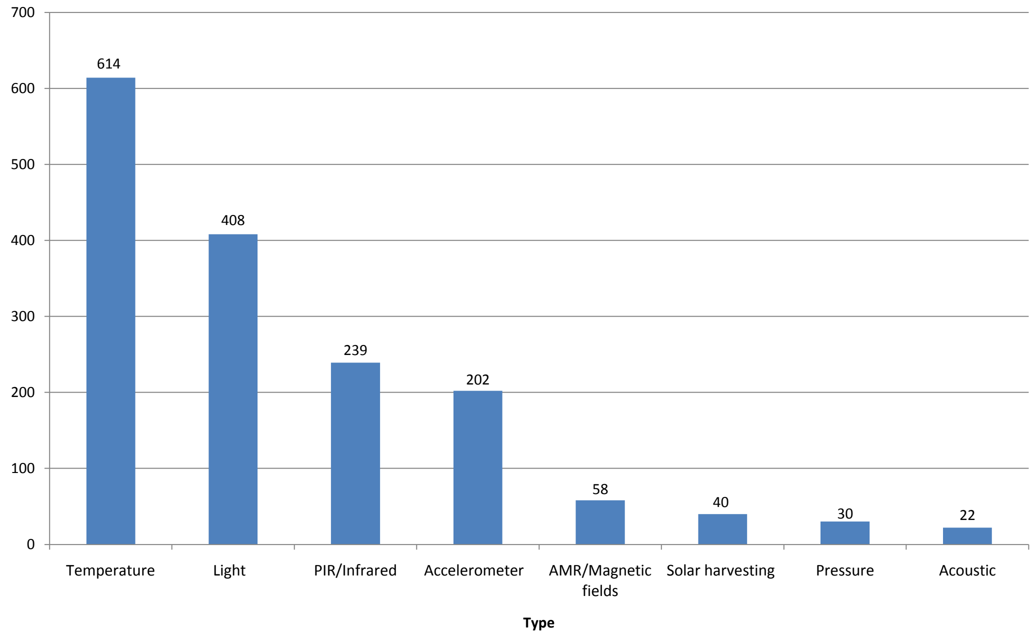

Figure 7: Number of sensors at partners. The graph shows the number of sensors of different types at partners.

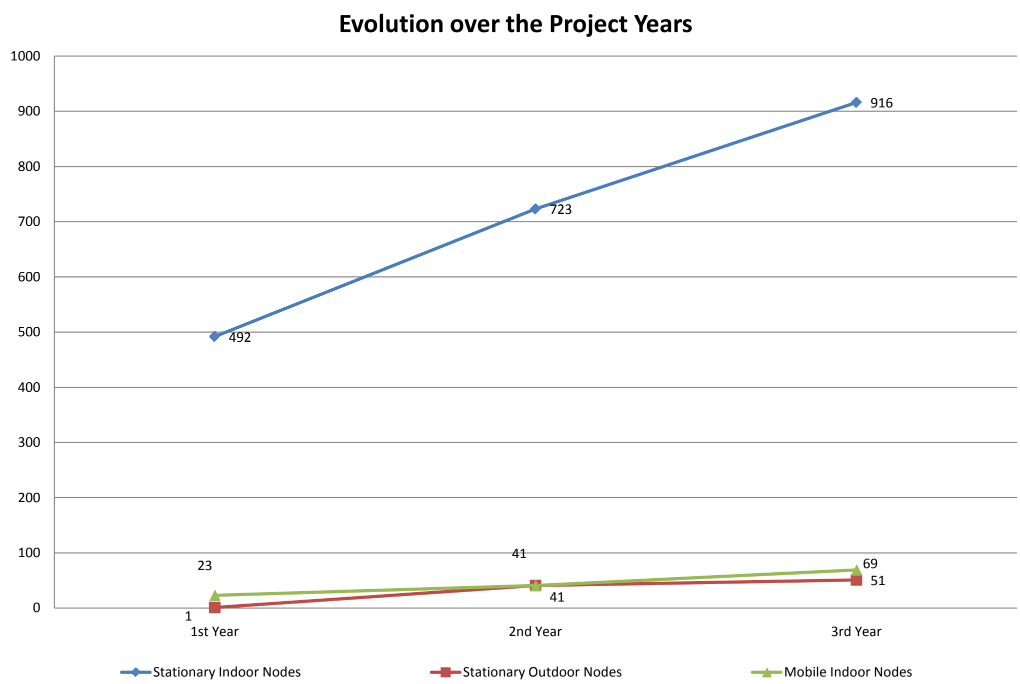

Figure 8: Evolution of number of wireless sensor nodes at partners. The graph shows the number of wireless sensor nodes over the tenure of WISEBED.

3 Maintenance

The maintenance of a large wireless sensor network testbeds is a very important issue. To ensure proper maintenance, an efficient mechanism needs to be in place at every testbed. These mechanisms can be divided into two types namely, *self-monitoring* and *periodic maintenance*.

3.1 Self-monitoring mechanism

A self-monitoring system is important to enable the testbed to recover from minor errors or malfunctioning. Currently, all the WISEBED partners have a custom self-monitoring tailored to their individual needs and requirements. The aim of such a system is to keep track of all the wireless sensor nodes in the testbed. It also ensures proper triggering of a self-healing system which enables the sensor nodes to come back to their normal state in case of any failures or malfunctioning.

3.2 Benchmarking

There are many other factors that contribute to the overall characteristics of a deployed testbed. The characteristics of the network define the performance limitations for the respective WSN. The strengths and weaknesses of a testbed deployment needs evaluation to quantify them into certain performance metrics for categorization of different testbeds according to application areas. Therefore, benchmarking according to some standardized performance metrics enables the evaluation of the testbed. Benchmarking assists a non-expert user to benefit from the available testbeds at the fullest. Researchers from other fields such as biology, environmental sciences etc., also use different testbeds for experimentation. Such benchmarking assists them to select the most appropriate testbed to meet their experimental requirements. For example, if an environmental scientist wants to run certain experiments to collect data of humidity, temperature, and other environmental indicators, benchmarking assists to find the most appropriate testbed with minimum technical detail required as an input.

The periodic benchmarking helps in performance evaluation of the respective testbed. This evaluation enables to record the different performance parameters to keep track of the overall testbed performance. It also helps the testbed administrators to monitor the performance of their respective testbed and to take appropriate action where necessary. Moreover, the values of performance metrics from different testbeds enables comparison of two or more testbeds. Figure 9 shows the spider chart showing the different possible performance metrics. The testbed comparison elaborates the

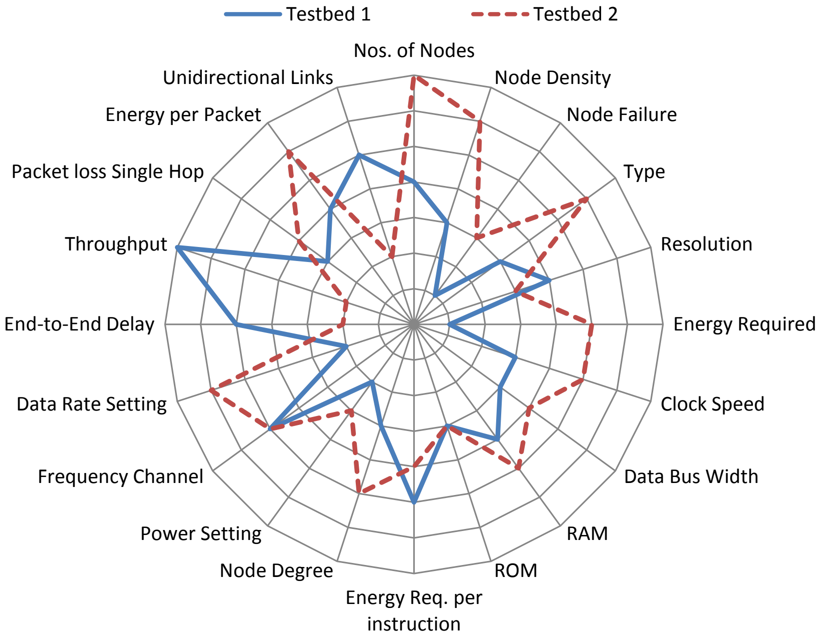

Figure 9: Benchmarking of different testbeds. The strengths and weaknesses of both WSN testbeds are visible from the differernt values of performance metrics.

strengths and weaknesses of the two testbeds.

Currently, FUB is working on developing *WiseBench*, which is a framework based on *Wiselib* to enable benchmarking of wireless sensor network testbeds. Although its development is still under-progress, but the framework will be completed after the end of WISEBED.

3.3 Periodic maintenance

There are some cases when the self-healing system cannot recover the wireless sensor node(s) in a testbed from its state of malfunctioning. In such cases, respective administrator(s) intervention is necessary to ensure proper recovery of the affected wireless sensor node(s). Pre-defined maintenance time slots can also help the administrators to fix any malfunctioning. This helps to fix any malfunctioning without affecting the results of any experiments.

4 Conclusion and Future Dimensions

In this document we have presented, the description of the hardware capabilities of testbeds at the different partners. Moreover, we gave an overview of the different testbeds at all WISEBED partners. A brief overview of the different maintenance aspects are also presented.

The project aimed at establishing a pan-European infrastructure of interconnected wireless sensor network testbeds. The goal is achieved by the deployment of more than 1000 heterogeneous wireless sensor nodes across all partners. The use of a similar general network infrastructure at each partner, allowed to establish an interconnection among all testbeds. Federation of all testbeds is the state of the art to provide the end-user with variety of options while experimenting. Deployment of indoor mobile nodes along with the stationary outdoor wireless sensor nodes further enhances the capabilities of these testbeds. Furthermore, different testbed maintenance and repair mechanism ensures maximum availability of these testbeds to their end-users.

The WISEBED consortium agreed to collaborate and make use of their experience expertise in future research projects. Most partners also agree to make their testbed available beyond the life of WISEBED. Similarly, the testbed infrastructure is also used in other existing/upcoming research projects where WISEBED partners are participating.

References

[1] M. Baar, H. Will, B. Blywis, T. Hillebrandt, A. Liers, G. Wittenburg, and J. Schiller. The scatterweb msb-a2 platformfor wireless sensor networks. Technical Report TR-B-08-15, Takustrae 9, 14195 Berlin, Germany, 09 2008.

[2] coalsesenses GmbH. http://www.coaelesenses.com.

[3] MicaZ. The MICAz is a 2.4 GHz, IEEE/ZigBee 802.15.4, board used for low-power, wireless, sensor networks. http://www.xbow.com.

[4] Tmote SKY. Reliable low-power wireless sensor networking platform for development - platform for self-configuring wireless sensor networks. http://www.moteiv.com.