ANALYSIS OF IoT TEST BEDS

Chandana jayaram, Sri lalitha devi
Department of Computer Science Engineering
National Institute of Technology, Karnataka

INTRODUCTION

The Internet of Things is a technological revolution that represents the future of computing and communications, and its development depends on dynamic technical innovation in a number of important fields, from wireless sensors to nanotechnology. Internet of Things (IoT) is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are designed and made capable of data transfer over a network without manual intervention.In simple terms, the concept of IoT is connecting things to the internet. This ability of the things to receive and send information makes them smart. The concept of IoT has been drawing a lot of attention for its research for a considerable amount of time now.

Recent advances in the Internet of Things (IoT) area have progressively moved in different directions (i.e. designing technology, deploying the systems into the cloud, increasing the number of inter-connected entities, improving the collection of information in real-time and not less important the security aspects in IoT).In spite of different advancement in technology, challenges related to assessment of IoT solutions under real scenarios and empirical deployments still hinder their evolvement and significant expansion. To design a system that can adequately bolster substantial range of applications and be compliant with superfluity of divergent requirements and also integrating heterogeneous technologies is a difficult task. Thus, simulations and testing to design robust applications becomes paramount elements of a development process. For this, testbeds are developed in order to test and manage the applications. Testbeds provide platforms to think through innovations and test new applications, processes, products, services and business models to ascertain their usefulness and viability before taking them to market. They uncover the technologies, techniques and opportunities essential to solving these and other important problems that benefit businesses and society.

But the infrastructure for IoT experimentation and testing is very scarce. Many efforts are being put to develop the test beds with real world circumstances to encourage the research. Any piece of technology should be properly tested, their behaviour and performance must be thoroughly analyzed before introducing to the real world, which explains the importance of real-time experimentation in developing a new software. These innovative developments have greater acceptance and take less time to market. The large scale development and maintenance of the testbeds encounters many challenges owing to their physical and virtual aspects.Despite of being a very popular research domain, the amount of work being carried out is very limited. This is because of the lack of awareness of the test beds available and how to access these test-beds. In this paper we have analyzed various test-beds that are available around the world and have listed out main features for those test-beds.

CATEGORIES OF TESTBEDS

Serial No:	Name of the testbed	Type of the testbed	URL
1	FIT/IoT lab	Public	https://www.iot-lab.info/
2	FlockLab	Public	https://gitlab.ethz.ch/tec/public/flocklab/wikis/home
3	Fiesta	on-demand	http://fiesta-iot.eu/
4	GENI	Public	https://www.geni.net/
5	Orbit	Public	https://www.orbit-lab.org/
6	Phantomnet	Public	https://www.phantomnet.org/
7	Tutornet	on-demand	https://anrg.usc.edu/www/tutornet/
8	Twist	Public	https://www.twist.tu-berlin.de/testbeds/sensor.html
9	Kansei	Project in progress	Research being carried out at Ohio University
10	Jose	Project in progress	Undertaken by NCIT, Japan
11	Wishful	on-demand	http://www.wishful-project.eu/testbeds.html

I FIESTA-IoT testbeds

1.1 INTRODUCTION

The FIESTA-IoT facility is technology and domain agnostic (federating multiple smart city, smart home, crowd sensing testbeds) to allow experiments that demonstrate IoT interoperability across highly heterogeneous IoT environments. Fiesta-IoT platform federates 10 testbeds each which supports different domains and provides distinct resources to IoT experimenters. Among 10 the core testbeds are SmartSantander, SmartICS, SoundCity and KETI.

1.2 DESCRIPTION

SmartSantander is a large scale smart city deployment with thousands of fixed and mobile sensors for various domains such as Environment monitoring, Traffic monitoring, Augmented reality and many more. SmartICS mainly focuses on the domain of Smart Buildings and Smart Campus. It is based on indoor sensor nodes. SoundCity is a large scale crowd sensing testbed comprising of data that is collected from an application named Ambiciti. This application uses in-built sensors on mobile phones to sense various phenomena such as noise, motion and proximity. With KETI one can collect information about physical status of indoor and outdoor building environment and transfer it to the IoT server platform which can be used for IoT experiments.
The FIESTA infrastructure enables experimenters to use a single EaaS API (i.e. the FIESTA-IoT EaaS API) for executing experiments over multiple IoT federated testbeds in a testbed agnostic way i.e. like accessing a single large scale virtualized testbed.

1.3 HOW TO USE

In order to conduct IoT experiments using Fiesta testbeds, one must apply for rolling open call for experiments. The user must submit a brief description of their experiment through email to oc-info@fiesta-iot.eu as a proposal. Those proposal that get accepted will have guaranteed access to testbeds and will also get support from fiesta-IoT consortium partners.

II GENI

2.1 INTRODUCTION

GENI (Global Environment for Network Innovations) provides a virtual laboratory for networking and distributed systems research and education.GENI allows experimenters to obtain resources from locations around the United States. It is a federated testbed, which means that resources that are accessible through GENI are owned and operated by different organizations. Users can also ferderate their testbed with GENI.

2.2 RESEARCH AREAS

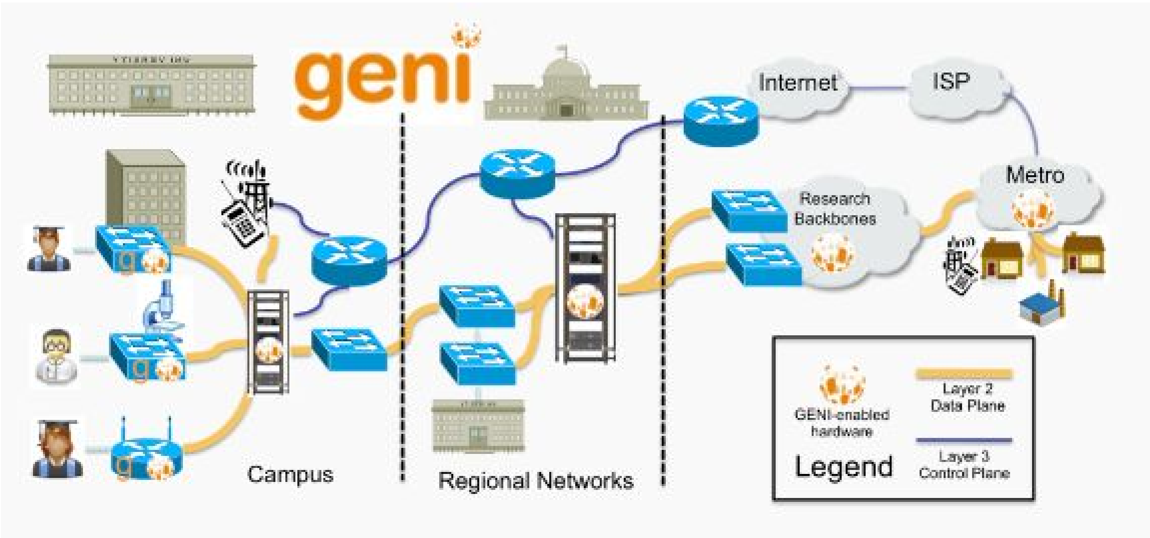
GENI is used for research in

- Future Internet Architectures
- Software defined networking
- Novel protocol suites
- 4G wireless networks
- Cloud computing

2.3 FACILITIES AND SERVICES

GENI provides a large scale experiment infrastructure that gives you access to hundreds of widely distributed resources. You can setup Layer 2 connections between computer and resources and run your own Layer 3 and above protocols. With GENI you can even program the switches in the core of your network which helps with novel network protocols or with novel IP-routing algorithms. Architecture of GENI testbed mainly consists of control plane, data plane and base stations as shown in the figure below. Here is a brief description about each component of GENI architecture:

- The control plane is used to discover, reserve, access, program and manage GENI compute and communication resources.
- The data plane is set up on demand according to experimenter's specification of resources.
- GENI wireless base stations have backhaul connections to a local GENI rack and connect through the rack to the rest of the GENI network.
- GENI provides a dataplane on GENI rack which is the best way to connect to campus resources.



Source: https://www.geni.net/documentation/geni-architecture/

2.4 HOW TO USE

Here is a brief overview about the workflow for a typical GENI experiment.

1. Experiment setup

a. Get a GENI account.
b. Join an existing project or create a new project. Only faculty and senior technical staff with project-lead privileges can create projects.
c. Create a slice.
d. Use an experimenter tool to:
    - Craft a Request RSpec that specifies the resources needed
    - Make the appropriate GENI AM API calls on the aggregates from where the resources are being requested.

2. Experiment execution

a. Use information in the manifest RSpec returned by the aggregates to log into compute resources, install software, send traffic on the network links, etc.

3. Finishing up

a. Delete resources obtained from the aggregates by using an experimenter tool to make the appropriate GENI AM API calls on these aggregates.

III PHANTOMNET

3.1 INTRODUCTION

PhantomNet is a mobile networking testbed that enable the fundamental research and innovation demanded to advance mobile networking beyond the state-of-the-art. The software stack that manages PhantomNet is based on Emulab, a testbed control suite that has been developed by the Flux Research Group at the University of Utah.

3.2 FACILITIES AND SERVICES

Phantomnet provides

1. Mobility realism is provided through a fully programmable attenuator array to mediate the Radio Access Network(RAN).
2. Phantomnet provides the ability to modify most of all mobile networks functions at multiple levels through network configuration and software extensions.
3. This testbed provides both the preconfined experiments for beginners and deep programmability for experts.
4. Phantomnet uses real wireless signals over real devices and the program that simulates the motion of those devices is repeatable.
5. Phantomnet sits over Emulab and it inherits the feature that promote repeatability along with many other features.

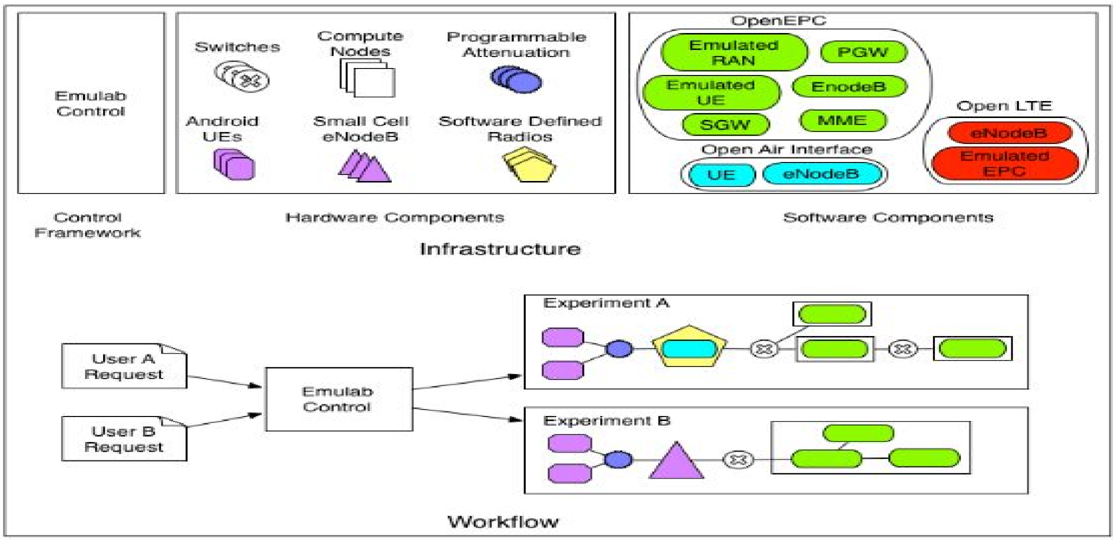
Resources available in *PhantomNet* include evolved packet core (EPC) software (OpenEPC, OpenLTE and Open Air Interface), hardware access points (ip.access and SDR-based eNodeBs), mobile user equipment (Nexus 5 phones and SDR-based), and a large set of commodity bare metal nodes, virtual nodes and other resources inherited from the main Emulab infrastructure.

- With Phantomnet you can explore traditional mobility platforms(3GPP), EPC setup with emulated endpoints and access points.
- One can mix an EPC core software with real, off-the-shelf eNodeBs and UEs.
- You can also experiment with RAN with software defined ratios and software implementation such as OpenAir Interface.
- With Phantomnet user can put in his own clean-slate core components and bridge off-the-shelf endpoints to it using OpenLTE.

3.3 HOW TO USE

Simplified workflow of Phantomnet

- Users of the testbed submit a description of their desired resources and topology as an NS script. This user-supplied resource and topology specifications are mapped to available resources by Emulab's constraint solver,and then the actual resources are allocated and configured as requested.
- At the tail end of the provisioning process, PhantomNet hooks in to the Emulab setup process to perform tasks that are specific to its unique resources.
- The node-side setup code also allows for user-provided hooks, which are run before and/or after the rest of the PhantomNet setup pieces.
- Users specify setup directives via the NS file, which are opaquely passed through by Emulab to the PhantomNet setup code.



Source :https://www.phantomnet.org/index.php

Tutorial: https://www.phantomnet.org/tutorials.php

IV Tutornet testbed

4.1 INTRODUCTION

Tutornet testbed is 3-tier low power wireless network testbed deployed at Ming Hsieh Department of Electrical Engineering at the University of Southern California (USC).
It is extensively used for research and teaching at USC.

4.2 FACILITIES AND SERVICES

Tutornet is currently composed of 113 sensor nodes , 13 concentrated nodes and servers.
The USB hubs are plugged into the Stargates which are kind of a master. They act as a base station and they communicate back and forth with the server over 802.11b standard.
Tutornet has a three-tier heterogeneous architecture depicted below.

- At Tier 1, a central server is responsible for the testbed reservation system and for redirecting communication between the sensor nodes and the remote user.
- At Tier 2, 13 concentrator nodes are physically connected through USB cables to the sensor nodes, and through Ethernet cables to the central server.
- At Tier 3, 113 sensor nodes use USB cables as a communication backhaul and as power source.

Main features of Tutornet are:

- It provides wireless multi-hop routing between the testbed server and the Stargate and among Stargates.
- It supports for remote and parallel re-programmable for sensor nodes.
- It enables pre-authorized external users to reserve the testbed through a web interface at a granularity of 1 node-hour, default 100 node-hours/user.

4.3 HOW TO USE

This testbed is accessible only to authorized users. A live dashboard that provides a visualisation of Tutornet testbed at http://testbed.usc.edu/dashboard/ .

V TWIST

5.1 INTRODUCTION

The TKN Wireless Indoor Sensor network Testbed (TWIST) is a scalable and reconfigurable Wireless Sensor Network testbed for indoor deployments. It is developed by the Telecommunication Network Group (TKN) at the TU Berlin.

5.2 FACILITIES AND SERVICES

TWIST mainly provides three components:

1. TWIST sensors
   With TWIST sensors one can do node configurations, network wide programming , out-of-band extraction of debug data and gathering of application of data.TWIST instance which spans the 3 floors of FT building in TU Berlin is one of the largest

academic testbeds for indoor deployments scenarios. This testbed is a 3 tier architecture.

- At the lowest tier is the sensor nodes which are connected via USB cabling and USB hubs to the testbed infrastructure.
- Second tier is formed by the super node which are able to interface with the previously described USB infrastructure.
- Third tier of the architecture is the server and control station which interact with super nodes using testbed backbones.

2. TWIST wireless

Wireless testbeds enable to effectively test the wireless protocols or applications in a real-life environment. At our group we already have a scalable and flexible testbed architecture for experimenting with wireless sensor network applications in an indoor setting.

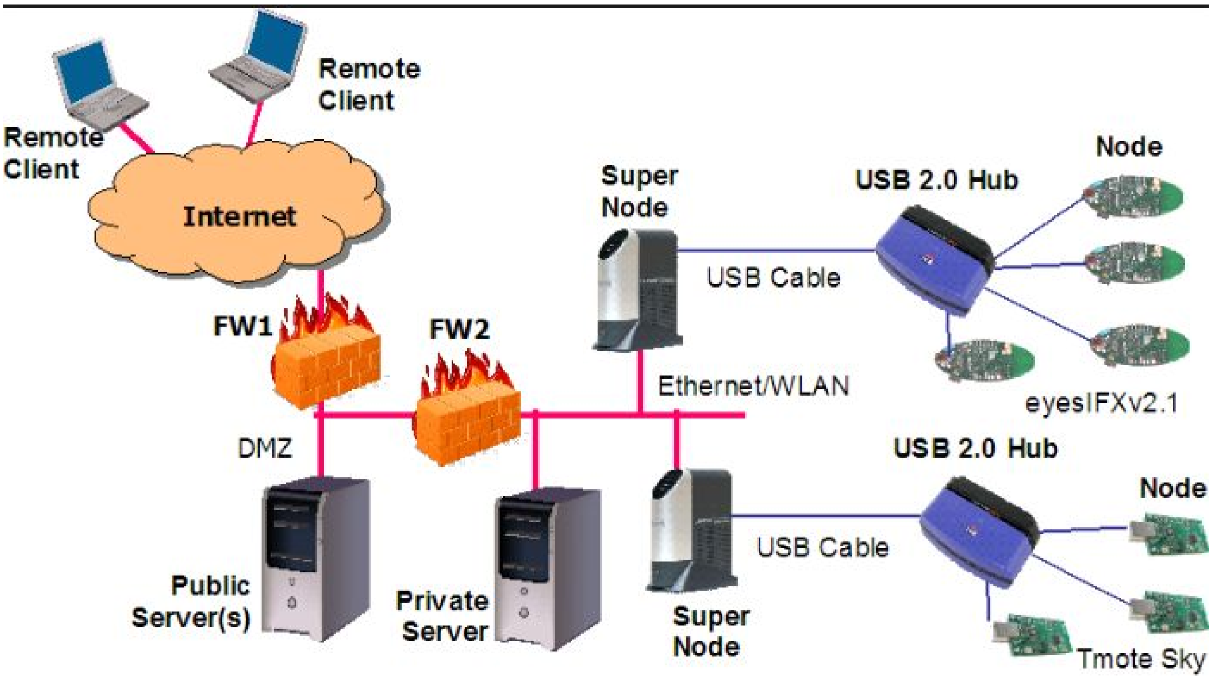
The following devices are supported:

- Intel NUC Embedded PCs
- TP-Link WDR4300 routers distributed in the whole TKN building

Users are given root access to the devices and can thus install any software required for experiments at will.

3. TWISTrobots

TWIST provides a modified version of TURTLEBOT called TWISTbot which operates over ROS system. The coordinate system for TWIST robots is the same as for TWIST sensor which allows a joint experiment without need to transform coordinate systems.



Souce :www.twist.tu-berlin.de/testbeds/

5.3 HOW TO USE

In order to use TWIST testbed one need to register at TWIST web interface and login. And also install the TinyOS 2 *Oscilloscope* application on a set of Tmote Sky nodes in the TKN TWIST testbed. A proper tutorial about how to get started with TWISTsensor and TWISTwireless is given at https://www.twist.tu-berlin.de/tutorials/index.html .

VI Flock Lab - Wireless Sensor Network(WSN) test-bed.

Description :

The test-bed allows detailed monitoring and stimulation of wireless sensor nodes. This test-bed allows multiple services to run simultaneously and synchronously against all nodes under test. It is available for research and development community.

Location :

Swiss Federal Institute of Technology, Zurich, Switzerland.The test-bed is run by the Computer Engineering and Networks Laboratory.

Deployment :

Current deployment consists of 27 observers and 1 server, spread across one level of the ETZ - building at ETH Zurich. LAN is used as backbone network
Architecture :
The test-bed has a 3-tier architecture. The tiers are independent of each other and introduce as low interference as possible to the WSN under test. The three tiers are as follows :

Lower tier :

This is the system layer which consists of sensor nodes, actual wireless sensor network which will be tested. These nodes build a communication network as they would in a real deployment. An observer node is attached to each of the sensor node, former more powerful than the latter.

Second tier :

This is the observation layer with observation nodes. Observation nodes are small computer based which runs Linux and they communicate over LAN or WLAN. This tier provides all services and efficient means for out - of - band extraction of data. It avoids interference with the system layer.

Third tier :

This consists of a dedicated server to which all the observer nodes connect. This server takes up the responsibility of configuration distribution to nodes, start and stop of test runs, collection, analysis and display of test data to the tester. The server also acts as the local synchronization server for the observer nodes to synchronize their local time.

An attached interface accomplishes the connection between sensor and the observer nodes. This architecture provides excellent scalability and flexibility.

Services :

- For detailed testing of sensor nodes :
    - Interfaces can be used by observer for testing.
    - Actuation and/or tracing of GPIO pins accurately, which provide distributed logic analyzer capabilities.
    - Controlling the serial port via TinyOS or Contiki serial forwarder
    - Profiling power measurements.
    - Distributed voltage control.
    - Serial interface logging and writing
- Upto 4 arbitrary wireless sensor nodes can be attached over a generic hardware interface flexibility.
- Network-wide programming and configuration of testbed and sensor nodes.
- Data from all services is merged by the architecture for a consistent global view .
- High-speed, flexible and reliable backbone for out-of-band extraction of data.
- Testbed consists of 30 organized observers in a mixed indoor/outdoor topology.

How to get started ?

1. Register for a FlockLab user account.The processing of request might take a day or two. In the meantime one can set up all the needed toolchains and get ready to start. Once the registration is processed, a confirmation mail will be received by the user.
2. Sign up for the FlockLab user mailing list.
3. If one wants to use TinyOS : Download the FlockLab sensor board definitions available on the website.
4. The template for test configuration of XML files are also to be downloaded from the website.
5. Login to FlockLab on user.flocklab.ethz.ch and register one's first test.
    - Configure the test
    - Upload target images
    - Verify and upload test configuration
    - Run the test
    - Interpret the test results
    - Delete tests

The detailed explanation for each step are explained in the tutorials provided by the test-bed’s website.

VII Open - Access Research Testbed for Next - Generation Wireless Networks [ORBIT]

Description :

NSF Networking Research Testbeds (NRT) program started this project in 2003 with a major grant and subsequently followed by other grants. It has been widely used for evaluation of emerging wireless network architectures and protocols. This test-bed is being used to support wireless aspects of the GENI and it's OMF(ORBIT Management Framework) is used as one of the core control frameworks in GENI. This test-bed supports wide range of experiments, a few of them are multi-radio spectrum coordination, dense WiFi networks, vehicular and ad hoc network routing, mobile content delivery and many more.

Location :

WINLAB Tech Center building in North Brunswick.

Deployment :

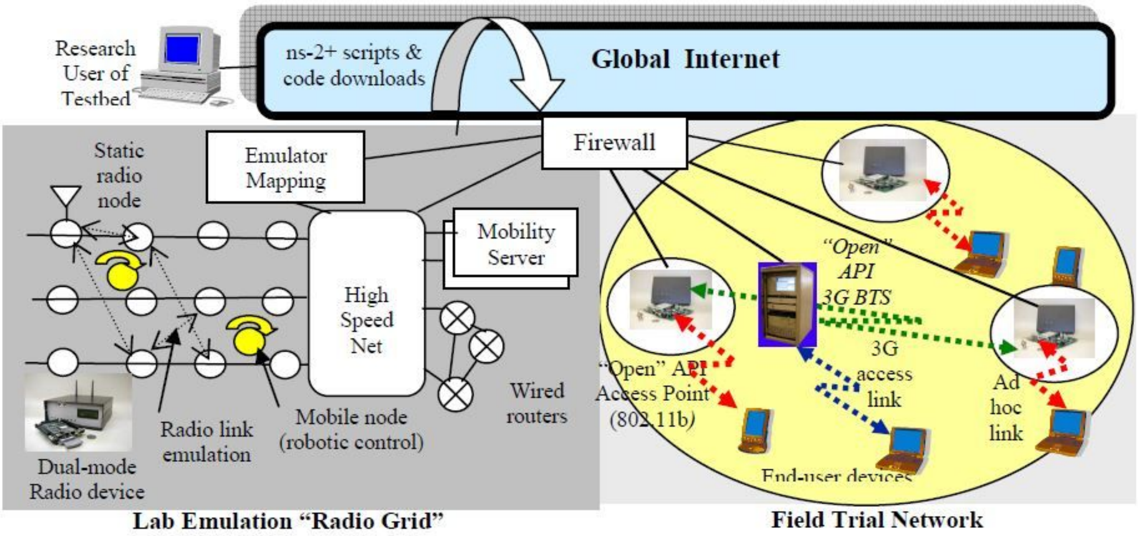
400 node radio grid emulator in a dedicated 5000 sq.-ft along with the outdoor set up of ORBIT nodes are deployed in North Brunswick.

Architecture :

This test-bed has a two-tier architecture : Indoor and Outdoor.

Indoor :

Radio grid emulator, for large scale reproducible experiments. This is central to the ORBIT facility. This uses 20X20 two-dimensional grid of programmable radio nodes. These radio nodes can be interconnected into specified topologies with reproducible wireless channel models.



Outdoor :

Field trial system, for subsequent real-world evaluations. It provides a configurable mix of both 802.11 wireless access and high speed cellular (LTE,WiMAX) in a real-world setting.

Users can migrate their experiments to the OUTDOOR ORBIT network after the validation of basic protocol or application concepts on radio grid emulator.

A number of SANDBOX networks are also included in this testbed. These are useful in controlled experimentation and debugging on specific aspects.

The test-bed is available for remote or on-site access by academic researchers both in the U.S and internationally.

The following resources can be accessed by the users :

- Base-stations and clients of LTE and WiMAX
- Cloud resources(a number of nodes with Tesla-based GPUs are included)
- Software defined networking(SDN) resources : NEC and Pronto switches, NetFPGA and NetFPGA-10G platforms
- A wide range of radio resources.

How to get started?

- One should have a registered ORBIT account.
- Configure your ssh client to use key based authentication.
- Following six steps are followed for a typical experiment :
  - Create a resource reservation
  - Login into reserved domain
  - Load an image onto the nodes
  - Turn the nodes on
  - Execute the experiment
  - View experimental results
  - Save the node image (optional)

The detailed description for setting up the account , to carry out the experiment and all other specifications are provided in the website

VIII FIT/IoT LAB

Description :

FIT/IoT Lab is the evolution and extension of the SENSLAB test-bed(2010-2013) The test-bed provides a very large-scale federated experimental platform for testing small wireless sensor devices and heterogeneous communicating objects. It provides full control of network nodes and direct access to the gateways to which nodes are connected.

Location :

There are a total of 1786 wireless sensor nodes located in different sites across France.

Deployment :

Sites (→) Nodes (below)	Inria Grenoble - Rhone Alpes	Inria Lille - Nord Europe	Inria Saclay - Ile-de-France	ICube - Strasbourg	Institut Mines - Telecom - Paris	CITI Lab - Lyon	Total
WSN430 node(868 MHz)	-	-	-	256	-	-	256
M3 node	384	259	12	120	90	18	883
A8 node	256	-	163	24	70	11	524
Custom node	-	34	89	-	-	-	123
Total nodes at each location	640	293	264	400	160	29	1786

Architecture :

IoT-LAB Node has three components :

The Open Node(ON) :

This is the low-power device the user reprograms. This node’s serial port is connected to the Gateway.

The Gateway(GW) :

Gateway is a small Linux computer. It is connected to the serial port of both the ON and the Control Node.It is itself connected to the backbone over Ethernet. On top of monitoring the On, it forwards the ON’s serial activity to the back-end servers.

The Control Node (CN) :

This coordinates reprogramming of ON, starts/stops/resets it and selects its power source.The Cn monitors the ON’s power consumption, drives its sensors and can serve as a wireless packet sniffer or inject arbitrary packets traffic.
The IoT-LAB nodes are interconnected through a backbone.

IoT-LAB provides three layers of API : allowing users to program embedded applications

Drivers :

Drivers offer direct access to the open - node hardware. They expose the details of WSN430 and M3 open-nodes.

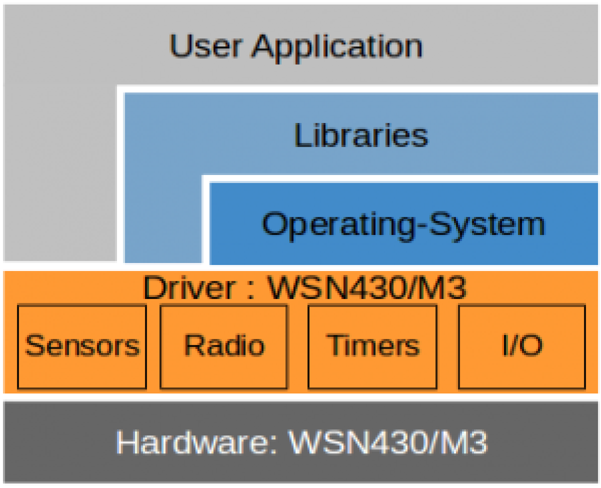
Operating Systems :

Various operating systems can run on open nodes. They provide higher-level features.

Communication Libraries :

They offer various levels of API on top of raw 802.15.4 chips drivers. Libraries are provided as standalone building blocks or integrated on top of an OS. Using these libraries users can develop connected application quickly. Libraries offered are CSMA, TDMA, 6LoWPAN

Users can develop applications built on top of supported OS-es or directly on top of the Drivers layer, without any OS.



IoT-LAB nodes satisfy the requirements such as reliable access to all nodes, non intrusive and application transparent real-time monitoring, real-time control of the experiments, security and data integrity.

How to get started?

- Log into the webportal
- Start a new experiment
- Select architecture, site, number of nodes and add them to your experiment
- Open the firmware selection dialog by clicking on the “Add firmware” button
- In the “Presets” tab, choose the “iotlab_m3_tutorial” firmware.
- Verify that everything is correctly configured and then click on “ Submit experiment”
- The user will now be redirected to the personal dashboard. The experiment changes the state from waiting, then launching and will finally be in running state.

CONCLUSION

The idea of IoT is growing in multiple dimensions and one need platform for conducting rigorous, transparent, and replicable testing of scientific theories, computational tools, and new technologies. That platform is provided as testbed by many institutes and companies. With so many test beds in picture is it hard to select an appropriate one for our experiment. In this report we have listed out some of the important test beds and their features. Also we have briefly mentioned the process to access those test beds. For detailed information about the test beds one can visit the websites mentioned in this report. Each of the test beds have tutorial explicitly provided by their developers about how to start and conduct experiments using the respective testbed. Experimenters can select the testbed according to their experiment and test it using these test beds.