Real-World G-Lab: Goals, Current Status and Future Plans

D. Bimschas*, S. Fekete†, S. Fischer*, M. Güneş‡, O. Hahm‡, H. Hellbrück§, A. Kröller†, R. Mietz¶, M. Pagel†, D. Pfisterer*, K. Römer¶, K. Schleiser‡, T. Teubler§

Institute of Telematics, University of Lübeck
Lübeck, Germany*

Technical University of Braunschweig
Braunschweig, Germany†

Free University of Berlin
Berlin, Germany‡

University of Applied Sciences Lübeck
Lübeck, Germany§

Institute of Computer Engineering, University of Lübeck
Lübeck, Germany¶

***Abstract*—The emerging Future Internet will bring a number of new challenges due to the inclusion of an enormous amount of distributed heterogenous mobile devices such as wireless sensor networks, mobile phones, and other sensor equipped embedded systems. Key challenges will be energy efficiency of protocols and algorithms due to the scarce resources of the used devices, the real-time search for real-world states as well as easy high-level application development. Real-World G-Lab will contribute to solutions of these problems by developing algorithms and techniques on different abstraction levels beginning from low level energy efficient protocols to high level application development.**

I. Goals

Based on technologies and algorithms that were developed about 30 years ago, today's Internet is approaching the limits of its legacy architecture. This has spawned a wide range of intensive studies on the Future Internet, including the German-Lab (G-Lab) initiative.

One of the promising emerging technologies of more recent years are wireless sensor networks (WSNs). The idea is to use sensor-equipped devices such as cellphones and other embedded systems that sense and interact with their environment for obtaining valuable information about the real world. Only a few mature techniques exist to integrate heterogeneous WSNs with the Internet; it is clear that upcoming massive amounts of data widely exceed the capabilities of classical approaches. The goal of *Real-World G-Lab* is to overcome these obstacles by working on the different levels of protocols, services and applications. We will enable developers to realize applications that rely on sensor data, without knowledge of the underlying hardware platform and the network protocols. This implies that sensors are able to participate in the Future Internet as peer hosts, enabling new fields of applications but likewise opening a set of new challenges in the context of efficient request processing by WSNs. We verify our concepts and applications inside the controllable environment of the G-LAB research network, by adding several outdoor WSN deployments to the experimental facility of the G-LAB project.

In summary, Real-World G-LAB contributes to the integration of resource-constrained (wireless) sensor devices into the Future Internet by investigating several key challenges, ranging from low-level energy efficiency to improved high-level application development.

II. Current Status

The project is currently in a state where many parallel conceptual, experimental and (software) development efforts are taken. These are prerequisites for and form the basis of our future research work. The following sub-sections will more precisely describe the status of the several areas of activity of the Real-World G-Lab project:

A. Testbeds

We successfully deployed the first outdoor testbed at the manors' garden at University of Lübeck. As a first experimental step, a software was developed and deployed that collects long-term data, which consists of status information about individual sensor nodes and the overall sensor network, as well as of sensor readings. The collected data will serve as a basis for our future research in the field of efficient sensor network monitoring, as well as for our research on sensor discovery and energy efficient protocols. Furthermore, the testbed has been made remotely accessible for administration, diagnosis and experimentation. Apart from that we are in the progress of integrating the testbed management and experimentation software, which was developed in the WISEBED [1] project, with the Real-World G-Lab outdoor testbeds in Lübeck and Braunschweig.

The hybrid DES-testbed at Freie Universität Berlin has been successfully extended to one hundred nodes. It is now spread over three buildings. Its testbed management and experimentation software has been further refined. The testbed now serves as a stable basis for research on hybrid technologies where traditional wireless multi-hop networks communicate and interact with wireless sensor networks. Experimental mobile and outdoor nodes have been developed and are in the process of being integrated into the testbed.

The remote access capabilities of our testbeds will allow third parties, such as the G-Lab project members, to use the testbed for experimentation. Above that, conceptual work is currently being done on the integration of the G-Lab experimental platform with the Real-World G-Lab testbeds which aims to make the usage of the testbeds as easy and transparent as possible.

B. Protocols

For our research on energy efficient protocols we implemented various building blocks that will provide us a basis for the next steps. An IPv6 protocol stack, as well as the 6LoWPan adaptation layer for the iSense operating system were successfully implemented and are currently in the evaluation phase. By that, our sensor network testbeds are now able to participate as peer hosts in the Internet, which is a prerequisite for the efficiency improvements we plan to develop in the upper layers of the protocol stack.

The sensor nodes of our testbeds are attached to gateways via a USB connection. These gateway machines act as a border router between the Internet and the WSN. The connection uses different protocols for WSN specific messages and can also be used to trigger hardware functions such as node flashing. Because of that we implemented a TUN/TAP device [2] that lets an attached sensor node participate in an IPv6 network while, at the same time, supporting the various programming and debugging tools already available for the iSense hardware platform, node flashing, monitoring, etc.

EZnet [3], a Java-based user-space TCP/IP stack, will contribute to our gateway solution as an easy-to-use protocol stack for packet inspection and creation. It will work on top of the mentioned TUN/TAP device which bridges between the Internet and the WSNs. Due to the easiness of extending existing protocols and building new low-level protocols, new ideas can be tested in a fast and transparent way. However, it lacks stable and complete support of IPv6. The integration of IPv6 and the adaptation of layer 3 and 4 protocols like ICMPv6, UDP, TCP in EZnet is currently in progress.

C. Services

A key challenge in the Future Internet will be the real-time search for real-world entities with a certain current state. However, it is infeasible to use today's search engine techniques like indexing due to the dynamic nature of monitored real-world phenomenas and the scarce resources of the used hardware. We proposed sensor ranking [4] as a technique based on prediction models to rank sensors according to their probability of matching a query. Highest ranking sensors are contacted first to check their actual state. We examine a new type of prediction model based on a Bayesian Network to explore the potential of correlations between sensors. When the actual state of a sensor becomes known, it is fed to the Bayesian Network to improve the ranking of correlated sensors.

Another important issue will be the monitoring and management of the enormous amount of embedded devices in the Future Internet. We are developing a scalable and energy efficient monitoring solution for WSNs. Therefore, in a first step, we are collecting real-world parameters, like latency and yield of produced data, from our testbeds. In a next step we will analyze and visualize these data. Based on the results of this analysis, we will devise a framework for online monitoring of these parameters which offers aggregated views over selectable sets of nodes and timescales.

D. Applications

We are currently investigating several application scenarios that will both help us to evaluate and improve our technical solutions and/or can be used to demonstrate the project achievements. Currently, there is no final decision made yet which of our scenarios is going to be realized.

III. Future Plans

In the near future we will come up with a use case application for the later evaluation of our approaches. Before that we will improve our algorithms in an iterative process with the use of simulations and real-life experiments on our testbeds in Lübeck, Braunschweig and Berlin.

Another line of research is the indirect optimization of WSN routing, as it appears when running 6LoWPan/RPL [5] on sensor nodes. We are investigating routing optimization techniques with the goal of reducing the energy footprint. These are based on distributed algorithms for Inverse Shortest Path Length problems [6].

References

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