NETWORKING ACHIEVED WITH LOW POWER

Internet-based control and monitoring systems have conquered everyday life. Under the slogan 'Internet of Things' (IoT), these technologies provide comfort – and often contribute to the economical use of energy in and around the home. These advantages are offset by the energy consumption of the IoT infrastructure itself. In a recent study, researchers at the iHomeLab (University of Lucerne) estimated standby power requirements and identified the area of home automation as the largest consumer. Those who currently use available networking technologies correctly make a major contribution to energy efficiency.

The Internet of Things includes, for example, sensors that record the occupancy of parking spaces and report the information to the parking guidance system. In the photo, drill work for the installation of sensors in a pilot project in Lenzburg. The battery-powered sensors require only one borehole, no further cabling is necessary. Photo: Swisscom, André Portner

A technical report about the results of a research project in the field of electricity technologies, which is financially supported by the Swiss Federal Office of Energy. The report has been published in the technical magazine Sysdata (issue November 2016).

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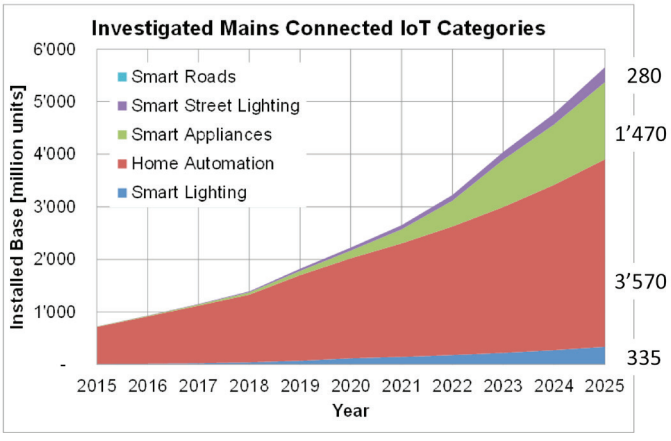
"Machinery, vehicles, elevators, oil tanks and many other things today communicate electronically and provide more efficiency and safety. But that's clearly not enough: In the future even everyday objects such as bicycles, mailboxes, water or newspaper dispensers, garbage bins, shoes, etc. will be connected too." This statement comes from Swisscom – it is a future vision and an advertising message at the same time. The telecommunications company's aim is to give the 'Internet of Things' (IoT) mass appeal. For this, it needs customized technologies. For once, the problem is not about how to transfer ever greater amounts of data faster. On the contrary: The 'Internet of Things' comprises mainly applications whereby small amounts of data are transmitted with little power consumption and hence at low cost.

Given this background, Swisscom is currently building up a Low-power Network (LPN) in Switzerland. LPN works with a relatively modest bandwidth of 300 bit/s to 11 kbit/s. The LPN should help the IoT, particularly in Smart City applications such as logistics (asset tracking), building management and agriculture, achieve a breakthrough. More specifically, this could for example provide waste containers with level sensors, so that garbage trucks only empty those containers that are full—Swisscom and the Geneva-based company OrbiWise are already working on such systems. Further examples are IoT solutions that can detect the availability of parking spaces and feed the data into a traffic control system; or heating controls that optimize their own operation with consideration to occupancy and weather influences. "These examples illustrate that IoT can and will make an important contribution to the promotion of sustainability," says Res Witschi, Head of Corporate Responsibility at Swisscom.



The number of IoT devices in the area of household and mobility is expected to increase sevenfold by 2025. Graphic: Final Report on Energy Efficiency IoT. Sources: ON World, ABI Research, Machina Research, Estimates and Extrapolations of iHomeLab

Application Area	Application	Edge Device	Power Source	Proliferation
Smart Home	smart lighting	smart LED bulb	mains	high
		gateway	mains	high
	home automation (security, comfort, energy)	mains connected sensors (e.g. light buttons)	mains	high
		camera	mains	high
		gateway	mains	high
		actuators	mains	high
	smart appliances (convenience, energy)	washing machine, dish washer, clothes dryer, coffee machine, oven, refrigerator, etc.	mains	high
		gateway	mains	high
Smart Mobility	smart roads	roadside gateway	mains	high
	smart street lighting	street light luminaires	mains	high

Overview of IoT applications, which were included in the iHomeLab researchers at the Lucerne University of Applied Sciences report on the energy efficiency of the 'Internet of Things.' Table: Final Report Energy Efficiency IoT

Consumption by IoT devices grows strongly

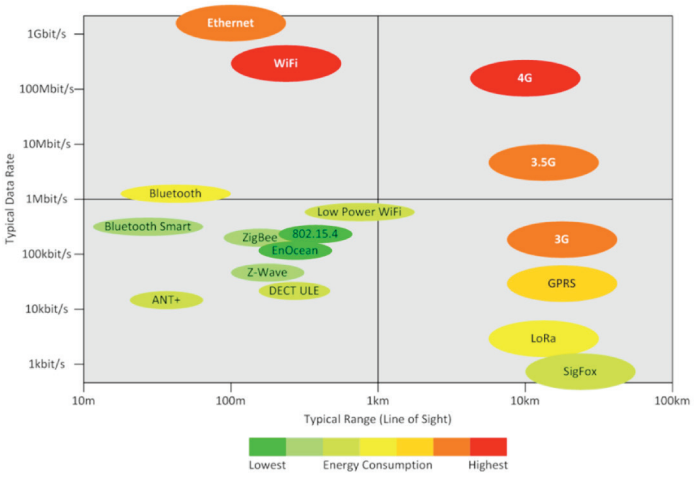
The three letters IoT represent a promise of the future—but they also represent reality. Already today each person on the planet uses more than one Internet-connected device, according to experts. According to projections, the number of networked devices could rise in the future to 200 per person. Some of these devices will help to save energy. However, each unit does have a small but real continuous energy consumption in standby-mode. Researchers at the iHomeLab at the University of Lucerne (HSLU) have, within the framework of 'Technology Collaboration Programs' of the International Energy Agency (see p.5), measured the energy usage of IoT devices and estimated the contribution to global energy consumption. For their investigation, they focused on household and mobile applications. The contribution of IoT devices in offices, production facilities, environmental monitoring, logistics, agriculture, health and retail trade are therefore not included in the figures (see graphic above).

According to market forecasts, the number of IoT devices in households and mobile applications will multiply worldwide from 700 million today to around 5.6 billion units by 2025 (see graphic on the left). Based on measurements, manufacturers' data and estimates of the associated standby power consumption, Lucerne researchers estimated that energy consumption will reach 46 TWh in 2025. This corresponds to three quarters of the current annual electricity consumption in Switzerland (see graphic p.3). "These calculations show that the power consumption of IoT devices will by no me-

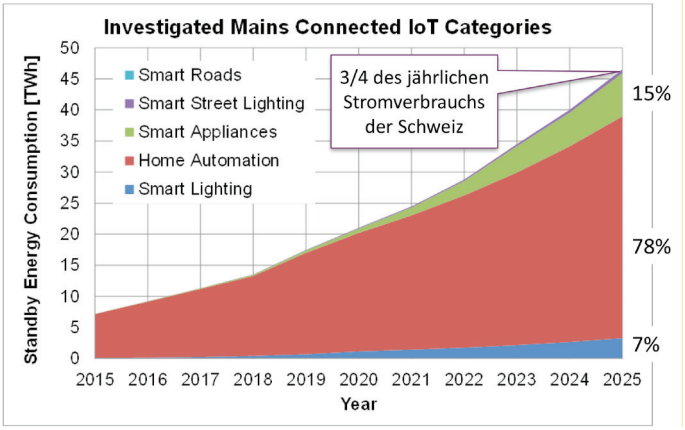
ans be negligible," says iHomeLab Director Prof. Alexander Klapproth. "That said, comparing this number to world wide electricity consumption puts this number into perspective. Efficiency measures of IoT devices are important, but they represent only one of several measures necessary to counteract increasing power consumption. In addition, IoT devices can make a significant contribution to increasing energy efficiency, which is not shown in these calculations." The iHomeLab researchers focused their study on new networked devices that draw energy from the power grid (not batteries). By this definition, mobile devices are not included (such as smartphones, tablets), computers (such as PCs, laptops) and home entertainment devices (such as set-top boxes, smart TVs). Also components of the network infrastructure (such as routers) and the data processing centers necessary to process information were not included in the study.

Low Power Versions of Known Technologies

Such consumption forecasts are of course subject to uncertainty and can only provide guidance. Therefore equally as important is a second central point of the Lucerne researchers in their report on 'Energy efficiency in the Internet of Things': the power consumption of IoT applications is highly dependent on the technology installed and its operation. In other words, the choice of suitable technologies and their efficient operation enables energy savings since less powerful technology consumes less energy (see graphic on the left). "Suitable is such technology that makes available as much range and bandwidth in accordance with the desired response time (latency) and response frequency that is actually needed for the particular application. Such requirments bring Swisscom with its low-power network, in focus: it is based on the LoRa technology that offers significantly less bandwidth than modern mobile networks, but is sufficient for most IoT applications and enables efficient use of energy.



Overview of today's technologies for wireless communication: On the right, mobile radio standards from GPRS to 4G, which have a range of 10 km and farther. Newer technologies such as LoRa and SigFox have the same or even greater range, but need less energy with less bandwidth. On the left is the short-range technology: Wi-Fi and Ethernet are generally known to the general public (although Ethernet is not a wireless technology, it is specifed here; it is known from the Ethernet cable that transfers the TV signal from the router to the set top box before it reaches the TV). Bluetooth and its energy-efficient version Bluetooth Smart are also known to end consumers. In addition to this are the home automation technologies ZigBee, 802.15.4, EnOcean, Z-Wave and DECT ULE, as well as the energy saving versions of Wi-Fi (low power WiFi) and the cordless telephone technology DECT (DECT ULE). ANT + provides for example in pulse timers for the data transmission from the sensor to the 'data center' of the clock. Graphic: Final report Energy Efficiency IoT



The area of Home Automation uses the largest share of standby energy consumption of the IoT devices under investigation. Graphic: Final report Energy efficiency IoT

Even at short ranges, low power and thus energy-saving technologies are available as compared to the widespread Wi-Fi (see graphic on the left). Soon, a low-power version of Wi-Fi will be available. While not suitable for the transmission of TV signals or computer downloads, it can serve well in the home automation sector, for example for control of LED lights or for the remote control of a shutter. Low-power Wi-Fi is thus in competition with already established technologies in this area such as ZigBee, 802.15.4, EnOcean or Z-Wave. Also Bluetooth, which connects your phone and headset, for example, has also grown a more energy efficient sprout in the form of Bluetooth Smart. This supports data transmission from heart rate monitors, fitness bracelets and other portable electronic devices ('wearables') to mobile phones. Also DECT technology used in cordless phones is now available in an

The primary result of the study shown in table format: The available technologies (above) are more or less suitable for applications shown (left). The color fields show whether a technology is very suitable (dark green) or at least acceptable (light green). On the other hand, applications of certain technologies, which are marked with bright red fields, are not recommended from the viewpoint of energy consumption. Table: Final Report Energy Efficiency IoT

Appl. Area	Application	Edge Device	ANT+	Bluetooth	Bluetooth Smart	DECT ULE	Z-Wave	ZigBee	802.15.4-2011-based	EnOcean	WiFi	Low Power WiFi	Ethernet	GPRS	3G (UMTS)	3.5G (HSPA)	4G (LTE)	LoRa	Sigfox
Smart Home	Smart Lighting	smart LED bulb	y	n	b	y	y	y	y	y	n	y	x	x	x	x	x	x	x
		gateway	x	x	x	x	x	x	x	x	y	b	y	y	n	n	n	x	x
	Home Automation	sensors	y	n	y	y	y	y	b	b	n	y	n	x	x	x	x	x	x
		actuators	y	n	y	y	y	y	b	b	n	y	n	x	x	x	x	x	x
		camera	x	x	x	x	x	x	x	x	y	x	b	x	y	y	y	x	x
		gateway	x	x	x	x	x	x	x	x	y	x	b	x	y	y	y	x	x
	Smart Appliances	smart appliance	y	n	b	y	y	y	b	b	n	y	n	x	x	x	x	x	x
		gateway	x	x	x	x	x	x	x	x	y	b	y	y	n	n	n	x	x
Smart Mobility	Smart Roads	roadside unit	x	x	x	x	x	x	x	x	b	x	x	x	x	x	x	x	x
	Smart Street Lighting	street light luminaires	x	x	x	x	x	x	x	x	x	x	x	y	n	n	n	b	b

y Possible Technology
x Not Appr. Technology
b Best Available Technology
n Not Recommended Technology

ultra-low energy version (ULE). It transfers data, for example, by connecting door sensors to the alarm system.

For Each Application the Right Technology

A major finding of the Lucerne researchers: Most IoT applications in the domestic area do not make high demands on data transfer and could therefore be implemented with power-saving communication technologies. An exception is surveillance cameras, which require wide bandwidth to transfer video to mobile phones. The iHomeLab scientists have summarized their findings in a matrix, that for various household and mobile applications from the perspective of standby power consumption, identifies appropriate and less appropriate technologies (see graphic above).

In the area of Smart Lighting, the results prove to be exemplary: The web-based control of LED lighting succeeds over short distances (short range), requires little data (low band-

CONSUMPTION OF IOT DEVICES NOT TO BE NEGLECTED

Part of the technologies that are today being discussed under the umbrella term ‹Internet of Things›, are attributable to ‘building automation’. A typical example is ‘intelligent’ technologies for monitoring and (remote) control of heating, ventilation and air-conditioning (HVAC), window blinds (shutters), household electrical appliances or decentralized photovoltaic systems. From building automation technolgoy, it is understaood that the energy consumption of the devices in standby mode should be considered. This finding was confirmed in early 2016 by the report ‘Energy Consumption of Building Automation’ commissioned by the BFE: “With average energy-efficient buildings, the annual electricity consumption of the building automation (Space automation and primary-side building automation) amounts to one to two-digit percentage points of the annual final energy demand of the building services (HVAC and lighting).”

“In the face of rapid technological development, the market players in building automation must consistently focus on quality and energy efficiency of the solutions used. We need a consolidation of standards and transparency with regard to power consumption,” says Olaf Zanger, head of a new innovation group working under the umbrella of the Knowledge Transfer Institution energie-cluster.ch, with support from Safe Home Automation (IG SHA). In the field of home automation, IG SHA directs attention to building infrastructure (window blinds, inverters, white goods), but not to consumer goods. The Innovation Group brings together two to three dozen industry representatives with the aim of improving the energy consumption and the electricity grid compatibility of buildings through the use of home automation systems. The targeted stakeholders are tenants, owners, suppliers and property managers. BV

Info: https://www.energie-cluster.ch/de/wissenstransfer/innovationsgruppen-(ig)/sichere-hausautomation-(ig-sha)-2799.html

width) for on/off commands, occurs sporadically and does not need an extremely short response time (latency). Ideally suited for this application, according to the Lucerne researchers, is Bluetooth Smart because this technology has a low standby power consumption and no separate gateway needs (because Bluetooth Smart is already standard in smartphones). Acceptable for this application would also be Z-Wave, ZigBee, DECT ULE and Low Power WiFi, which also all consume little power in standby-mode. However, they carry the disadvantage that the smartphone as an end user device requires an additional gateway, resulting in higher power consumption and consequently higher costs. From the viewpoint of standby-energy unsuitable (and yet still used in some products) is in this case, WiFi (oversized bandwidth, designed for continuous transmission, high consumption). If energy-efficient technologies were systematically exploited, it would lead to a noticeable reduction in energy consumption, says scientist Klapproth. Through consistent use of the best technology, the forecasted consumption in the area of Smart Lighting would be reduced by around 45%, estimate the iHomeLab researchers.

Realizing Technical potential

Prospects for an energy-efficient 'Internet of things'are favorable. As smartphones and other devices in the 'Internet of Things' are battery-operated, energy efficiency is a strong driver of technology—and power grid-bound IoT applications are benefiting. "Given the expected huge growth of the IoT, the efficiency potential should also be exploited," says Mihaela Grigorie from BFE. For this, the various manufacturers should use the most appropriate technologies in their products, so that the potential to reduce energy consumption can be fully realized.

- The report **'Energy Efficiency of the Internet of Things'** is available here: edna.iea-4e.org/news/energy-efficiency-of-iot and further information edna.iea-4e.org/

- For **further information** on the project, please contact Roland Brüniger (roland.brueniger [at] r-brueniger-ag.ch), head of the BFE-research program Electricity Technologies.

- For more **technical papers** on research, pilot, demonstration and flagship projects in electricity technologies, see www.bfe.admin.ch/CT/strom.

POLICY OPTIONS

Programs with accredited expert groups under the framework of the International Energy Agency (IEA) are an important tool through which Switzerland promotes international exchange in the field of energy technologies. The IEA currently has 39 programs ('Technology Collaboration Programs'/TCP) that are each dedicated to a specific energy area. Switzerland participates in 20 of these programs. One of the programs focuses on the energy efficiency of devices (Energy Efficient End-Use Equipment, abbreviated as 4E). In this 4E program, specialists from 12 countries including Switzerland exchange information and experience and develop proposals for the efficient use of energy. The content of the topics is guided and determined by the 'Executive Committee,' in which all participating countries are represented.

EDNA (Electronic Devices and Network Annex) is one of three sub-programs (so-called 'Annexes') of the 4E program. In agreement with and within the framework of EDNA, the study 'Energy Efficiency of the Internet of Things' developed between November 2014 and July 2016. In an additional report, the researchers also address transmission technologies that serve to wirelessly stream music to speakers (Sonos, for example). The two studies were conducted by a team of iHomeLab researchers at the 'University of Luzern - Engineering and Architecture,' headed by Prof. Alexander Klapproth. The primary study produced concrete recommendations. These recommendations will be discussed by the 'Executive Committee' of the 4E program and will serve as suggestions for regulatory or other implementation-effective steps for the political authorities in Switzerland and in the other countries involved.

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