# Half a Century of Renovating

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**Abstract.** This story is set in a future 80 years from today. The protagonist, an elderly man who would have been a pensioner nowadays, is restoring an old building. While performing this pragmatic work he remembers the evolution of different kinds of technology from when he was a kid to when he grew up. In the course of painting his study, he thinks about research topics which are actively under investigation today such as wireless sensor networks, context and activity recognition, smart grid and smart energy, organic and printed electronics and wireless communication. Over the course of the story it is uncovered that technologies from the long gone age of wireless sensor networks still played an important role in this man's past; enabling the bundling of the visions behind aforementioned research into a single self-contained domain working unsupervised in the background, hidden from the human eye.

## Introduction

Currently, wireless sensor network (WSN) technology has not yet reached the mainstream. This is related to a number of facts regarding their organizational possibilities, sensory capabilities and power requirements. In our research we try to tackle several of these challenges in order to push the borders of what is possible with WSN technology. In this effort, we are guided by possible visions of how this technology might change the way we live today.

The focus of this story is on networks of massive amounts of nodes. We explore a technology path of increasing numbers of relatively simple nodes. Starting with medium scale dense networks of an airport security scenario, we encounter smart homes, the smart grid, and see how such technologies could be established through an evolution of programming interfaces and advances in self-organization technologies. We finally explore printed organic electronic wallpapers and smart labels in the Internet of Things and their role for creating a far-away future.

## 1. Discussion of Related Scientific Research

In the past, TecO has conducted research in several areas relevant for this story. The main focus of our group is on Ubiquitous Computing artifacts, from Wearables, such as [16], to smart office objects, such as the DigiClip[6] or the UbicompBrowser[4].

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Applications we are currently working on include ad hoc sensor networks for civil safety. In a recent work we have developed a middleware for firefighters[21, 23].

Our group also works on low-cost wireless sensor networks[3], which play a key role in our story. TecO has developed a novel hardware software concept to facilitate the simple development of sensor node software solely by using a web browser for software development[7]. Code generation for heterogeneous WSN environments in an Internet of Things (IoT) setting is studied in [15].

Moreover, we work on methods for cooperative transmission[10]. Currently, WSNs use well-established multiple access methods to communicate. However, implementing protocols that assign a distinct channel to each sender is not feasible in large-scale scenarios, where sensor nodes need to be simple, cost effective and come in large numbers to monitor space at a low cost. Therefore, we need special *collective*, *approximate* versions of the traditional multi access techniques. Where traditional communication protocols strictly avoid interference during data transmission, new protocols should embrace interference to improve robustness or strength of the signal. A robust system for counting sensor nodes using constructive interference and statistical properties has been introduced with Synchronous Distributed Jam Signaling[11, 13, 9, 12]. The first system able to actually transmit data collectively from 21 sensor nodes has been shown recently in [2]. The system is developed as a test bed for IoT scenarios of business process support with organic printed electronic smart labels. Such organic electronic circuits can be produced faster, cheaper and simpler than RFID allowing massive deployment[1] e.g. on tomorrows milk bottles.

The third focus area in our group is context-awareness. We investigate new sensors[8] and sensing techniques[14, 22], develop tailored machine learning mechanisms[5] and reasoning systems[18, 19], and we also explore the foundations of context-awareness[17, 20], with the goal of building intelligent self-organizing, adaptive systems.

## 2. Half a Century of Renovating

A dull grey sky with large dark clouds hung over the old country house. Light rain was falling onto its roof tiles and window panes. Standing behind the panes I watched the wonderful random play as several drops combined into a larger pool until suddenly all of them flowed down together as a single rivulet. While this weather should have gotten me intoa depressing mood, I felt the opposite. To me this rain was like a relief. I felt that this world was a good place to be. But I also recognized that something was missing.

The cool high-tech of the previous half of the century, how could it disappear? Where were the tasks for which you needed to be smart to get something done, to move something? Again I felt vindicated in my decision to be out here, renovating the country house of my forefathers and getting something done like it used to be in the old days.

Eye in eye with the stained wall, I clasped my brush and soon started painting again, evenly spreading the paint over the contours of the clinkers. Soon I returned to the magical rhythm until it seemed I had never done anything else than painting. Being absorbed in my activity, I was suddenly interrupted.

“Hey grandpa!! What's this?”, my granddaughter Anna asked, while holding and flexing a long piece of black plastic in her hands which she must have found somewhere in the basement.

“Ah that, it's something we don't need anymore. It's called cable and it's not even useful for rope jumping.” I replied. But she didn't look quite satisfied with my answer and prepared the next question.

“Hmm, but what IS it? What was it used for? Is it some kind of game? Look what a nice knot I can create with it”, she said while creating several probably uncuttable coils.

“Well my dear, about 60 years from today, when I just got about your age, something like this used to be the foundation for power and comm…”

“Oh very interesting grandpa, I think I have to go looking for my doll.” she said and ran off. Thinking closely I noticed that this was probably a natural reaction when the old 'pa starts telling stories of the good old times again. However, things used to be quite different back then, more experimental and exciting.

I clearly remember the excitement of my mother about the news casts when I was around ten years old. Back then she was a PhD candidate working in a classical research area called ubiquitous computing. The news were about the installation of the first large scale security sensor network installation in the world's biggest airport to automatically identify potential terrorists. I also clearly recall the podcasts and the keen discussions around the kitchen table. My parents used to argue that these technologies were really useful, whereas my grandfather was pointing at all the unresolved issues, such as security and privacy concerns.

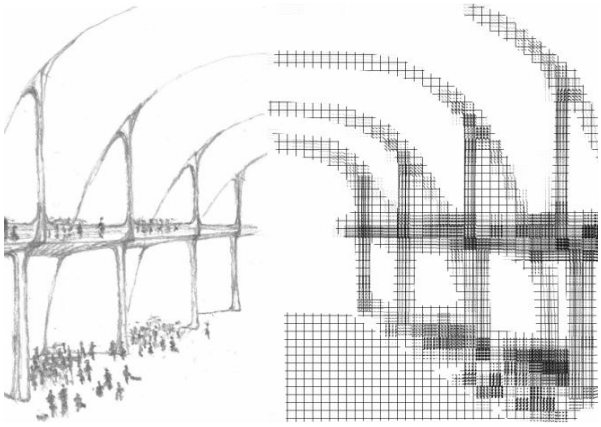

**Figure 1.**Security on international airports was insured by huge wireless sensor networks. These first practical large scale installation allowed the continuous surveillance of hundreds of individual activities silently in the background.

However, soon after the installation of the system three terrorists were arrested based on suggestions by the network. It had been their conspicuous behavior, their activity context, which had betrayed them. It had been different from the behavior of normal passengers and would not have been recognized by traditional human surveillance. Surely, these systems were still in their infancy as they only then developed from pure

scientific experiments and sporadic small scale use to commercial everyday technology. However, after these first successes of the technology in public, things accelerated. My mother finished her PhD and changed into the industry with the strongest potential for economic success: the WSN applicators. There she started work as a context and deployment engineer. According to the description of her job, her tasks were the development or adaption of algorithms which could cope with the special topologies requested by the customers and with the costly calibration of the systems after the installation.

As it became standard policy to outfit rescue forces like firefighters, the police or disaster protection institutions with wireless sensor assistance systems, one of her first jobs was outfitting the local firefighters with this technology. She told us that while the nodes were still relatively large, it was proven that they helped to increase mission efficiency and safety as they could monitor escape routes and detect possible hazards in a self-governed fashion.

Mom was especially proud when the system she had installed and trained the rescue personal on, helped to recover a young girl from a burning family home. While the girl was overseen when the rescue forces passed by her room, the girl was detected by the nodes which were deployed in the corridor when she ran out in panic. Due to their perception enhancing protection suits the rescue workers instantly felt the presence of the girl at that specific node as if she was hastily running over their backs. Using the integrated augmented vision system the firefighters could rapidly discover and retrieve her although the house was filled with dense black smoke. When telling me about the incident my mother emphasized that the technology which actually helped to detect the girl was the same which was used to transmit information between the nodes: wireless communication. Back at university, she told me with an impish smile on her face, her research was directed at the question how human activity and environmental changes related to specific signatures on the communication channel and what method could be used to provide accurate predictions for these events.

From this time many positive stories regarding the successful application of WSN technology and context recognition were reported, leading to an enormous growth of public awareness for the potential of this technology. When a series of faulty products nearly burned down Amsterdam in '25, many people felt the need to monitor and supervise their own living environments and spaces. And, there was an instant demand for personal access to such technologies.

But WSN was a technology still only in the hands of experts like my mom, requiring deep system knowledge and manpower to install and deploy. This changed now. Concepts which had been in research like the simplification of programming such nodes and self-organizing, decentralized approaches to topology discovery and work distribution were adapted and prepared for the masses. At first, users still needed to correctly place and calibrate the nodes and use their ubiquitous mobile devices to customize the sensor logic - while not forgetting to periodically check on the batteries. Later, alternative power and control concepts such as harvesting wireless power and programming via a common brain interface allowed a much simpler interaction.

However, it was not the simplicity or availability of these systems that changed the world, it were its applications. By closely monitoring themselves and their surroundings people developed an augmented awareness for their personal unadorned ecologic footprint. They analyzed closely how plants and pets behaved using algorithms that showed them the direct consequences of their very own habits. Some people overreacted and began to immerse completely into a different identity: my

mother once told me of a colleague who began to act like the cacti he was monitoring, growing a beard and only drinking a spoonful of water a day, but for most people this new ability created a strong feeling of responsibility for the environment and an unprecedented identification with earth and nature in the western world. This in turn translated to a direct request for cleaner energy production and wiser use of resources. Looking back today, I would say that it was this insight that rang in the end of fossil fuel based energy supply.

### 3. A Thunderstorm That Clears the Air

Thunder struck outside, and I realized that the light rain had turned into a heavy storm. Looking through the windows it seemed like the end of days had come. As I continued painting the wall I became fulfilled with a deep feeling of shame. This was the guilt all of my generation carry with them today. It is the guilt for the strong impact mankind took on the ecosystems of our planet. While it was good that we had learned how our individual behavior affected earth and we realized that we needed to change, the change was also inevitable.

This was around 50 years ago, at the beginning of the 30s, when the lion's share of electricity was generated from fossil fuels in coal-fired power stations and nuclear power plants. The production of greenhouse gases by burning fossil fuels, deforestation and mining, the accidental leakage of oil, gas and radioactivity had caused the earth indelible stains and scars, and had been threatening the lives of various species including ours.

In order to make the change happen, the percentage of renewable energy had to be increased considerably. The EU was a vanguard in this case; it had already reached a 20% share of renewable energy in the 20s. It was realized by combining early smart grid ideas, meaning automation of previously manually controlled processes, with the first available electric vehicles. However, a further increase of renewable energies enforced the adoption of new energy concepts and the attached infrastructure.

A new design was proposed which broke with the classical view of dividing power and information transmission. In contrast, this system combined power transmission, communication and Internet of Things technology into a new architecture. It was leveraged by a sophisticated decentralized process control and optimized decision support systems. The system was further designed to incorporate all of the world's energy generation facilities and provided the capability to switch rapidly between power sources and demand up to 20.000km apart. Many of the newly industrializing countries made a fast transition to this new concept of global regenerative power, China was one of the strongest advocates of the new system, realizing that its demands would not be satisfied by fossil fuels in the long run. The new system also profited from the technological developments of previous years, i.e. the high number of personal sensor networks. These networks were now attached to and wirelessly powered by the new system allowing a more fine grained control and prediction of power use and expected demand.

I remember when I moved to my first own flat, some rainy spring around 2030, when the employment of the new system was in full progress. I moved into one of the new energy aware buildings which were outfitted with a combined, self-organizing power/communication network with embedded power collectors on the surface of the structure. These buildings automatically collaborated with other buildings and electric

vehicles nearby to optimize energy consumption and storage. In the frame of the national energy savings day there was a contest for achieving the lowest energy consumption in the city. However, winning this challenge would be pretty tricky because the employed smart home algorithms were perfectly adapted to your individual life style. Hence, they would react and plan based on your typical energy consumption, so changing your behavior for the single day would actually not do the trick.

Fortunately, I had started early to plan that day. I had established a very volatile behavior in the days before, which actually also coincided with my typical sleep-wake-rhythm as a university student. Due to the magnitude of false predictions the smart home system had switched to its fall back mode which was basically a manual override, meaning no automatic coffee preparing in the morning and no preheating of the rooms for the expected return time. Thus, on energy savings day I sneaked out my flat early in the morning without turning on the lights and only returned late avoiding switching on any power consuming devices. Until today, I am convinced I would have won the e-magnet hover board if not my cat would have triggered the automatic pet food dispenser mechanism.

In 2041, the system was finally completed. It exceeded our expectation as it allowed the continuous use of earth's most constant energy source, the sun, while providing a previously unreached reliability, safety, cost-effectiveness and efficiency. A really huge installation, a prime example of mankind's engineering power and global collaboration.

**4. Tearing Down the Old Wallpaper**

“What a wonderful world”, a great song sung by Louis Armstrong in the 1960s, about 120 years ago. When I look out the window and see the small hills, green trees and the positive rain, this song best describes my feelings. Sure it was not always like this, there were centuries of conflicts and problems. Now, however, we are all living in peace and harmony, without pollution and hunger.

It is the year 2084, all world problems are finally solved. One may think this might become dull. Anyway, I am happy to have this old house where I can relax and recharge my inner batteries renovating it. My grandfather lived in this country house a long time ago and I do still remember when I was young, as if it was yesterday how he was talking to my father about the inceptions in the 20s - novel revolutionary printed organic electronics based on plastic materials.

Can you imagine how people were excited to see the first computers embedded in wall paper? Also for the first time, you could get a printed flexible display of an arbitrary paper size. Just draw your application on the paper and you got what you wanted. They called such environments smart rooms or thinking spaces furnished by diverse printed sensors, actuators and mediated by so-called human computer interfaces. Of course, everything was linked to each other either by printed lines or wireless.

I am really glad to tear down the remainders of this old stuff from the walls.
My father always loved novelties as I do. Fifty years back in the past printed electronics were the hype. I would never forget how my father told me the funny story about the first Mars mission in the year 2029 again and again:

The international mission led by Americans and Russians passed off successfully until a small undiscovered comet intercepted the course of the spaceship Mercury 1 on their flight back from Mars so that they had to fly around the dust tail which cost them

a lot of fuel. Additionally, the bypass maneuver led to a complex trajectory for the return to earth for which they did not have enough fuel and food. Even a rescue ship would not reach them in time.

The Mercury 1 was in a serious situation. A world wide appeal for help was sent out in order to collect rescue ideas. Who would have thought that a two star French cook would have the enlightening idea for generating sufficient fuel to bring the crew home safely. The cook provided the crew with a recipe how to transform some parts of the polymer computers which were non-essential into fuel. Using an old Russian oven and the recipe the crew was able to extract enough fuel so that they could arrive earth with negligible delay. The cook had also made the suggestion that the secreted sugar from the fuel could provide nutrition for the crew. However, they kindly refused this offer.

**Figure 2.** In the old days, wallpaper based printed organic electronics brought the smart home to the masses. Today it just causes extra work since the paper shreds seem to be stubbornly plastered to the brick wall.

A few years before this mission these polymer electronics had strengthened the world economics enormously. Organic printed solar cells were hyped as they provided people with electricity supply for any kind of device and could be integrated seamlessly into structures and furniture. Various companies who had previously worked with polymers developed into the power sector and became multinational organizations. Printed electronics became so famous that the clothing industry was selling underwear with printed organic LEDs and integrated printed circuits. They called this technology “smart textiles”. When I cleaned up the attic I was surprised to find this kind of clothing. I did not know that my father was so fascinated by these printed organic electronics.

Another story which I very clearly remember was about the first use of massively deployed printed smart labels in supply chains and logistics. The story happened in a warehouse where pallets with thousands of bottles equipped by these labels were monitored. The monitoring was performed by warehouse workers which were also responsible for filling up the shelves and removing adulterate goods. Thus, this used to

be a good, uneventful, ordinary work. Then one day something strange happened. A fork lift attacked one of the workers suddenly and without warning. The security staff was not able to discover any defects or traces of manipulation. Thus, it remained unclear how the fork lift could act alone without any remote control. In the following days similar incidents occurred until it was decided to call in the national security. But they could not help either. An attempt to shut down the warehouse by disconnecting it from the power supply also failed because the building was completely outfitted with printed solar cells. Some computer scientists believed an artificial intelligence had emerged in the warehouse. They formulated theories and performed proofs, relating this phenomenon to an emergent version of the smart room technology. More naive souls panicked as they believed this to finally be the end of the world.

The weird self-organizing warehouse however, found its end in the discharge of a high energetic electromagnetic pulse. Later, thorough investigations revealed that a single smart label was infected by an undisclosed virus which spread rapidly through the warehouse. A chain reaction was triggered among the smart labels which mounted in the strange behavior of the electronic warehouse appliances. Unfortunately, the chain reaction could not cool down itself so that a violent intervention was required.

**5. Painting My Grandfather's Old Desk**

One final stroke with the brush and I had completed this room. I climbed down the ladder and checked the paint on the desk. The paint layer had dried; it was time to apply the final coating and to finish the process. I closed the door so as not to be disturbed by Anna and unpacked the fresh brush. I held it in my hand for a few seconds, then opened the can with the coating and dunk the brush in for another few seconds. Then, I wiped off the brush at the rim of the can and -- not wasting a single drop as I'd like to emphasize -- I applied a first layer of the coating to a leg of my grandfather's old desk and carefully spread the coating.

This warehouse incident had been both unforeseen and predicted long ago both by scientist and by countless movies: the emergence of an Artificial Intelligence. While the movies had been almost right in predicting it would emerge going about to destroy all of mankind, they had by far overrated its power: first, it had emerged not on the intranet of a military facility controlling a silo of nuclear missiles, but on some ten thousand milk bottles taking over a warehouse, second the EMP had wiped it out within the fraction of a second. The security of our military facilities had of course been much higher than on our milk bottles.

However, this of course started quite some discussion, people with no real understanding of the technology arguing all of technology should be abandoned, everything that fed the billions of people on our planet be switched off. However, they did have a point: at the heart of all our fabulous technologies had evolved the same technology, a network of simple hardware components capable of organizing themselves into fantastic organizations that could principally fulfill the most complex computational and sensing tasks. From the first context-aware systems embedded into our airports to track suspicious human behavior, via the intelligent sensing network structures of the Smart Grid and the electric vehicles connected to it, to the smart labels attached to every object in the supermarkets of the 30s, which had finally come to life like in a bad 20th century horror movie.

I looked around me and realized the naturalists would have been very happy to see me here in this old house in the country side. This had been their suggestion: no cable, no sensor node, no camera, and no wall paper, not even a lamp in this building of bricks, mortar, and wood and some paint.

When I was a little boy, I remember my grandfather sitting at this desk staring at the monitor of his “desktop personal computer”. He'd have been very surprised to see this room looking again like the 19th century place he had inherited from his mother after another 50 years into the future.

The rain had finally passed and some last rays of yellow sunset light found their way into the room. Evening was close and the splendor would soon be gone. I took the minutes to contemplate this naturalists' dream around me and to remember a fantastic century of shiny, smart high-tech revolutions.

Then, I told the freshly painted wall to lighten up and uncapped another petabyte can of transparent nano-coating. I dipped the authenticated brush in and resumed my work to get my new desktop computer ready before dinner.

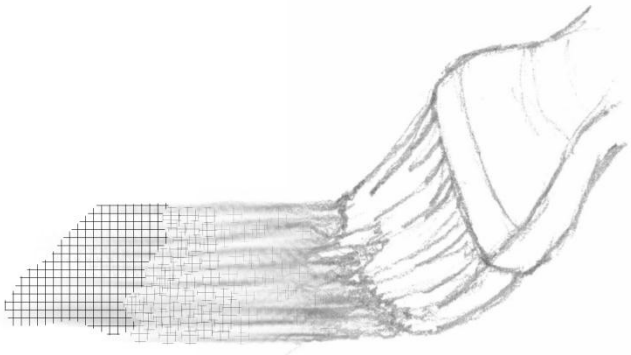

**Figure 3.**The computer of today is everywhere. You basically just need a can of the right paint and it will do what you want, where you want it. The sub computer particles in the paint, automatically arrange themselves in a meaningful way to realize ubiquitous environments and artifacts. These systems harvest their power, transceive data and sense their surroundings using the same calm wireless interface.

## 6. Summary

This story is set in a future 80 years from today. The protagonist, an elderly man who would have been a pensioner in our times, is restoring an old building. While performing this pragmatic work he remembers the evolution of different kinds of technology from when he was a kid to when he grew up. He lets his mind wander to research topics which are actively under investigation today such as wireless sensor networks, context and activity recognition, smart grid and smart energy, organic and printed electronics as well as wireless communication. Over the course of the narrative it is uncovered how these technologies could lead to a new vision of computing technology that is truly pervasive.

Our story explores two of today's key technologies: wireless sensor networks (WSN) and the smart grid. Main shortcomings of WSNs, such as high development and deployment cost, lack of abstraction, and resources and energy usage are studied. We

investigate concepts we believe will be crucial to overcome these shortcomings. Our Science Fiction prototype explores the computing concepts of self-organization, resource efficiency, and simplicity of use. These concepts together with advances in the material sciences could be driving forces that lead to a totally unpredicted and exciting variation of the idea of calm and invisible technology.

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